Operations Management Research (2024) 17:754–783
https://doi.org/10.1007/s12063-024-00469-1

Scheduling in services: a review and bibliometric analysis

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Received: 21 July 2023 / Revised: 12 December 2023 / Accepted: 13 February 2024 / Published online: 11 March 2024
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Abstract
Scheduling problems are a fundamental aspect of various industries, wherein the effective allocation of resources and time management play a crucial role in optimizing operational processes. These problems can arise in any industry that requires the scheduling of resources, from manufacturing to healthcare and transportation. Despite the extensive scope of service system scheduling problems in the literature, research has yet to examine the bibliometric variables in this area. Based on bibliometric criteria, this research offers a picture of the structure, evolution, and potential future directions of studies on scheduling in service systems. With the application of the bibliometric analysis software VOSviewer and CiteSpace, 1991 publications related to service scheduling were identified from the Web of Science database between 1982 and 2023 and used in the analysis of this paper. This review used several bibliometric approaches, such as performance analysis and a scientific mapping of service scheduling. Several bibliometric variables, such as h-index, productivity, and citations, were included in the performance evaluation. Science mapping has used co-citations, bibliographic coupling, and the concurrency of keywords. Also, this paper introduces a novel and comprehensive framework for classifying scheduling models in service systems based on their characteristics. The highly cited implementation papers in the literature have demonstrated that scheduling problems in health care have been heavily utilized in the scholarly literature. This review which is the first bibliometric analysis in the service scheduling field provides a summary reference for scholars entering the subject for future research.

Keywords Service scheduling · Bibliometric analysis · Operations research · Queueing systems · Service systems · Optimization

1 Introduction

Service industries today are crucial to modern civilization, being the largest sector of the global economy by value-added. Services have garnered significant attention due to the global economy's increasing focus on service-oriented industries. This industry has proliferated over the past century and has become vital to a functioning society and economy. Industrialized nations worldwide have seen their economies shift toward a service-based model (Hofmeister et al. 2023; Smith et al. 2007). Domestic and international economies are heavily dependent on service industries. According to numerous studies, most countries' GDP is accounted for by the service sector (Karmarkar 2015; Witt and Gross 2020). In this regard, many forecasts indicate that services will dominate the global economy in the long run (Ravindran 2008). Therefore, it appears vital and unavoidable that research on service operations management will receive more attention, given the growing dominance of service businesses and concerns in the global economy (Wang et al. 2015). The importance of service operations management research arises from the needs of the ever-changing service industry and the abundance of operational management models that could provide insight into systemic problems (Hildebrandt 1977; Roth and Menor 2003).

Service operations management is an essential role in every service industry. It encompasses planning and strategically managing resources and processes to effectively fulfill client demand. Service firms must consistently pursue quality and efficiency due to the highly competitive climate that allows little margin for error (Chase and Heskett 1995; Handoyo et al. 2023). In this regard, increasing efforts have been made to conceptualize and formulate the mathematical

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structure of services. Customer behavior models, service quality impact models, and normative service models are all examples of models that come from service and service management (van der Valk and Axelsson 2015). Every service company faces numerous decision-making problems that operations managers should address, such as facility location, Quality management, service supply chain, capacity planning, staff rostering, skill management, and allocation scheduling. For example, the role of operations management in the health sector is to ensure that the right tools are available at the right time for proper health delivery. The system assists health professionals such as nurses, doctors, surgeons, and others in providing timely assistance (Lan et al. 2022; Taiwo et al. 2023; Tippong et al. 2022). Based on the time horizon, the problems in service industries can be broken down into three distinct decision-planning levels: strategic, tactical, and operational (Khalifa 2021). Decisions like capacity planning and allocation, which have a significant lead time, fall under the strategic level. The operational level entails controlling flows and coordinating activities, whereas the tactical level involves putting strategic decisions into action (Archetti et al. 2022; Bender 2017). In the case of a home healthcare firm, for instance, dividing patients into service regions is a strategic decision for the firm. On a tactical level, each customer's visiting days are identified, and daily routes must be arranged on an operational level (Di Mascolo et al. 2021).

In light of these three decision levels, operational decision-making seems to be less common in recent articles and studies for the service sector. However, operational decisions in the service industry frequently rely on planning and scheduling, which may deal with the allocation, assignment, scheduling, and reservation of resources. Service systems such as healthcare facilities, supermarkets, call centers, and online platforms are a few examples of situations where finite resources must be allocated to incoming clients. In such systems, resource allocation is crucial to achieving an organization's aims and objectives (Yahiaoui et al. 2023). Scheduling is challenging in these systems, and research on it continues because of its complexity (Ibrahim 2022; Mahes et al. 2024).

This paper uses bibliometric analysis to analyze articles addressing the service industry's scheduling problems. There has been a dramatic increase in the number of studies on scheduling services since 1991 when the modern economy underwent a fundamental shift that propelled the service sector to the forefront. This increase has led to a higher dispersion in this field. Therefore, it becomes crucial to conduct a study to organize these multiple studies and provide a reasonably comprehensive picture of the service scheduling field. In this regard, by examining and categorizing the existing literature on the topic, this paper establishes a structure for future studies on the aspects of scheduling problems in the service industry. This study investigated 1991 published Web of Science Core Collection documents up to 2023 in the "Operations Research Management Science" and "Management" categories.

To date, there are few review papers that, in particular, discuss and address scheduling problems in services. However, numerous research reviews are available when considering various categories of scheduling problems in service industries, such as vehicle routing problems (Salehi Sarbijan and Behnamian 2023; Zhang et al. 2022), appointment scheduling (Ahmadi-Javid et al. 2017; Ala et al. 2023), berth scheduling (Li et al. 2023), personnel scheduling (Özder et al. 2020), and maintenance scheduling (Raza and Hameed 2022). Each review complements previous works and addresses specific features of scheduling problems. In service scheduling, the initial endeavor was conducted by (Aggarwal 1982), who described the distinctive features of services and identified various types of service systems. The study highlighted the specific constraints, conflicting objectives, and commonly employed techniques, methods, and procedures associated with each type. (Pinedo et al. 2015) identified five primary domains for scheduling issues in service systems and discussed the similarities and differences between the problem formulations and solution techniques. Using research on the goal programming technique, (Gür and Eren 2018) examined scheduling and planning issues in service systems. The literature indicates that the previous reviews have not thoroughly analyzed the scheduling models by taking into account the shared characteristics of scheduling problems in service systems.

According to the authors' research into the service scheduling literature, there is a lack of a cohesive body of knowledge in this field, demonstrating the necessity of a bibliometric study of the topic. To the best of our knowledge, this article offers the first systematic categorization of literature on the scheduling of service systems. This research contributes to the current knowledge base by providing survey studies on subjects relating to service scheduling. A systematic literature review employing advanced bibliometric analysis tools is the unique contribution of this work. Overall, our evaluation adds to the existing body of knowledge in service scheduling problems by highlighting prior research, finding and debating relevant keywords in the literature, and suggesting future research directions. This research identified new topics, areas, and cutting-edge research directions in this domain. Additionally, modern research streams have been examined by conducting bibliographic coupling analysis. In general, the main contributions of this study can be regarded from threefold aspects:

1. *Theoretical contribution:* Describing the current status of service scheduling at the levels of countries, institutions, and journals, which considers fundamental and

classical indicators, such as H-index, numbers, citations, etc.
2. *Practical contribution:* Deep analysis is given to help scholars better grasp hot topics of service scheduling, including bibliographic coupling analysis and burst detection.
3. *Review analysis contribution:* Proposing a framework based on the characteristics of service scheduling problems.

The outline of this paper is as follows: In Section 2, we present the historical background of scheduling problems and then describe the differences in the attributes of scheduling problems in manufacturing and services. Also, a novel framework is presented in this section by considering the characteristics of scheduling problems in services. Section 3 outlines the methodology and data collection steps. The findings are demonstrated and interpreted with figures and tables in Section 4. Section 5 explores the significance of the results and presents the conclusion and suggestions for future work.

2 Short conceptual background of the review

This section describes the service systems and scheduling problems. Initially, we present the service systems and delineate the distinctions between manufacturing and service systems. In the following, we shall categorize the papers by examining the existing literature on service scheduling and highlighting their distinctive characteristics.

2.1 Service systems

Service, in its classical sense, encompasses a range of activities, actions, and performances (Zeithaml et al. 2017). The contemporary interpretation of service has expanded and refers to utilizing skills and knowledge for the advantage of another party. These competencies can be demonstrated through a multifaceted combination of goods, money, activities, and institutions within a service system (Vargo and Lusch 2008).

In service systems, human or mechanical power provides activities to meet people's needs and wants. In these systems, individuals, businesses, government agencies, or any combination of these can be both providers and customers, and they work together to create value through complex value networks (Böttcher and Fähnrich 2011; Pinedo 2009). In simpler terms, service systems are elaborate arrangements of individuals, systems, and resources that collaborate to provide services to others (Demirkan et al. 2011). Efficient management, design, and operation are essential components of service systems, just as they are in production systems. There are several issues that arise in service system such as facility location, capacity planning, pricing decisions, revenue optimization, security, logistics, admission control, and resource allocation and management (Ravindran et al. 2016).

2.2 Differences between manufacturing and service systems

Conceptually speaking, despite having similarities in operations management in manufacturing and service industries, they differ in several ways, which can affect scheduling and planning activities (Bouranta and Psomas 2017; Huang et al. 2017; Wang et al. 2015, 2020; Xing et al. 2013). One of the main differences is that changing operational procedures and hiring more people will be needed for service operations to keep up with the supply–demand balance. In contrast, manufacturing operations do not need to change their operations or engage additional resources when there is a high demand for a product. It is worth noting that this does not negate the need to account for potential uncertainties in manufacturing decision-making. Uncertainties in manufacturing systems may arise due to human, machine, or systems-related issues or may be attributed to external factors (Jain and Foley 2016). Moreover, manufacturing and service industries have different approaches to scheduling and planning. A manufacturing company prioritizes jobs to meet deadlines and reduce costs, while a service company schedules customers. Due to this, waiting time becomes more critical in services (Pinedo 2009). Therefore, given the time-dependent nature of demand and the instantaneous nature of both production and consumption, managers in charge of service operations must have a firm grasp on the connections between staffing and scheduling tactics and their organizations' ability to meet customers' needs (Siferd and Benton 1992). In sum, the inherent differences between manufacturing and service industries can be related to the products' nature, production process, labor requirements, timeframe, customer interaction, and supply chain. Manufacturing produces "goods" that are tangible, durable, consistent, and can be inventoried; however, service products are intangible, perishable, and inconsistent (Heizer and Render 2011; Nie and Kellogg 1999). Table 1 summarizes the most important differences between critical features of manufacturing and service scheduling systems.

Various paradigms have been developed to address the challenges involved in the service sector that need to be addressed using methods including mathematical modelling and optimization. The services industry uses several types of scheduling and planning models. Mathematical procedures and heuristics, which are employed for allocating and scheduling restricted resources in a firm, highlight the importance of studying the service industry using Operations Research (OR) perspectives (Schryen and Sperling 2023). As a result

Table 1 Scheduling problems in service and manufacturing organizations: a comparison

	Features	**Service industry**	**Manufacturing industry**
Number of Resources	Fixed		A
	Inconstant	a	
Scheduling	Machines & Materials	a	A
	Staffs	a	
Place	Facility-based	a	A
	Field-based	a	
Demand	Stationary		A
	Non-stationary	a	
Orientation	Short Term	a	
	Long Term		a
Measuring Quality	Hard	A	
	Easy		a
	Objective		a
	Subjective	a	
Input	Knowledge & Skill	a	
	Raw Materials		a
Uncertainty in	Lead Time		a
	Deliveries		a
	Forecasts		a
	Service Time	a	
	Backlogs	a	
	Capacity Utilization	a	
Uncertainty Management	Generating Queues	a	
	Generating Inventory		A
Operations	Labor Intensive	A	
	Capital Intensive		A
	Uncertain	A	
	Predictable		a
	Standardized		a
	Heterogeneous	a	
Models	Project Scheduling	a	
	Job shop Models		a
	Flexible Assembly Systems		a
	Lot Scheduling		a
	Supply Chain Models		a
	Reservation Systems	a	
	Timetabling	a	
	Workforce Scheduling	a	
Response Time	Short	a	
	Long		a
	Lead Time		a
	Patience Function	a	

Table 1 (continued)

	Features	Service industry	Manufacturing industry
Primary Objectives	Max the Throughput		a
	Min the Maximum Lateness		a
	Min the Setup Times		a
	Min the Inventory Cost		a
	Min Transportation Costs		a
	Min of Avg Response Time	a	
	Min Avg Customer Waiting Time	a	
	Min of the Avg Distance Travelled	a	
	Min Avg Number of Required Facilities or Crews	a	

of using the OR perspective, formal models of service systems can be developed (Goodarzian et al. 2023).

2.3 Service scheduling characteristics

Allocating resources to complete tasks within a specific planning horizon while considering various operational constraints like resource capacity or unavailability, due dates, priorities, cancellations, and more is a common decision-making process in many service systems. This process, called scheduling, has many uses in healthcare, logistics, distribution, workforce management, and computer science (Conway et al. 1967; Pinedo 2012). As previously stated, service systems are different from manufacturing ones in many aspects. There are a lot of these distinctions that have an impact on how the activities are scheduled (Aggarwal 1982). In general, Articulating the characteristics of a typical service organization's scheduling systems is more challenging than elucidating the features of a generic manufacturing system. The scheduling operations of a service company frequently encounter various challenges. They may need to address the reservation of resources such as trucks, time slots, or other resources. This includes the allocation, assignment, and scheduling of equipment, as well as the allocation and scheduling of personnel (Pinedo 2009). Scheduling plays a crucial role in this complex system due to the abundance of variants. The activities that are scheduled are influenced by a wide variety of elements (Gür and Eren 2018). There are many different types of service systems in the actual world, each with its own unique set of constraints and objectives (Georgiadis et al. 2019). Scheduling problems in service systems vary widely in the literature. However, from a broad perspective, scheduling problems in service systems can be categorized based on four characteristics: time horizon, service operation type, state of nature, and service component. These categories will be thoroughly detailed below.

(a) Time Horizon

Anticipating future events necessitates making decisions in advance, highlighting the importance of planning in service sectors. Based on the time horizon, planning problems in service systems are contextualized by researchers by differentiating between strategic (long-term), tactical (medium-term), and operational (short-term) approaches (Alvarez et al. 2020; Gkiotsalitis 2022). Decisions like capacity planning and allocation, which have a significant lead time, fall under the strategic level (Ksciuk et al. 2023; Sistig and Sauer 2023). These decisions are taken at a high level because they are not easily changed. The operational level entails controlling flows and coordinating activities, whereas the tactical level involves putting strategic decisions into action (Akhavizadegan et al. 2017; Pasha et al. 2020; Satici and Dayarian 2024; Teck and Dewil 2022). An initial plan for ongoing operations is established through tactical planning. The evaluation is based on approximate times and quantities for the flows and resources at this level. Detailed instructions for instantaneous execution and control are the focus of the operational level, where a high level of detail is anticipated (Stadtler and Kilger 2005). In other words, decisions at the strategic and tactical levels have repercussions at the operational level. In the case of a home healthcare firm, for instance, dividing patients into service regions is a strategic decision. On a tactical level, each customer's visiting days are identified, and daily routes must be arranged on an operational level (Di Mascolo et al. 2021).

(b) Service Operation Type

By primary function, service industries can be classified as Communications, Education, Entertainment, Financial services, Government services, Healthcare, Hospitality and leisure, Insurance, Professional Services, Retail and wholesale, Transportation, and Utilities (Daskin 2010). The significant problems of planning and scheduling should be addressed in these systems.

Numerous scheduling classifications have been described in the literature; however, (Pinedo 2009) classified service scheduling into five distinct models: project scheduling, workforce scheduling, transportation scheduling, timetabling and reservations, and entertainment scheduling. Project scheduling is common in services systems, including consulting, systems installation, maintenance, and repair. In project scheduling, all previous tasks must be completed in these systems before starting a new one. The objective is to reduce project completion time while adhering to the precedence constraints (Hartmann and Briskorn 2022; Herroelen 2005). Workforce scheduling involves arranging work schedules and assigning staff to shifts to meet changing resource demands. These issues are crucial in such organizations like telephone operators, hospital nurses, and transportation systems. These environments have extended, irregular operations and fluctuating staff needs (Bandi and Gupta 2020; Rählmann et al. 2021). Timetabling and reservation are mathematically similar yet have distinctions. In a reservation system model, every activity has a definite start and end time; thus, there is no slack. In timetabling, the activity must be planned inside a time window, and there may be space between the start and end times. Namely, in timetabling, job start and end times are not set. Exam scheduling and hospital operating room scheduling are examples of service timetabling issues (Chamberlain et al. 2021; Thepphakorn and Pongcharoen 2023; Sylejmani et al. 2023). Scheduling is essential for airlines, railroads, and shipping. These forms of transportation with distinct characteristics have caused various scheduling problems in the transportation systems. A trip or flight leg must be completed within a specific timeframe and processing limits in these systems (Abdelghany et al. 2017; Ksciuk et al. 2023). Entertainment scheduling includes tournament and broadcast scheduling. Tournament scheduling incorporates a league with teams and a specified number of games in specific time windows (Dong et al. 2023; Ribeiro et al. 2023). Major television networks have many shows to broadcast, which must be assigned to time slots to optimize a given objective function (Commander 2009).

(c) State of Nature

Considered characteristics in the existing service scheduling models indicate the differences between service firms' operations. Many modelling choices have been developed due to the characteristics incorporated into the problem formulation. A key attribute is whether a system's state is deterministic or stochastic. In deterministic scheduling models, a collection of activities needs to be executed by servers to optimize specified performance metrics. Deterministic scheduling is distinguished by predetermined knowledge of processing timings, setup times, due dates, ready times, and weights. They are presumed to be unaffected by uncertainty (Baker and Trietsch 2019; Framinan et al. 2019). Stochastic scheduling problems, on the other hand, do not take the variables utilized in the scheduling model for granted. In place of the deterministic values, appropriate probability distributions are used. When working with processes whose behavior can be foreseen as a whole, from beginning to end, deterministic models are utilized. When insufficient data or the input variables fluctuate within a specific range, making accurate estimates of them impossible, stochastic models are employed instead (Constante-Flores et al. 2023; Pinedo 1983). Stochastic models are utilized when it is impossible to determine input variables precisely due to insufficient information or their fluctuation within a specific range (Shabtay and Gilenson 2023).

These scheduling models fall into one of two categories: static and dynamic. Static models depict a process at a specific moment in time. The inputs and internal variables of the model solely determine the outcomes of these models. Dynamic models can represent processes that undergo changes and evolve over time. These models take into account current inputs and outputs from prior time points. The results of dynamic models are also time-dependent. The complex nature of services makes real-world scheduling problems challenging to resolve, as many service scheduling problems fall within stochastic and dynamic settings (Cheng et al. 2019; Mahes et al. 2024). When these groups are considered together, a new set of scheduling problems arise for which many techniques exist in the literature. The complex nature of services makes real-world scheduling problems challenging to resolve, as many service scheduling problems fall within the categories of stochastic and dynamic settings (Shen and Yan 2023).

(d) Service Component

When it comes to scheduling problems in the service industry, our literature reveals that those features can be divided into three groups depending on whether they concern the "service type", "customers", or "servers" (Núñez-del-Toro et al. 2016). The term service means using skills for another's benefit and providing a solution and experience that meets client needs. Besides, a service system is a set of operations carried out by resources to satisfy a customer's requirements or gratify their wishes. Service systems comprise providers and customers collaborating to co-produce

Table 2 Common service scheduling problems based on features

Type of Service	Customers	Servers
Call Centers	People	Phone agent
Maintenance Systems	Machines	Repair crew
WEEE (emptying boxes)	Collection stations	Trucks
Home Health Care	Patients	Nurses and doctors
Bank services	People	Tellers
Performing selling activities	Supermarkets	Salespersons
Page transmission	Pages	Channels
Stock Replenishment	Retailers	Vehicles

value through intricate value networks (Vargo and Lusch 2008).

Service scheduling models result from combining these three key attributes in formulating the problem. Each of these terms has its characteristics in scheduling problems and can be grouped according to their nature. Some well-known scheduling problems that consider these three factors are listed in Table 2 (Jafar-Zanjani et al. 2022; Phusingha 2021; Rasmussen et al. 2012). For example, in the Waste Electrical and Electronic Equipment scheduling problem (WEEE), companies selling electrical or electronic equipment collect the full storage containers from stations and recycle their contents. They can plan for a truck to visit numerous collection points daily. Therefore, there is a group of customers (collection stations) who want a service (such as emptying boxes) and a set of servers (such as trucks) who can provide that service (Elia et al. 2018; Fernández et al. 2017). The home healthcare scheduling problem is another example; it involves a set of customers (patients) with a variety of service requests (medical and paramedical needs) that must be fulfilled by a set of servers (including doctors and nurses).

In this section, we propose a framework based on the main characteristics of scheduling problems in the service sector, as shown in Fig. 1. The proposed framework has considered the various characteristics of service scheduling problems by considering the queueing attributes. Service scheduling models can be broken down into several categories based on the service type, customers, and the number of servers, which will be explained in detail below.

2.3.1 Customers

A customer is called an individual, group, or organization arriving at a facility and requires a response or action, such as people, machines, trucks, and emails. However, in field

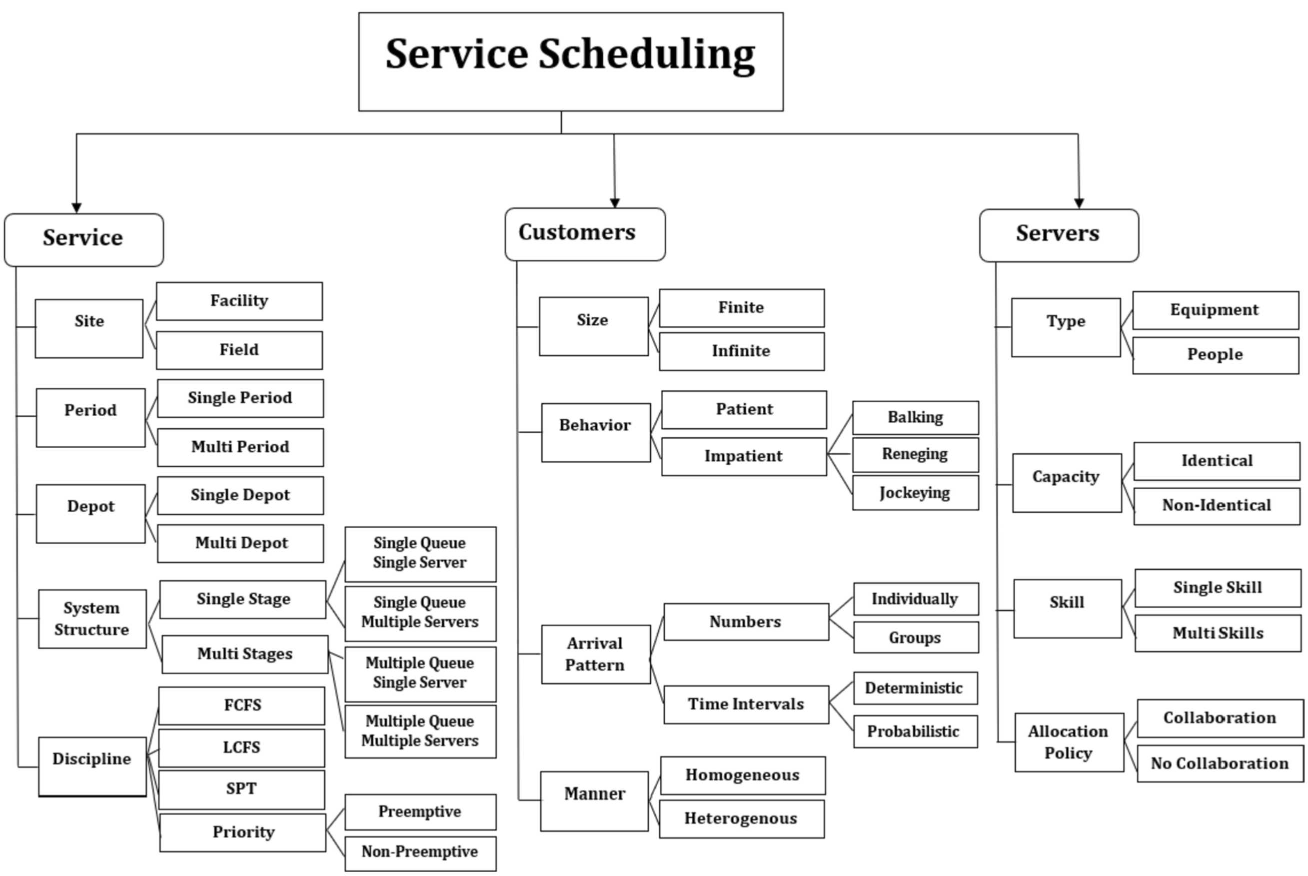


Fig. 1 Classification of Service Scheduling Models

services, it is the workers who need to get to the customers' locations to provide field services (Frits and Bertok 2021). Customers can be defined or classified in service scheduling problems based on four main attributes: size, behavior, arrival pattern, and type.

(a) Size

Regarding the first attribute, size, for potential customers, finite or infinite populations can be assumed. When dealing with large service systems, we usually assume the population is infinite. For example, (Mtonga et al. 2022) considered an infinite population source for the healthcare staff scheduling problem, where the number of patients arriving at any given time is unlimited, making it possible for the system to exceed its capacity at any time. Despite its prevalence in queueing applications, the theoretical analysis of queueing systems rarely considers the scenario of a finite population of customers arriving and being served within a particular duration (Haviv and Ravner 2021).

(b) Behavior

Customers can be broken down into two groups—the patient and the impatient—based on their behavior in line. Impatience is the predominant characteristic exhibited by those who desire to receive a service but are required to wait in a queue. Despite being overlooked by researchers in the study of service scheduling, it is crucial to consider the impatience of consumers while analyzing queueing systems, especially for urgent on-demand services with time-sensitive clients, to represent real-world scenarios accurately (Bai et al. 2018; Wang et al. 2010). There are two terminologies employed in a queueing system to characterize customers' impatient behavior. Impatient customers can balk at joining the queue, leave the queue before receiving service (reneging), or switch to a different queue if they believe they will be serviced more quickly there (jockeying) (Dudin et al. 2023). If the service provider wants to keep as many clients as possible in the queue while demand is high, they are incentivized to increase the service rate (Lin et al. 2022; Puha and Ward 2019).

(c) Arrival Pattern

As the name implies, the arrival process concerns information about how, when, and where customers or jobs join the system. Customers can enter the system individually, in batches, or in bulk (Medhi 2002). An adaptable bulk-service queueing system with a single server is studied by (Pradhan et al. 2022). In this system, clients arrive using the compound Poisson process, and the service time depends on the batch size being processed. (Wirth and Emde 2018) examined the scheduling problem when a truck fleet shows up at a manufacturing facility to deliver components to designated dock doors. In this study, trucks visit a given set of doors and have individual arrival and due dates. According to the research by (Zhang et al. 2020)the pickup and delivery vehicle routing issue is examined by considering multi-batch arrival patterns.

(d) Manner

Customers can be defined based on their required service type, which refers to the duration of the service and interarrival times. They can be considered homogeneous (Lei et al. 2015; Qiu et al. 2022) or heterogeneous (Jafar-Zanjani et al. 2022; Keskin et al. 2019; Wang et al. 2022). A homogeneous customer population is one in which customers require essentially the same type of service. In fact, the service time or interarrival times are equal for all customers. In contrast, a heterogeneous customer population is one in which customers can be categorized according to different service times and inter-arrival times (Núñez-del-Toro et al. 2016). Many service systems are naturally heterogeneous but can also be engineered into their design and management. Even though the system has the same total workload, heterogeneity can result in different performance levels due to different inter-arrival and service time features. When there is evidence that the typical assumption of evenly distributed interarrival and service times is not supported, it is crucial to account for arrival and service time heterogeneity (Wang et al. 2014).

2.3.2 Service

In every service firm, the customer enters the system, waits for the requested service, and exits it after receiving it. This is the core of a service system. The service itself discusses numerous aspects, including the location of the service, service discipline, system structure, service type (depending on the period and depot), and service pattern.

(a) Site

Depending on the planned operations, service planning can be accomplished in two primary ways: in the field or at the factory. In contrast to "field service," where all operations occur at locations chosen by the customer, "factory-based services" encompass all service processes that can be performed at a centralized location (Yang et al. 2022). Namely, any service provided to customers at their location is called "field services" (Bender 2017). There are various field services, including sales personnel of consumer goods manufacturers, engineering technicians for service maintenance, and home health care nurses. For most companies, field service scheduling is one of the most operationally complex tasks, as service personnel must be divided among numerous jobs at numerous locations. Moreover, this problem involves numerous rapidly changing variables and moving parts(Frits and Bertok 2021). Allocating employees efficiently and establishing proper planning routes are two crucial factors in maximizing the effectiveness and quality of field services (Wu et al. 2021). In field service operation problems, the number of tasks within the planning horizon typically exceeds the number of available service groups. Consequently, each group is required to carry out additional activities at various locations. Hence, the workforce scheduling and routing problem (WSRP) emerges as a problem that encompasses task assignment, scheduling, and routing (Wang et al. 2014).

(b) Period

In the literature, service scheduling problems are classified as either single-period or multi-period, depending on the planning horizon. Whereas single-period problems refer to settings where a single working day is assumed as the planning horizon (Harahap and Rahim 2022; Ceyhan and Özpeynirci 2016; Fathollahi-Fard et al. 2020; Yalçındağ et al. 2016), multi-period service scheduling involves satisfying customers' needs with recurring requests for services like delivery, collection, maintenance, and care (Fikar and Hirsch 2017; Núñez-del-Toro et al. 2016). It is important to note that periodic and multi-period services are sometimes used interchangeably but have distinct meanings in the literature on service scheduling issues. Despite their distinctions, there is no definitive way to separate these two words in the existing literature.

Periodic service scheduling is a subset of multi-period service scheduling. In other words, "periodic scheduling" is a "multi-period scheduling" generalization considering a repeated planning horizon and a fixed level of client demand. While periodic scheduling focuses on the tactical or strategic level, multi-period scheduling is used on a more operational short-term planning horizon. However, it is not necessarily restricted to single visits only. The features that distinguish multi-period scheduling from periodic scheduling are each customer's single visit frequency and the service's lack of periodicity. The concept of periodicity suggests that the created tour plan is cyclical, with the final day of a planning period followed by the first day again. A survey of the relevant literature on multi-period and periodic service scheduling can be found in (Archetti et al. 2017; Liu et al. 2021; Phusingha 2021; Rothenbächer 2019; Salazar-Aguilar et al. 2019; Vogl et al. 2019).

(c) Depot

In the case of field services, where operations occur at customer-specified locations, service scheduling problems can be divided into a single depot and multiple depots based on the location from which resources are dispatched. The main distinction between the two terms is whether or not the assigned resource comes from a centralized location or several distribution centers (Teng et al. 2015). The Multiple-Depot Scheduling Problem plays a crucial role in scheduling transportation systems. It involves allocating a group of journeys to a fleet of vehicles to minimize a specific overall cost. The problem becomes much more complicated when considering multiple depots where vehicles must begin and end their path across the network. While several polynomial time solutions have been created for the scenario with a single depot, it has been proved that the problem becomes NP-hard when considering multi-depots (van Lieshout and van der Schaft 2023).

(d) System Structure

The system structure considers how customers enter and exit the service system. A customer enters the system and is either instantly served or invited to join a waiting line based on whether or not the server is currently busy at the moment of the customer's arrival. Single-stage and multi-stage service mechanisms exist, depending on the service's specifics. Most prior research on service scheduling issues has been conducted in single-stage service systems, which involve only one service process. Numerous new research projects focus on multi-stage service systems, where customers undergo several service phases before being satisfied (Zhou and Yue 2021). To enhance queue efficiency, the service facilities can adopt either of the following services structure based on the nature of the service (Ranadheer Donthi et al. 2019).

1. Single queue single server: Each customer goes through a single waiting phase and receives service from a single server. Just for one service, they have to stand in line once.
2. Single queue multiple servers: Under this setup, multiple servers are available to serve a single line of customers at once. When a single service becomes accessible, they wait in line once and then head to the server that opens the quickest.
3. Multiple queues single servers: In this scenario, customers wait in line after line before receiving service from a single server at a time. They use the service multiple times, requiring them to wait in line
4. Multiple queues multiple servers: This structure consists of multiple queues and servers doing the same type of a task. Customers must wait in line multiple times for various service phases, and the first available server serves them throughout each step.

Hospital settings and outpatient clinics are other examples of this type of service. Patients entering a clinic environment will pass through facilities such as registration, pre-exams, post-exams, x-rays, laboratories, and checkouts (Behnamian and Gharabaghli 2023; Cayirli and Veral 2003; Klassen and Yoogalingam 2019).

(e) Discipline

When a queue of customers has to be served, "service discipline" is the rule by which they are logically prioritized. Waiting times could be considerably altered depending on how service discipline is adhered to (Lakshmi and Iyer 2013). The most common Discipline is FCFS (First Come, First Served), in which requests are executed in the order of arrival. There are also SPT (Shortest Processing Time), LCFS (Last Come, First Served), EDD (Earlier Due Date), and priority systems (Preemptive and Non-Preemptive). Sometimes it is important to execute higher-priority tasks immediately, even when a task is currently being executed, called preemptive priority scheduling (Ghanbari et al. 2022). Unlike preemptive priority scheduling, in non-preemptive scheduling, even if a task with higher priority does arrive, it has to wait for the current task can be executed (Master et al. 2018).

2.3.3 Servers

Services are a set of functions carried out by servers and resources to fulfil customers' needs. Each server's capacity and the number of servers in operation determine a system's capacity. The term server, another key element of a service system, refers to the resources such as receptionists, repair personnel, runways in an airport, nurses, and so on that provide the requested service. Depending on the type of service system, servers can be classified by several attributes, including type, class (capacity and skill), and allocation policy.

(a) Type

Every service firm has a set of servers or operators that can provide the service in the facility, at the customer location, or remotely. Depending on the situation, servers can take many forms (Leung 2004). They may include nurses, call center operators, vehicles, repair crew, machinery, and equipment in service enterprises (Blazewicz et al. 2023; Özder et al. 2020). Managing machinery, trucks, tools, and facilities are all part of equipment scheduling. On the other hand, people scheduling is concerned with the administration of human resources in the service systems. Scheduling for Vehicle Routing, and Maintenance are the two most often cited equipment scheduling problems in the literature (Afsharnia et al. 2014; Jafar-Zanjani et al. 2022; Mohammadi et al. 2023). The most well-known problems regarding people scheduling include healthcare staff scheduling, shift scheduling, and crew scheduling (Amberg and Amberg 2023; Anderson et al. 2023; Becker et al. 2019).

(b) Class

Scheduling of services relies heavily on the accessibility of resources. The capacity of a resource and the time required to complete each service determine how many services can be provided in a given time frame. In particular, resources can have the same capacity (homogeneous or identical) or wildly different ones (heterogeneous or non-identical) (Saravanan et al. 2023). In the homogeneous context, each server exhibits uniform processing capabilities, enabling it to handle activities or tasks at the same rate (Fernández et al. 2017). For heterogeneous servers, each server can possess distinct processing speeds, capabilities, or efficiencies. This adds an extra level of intricacy to the scheduling problem, as activities must be allocated to resources while considering their differing capacities (Keskin et al. 2019). When taking into account potential service times, scenarios with identical service durations lead to identical capacity scenarios. Conversely, a heterogeneous capacity situation results from a scenario with varying service durations (Núñez-del-Toro et al. 2016). When considering homogeneous and heterogeneous attributes, servers can be placed into these two categories concerning the required skills: single-skill scheduling problems and multi-skill scheduling problems (Bocewicz et al. 2023; Demirbilek et al. 2021).

(c) Allocation Policy

The allocation of resources may arise in several situations. In some of them, more than one entity is responsible for the execution of the service. In most cases, each entity operates alone in a no-collaboration setting. As a result, each group makes its own decisions. When there is no coordinated effort, each individual or group handles its allocation of resources for the services it is responsible for (Núñez-del-Toro et al. 2016). In contrast, joining a coalition and collaborating in a horizontal logistics coalition can significantly enhance operational efficiency. In this context, transportation companies are teaming streamline their operations to share trucks and meet client demand (Pan et al. 2019). According to practical studies, alliance formation is advantageous for suppliers and customers since it reduces prices and travel distances (Fernández et al. 2018).

3 Materials and methods

This section contains a description of the techniques that were carried out for this investigation. This study presents a picture of the structure, evolution, and dynamics of scheduling problems in service systems by conducting a bibliometric analysis of academic and social networks.

3.1 Bibliometric analysis

Scientific fields and publications increasingly use bibliometrics to study patterns in time, content, collaboration, and citations (Laengle et al. 2017; Merigó et al. 2018). This analysis combines diverse frameworks, tools, and methodologies to identify global research trends on a given topic. This study uses the bibliometric technique to survey and assess the preexisting literature. Bibliometrics, the study of bibliographic data using quantitative methods, is being utilized more frequently to examine temporal, content, collaboration, or citation patterns in scientific areas or journals (Cancino et al. 2017). Using this quantitative method, we can gain insight into the history, current state, and possible future research orientations of a field of study (Arora and Chakraborty 2021).

3.2 Software tools

Two software tools, including CiteSpace and VOSviewer, are employed in our research. These software tools, which specialize in bibliometric analysis and science mapping, are used at various levels of analysis in this study.

CiteSpace runs network analysis and burst detection using data from scholarly publications' bibliographies. Collaboration, author, and document co-citation networks are only some types of networks that can be analyzed structurally and temporally in CiteSpace (Chen 2006).

VOSviewer is a software tool for building and visualizing bibliometric networks. This software can work with different data formats and built-in network analysis toolboxes (Geng et al. 2020; Van Eck and Waltman 2010). Moreover, it aids in delivering clear visual findings that better comprehend the results (Abdollahi et al. 2021). VOSviewer is employed in this paper mainly to generate a better visualization of networks.

3.3 Data collection

In this article, we employed the Web of Science (WoS) database as a source of bibliometric data for the research sampling procedure. This is due to WoS's extensive coverage of the world's best journals and pertinent publications. The software tools can directly read the format of articles downloaded from the WoS we introduced above. This gives WoS an advantage over other databases. WoS is a well-known scientific citation index database that collects metadata such as abstracts, references, the number of citations, author lists, institutional affiliations, geographic regions, and the journal's impact factor. In this bibliometric review, we followed several stages for identifying and searching for the appropriate documents from WoS (Fig. 2).

The terms "scheduling" and "service*" were searched in the topic section. We identified 17,138 documents. The results were then filtered based on the "Document Type,". We only selected the "Article" document type as these documents undergo a peer review process and provide complete metadata for bibliometric analysis. In addition, we only selected English for the language of the articles under analysis in this study. Our analysis includes publishing data spanning from 1982 to 2023. Two Web of Science

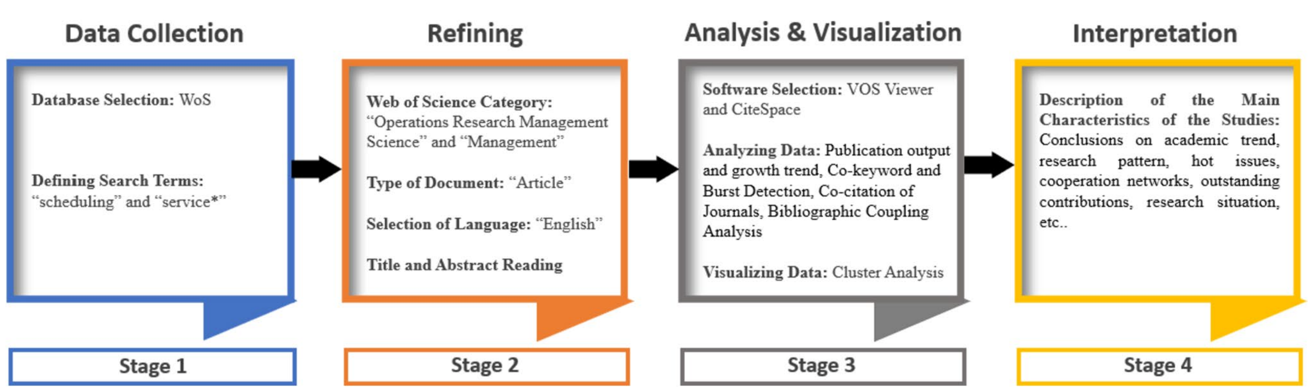


Fig. 2 Stages of Bibliometric Analysis on Service Scheduling

Table 3 Search criteria

Filters	Search Criteria	Number of Articles
Topic	"Scheduling" AND "Service*"	17,138
Document Type	Article	16,685
Language	Only English	16,574
Research Years	1982–2023	16,554
Web of Science Category	"Operations Research Management Science" And "Management"	2524
Title and Abstract Reading	Remove irrelevant Articles	1991

categories, "Operations Research Management Science" and "Management," have been considered. Next, we evaluated the titles and abstracts of the remaining papers to determine if they were relevant to the purpose of this research. Articles unrelated to the topic (such as those about wireless network scheduling) were excluded. A total of 1991 scholarly journal articles were found due to this procedure. Table 3 presents the criteria and filters used in our data collection.

4 Findings

4.1 General analysis of scheduling in services

This section examines the topic from a broad perspective, looking at the most productive regions, organizations, and publications. We give a performance analysis using bibliometric variables such as the number of documents published, citations received, the H-index, and a variety of other ratios.

4.1.1 Publication and growth trend in service scheduling

Figure 3 presents the annual number of documents published. The number of publications relating to service scheduling has grown during the studied period. Between 1982 and 2023, 1991 scientific documents were published. In 1982, (Aggarwal 1982) article, one of the most influential papers, contrasted the specific characteristics of services to manufacturing systems in this study. Compared to later years, the number of publications remained limited until 1990. Since 1991, many scientific papers have been published, and the development of published articles has followed an upward trend. This is because, during the 1990s,

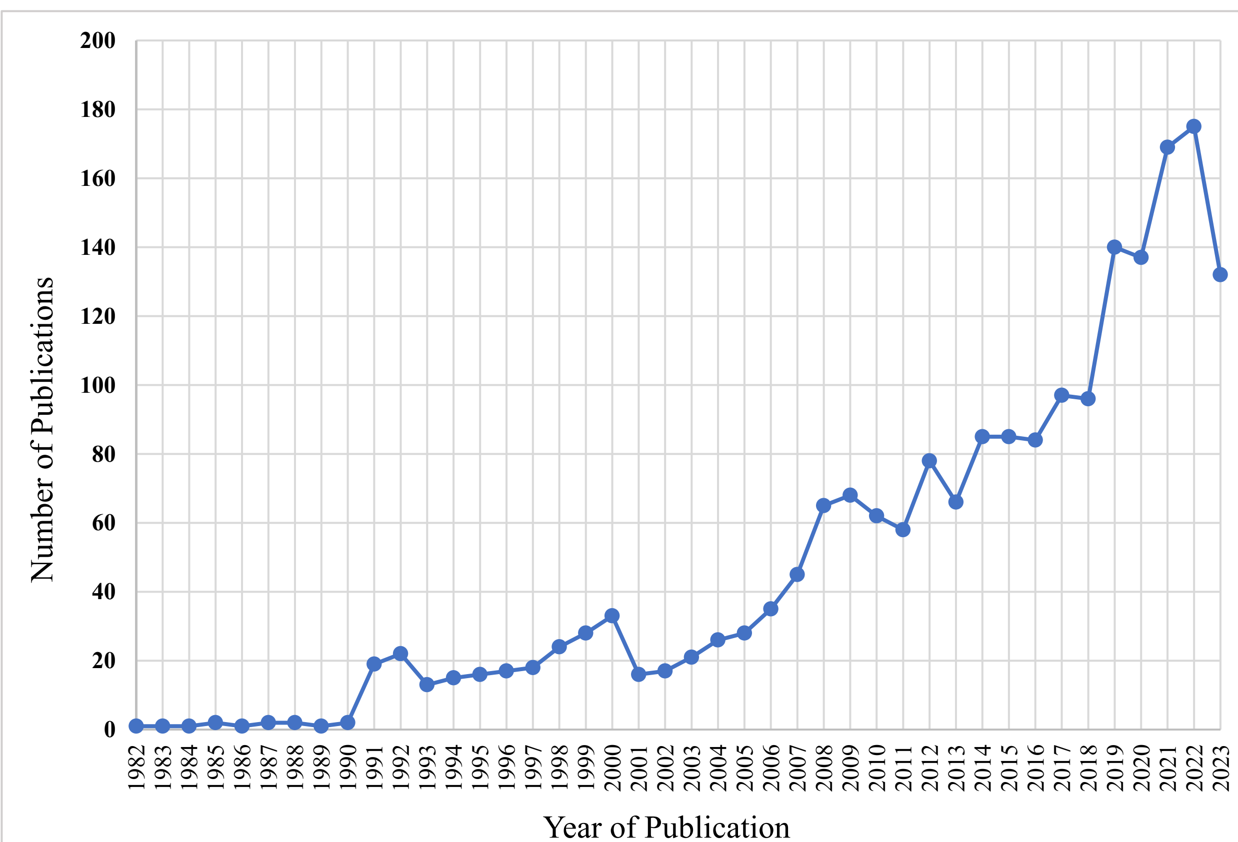


Fig. 3 Yearly Output of Articles from 1982 to 2023

the modern economy experienced a structural transition, with the service sector increasingly becoming its focal point (Xing et al. 2013; Xu et al. 2012). As can be seen, there is a decrease in the number of papers for this year (2023) since not all publications from this era have been included in the study. This is because 2023 is still underway. Although the final results show a rise in the total number of published articles, particularly after 2019, this evolution has been erratic, with sequential upward and decreasing trends over several years. However, we can anticipate that the research publication will sustain its continuity and rise in the upcoming years.

4.1.2 Influential countries

Regarding the country factor, we use nine indicators to evaluate publications: the total number of publications (TP), the total number of citations (TC), the average number of citations per publication (TC/TP), the percentage of TP accounting for total publications (%TP), the number of publications that are cited at least 200, 100, 50, and 20 times, and the H-index, which can measure both the productivity and citation impact of a scientist's or scholar. Two key factors justify using these indicators. First, these variables can indicate the general situation of publications and are utilized in the bibliometric analysis. Second, with several indexes, these metrics can indicate publication characteristics. Table 4 lists the top 12 countries/regions based on statistical analysis.

According to TP, TC, and %TP, the USA is the most prolific country with 667 publications, followed by China (367) and Canada (185). Canada is the most TC/TP country with 38.83, denoting that they have received the highest recognition per publication, followed by Italy (33.70), the Singapore (31.04), USA (30.52), and Belgium (29.70). In order to understand these publications in detail, the top 15 highly authoritative publications are listed according to the number of citations, shown in Table 5.

Table 5 The information of top 15 highly authoritative publications

Rank	Author	Citation	Citation/Year
1	(Desrochers et al. 1992)	641	20.3
2	(Gupta and Denton 2008)	585	36.56
3	(Crainic 2000)	387	16.13
4	(Dumas et al. 1991)	353	11.36
5	(Cachon et al. 2017)	375	48.29
6	(Crainic et al. 2009)	338	22.2
7	(Potts and Wassenhove 1992)	333	9.75
8	(Drexl 2012)	300	25
9	(Agarwal and Ergun 2008)	281	17.56
10	(Gendreau et al. 1999)	270	10.8
11	(Cordeau et al. 2005)	252	13.26
12	(Rasmussen et al. 2012)	246	20.5
13	(Bertsimas and Van Ryzin 1991)	242	7.33
14	(Jabali et al. 2012)	225	18.75
15	(Patrick et al. 2008)	220	13.75

4.1.3 The most cited publications

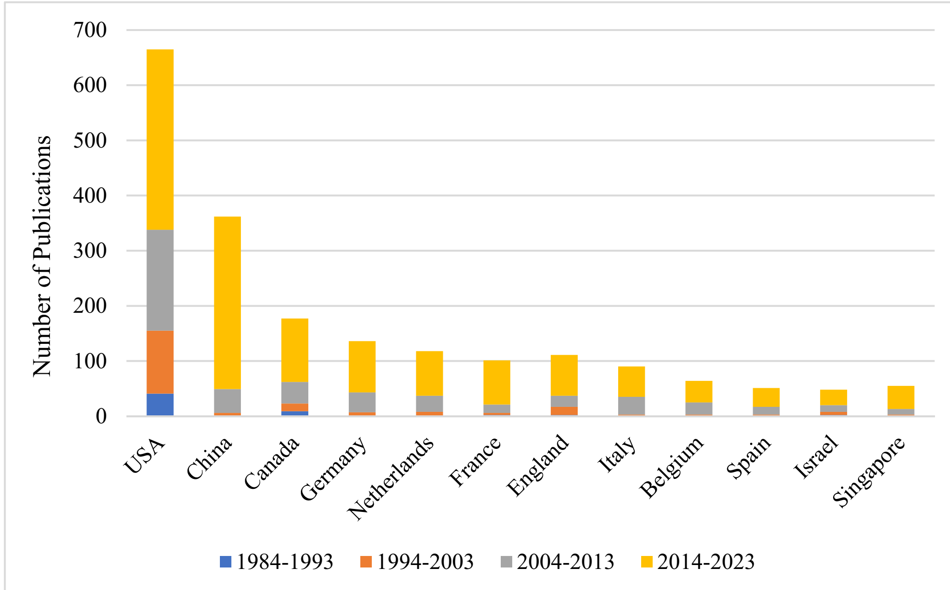
Table 5 shows the 15 highly authoritative publications. According to citation, the first place is the work of (Desrochers et al. 1992), followed by (Gupta and Denton 2008) and (Crainic 2000). Besides, the article of (Cachon et al. 2017) is the best in line with citation/year, indicating that it has been widely recognized since the paper was published.

In order to better describe the development from different times, the forty last years is separated into four subperiods (1984–1993, 1994–2003, 2004–2013, 2014–2023). The publication count for each period is displayed in Fig. 4. This figure can be split into four sections based on the total number of articles. The number of publications in the United States is the highest, followed by China. Around 65% of global publications were published during 2014–2023, while 1984–1993 publications account for a disproportionately

Table 4 The 12 most prolific countries

Rank	Country	TP	TC	TC/TP	%TP	H index	> = 200	> = 100	> = 50	> = 20
1	USA	667	20357	30.52	33.50%	72	7	37	128	318
2	China	367	6995	19.06	18.43%	44	0	8	35	119
3	Canada	185	7184	38.83	9.29%	46	8	15	40	89
4	Germany	139	3770	27.12	6.98%	35	2	7	20	51
5	Netherlands	121	3020	24.96	6.08%	32	1	4	15	51
6	England	111	2905	26.17	5.58%	32	2	8	20	45
7	France	106	2651	25.01	5.32%	28	2	4	15	38
8	Italy	91	3067	33.70	4.57%	31	3	5	19	41
9	Belgium	64	1901	29.70	3.21%	24	1	5	10	27
10	Singapore	57	1769	31.04	2.86%	23	0	5	11	24
11	Spain	53	1090	20.57	2.66%	20	0	0	4	20
12	Israel	50	964	19.28	2.51%	16	0	2	5	12

Fig. 4 The Development of the Publications in the Top 12 Prolific Countries



small portion, accounting for just about 3%. In the fourth period, the number of publications in China accelerated rapidly.

4.1.4 Journals with the most publications and citations

We assessed the most referenced and influential journals to determine the most influential ones affecting the various research streams. Table 6 displays the 15 journals that have received the highest citations and editorial attention in service scheduling. Based on our analysis of the total number of articles in the sample database, the top 15 journals by total citation count account for over 61% of all articles. As an absolute number, we identified 1216 out of 1991 papers published in the top 15 journals. The most cited journal is the European Journal of Operations Research, with 256 documents and is cited in a total of 8957 citations with an average citation per document of n = 34.99. Second, the most-cited journal is Computers Operations Research, with 142 documents and 3645 citations, with average citations per document TC/TP of 25.67. The third most-cited journal is Transportation science, with 81

Table 6 The most cited publications

Rank	Journal	Documents	Citations	H-index	Total Cites Per Doc
1	European journal of operational research	256	8957	51	34.99
2	Computers Operations Research	142	3645	37	25.67
3	Transportation science	81	4800	39	59.26
4	Transportation Research Part B Methodological	80	3359	34	41.99
5	Operations research	75	3615	32	48.20
6	Annals of Operations Research	69	1191	18	17.26
7	Queueing Systems	68	901	17	13.25
8	Transportation Research Part e-logistics and Transportation Review	67	1907	27	28.46
9	Expert Systems with Applications	63	1307	22	20.75
10	Omega-international Journal of Management Science	61	1706	25	27.97
11	Production and Operations Management	61	2081	25	34.11
12	International Journal of Production Research	52	1144	18	22.00
13	Journal of the Operational Research Society	50	1495	19	29.90
14	IEEE Systems Journal	46	351	12	7.63
15	Management Science	45	2051	27	45.58

documents and 4800 citations, with average citations per document n = 59.26.

4.1.5 Institutions with the most publications and citations

Similar to the analysis of prolific countries, eight indicators are used to evaluate institutions of publications. The top 10 prolific institutions are given among 1450 institutions, listed in Table 7. When looking at all indicators, the top spot goes to the University of Montreal (Canada), which demonstrates with 66 publications, this university outpaces the State University System of Florida (US) and the Shanghai Jiao Tong University (US). Six are American, while the others are from Canada, China, and France. Furthermore, only two universities, the University of Montreal (Canada) and the University System of Georgia (USA) have more than 200 citations for their publications.

4.2 Deep analysis of service scheduling literature

The preceding section provides a rather thorough performance analysis of service scheduling literature. Science mapping, which depicts a study topic's structural and dynamic elements, is offered in this section to strengthen and supplement this analysis (Cancino et al. 2017). This analysis uses approaches including co-citation, keyword co-occurrence, and bibliographic coupling.

4.2.1 Co-citation analysis of journals

Journal co-citation analysis aims to identify highly-cited works (McCain 1991) and their relationship with each other. Each journal's co-citations are represented on the co-citation map by a cluster of "bubbles" or "nodes," each representing a publication in the network. The periodicals are clustered close together because of their high degree of co-citation. The greater the proximity between two periodicals, the more significant the overlap between their articles. This points to a trend of pieces sharing similar themes or subjects. Additional information is provided through a series of lines showing the co-citation relationships between publications from different journals. The same color theme represents comparable topics.

After identifying 13,535 sources in our sample of 1991 articles and setting the minimum number of citations of a source to 20, 322 articles met the criterion and are shown in Fig. 5. he larger the node, the more citations the journal has got.

The investigation of co-citations revealed five unique and coherent clusters, which were depicted on a network diagram. The red cluster is the most significant, with 138 entries, and some journals stand out. "International Journal of Production Research", with a total link strength of 21,724, has the most significant number of direct citations, with 703. Another critical journal in the cluster is the "Queueing Systems", which has 626 direct citations and a total link strength of 15982. "Operations Research Letters" is another publication that stands out, with 402 direct citations and a total link strength of 11,976.

The second cluster, in terms of the number of elements, is the green cluster with 89 items. "Management Science" is the most noticeable journal in this cluster, with 2,334 direct citations and a total link strength of 66,869. Other prominent journals in this cluster are" Operational Research", which has 3,369 direct citations and a total link strength of 91,135, and "Production and Operations Management", which has 1008 direct citations and a total link strength of 35,628.

The blue cluster is the third in size, with 54 items. The "European Journal of Operations Research" stands out from the entire map while being part of the third most numerous clusters. It has received 5,066 citations directly and has a total link strength of 147,688. "Transportation Science", another publication in this group, has received 2,292 citations directly and has a total link strength of 66,840. Another blue cluster publication, "Computers and Operations Research", has 69,425 links and 2,195 direct citations.

Table 7 The top 12 most prolific institutions

Rank	Institution	Country	TP	TC	TC/TP	H index	> = 200	> = 100	> = 50	> = 20
1	Universite De Montreal	Canada	66	4573	69.29	31	7	10	23	40
2	State University System of Florida	USA	50	1618	32.36	25	0	3	12	28
3	Shanghai Jiao Tong University	China	48	1038	21.63	16	0	2	6	14
4	University of Texas System	USA	46	1386	30.13	20	0	1	9	21
5	Hong Kong Polytechnic University	China	44	1025	23.30	20	0	1	6	22
6	Centre National De La Recherche Scientifique	France	42	630	15.00	14	0	0	3	9
7	University of California System	USA	42	1240	29.52	21	0	3	7	23
8	University System of Georgia	USA	38	1129	29.71	18	1	2	5	18
9	University of Michigan	USA	37	705	19.05	17	0	0	2	15
10	University of Texas Austin	USA	37	1015	27.43	17	0	1	5	16

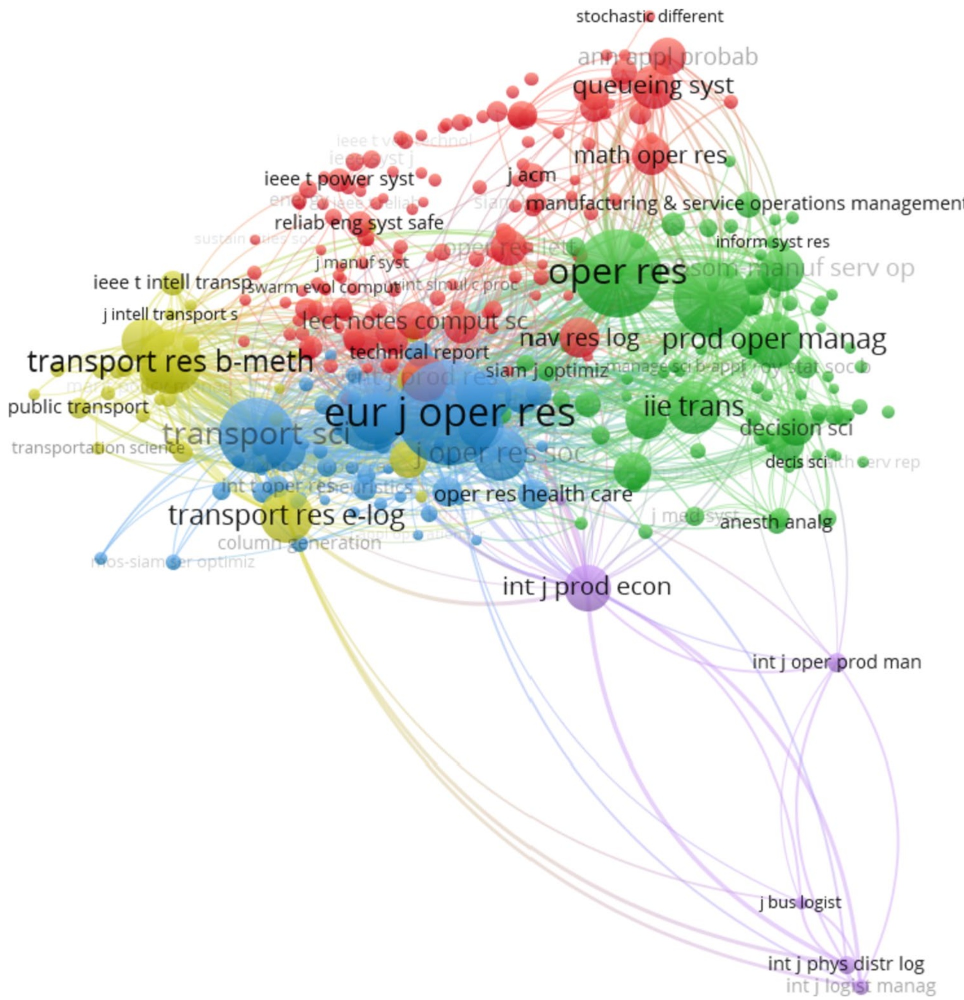


Fig. 5 Yearly Output of Articles from 1982 to 2023

The journals with the fewest cited papers are grouped into the fourth and fifth categories. "Transportation Research Part B Methodological", one of 35 items in the yellow cluster, has received 1454 direct citations and has a total link strength of 47,822. The fifth cluster is colored purple and contains six different things; the "International Journal of Production Economics" stands out among them with 701 direct citations and a total link strength of 27,800.

4.2.2 Co-keywords and keyword citation bursts analysis

The co-occurrence keyword analysis is a method for examining the conceptual framework of a field of study using keywords (Callon et al. 1983). When keywords appear together, it may indicate a wide range of research topics and reveal the domain's multidisciplinary nature and potential growth avenues (areas/sub-areas). In other words, by conducting a keyword co-occurrence analysis, we can see which sets of terms are frequently used by authors. This analysis can reveal general tendencies and patterns in the investigated fields (Callon et al. 1991; Cambrosio et al. 1993).

We built a network map of keywords using the author and Keywords Plus to conduct this analysis. A thesaurus file was created to combine similar words in which similar words were replaced with just one word. For example, the terms "queues," "queueing," and "queueing-system" were all replaced by the term "queueing systems." This gives a better image of the conceptual structure of the topic. Each keyword must occur at least 15 times to be included in the network (Fig. 6). The size of the circles represents the number of keywords being used, the distance represents relatedness and similarities between keywords, and the colors represent clusters. Accordingly, out of 6491 keywords, 220 were used in network mapping. Total co-occurrence link strength was determined for all terms, and they ranked accordingly. Table 8 shows the top 10 keywords related to service scheduling. As expected, the notions of "scheduling problems" and "models" are the major topics in this field. "optimization" and "algorithms" are other significant issues in this area. "Healthcare" is also one of the most widely used terms in scheduling services, which can be attributed to the increasing importance of healthcare services worldwide.

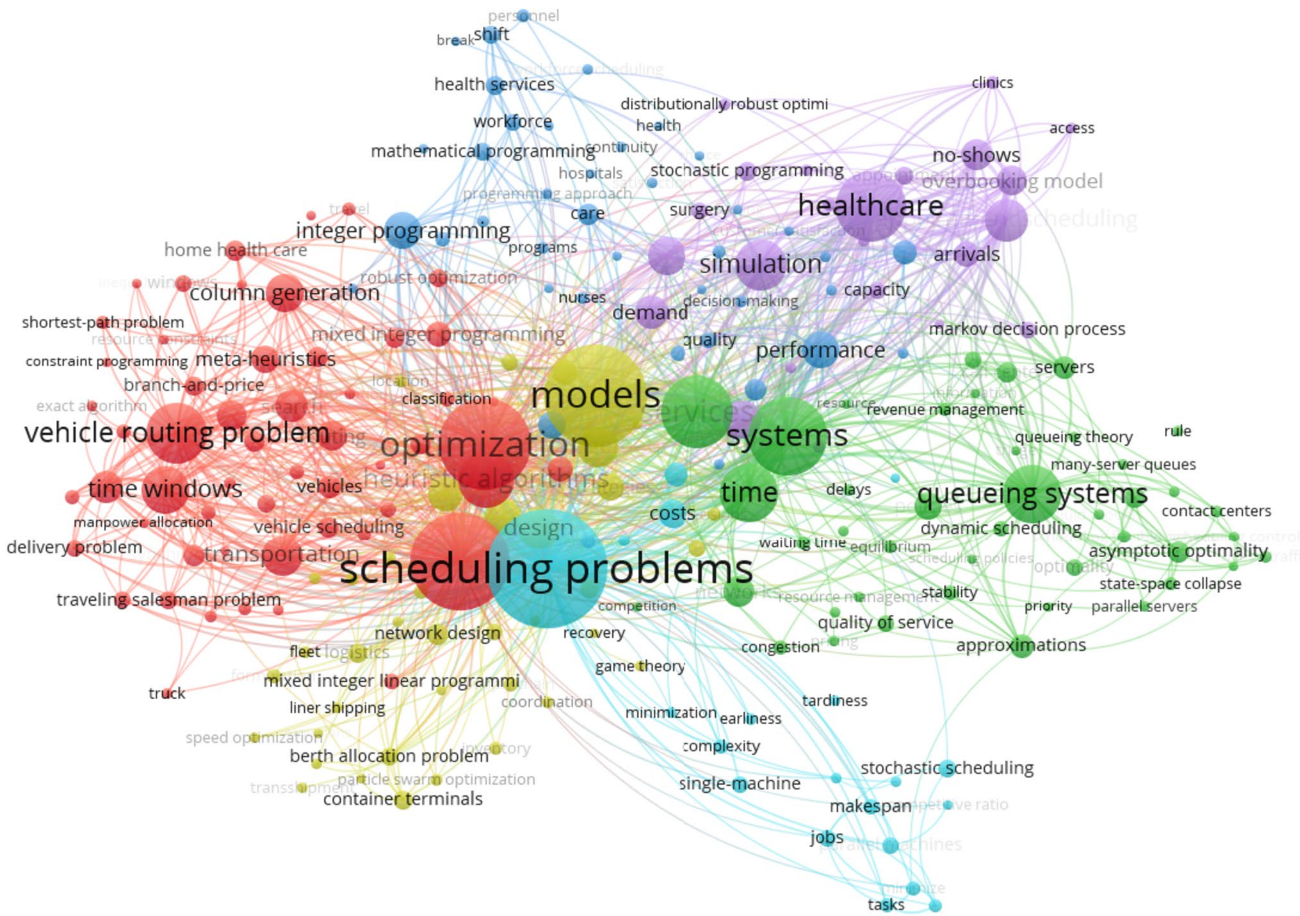


Fig. 6 Keywords Co-occurrences Network

The concepts of "services," "systems," and "time" are also among the concepts that have been of interest to researchers in service scheduling. By changing the view of the network to overlay visualization, concepts and topics can be seen by the year they occurred, whereby emerging themes can be identified. Accordingly, emerging topics in the field of scheduling of services are "no shows," "adaptive large neighborhood search", "synchronization", "abandonment", "distributionally robust optimization", "home healthcare," "fairness," "physician scheduling," and "resource management." Given the growing demand for healthcare services, mainly home care services, the emergence of the concepts that generate the most benefits with the least resources can be expected.

Table 8 The information of top 10 keywords

Keyword	Co-occurrences	Total Link Strength
Scheduling Problems	472	1893
Models	370	1739
Algorithms	351	1560
Optimization	316	1448
Systems	248	1132
Services	218	1052
Healthcare	206	1115
Vehicle Routing Problem	167	835
Queueing Systems	157	633
Time	156	756

Figure 7 provides a map of keyword density, another fascinating perspective on the co-occurrence of keywords. The terms in the yellow area of this map have been used more frequently in the academic literature than their green counterparts. Density visualization maps can potentially alert scholars to developing trends in their field.

Another keyword network analysis is the evolution of keywords over time. For this purpose, the keywords were studied in four 10-year periods according to the last forty years. Accordingly, one can observe the evolutionary process of scheduling problems in the service sector. Some topics are of greater interest in each period, but they receive little attention in another period. Table 9 shows the

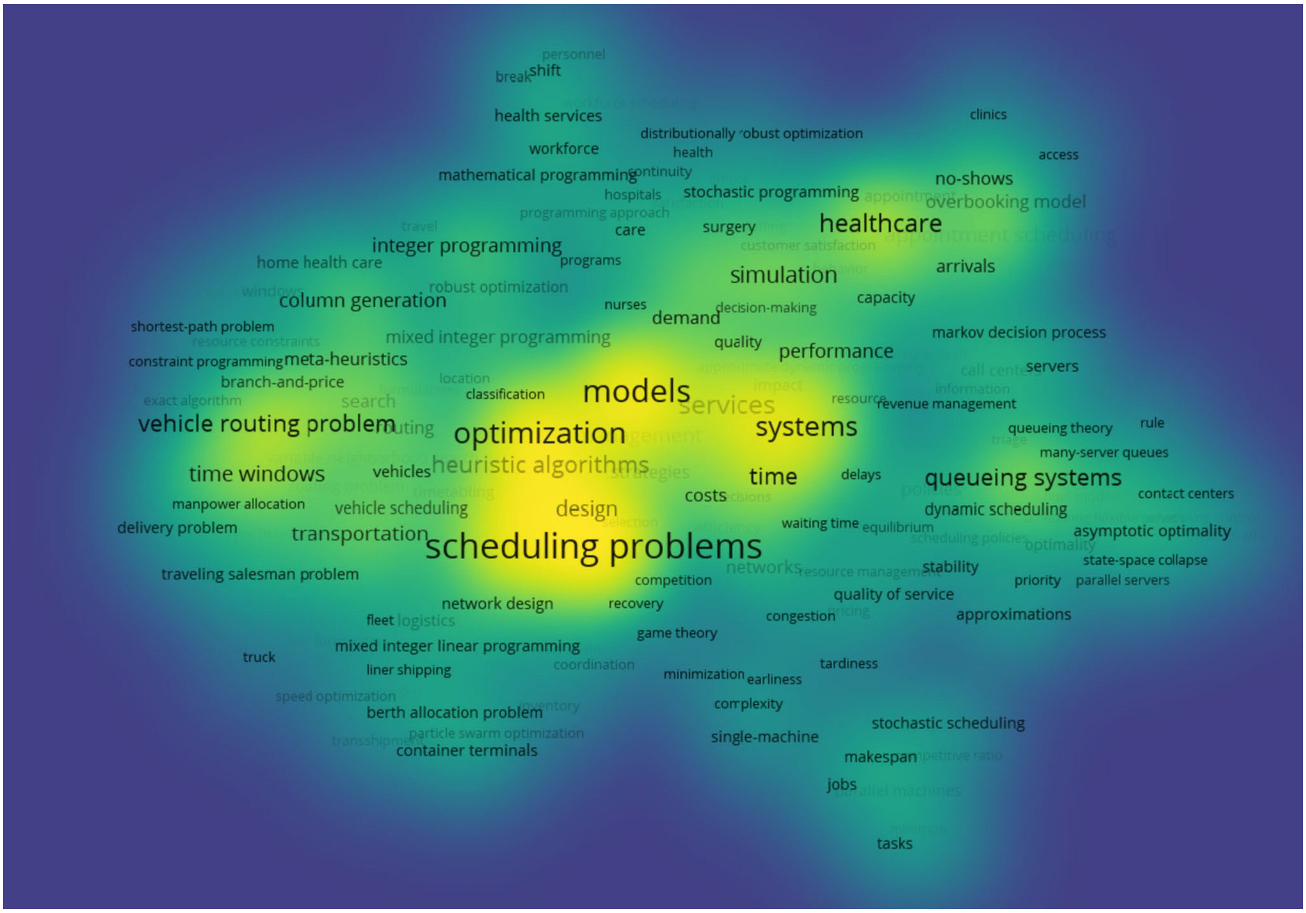


Fig. 7 The density visualization of keywords

keywords for the 1984–1993, 1994–2003, 2004–2013, and 2014–2023 periods:

As seen in Table 9, the concept of "scheduling problems" is of interest in all periods. The researchers emphasized using "heuristic algorithms" for the first three periods. In the second and third periods, attention to queueing systems and optimization models was emphasized more. The concept of "services" is other issues that has been more or less the same

Table 9 The information of top 10 keywords in periods

1984–1993 Keyword	1994–2003 Keyword	2004–2013 Keyword	2014–2023 Keyword
Scheduling Problems	Scheduling Problems	Scheduling Problems	Scheduling Problems
Systems	Systems	Algorithms	Models
Heuristic Algorithms	Heuristic Algorithms	Models	Optimization
Shift	Shift	Systems	Algorithms
Service Operations Management	Services	Optimization	Healthcare
Algorithms	Optimization	Queueing Systems	Services
Mathematical Programming	Algorithms	Services	Vehicle Routing Problem
Tasks	Queueing Systems	Simulation	Time
Exponential Service Times	Models	Vehicle Routing Problem	Appointment Scheduling
Services	Simulation	Heuristic Algorithms	Queueing Systems

in all four periods. The application of vehicle routing problems in the service industry has been one of the research's attentions in 2004 and later. One issue raised in 2014–2023 is the concept of "healthcare systems."

In order to identify the emerging trends in the scheduling of services, we used burst analysis. When determining which keywords within a given time frame have attracted the most interest from their respective scientific groups, "burst detection" is a helpful analytical technique (Chen and Leydesdorff 2014; Kim and Chen 2015). The burst detection identifies keywords with more counts in co-word analysis in specific periods. Figure 8 shows the top 20 keywords with the most powerful burst. The period during which these keywords were more prevalent among scholars is depicted in red. Notably, the results were limited to 1993 to 2023 because the software could not assess results from years before 1993.

According to Fig. 8, "integer programming," "shift," and "algorithms" have the most extended burst duration of more than ten years. The strongest bursting keyword is "shift," with 8.66 strength, followed by "system." In the past ten years, there have been four bursting keywords which indicate the emerging trends of the service scheduling publications, including "vehicle routing problem," "overbooking", and "no-show". Both "overbooking" and "no-show" are interconnected terms that crop up in services such as healthcare, hospitality, consulting, and government. "no-shows" occur when clients either do not show up as planned for an appointment or cancel at the last minute, leaving the service provider scrambling to find a replacement. Overbooking is a strategy that can be employed to minimize the adverse effects caused by no-shows. Keyword explosions also demonstrated that the focus of the study shifted rapidly over time and that other subfields of scheduling in services research were experiencing simultaneous growth. Table 9 with Fig. 8 show that current service scheduling research focuses on studying algorithms and techniques, uncertainty systems, and using these models to address scheduling issues, most notably in the healthcare industry.

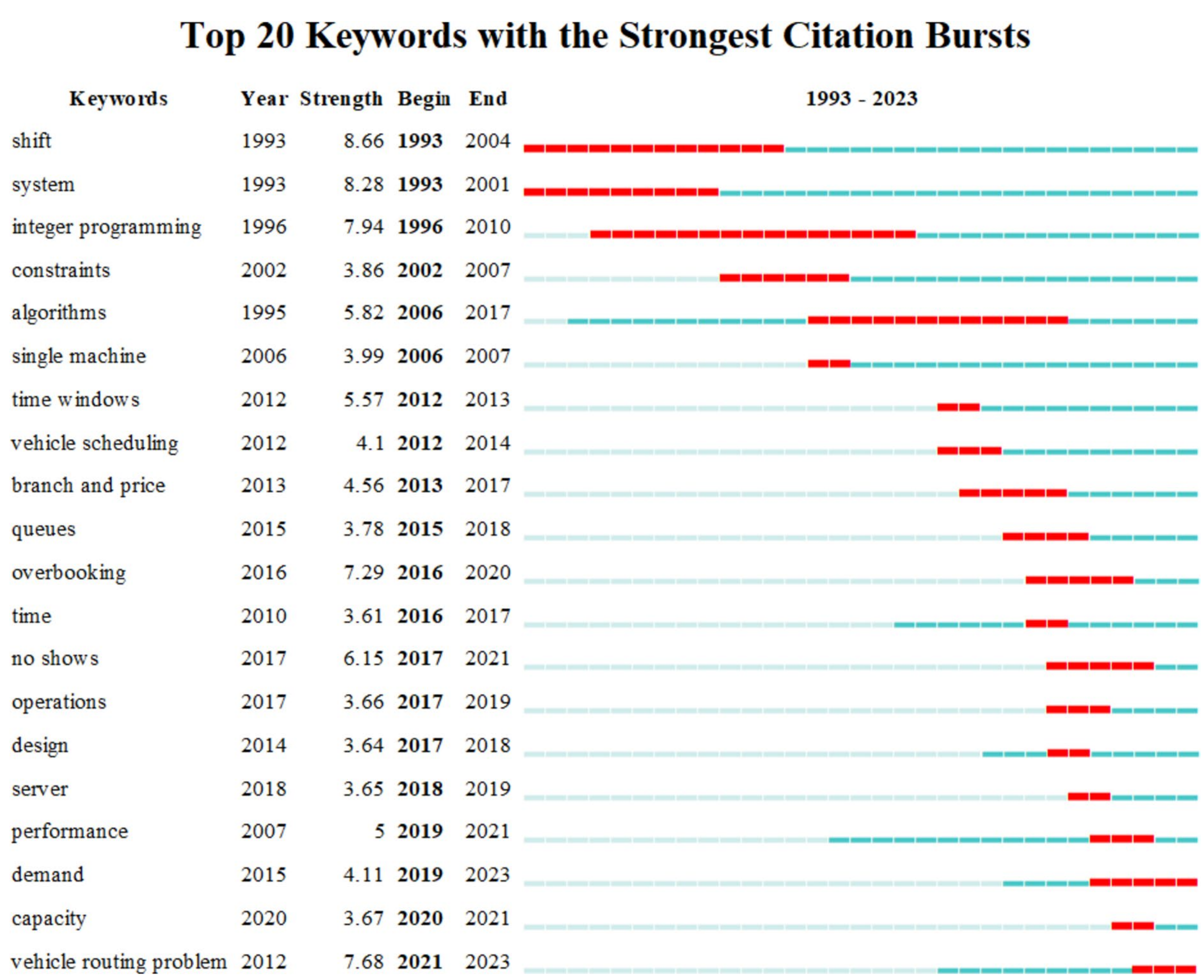


Fig. 8 The Top 20 Keywords with the Strongest Burst

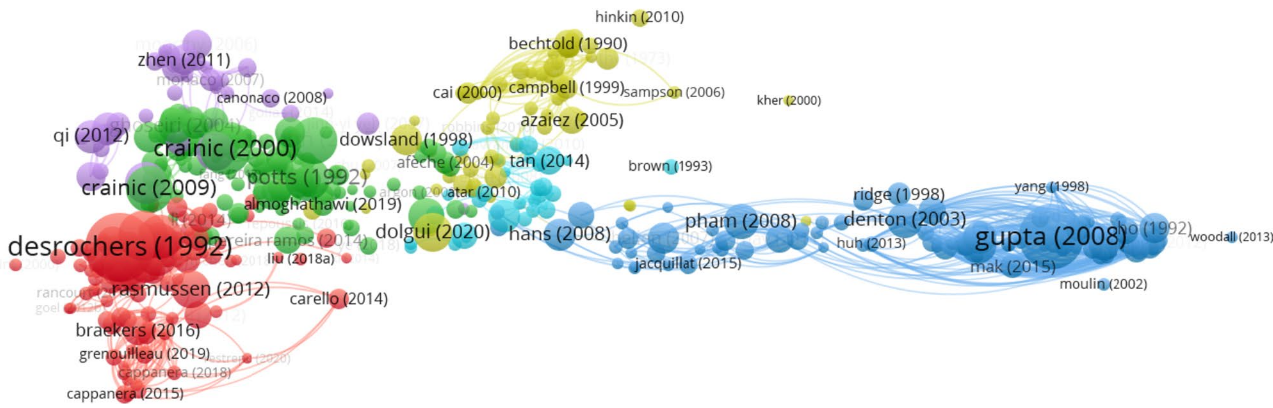


Fig. 9 Bibliographic Coupling Network

4.2.3 The bibliographic coupling network

Like co-citation, bibliographic coupling is a measure of publication similarity based on examining citations to determine whether or not two works are similar. Bibliographic coupling occurs when two documents cite the same third document. This suggests that the two works might be dealing with similar themes. The higher the coupling degree is, the closer the subject content and professional nature of the two publications are, and the closer the relationship between the publications is (Kessler 1963).This study used bibliographic coupling analysis to identify contemporary research streams. In mapping the bibliographic coupling network, each document was qualified with at least 30 citations. Out of the 1991 documents, 546 met the threshold, 536 of which were used in network mapping. Figure 9 shows the bibliographic coupling network: The documents were classified into six clusters with 10,430 links in this network. Table 10 shows the information associated with each cluster.

The first cluster, shown in red, contains documents related to the service systems that can be modeled as vehicle routing problems (VRP) with the potential application areas, including delivery, repair, inventory, and emergency service. VRP is a more general version of the famous NP-hard traveling salesman problem (TSP). As a classic combinatorial optimization problem, it has consistently attracted significant attention in operations research (Ni and Tang 2023). Optimal vehicle routes to service geographically distributed customers at minimum total travel costs are the aim of the basic VRP (Braekers et al. 2016; Salehi Sarbijan and Behnamian 2023). Vehicle Routing Problems with Stochastic Demand (VRPSD), Vehicle Routing Problems with Simultaneous Delivery-Pickup (VRPSDP), Open Vehicle Routing Problems (OVRP), Green Vehicle Routing Problems (GVRP), Multi-Trip Vehicle Routing Problems (MTVRP) are just a few of the numerous variants and extensions of the vehicle routing problem that have emerged in recent years in both theoretical and practical contexts (Zhang et al. 2022). The research community has shown considerable interest in vehicle routing problems due to their wide range of practical applications (Liu et al. 2023b). waste collection (Mohammadi et al. 2023; Tirkolaee et al. 2023), home healthcare (Bazirha et al. 2023; Ma et al. 2023), perishable goods delivery (Liang et al. 2023), home delivery

Table 10 The information of top 15 highly authoritative publications

Number	Count	Main Documents	Title
1	156	(Drexl 2012; Dumas et al. 1991; Gendreau et al. 1999; Rasmussen et al. 2012)	Vehicle Routing Problems
2	142	(Ahire et al. 2000; Cachon et al. 2017; Crainic 2000; Doostparast et al. 2014; Potts and Wassenhove 1992)	Transportation Scheduling
3	94	(Beliën and Demeulemeester 2007; Denton and Gupta 2003; Gupta and Denton 2008; Patrick et al. 2008; Pham and Klinkert 2008)	Appointment Scheduling
4	64	(Azaiez and Al Sharif 2005; Bard et al. 2003; Bechtold and Jacobs 1990; Cai and Li 2000; Campbell 1999)	Staff Scheduling
5	41	(Agarwal and Ergun 2008; Brouer et al. 2014; Cordeau et al. 2005; Qi and Song 2012; Zhen et al. 2011)	Liner Shipping Berth Scheduling
6	31	(Atar et al. 2010; Avramidis et al. 2010; Gurvich et al. 2008; Mandelbaum and Stolyar 2004; Tezcan and Dai 2010)	Queueing Systems

(Selvakumar et al. 2023; Waßmuth et al. 2023), bus route optimization (R. Liu and Wang 2022; Shang et al. 2021), ride-sharing services (Tafreshian et al. 2020), and others (Li et al. 2019; Miguel et al. 2019).

The second cluster, shown in green, is related to applying scheduling problems in transportation systems. The transportation system, particularly airlines (Wen et al. 2023; Xu et al. 2023), railways (Gattermann-Itschert et al. 2023; Heil et al. 2020), and urban mass transit (Liu et al. 2023a; Lu et al. 2022), is a common field where this is applied. Railway and train scheduling problems are the most cited papers in this cluster. Scholars' interest in more efficient ways for railway scheduling was sparked by the challenges of satisfying the ever-increasing transport demand while assuring a good quality of service under restricted resources (Corman et al. 2017). The cluster also emphasizes the maintenance scheduling problem as a primary topic of research. Maintenance is fixing or replacing worn-out or broken parts of machinery to keep the facility running smoothly (Duffuaa and Raouf 2015). Implementing a proficient maintenance scheduling procedure will result in substantial reductions in both maintenance expenses and machine downtime (Afsharnia and Marzban 2019). Applying optimization approaches to resolving maintenance planning and scheduling problems is one of the most fruitful contributions of operations research to improving decision-making in equipment maintenance management (Froger et al. 2016). Like industrial processes, the major equipment used to provide a service in the service sector must be kept in decent working conditions (Ahire et al. 2000). The main classification of maintenance scheduling in the literature is split between two major categories: Proactive and Reactive. Proactive maintenance is a strategy that corrects the source of underlying equipment conditions (Afsharnia et al. 2020). Proactive maintenance aims to reduce unplanned downtime, equipment failure, and risks associated with operating faulty equipment (Fox et al. 2022). In contrast, reactive maintenance is often unplanned. It may include corrective maintenance, minimal repairs, and replacement (Raza and Hameed 2022).

The third cluster, shown in blue, deals with appointment scheduling. Many customer service applications use appointment systems to manage staff time better, distribute work more efficiently, and save consumers from waiting in line (Denton and Gupta 2003). Despite the fact that appointment scheduling is applicable in any context where a service provider needs to keep track of a group of customers' schedules (e.g., between patients and doctors, between clients and consultants, between cars and service centers, or between students and teachers), the majority of the published works on the topic concentrate on the medical field. This might be because appointment scheduling systems for these services are notoriously difficult to implement due to their unique qualities, such as high demand relative to available capacity, importance, and inherent uncertainty (Ahmadi-Javid et al. 2017). There are two main types of patient scheduling in the literature: inpatient (where patients spend the night) and outpatient. Most papers in this cluster belong to appointment scheduling in outpatient clinics. When demand is scheduled this way, patient arrivals are spread out evenly throughout the session, minimizing fluctuations in demand. Demand and supply for physicians and other resources like facilities and support workers can be better coordinated (Kuiper et al. 2015). Also, Online and offline scheduling are two approaches that can be explored in the literature. Appointments are scheduled offline once all requests have come in, whereas, in the online method, patients are scheduled right away when their request arrives(Marynissen and Demeulemeester 2019). Wait times for patients, idle times for servers, system overtime, total patients seen, and total patients denied or postponed are the most popular performance metrics utilized in optimization studies (Ala et al. 2023).

The fourth cluster, shown in yellow, is related to staff scheduling, which is predicting labor needs, assigning employees to fill those needs, and adjusting in real-time. Due to the continuous operation of the service systems, demand is unpredictable, possessing challenges in the planning process. Poor personnel scheduling can result in an overstock of staff with excessive idle time or an undersupply with a resulting loss of business (Bard et al. 2003). Staff scheduling problems encompass several professions, such as call center operators, hospital nurses, police officers, and transportation staff (including aircraft crews and bus drivers) (Özder et al. 2020). In the literature, this problem can be recognized by keywords including "workforce scheduling," "labor scheduling," "employee scheduling," personnel scheduling," "crew scheduling," "manpower scheduling," and "resource scheduling." Compared to other resource allocation problems, workforce planning has a few unique characteristics. Staff planners encounter a highly diverse group of employees, and the decision-making environment becomes quite dynamic. Employee preferences, union restrictions, and the wide variety of skills on staff must all be considered. In general, the structure of the personnel scheduling problem can be divided into several categories, such as days-off scheduling (Bazrafshan et al. 2023; Mizutani and Sánchez Galeano 2023), shift scheduling (Becker et al. 2019; Gençer et al. 2023), periodic staffing problems (Xue et al. 2023), and crew scheduling (Wen et al. 2023). It is worth mentioning that some problems demand team scheduling rather than individual staff scheduling. This scheduling problem is used in transportation to schedule staff and route vehicles (Xu and Hall 2021).

The fifth cluster, shown in purple, consists of papers related to the berth scheduling problem. Designing an efficient and effective service network is a common challenge for liner transport companies (Dulebenets et al.

2021). Three phases must be completed before a ship can dock at a specific port. Before arriving at the berth area, it must first cross a waterway. Second, when it reaches the berthing area, it will be directed to a particular port with the necessary facilities to service the vessel. Quay cranes are also assigned to vessels at this time. Furthermore, once a ship is given clearance to leave the port area, it goes along the same channel it entered (Fatemi-Anaraki et al. 2021).With a list of ports and goods that need to be transported, a shipping company wishes to plan the most effective service routes for its vessels (Agarwal and Ergun 2008). During the last decade, shipping industries have been pressured to decrease fuel use due to increased worries about greenhouse gas emissions (Reinhardt et al. 2016). An influential work in this cluster refers to the work (Qi and Song 2012) that proposed a model to minimize the total fuel consumption (or emissions), considering uncertain port times and the frequency requirements on the liner schedule to seek the optimal vessel schedule. The methods in the literature measure performance based on factors such as deviation from a preferred berthing position (Jauhar et al. 2023), departure time (Jia et al. 2023), actual berthing position (Hu et al. 2022), waiting time (Kolley et al. 2023), and handling time of ships (Liu et al. 2022b).

The publications in the six cluster, shown in pale blue, discuss services that can be regarded as queueing systems. Queueing theory is a field of applied mathematics that focuses on the mathematical study of waiting lines or queues. Call centers (Hathaway et al. 2022), healthcare (Zychlinski 2023), the hotel and tourist industry (Khalili and Mosadegh Khah 2020), and retail (Mac-Vicar et al. 2017) are just a few examples of the many sectors applied researchers frequently use to study queuing models. Application of queueing models to capacity planning and control exists in these systems. For instance, when analyzing the impact of demand or process changes on queue lengths and waiting times or when calculating the capacity needed by a service process to attain an acceptable level of service (i.e., waiting time), queueing analysis will be a helpful tool (Lantz and Rosén 2017). In general, queue analysis involves examining multiple elements, including arrival rates, service rates, queue lengths, and waiting durations, to comprehend queues' dynamics and efficiency (Shortle et al. 2017). Papers in this cluster refer to the combination of queueing theory and scheduling decisions in service systems. These two separate but related areas aim to enhance a system's effectiveness with limited resources, albeit in different ways (Terekhov et al. 2014a, b).

The strengths of queueing theory and scheduling might be complementary depending on a service system's uncertainty, complexity, and dynamics (Atar et al. 2010). Queueing theory efficiently handles system dynamism and stochasticity, while scheduling may reason about combinatorics. whereas scheduling is more prescriptive and often only takes short-term performance metrics into account, a large section of queueing research has focused on building descriptive models to assess the long-term predicted behavior of a system. By conducting a deep analysis of the literature review in service scheduling modelling, the broad literature analysis revealed the close connections of two main research fields: service scheduling problems and queueing systems. Queueing theory and scheduling have developed dynamic resource allocation and sequencing techniques. Both seek to maximize the efficiency of a system with finite resources (Terekhov et al. 2014a, b). Albeit, scheduling uses entirely different assumptions and methods than queueing theory. Most scheduling research is devoted to deterministic and static problems while queueing theory examines uncertain and dynamic systems (Terekhov et al. 2014a, b). Although uncertainty and dynamics have been the subject of several scheduling studies, most of the literature is dedicated to deterministic models.

5 Conclusion

The research interest in service scheduling has significantly increased during the last 40 years. In this paper, we reviewed service scheduling literature and found various viewpoints to classify the current body of literature. We introduced a new classification of scheduling problems in service systems based on their characteristics. The main contribution of this review is to simplify tracking published work in relevant fields, identify patterns, and suggest areas for future research. Our analysis has reported significant aspects of research in this field, including the most relevant keywords, the most influential publications, journals, and institutional affiliations. Keyword burst analysis showed that the study's theme changed as time passed, and many branches of services were synchronously thriving. Through bibliographic coupling analysis of service scheduling research, we have identified six main clusters: vehicle routing problems, appointment scheduling, staff scheduling, liner shipping berth scheduling, transportation scheduling, and queueing systems. By investigating the literature, we have found that among service systems, scheduling in health services has recently attracted much scholarly interest, and the development of models in this area has the most impact on the development of subsequent research. In general, scheduling problems in healthcare systems arise in the contexts of scheduling staff, vehicle routing, appointments, and queuing systems. As an illustration, scheduling home healthcare problems accounts for around 20% of the scheduling problems inside the cluster of vehicle routing problems. The majority of issues within the appointment scheduling cluster pertain to the scheduling of appointments in healthcare services. Various scheduling problems in healthcare services have been addressed using the queuing theory technique. Scheduling physicians and nurses in hospitals is part of the problems found in the staff scheduling cluster. Also, during the past decade, there has been a substantial increase in the number of articles published in the area of home health service scheduling. Researchers have shown interest in utilizing stable optimization approaches and the branch and price algorithm. New research hotspots mainly concentrate on applying operations research in health services, considering no-shows, and overbooking in service scheduling modelling.

5.1 Limitation and future research

The comprehensive literature evaluation has led us to several conclusions that might serve as guidelines for future studies. To begin, the exponential growth of this area of study is plain to see. Researchers have shown remarkable innovation in optimizing service system scheduling by combining several techniques. Future investigations may prioritize the development of algorithms that are both more efficient and adaptable, capable of managing stochasticity, and applicable to a diverse array of service scheduling problems. Branch and pricing, branch and cut, branch-and-price-and-cut, and bender decomposition techniques are essential in solving scheduling problems, particularly in service systems that can be presented as vehicle routing problems. Our comprehensive analysis of existing literature revealed that researchers have recently focused on integrating strategic, tactical, and operational planning levels in service systems. Our systematic literature review also speculates potential future research avenues, such as the amalgamation of algorithms, incorporation into machine learning, real-time decision-making, multi-objective optimization, and collaborative allocation strategies. Future studies in service scheduling, particularly in multi-objective practical studies, should focus on investigating and developing more hybrid solution algorithms to solve complex models. More realistic models are being developed to address the growing complexity, volatility, and unpredictability. However, solution techniques like dynamic and stochastic, which are more practical, have room to grow. Many optimization studies in service scheduling need to integrate environmental elements. Although incorporating these aspects adds complexity to the mathematical models, it enhances the practicality of the resulting models. Therefore, this direction is strongly advised for future research. While there has been some recent research on online systems, further investigation could be beneficial, particularly considering realistic arrival patterns and future arrivals. Most proposed models utilize simplifying assumptions like offline scheduling, single-stage service, punctual customers. Therefore, the scheduling problem incorporating more realistic assumptions presents significant prospects for future research endeavors. In the literature on appointment scheduling, realistic issues such as patient and physician unpunctuality and no-shows are infrequently reported. Therefore, a potential avenue for further investigation would be to examine the influence of these characteristics on the difficulty of allocating patients to servers. Future research will focus on developing service scheduling models that simultaneously sequence and timing heterogeneous customers, which can be mathematically complex. As another potential avenue for future research, it may be worthwhile to incorporate the element of uncertainty arising from random service timings into the study.

Our review has its limitation, just like any other study. The first restriction is that we only searched the WoS database for relevant articles. Our database includes practically all scholarly contributions in service scheduling since 1982, but some crucial studies may have been missed. Therefore, it is recommended that future researchers compare results from many databases, such as Scopus and WoS. In addition, filters like "document kinds," "WoS categories," and "languages" were used to narrow the data set. As a further limitation, there are insufficient references to recent works. The bibliometric approach gives more credit to earlier works cited more often. Recent research needs a fixed time frame in order to gather citations. New findings and research introducing a new paradigm would not be included among the top ten most influential works. Another limitation arises from the forming of the sample database. Although acceptable keywords were utilized for this investigation, using different keywords could have resulted in different results. There is also the potential for some other valuable perspectives to be left out of the sample database. Therefore, future research may use different keywords and objectives to obtain different results.

Author contributions Setareh Boshrouei Shargh: Conceptualization, Research Methodology, Literature Search and Review, Writing-Original Draft Preparation. Mostafa Zandieh: Conceptualization, Research Methodology, Supervision. Ashkan Ayough: Writing-Review and Editing. Farbod Farhadi: Writing-Review and Editing.

Data availability Data is available on request.

Declarations

Ethics approval and consent to participate Not Applicable.

Informed consent Not Applicable.

Competing interest The authors have no relevant financial or non-financial interests to disclose. The authors have no competing interests to declare that are relevant to the content of this article. All authors certify that they have no affiliations with or involvement in any organi-

zation or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript. The authors have no financial or proprietary interests in any material discussed in this article.

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