



Systematic Mapping Study: Research Opportunities on Capacity Planning

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Abstract

The central idea of the research is to enhance the efficiency and sustainability of data centers by implementing accurate capacity planning, which will also improve their performance and availability. Various literature reviews have been conducted to understand the current status of capacity planning implementation across different domains and perspectives. However, a more organized and systematic approach is required to map research and implementation outcomes in the relevant areas of capacity planning that have the potential for further development. The present study is aimed at filling this gap by conducting a systematic mapping study, which combines both quantitative and qualitative methodologies. The quantitative approach involved the collection of literature and topic classification using the Latent Dirichlet Allocation (LDA) method. In contrast, the qualitative approach utilized content analysis to identify future research directions based on keyword trends and topics. The PRISMA framework was followed to guide the search for relevant studies in electronic research literature databases. The mapping results revealed 15 topics, with topics 8, 10, 11, and 15 showing significant potential for further research and exhibiting increasing trends. The identified topics encompass capacity planning, energy and resource management, computing and technology, data analysis and statistics, engineering, and industry, all crucial for businesses and industries to operate efficiently and sustainably. This study provides a comprehensive overview of the state of capacity planning implementation and highlights areas that require further investigation.

Keywords: capacity planning; review; systematic mapping study

1. Introduction

Capacity planning in information technology is business planning translated into IT infrastructure resource requirements to meet future expectations in organizational budgets based on the perspective of industry practitioners [1]. To reduce costs in resource provision, they have to purchase reserved instances and, as a result, estimate resources required in the long term [2]. The problem is complicated by unexpected resignations that can lead to labor shortfalls that jeopardize continuous operations [3]. However, Tactical capacity planning relies on future estimates of demand for the mid-to-long-term. On these forecast horizons, there is increased uncertainty that the analysts face [4].

To address the challenges in capacity planning, researchers and practitioners have conducted various studies to identify factors influencing and planning optimal capacity. However, background research is needed to find a comprehensive understanding of the current state, trends, and gaps in research on capacity

planning to develop more effective and efficient strategies.

Several researchers have conducted several literature reviews studies on Capacity planning and have become state-of-the-art in this research area. Xu, Xinzhi, et al. conducted a review that summarized various mainstream software tools for simulating operation and capacity planning in domestic and foreign countries and focused on analyzing the characteristics of various software tools, including general structure, temporal resolution, power flow model, unit commitment constraints, and solution algorithms. The study resulted in the current research status and trends in the development of power systems, as well as proposed ideas related to simulation tools for operation and capacity planning in the future power system [5].

Shehadeh, Karmel S et al. reviewed the stochastic optimization (SO) approach for scheduling elective operations and downstream capacity planning. This paper explains the art of formulating and solving classes of stochastic resource-constrained scheduling

problems. The study resulted in the analysis of existing SO approaches and their challenges. It highlighted opportunities for developing traceable, implementable, and data-driven approaches that may apply to downstream operations, especially where multiple entities/jobs share the same limited resources [6].

Banerjee, Nilabhra, et al. conducted a review to provide a critical synoptic evaluation of the extensive research that has been conducted in demand forecasting in the scheduled passenger transportation industry, particularly over the past few decades. This study conducted a systematic mapping study that discussed (i) research trends through co-occurrence keyword mapping, (ii) Discussion of research trends through topic mapping (iii) Providing directions for future research on Capacity planning [7].

Therefore, this research classifies and analyzes topics related to capacity planning, providing a better understanding of some metadata properties. A Systematic Mapping Study was conducted to identify and manage the characteristics of selected articles and classify them according to the quality characteristics considered and their impact on further research sustainability [8].

The results of this research enhance the body of knowledge on Capacity planning by providing a systematic keyword map of the subject and capturing the main topics in the field of research. This paper is intended to support academic and industry researchers working on Capacity planning with semantically enriched and knowledge-based information.

2. Research Methods

2.1 Development of Review Protocol

In this study, we conducted a systematic mapping study of Capacity planning research by combining quantitative and qualitative approaches. Figure 1 illustrates the process of the systematic mapping study, depicting the various stages involved in the research. The quantitative approach involved collecting literature on Capacity planning and conducting a systematic mapping study to identify influential researchers and keywords used. The stages of the study can be shown in Figure 1.

We then classified topics using the Latent Dirichlet Allocation (LDA) method. LDA is a probabilistic graphical model, as it can find the proportions of one variable given the values of other variables [7]. Perplexity is a widely used method to determine the optimal number of topics. It can be calculated in Formula 1 and 2.

$$Perplexity(Dtest) = \exp\left\{-\frac{\sum_{d=1}^D \log p(wd)}{\sum_{d=1}^D Nd}\right\} \quad (1)$$

Dtest is the the complete set of text, D is the the total number of documents within that set, wd is the the sequence of words in a particular document, and Nd is the the non-repetitive vocabulary found within that document.

$$P(wd) = \prod_{i=1}^{Nd} \prod_{k=1}^K p(Zk|d) * p(wi/zk) \quad (2)$$

The probability of the word sequence wd, denoted as p(wd), is calculated by multiplying the probabilities of each individual word in the document. Each word in document d is denoted as i.

K is the assumed number of topics, p(zk|d) is the probability of topic K being present in a given document, p(wi|zk) is the probability of word i being associated with topic zk.

Output results topic distribution matrix $\theta D \times K$ showed the probability distribution of the K topic in the total text sets, representing the degree of topic contribution to the whole text [9].

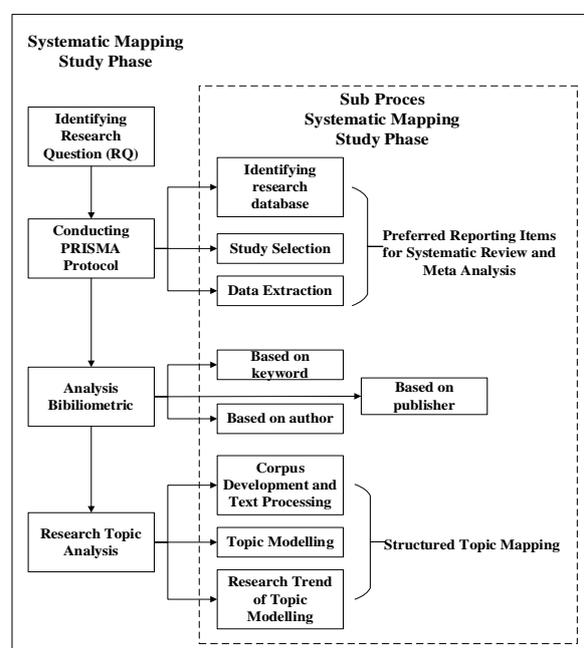


Figure 1. Systematic Mapping Study

Next, we conducted qualitative content analysis to compile directions for future research by synthesizing and discussing the latest keyword trends and topics. Table 1 provides an overview of the research questions identified in the literature.

Table 1. Research Questions Literature

Research Questions	Objective
RQ1. What are the publication trends in Capacity planning?	One key to getting an overview of the area to be researched is to look at the extent of existing research on Capacity planning. The most influential publishers and authors also need to be identified to gain significant
RQ1-1. Who are the most influential publishers in publishing Capacity planning?	
RQ1-2. Who are the most influential authors in	

Research Questions	Objective
publishing Capacity planning?	knowledge of Capacity planning.
RQ2. What are the common keywords used in Capacity planning research?	This research question aims to identify the main keywords commonly found in Capacity planning research.
RQ3. What are the opportunities for open topics in Capacity planning?	This research question aims to answer which topics still have the potential for research and the Taxonomy of Capacity planning in research.
RQ3-1. What are the trending taxonomies in Capacity planning research?	

2.2 PRISMA Protocol

This research study used the PRISMA (Preferred Reporting Items for Systematic Review and Meta-Analyses) protocol [10] for study selection. The protocol included search terms, literature sources (Scopus, IEEE, ACM, Sciencedirect), study selection criteria, and study selection procedures, as shown in Figure 2. Boolean operators AND and OR combined terms related to Capacity planning AND (workload OR performance). Data were filtered based on document type (e.g., "articles"), source (e.g., "journals"), and language (e.g., "English"), as well as the primary research question and review protocol are shown in Figure 2.

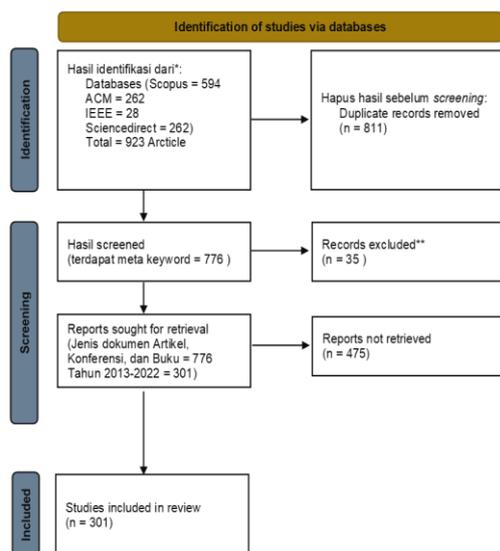


Figure 2. PRISMA Protocol



Figure 3. Keyword Analysis in Orange

We used the Vos Viewer and Orange applications with the analysis structure to map the topic structure for analyzing many articles and obtaining comprehensive insights. Figure 3 depicts the keyword analysis conducted using the Orange application.

3. Results and Discussions

3.1 Result

What are the publication trends in Capacity planning?: The research on Capacity planning has been around for a long time and has experienced a growth in document publications in recent decades. Documents related to Capacity planning were first published in 1979. Table 2 presents the total number of document publications on Capacity planning categorized by periods, with an increasing frequency shown in Table 2.

Table 2. Capacity planning document publications

Years	Total Document
1979 - 1988	40
1989 - 1998	99
1999 - 2008	171
2009 - 2018	348
2019 - 2021	83
Total	741

Publishers in the Topic of Capacity Planning: The most impactful publisher sources in Capacity Planning research are shown in Table 3. Table 3 presents the top 5 journals that researchers in Capacity planning target. CMG (Computer Measurement Group) PROCEEDINGS ranked first with 54 publications worldwide.

Table 3. Capacity Planning Document Publishers

Element	Index	TC	NP	Initial publication		
h	g	m				
Cmg Proceedings	1	1	0.03	6	54	1992
Lecture Notes In Computer Science International Journal Of Production Economics	9	17	0.33	310	29	1996
European Journal Of Operational Research International Journal Of Production Research	5	11	0.15	142	21	1991
Journal Of Production Economics	2	11	0.05	128	19	1988
International Journal Of Production Research	10	14	0.33	247	14	1993

The journal Lecture Notes In Computer Science (Including Subseries Lecture Notes In Artificial Intelligence And Lecture Notes In Bioinformatics) is the most cited with 310 citations, followed by the International Journal Of Production Research with 247

citations. Journal Of Production Research also ranks first in h-index (10), g-index (14), and m-index (0.33) values. This result strengthens the notion that journal articles have a more significant impact than proceedings.

Authors in the Topic of Capacity Planning: The most impactful author in producing publications and citations in Capacity planning is Ludmila Cherkasova, with 11

documents published and 652 total citations. Figure 4 illustrates the authors involved in Capacity planning, highlighting the impact of Ludmila Cherkasova and her most impactful title. Her most impactful title is 'Workload Analysis and Demand Prediction of Enterprise Data Center Applications,' with 217 citations. The authors and titles produced can serve as a reason for researchers to select literature studies, followed by other authors, as shown in Figure 4.

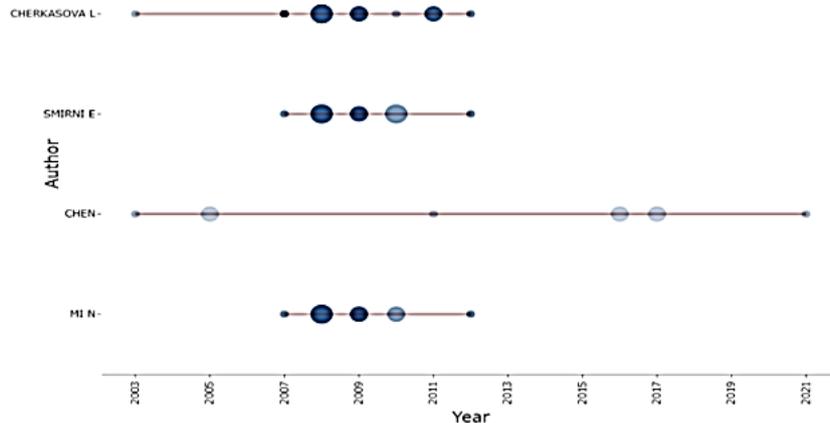


Figure 4. Authors in Capacity planning

Keyword in Capacity Planning Research: A network map visualizes a research area by creating a landscape map that can represent scientific concepts. The network map used in finding relevant research topics in Capacity Planning uses a set of author keywords in each article. There are 6 clusters formed from the results of co-occurrence words commonly used by authors in their studies. Figure 5 displays the Keyword Network Map by VosViewer, which illustrates the 6 clusters formed based on the co-occurrence of keywords commonly used by authors in Capacity Planning research.

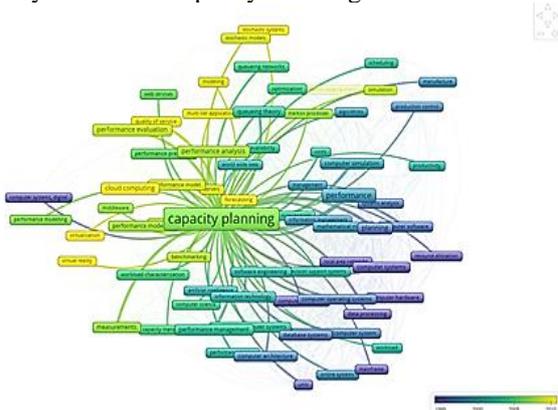


Figure 5. Keyword Network Map

Next, the topic keywords obtained are classified using the LDA (Latent Dirichlet Allocation) method. LDA is a generative model that can also model topics for unseen documents. LDA is a probabilistic graphical model because it can find the proportions of one variable given the values of other variables [11]. The

results of the topic classification grouping are then analyzed for potential research trends.

Research Topic Opportunities in Capacity Planning: A set of related keywords were identified to form a group called a theme and classified into four categories according to centrality and density. Figure 6 illustrates the mapping of the identified themes, which have been categorized into four groups based on their centrality and density.

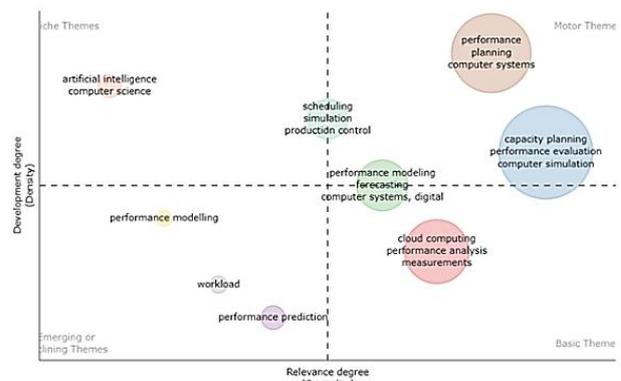


Figure 6. Mapping of Themes.

Based on the results in Figure 6 on mapping themes, the research opportunities in Capacity Planning can be classified into four categories according to centrality and density.

Motoric Theme (Q1, upper right quadrant): These themes are well-developed and essential for the structure of the research field, such as performance planning, computer systems, Capacity planning,

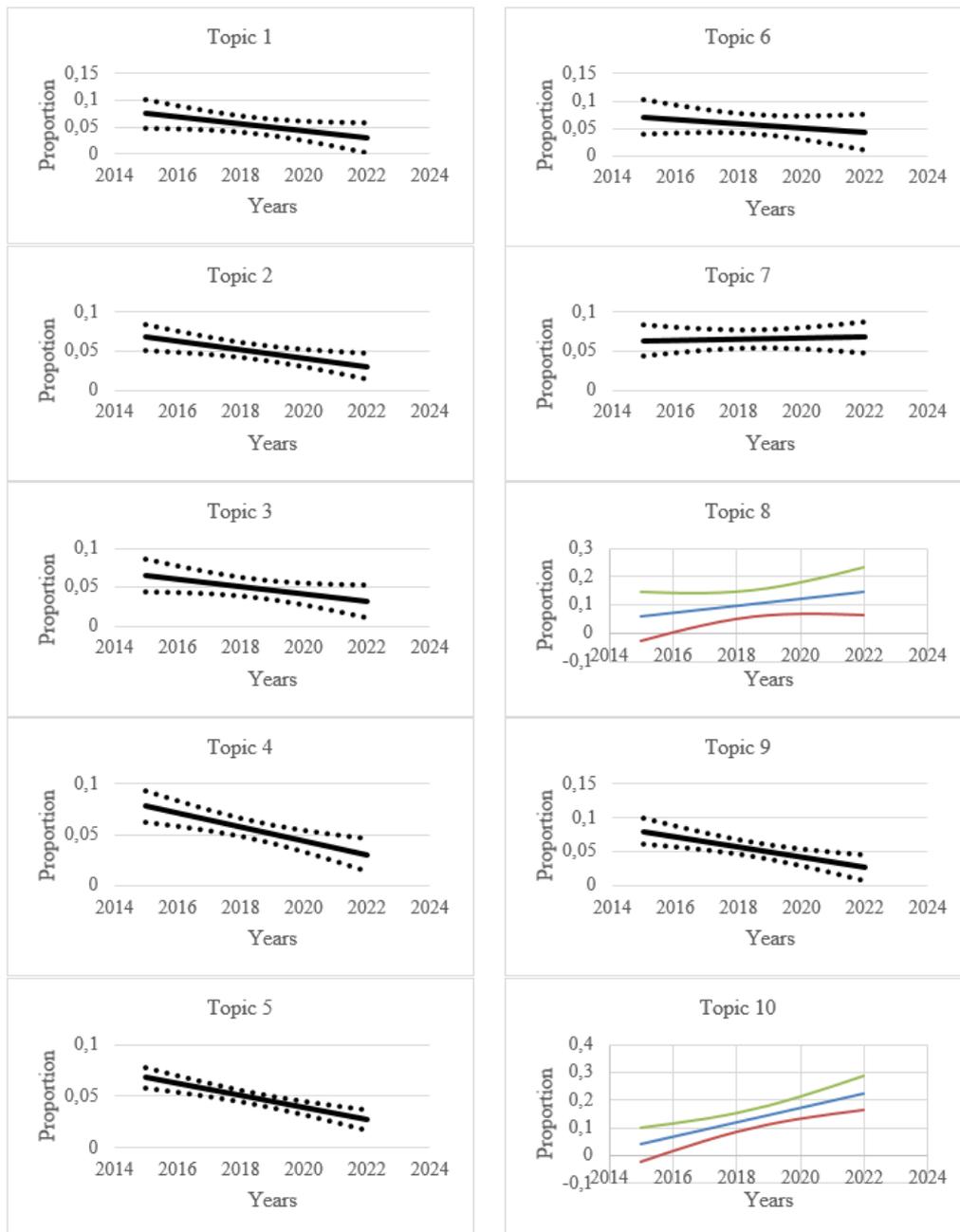
performance evaluation, computer simulation, performance modeling, forecasting, scheduling, simulation, and production control.

Niche Theme (Q2, upper left quadrant): They have good internal ties but unimportant external ties, thus having a marginal role in the development of the scientific field, such as artificial intelligence, computer science, scheduling, simulation, and production control.

Emerging or Decline Theme (Q3, lower left quadrant): Both are less developed and marginal, such as performance modeling, workload, and performance prediction.

Essential and Transversal Theme (Q4, lower right quadrant): Important topics for the research field but not well-developed, such as cloud computing, performance analysis, and measurements, performance modeling, forecasting, scheduling, and computer systems.

The results of the probability of research topics still open in Capacity planning, based on the analysis of the proportion weight values using the LDA method on keywords in each article, reveal that 15 topics have been formed. Topics 8, 10, 11, and 15 show a higher potential for research than other topics, as seen in Figure 7, indicating an increasing trend in research interest.



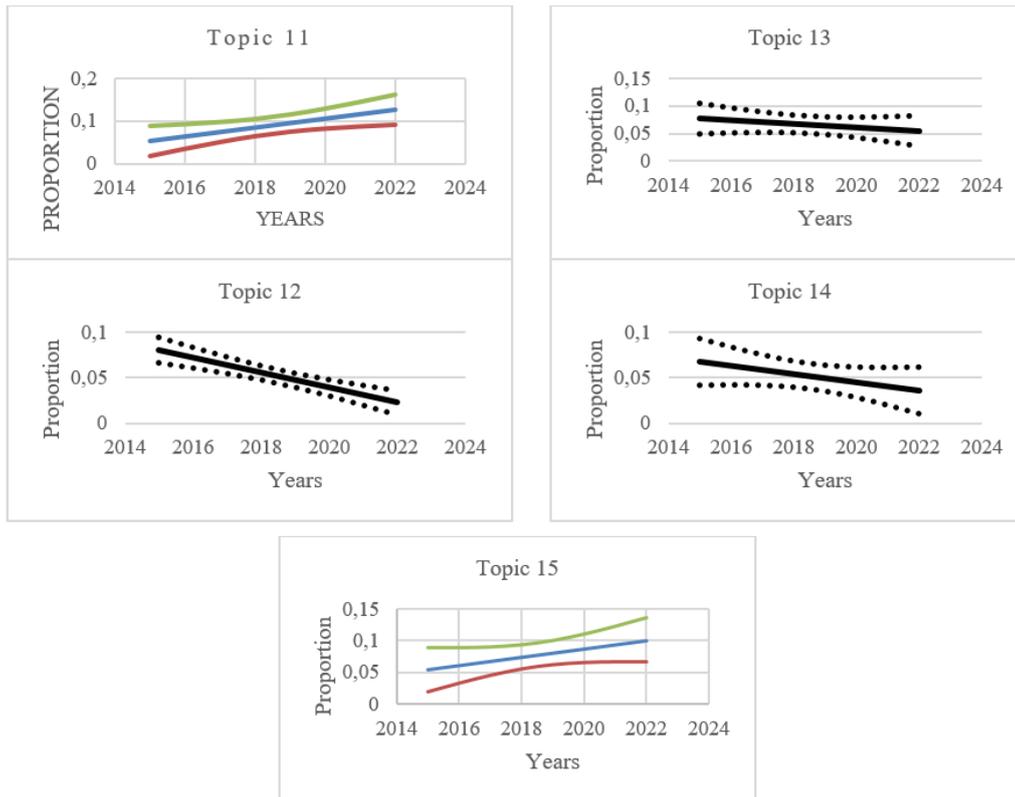


Figure 7. Trend Topic

Based on Figure 7, Capacity planning falls under topic 8, which has a proportion weight value on keywords showing an increasing trend in research interest over the

past few years. Further analysis has been conducted on the taxonomy of Capacity planning within topic 8, as illustrated in Figure 8.

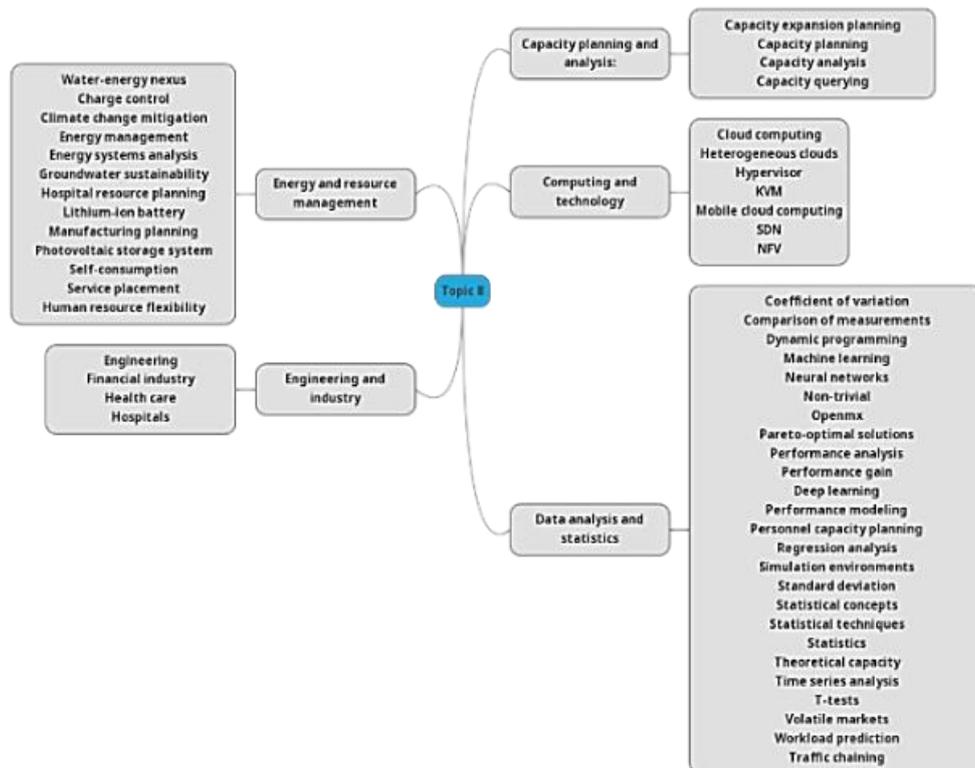


Figure 8. Topic Taxonomy 8

3.2 Discussions

Capacity planning plays a crucial role in the effective functioning of businesses and industries. It ensures that organizations have the necessary resources and infrastructure to meet user demand and maintain smooth operations. The importance of capacity planning lies in its ability to optimize resource utilization, enhance productivity, and improve customer satisfaction. By accurately forecasting future demand and aligning resources accordingly, businesses can avoid underutilization or overutilization of resources, which can lead to inefficiencies, increased costs, and potential customer dissatisfaction.

Capacity planning on energy and resource management, computing and technology, data analytics and statistics, engineering, and industry are all critical areas that play significant roles today. Each area is crucial in ensuring that businesses and industries operate efficiently and sustainably. The mapping study of topic 8 is explained in Table 4.

Table 4. Capacity planning document publications

Topic	Description
Capacity planning and analysis. [12][13][14]	Capacity planning and analysis uses statistical techniques to study the impact of available time and its fluctuations on critical machines in production to determine overall capacity and output performance and generate reasonable capacity plans. This process involves observing and describing reality in the form of numbers and graphs and using techniques such as averages, distributions, standard deviations, coefficient of variation, t-test, regression analysis, and time series analysis (also known as trending).
Energy and resource management. [15][16][17][14][18]	Energy and resource management uses available resources to meet energy needs efficiently and sustainably. It involves using energy efficiency, renewable energy, and energy storage techniques to reduce energy consumption and costs and reduce environmental impacts. In addition, energy and resource management also involve planning and forecasting techniques to ensure resource availability for future needs.
Computing and technology. [19][18]	Computing and technology involve using computers and related technologies to create, store, process, and analyze data and develop and deploy applications, systems, and services, including hardware, software, and networks. In addition, computing and technology also involve virtualization and cloud computing technologies to improve the

Topic	Description
	efficiency and scalability of computing systems.
Data analysis and statistics. [20][21][22][23][24][25]	Data analysis and statistics involve using various methods and techniques to analyze data and draw meaningful conclusions. This includes the use of descriptive statistics to summarize data, inferential statistics to make predictions and draw conclusions, and predictive analytics to identify patterns and trends in data. In addition, data analysis and statistics also involve the use of data visualization techniques to present data in a visually appealing manner.
[26][27][28][29][30][31][32][14][18]	
[33]	
Engineering and industry. [34][31][35][36][37][38][39][33][14]	Engineering and industry use engineering principles and technology to design, develop, and implement various industries' products, services, and systems, including using engineering and technology to create, store, process, and analyze data and develop and deploy applications, systems, and services. In addition, engineering and industry also involve virtualization and cloud computing technologies to improve the efficiency and scalability of engineering and industrial systems. It also involves using advanced analytics to gain insights into customer needs and behavior and machine learning and artificial intelligence to automate processes and improve productivity.

The findings in the field of capacity planning have practical implications that include improved capacity, efficient resource management, forecasting and planning, energy efficiency, computing system optimization, data-driven decision-making, and automation for productivity improvement. These implications contribute to better operational performance, cost reduction, sustainability, and enhanced decision-making capabilities for organizations in various industries. The practical implications can be summarized as follows:

Improved overall capacity: By studying the impact of available time and its fluctuations on critical machines in production, capacity planning and analysis can determine the overall capacity and output performance. This studying helps identify areas where improvements can be made to increase capacity and optimize resource allocation.

Efficient resource management: Capacity planning involves observing and describing reality using statistical techniques. Organizations can make informed decisions about resource allocation by analyzing data such as averages, distributions, standard deviations, and

time series analysis. This decision leads to efficient energy and resource management, enabling organizations to meet their energy needs sustainably and reduce costs.

Forecasting and planning: Capacity planning involves planning and forecasting techniques to ensure resource availability for future needs. Organizations can predict future demand using techniques like regression analysis and trend analysis and plan their capacity accordingly. This technique helps in avoiding bottlenecks and ensuring smooth operations.

Energy efficiency and environmental impact: Energy management and environmental sustainability have become increasingly important. The aim is to minimize energy consumption and costs while reducing the negative environmental impact caused by energy usage. Organizations across the globe are adopting various measures to optimize their energy usage. These measures include incorporating energy-efficient techniques, renewable energy sources, and energy storage solutions. These techniques not only help in minimizing energy wastage but also contribute to sustainability goals.

Computing system optimization: Capacity planning and analysis are essential in computing and technology. With the increasing demand for efficient and scalable computing systems, virtualization and cloud computing technologies have gained immense importance. Organizations can leverage these technologies to improve the efficiency and scalability of their computing systems. Virtualization and cloud computing allow for better utilization of resources and enable rapid scaling based on demand fluctuations. These technologies have proven to be immensely beneficial in optimizing the computing systems of various organizations.

Data-driven decision-making: Data analysis and statistics play crucial roles in capacity planning, serving as indispensable components of the process. Organizations can derive valuable insights into customer needs, behavior, and production processes by applying various techniques, such as data analysis, statistics, and advanced analytics. Such a data-driven approach empowers decision-makers to make informed choices and optimize capacity planning strategies, thus achieving better outcomes.

Automation and productivity improvement: Besides, engineering and industrial systems can benefit significantly from capacity planning, primarily through advanced technologies like machine learning and artificial intelligence. By automating processes and leveraging the power of data analysis, organizations in these sectors can attain greater productivity levels, reduce manual intervention, and improve overall efficiency. Integrating these technologies into capacity

planning strategies can help organizations stay ahead of the curve and remain competitive in their respective markets.

4. Conclusion

In summary, the methodical mapping investigation on capacity planning has yielded valuable perceptions into publication trends, influential publishers, authors, keywords, and prospects of research topics in this domain. The discoveries demonstrate the importance of capacity planning in numerous critical domains, encompassing energy and resource management, computing and technology, data analysis and statistics, and engineering and industry. This inquiry has accentuated the significance of decision-making based on data, statistical techniques, energy efficiency, renewable energy, computing advancements, and engineering principles in enhancing capacity and resource utilization.

There are several avenues for future research in capacity planning: Further investigation is warranted to explore emerging themes and topics, such as performance modeling, workload analysis, and performance prediction, which are relatively less developed but hold potential for advancements; Future studies can integrate emerging technologies like artificial intelligence, machine learning, and the Internet of Things (IoT) into capacity planning strategies considering the rapid technological advancements; and As sustainability becomes a key concern for businesses, future research can focus on developing environmentally conscious and sustainable capacity planning approaches.

Furthermore, research efforts can be directed toward addressing the challenges of scalability, dynamic workloads, and the impact of virtualization and cloud computing on capacity planning. This includes investigating innovative strategies for adaptive capacity planning in cloud-based environments and exploring the role of automation and optimization techniques in improving overall capacity management.

Overall, this systematic mapping study provides a foundation for further research and opens avenues for exploring new dimensions and advancements in capacity planning. By building upon the insights gained from this study, future research can contribute to developing more robust and efficient capacity planning frameworks that meet the evolving needs of businesses in a rapidly changing technological landscape.

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