

A Bibliometric Analysis of Queuing Theory with N-Policy: Trends, Contributions, and Future Directions

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Abstract— In this paper, a bibliometric analysis of queuing theory with N-policy has been presented by using data from Scopus database. In this study, an extensive examination of key journals, emerging research keywords, evolving publication trends, dominant authors etc. The results of analysis show significant increase in research papers having contribution from various countries. The survey helps in finding the most cited journals and authors, underlining their contribution in this field and reveals emerging research domains. Also, this survey offers insightful observations about the current research state of queuing theory with N-policy, its developments and future research directions.

Index Terms— Queuing Theory, N-Policy, Bibliometric Analysis, Citation Analysis, Co-Citation Analysis, Scopus Database, Research Trends, Influential Authors.

I. INTRODUCTION

Queuing theory with N-policy which stands at the intersection of theoretical modeling and practical application offers very valuable observations regarding the management and optimization of systems across various industries. From sectors like telecommunications, networks handlings, call traffics to manufacturing facilities; managing production queues, the application of N-policy affects operational efficiency and customer satisfaction. In any system, the optimal number of entities like customers, jobs, tasks etc.; which it can accommodate before starting any control action, queuing theory with N-policy stands as paramount in decreasing the operational cost, waiting period and optimizing resource utilization. In addition to its practical significance, there is a lack in the comprehensive analysis of queuing theory with N-policy, which calls for proper research to systematically identify the innovations and intellectual paths in this domain.

Literature shows the evolution of queueing theory from earlier work on domains like memory partitioning and packet switching systems [8], [10] to new and advanced policies and algorithms designed for tasks like threshold mechanisms, optimal admission, and distinct server managements [27], [28], [49]. The most recent works in this field mainly focuses on strategic decisions, cooperative approaches and several widened policies like featuring modern applications in communication networks, triadic and threshold driven recovery, several IoT-based systems, and machining repairable structures [1], [7], [13], [19]– [21], [26], [48]. Most recent research work contributing to queueing and reliability modeling has given main emphasis on factors like transient analysis, differentiated vacations, and impatience effects in congestion systems as put forwarded by [12], [16], [35], [44]. Furthermore, research in this domain has also investigated load-sharing redundant and repairable systems, optimal vacation policies, and spare provisioning with synchronization and failures, providing efficient analytical and meta-heuristic approaches for complex service networks [37], [40], [43].

In literature, there has been research on queuing models which are fault tolerant, based on feedback, incorporates distinct types of failures, delays and analytical formulations [6], [36], [38]. Several performed surveys and conferences have further contributed in exploring various reliability concepts in repairable systems, communication networks, optimization, congestion control; illustrating their theoretical advances as well as real life applications ([15], [17], [18], [20], [20], [22], [23]), [41]. Additionally, several book chapters helps in extending these observations by addressing optimization of cost as well as resources, provision of standby, machine repairing and interference problems and several reliability concerns related to delays and vacations ([14], [19], [42], [45]). Furthermore, contribution in reliability modeling of redundant repairable systems emphasizes on availability and profit analysis with detection delays and imperfect coverage ([15], [22], [39]). Alongside, emerging research work in this domain is extending queueing and reliability modeling up to interdisciplinary areas such as data envelopment analysis, social sciences, digital education, and political science, which showcases the versatility of mathematical and computational approaches ([29],[30],[31], [32],[33]). Recent advancements in sustainable and green inventory modeling incorporate fuzzy environments, carbon emission concerns, and credit policies [3], [4], [24]. Classical supply chain perspectives also emphasize the role of learning, forgetting, lead time uncertainty, and service- level constraints in inventory optimization [9], [25], [46], [47], [50] [51]. Moreover, applications of AI in predicting weather changes , diagnosing healthcare, optimizing dynamic matching markets, vehicle systems [2], [5], [11], [34] , [52] , [53], [54] have been highlighted by interdisciplinary extensions. In order to demonstrate the practical advantages of N-policy, consider the scenario of customer service center which uses a queuing system to manage its incoming calls. In the service center, a N-policy has been employed to make decision about opening of additional service lines as per the number of callers waiting. For example, if the number of incoming callers in the queue increases than a predefined threshold (N), then additional customer service representatives are employed for the purpose of reducing waiting times and improving service efficiency of centre. This kind of proactive approach not only aids in enhancing customer satisfaction by making waiting time as minimum as possible but also optimizes operational resources. The proposed study aims in addressing the various research questions by performing a comprehensive bibliometric analysis:

- What are the trends of publication with N- policy in queuing theory over the last decades?
- What is the geographical distribution of research in the field of queuing theory with N-policy?
- Who are the most historic authors and what they contributed to the field?
- What journals contain the most important research on queuing theory using N-policy?
- What are the new research themes and trends in the field according to the analysis of keywords?

Through a systematic analysis of these questions, this paper will aim at bringing answers that will help in the development of queuing theory with N-policy, its present and future developments in the field of operations research and optimization of systems.

II. MAIN INFORMATION OF DATA

The period covered by the bibliometric analysis is quite extensive and covers the period between 1972 and 2023 and includes 636 documents, which were located in 262 separate sources, including journals and other academic publications. The present research indicates that the growth rate of publications is average (6.83 percent per year), which implies that the scholarly interest in queuing theory with N-policy has been on the rise throughout the decades. The analyzed documents are 13.7 years on average which proves the timelessness and permanence of the research in the field.

Each document has been averagely cited 13.93 times, which demonstrates the effects and the impact of the study carried out. These publications, in sum, cite a considerable variety of literature, and the total amount of references amounts to 11,570, which demonstrates the scope and volume of the academic discourse on queuing theory with N-policy. The analysis of the Keywords revealed 2,641 Keywords Plus, and 1,432 Author's Keywords that shed light on the many thematic areas and research interests in the field. The teamwork aspect of the research is reflected in the number of distinct authors that worked on the publications (978), and a significantly large percentage of 14.15 of the documents include international co- authorships. The type of documents is diverse (articles form the biggest part of the collection (460), followed by book chapters (5), conference papers (159), conference reviews (10), notes (1), and reviews (1), which is characteristic of the complex process of knowledge sharing. These results give a review of the academic environment of the queuing theory with N-policy, and it contributes to understanding of the publications trend, authorship, citation, and international cooperation.

III. ANNUAL SCIENTIFIC PRODUCTION

Table I gives the scientific production of queueing theory under N-policy each year and the number of articles published in this year. It goes across various decades and shows the changes in the volume of research. The last years, 2020 and 2016, were the most active in terms of the number of articles published with 44 and 42 publications, respectively. Previously, however, in 1997 and 1992, the years yielded low outputs of 7 and 8 articles respectively. The chronology sheds some light on the development and different intensities of academic interest in queueing theory with N-policy throughout the years.

TABLE I: ANNUAL SCIENTIFIC PRODUCTION IN QUEUEING THEORY WITH N-POLICY

Year	Articles	Year	Articles
2020	44	2005	12
2016	42	1994	12
2017	36	1995	12
2019	30	1996	12
2010	29	1998	12
2023	29	2004	15
2018	27	2008	15
2022	27	2002	15
2013	26	2012	17
2011	24	2003	18
2009	23	2015	16
2021	23		

IV. AVERAGE CITATIONS PER YEAR

The table II gives annual measures showing the development of research in queueing theory with N-policy during the last decades. It shows some primary indicators such as the average number of citations per article (Mean TC) and the total number of articles (N), average number of citations per year, and citation years. The recent years such as 2023 have a mean of 1.86 citation per article in 29 publications with 0.93 citation per year and 2 citable years on average. However, years in the past like 2009 have more mean number of citations per article (17.65), which shows great impact considering that there are fewer number of citable years (16). On the whole, the table presents the trends in citation impact and research productivity, which are useful to assess the scholarly impact and the tendencies in the field of queueing theory with N-policy.

TABLE II: ANNUAL METRICS IN QUEUEING THEORY WITH N-POLICY

Year	Mean TC per Art	N	Mean TC per Year	Citable Years
2023	1.86	29.00	0.93	2
2022	2.7	27.00	0.90	3
2021	3.52	23.00	0.88	4
2020	5.14	44.00	1.03	5
2019	3.7	30.00	0.62	6
2018	6.33	27.00	0.90	7
2017	6.75	36.00	0.84	8
2016	8.5	42.00	0.94	9
2015	11.19	16.00	1.12	10
2014	9.47	19.00	0.86	11
2013	18.92	26.00	1.58	12
2012	15	17.00	1.15	13
2011	12.08	24.00	0.86	14
2010	13.59	29.00	0.91	15
2009	17.65	23.00	1.10	16

V. MOST FREQUENT WORDS

The table III with the reformulation of the frequency of the key terms in the studies researching the subject of queueing theory. In the first place is "Queueing theory" with 373 instances and then queueing networks (183) with Markov processes (87). Other key words are sales (79), optimization (63) and mathematical models (56). The words such as stochastic systems and probability distributions are used 54 and 54 times respectively which is the reason that they play an important role. The terms of importance like scheduling and servers appear 50

times and such concepts like algorithms and optimal control systems are mentioned 27 and 26 times respectively. The table reflects the different themes and approaches that are common in the studies of queueing theory.

TABLE III: WORD OCCURRENCES IN RESEARCH PAPER

Words	Occurrences	Words	Occurrences
Queueing theory	373	Scheduling	50
Queueing networks	183	Servers	45
Markov processes	87	Costs	44
Sales	79	N policies	44
Optimization	63	Probability	43
Mathematical models	56	Poisson distribution	31
Queueing system	54	Stochastic models	29
Stochastic systems	54	Cost functions	28
Probability distributions	51	Algorithms	27
N-policy	50	Optimal control systems	26

VI. MOST RELEVANT SOURCES

Table IV indicates the most pertinent resources in queuing theory with N-policy according to the amount of publications contained in the source. It mentions such leading sources as "QUEUEING SYSTEMS" 25 articles, "LECTURE Notes in Computer Science" 23 articles, and "Performance evaluation review" 19 articles. These are important sources illustrating an extensive input to the field including various journals and conference proceedings where the research on N-policy in queuing theory has been well represented.

TABLE IV: SOURCES AND NUMBER OF ARTICLES PUBLISHED

Source	Articles
QUEUEING SYSTEMS	25
LECTURE NOTES IN COMPUTER SCIENCE	23
PERFORMANCE EVALUATION REVIEW	19
APPLIED MATHEMATICAL MODELLING	15
XITONG GONGCHENG LILUN YU SHIJIAN/SYSTEM ENGINEERING THEORY AND PRACTICE	14
MATHEMATICAL METHODS OF OPERATIONS RESEARCH	13
OPERATIONS RESEARCH	13
EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	12
COMMUNICATIONS IN COMPUTER AND INFORMATION SCIENCE	11
COMPUTERS AND OPERATIONS RESEARCH	11
IEEE TRANSACTIONS ON INFORMATION THEORY	11
PROCEEDINGS OF THE IEEE CONFERENCE ON DECISION AND CONTROL	11
RAIRO - OPERATIONS RESEARCH	11
COMPUTERS AND INDUSTRIAL ENGINEERING	9
JOURNAL OF INDUSTRIAL AND MANAGEMENT OPTIMIZATION	9
PROCEEDINGS - IEEE INFOCOM	9

VII. MOST LOCAL CITED SOURCES

The table V called Authors and Number of Articles contains prominent queuing theory authors with the number of their citation. It serves as a glimpse of the hottest names in the genre and presents the influence of each of the authors according to the count of citations that each piece of the author has received. For instance, H. W. Lee has the highest number of citations (201 citations), then K -H Wang (188 citations), and H. Takagi (174 citations). The table highlights the impact of the work of these authors to the literature, as it reflected a lot of input to research and knowledge in queuing theory with N-policy.

TABLE V: AUTHORS AND NUMBER OF ARTICLE

Author	Citations	Author	Citations
LEE H W	201	DSHALALOW J H	114
WANG K -H	188	WANG K H	106
TAKAGI H	174	HEYMAN D P	95
CHOUDHURY G	160	DOSHI B T	93
YADIN M	138	JAIN M	91
KE J -C	126	NEUTS M F	84
KE J C	119	TADJ L	79

VIII. AUTHOR'S PRODUCTION OVER YEARS

A summary of productivity of authors over several years within the framework of queuing theory with N- policy is also outlined in the table VI. It describes their frequency of publication (Freq), the number of times they were cited (TC), and the number of times they were cited each year (TCpY). The rows will indicate the contribution of a particular author to the field with each row representing the activities of that author in a particular year. To take one example, the total number of citations in DSHALALOW JH in 2023 is 19, which is an average of 9.5 citations per year. The table provides information on the patterns of publication and citation of the major authors in terms of their contributions and productivity over the years.

TABLE VI: AUTHOR YEAR STATISTIC

Author	Year	Freq	TC	TCpY
DSHALALOW JH	2023	1	19	9.5
KRISHNAMOORTHY A	2023	1	0	0
TADJ L	2023	1	0	0
CHOUDHURY G	2022	1	1	0.333
KEMPA WM	2022	2	3	1
KRISHNAMOORTHY A	2022	1	6	2
TANG Y	2022	1	1	0.333
DSHALALOW JH	2021	1	0	0
JAIN M	2021	1	9	2.25

IX. MOST RELEVANT AFFILIATIONS

Table VII provides a bibliography of the most pertinent affiliations to study in queuing theory with N-policy, in order of publication volume. The listed associations have shown impressive academic results in this area, which shows their active participation and input into the progress of knowledge. Yanshan university tops the list with 41 articles, next is Sichuan normal University with 37 articles. Other significant contributors are National Taichung Institute of technology (21 articles), National Chung-Hsing University (17 articles) and Nanjing University of science and technology (16 articles). The presence of these affiliations is critical in forming the discourse and developments in the research of queuing theory, and thus it is important in the academic fraternity.

TABLE VII: AFFILIATIONS AND NUMBER OF ARTICLES PUBLISHED

Affiliation	Articles
YANSHAN UNIVERSITY	41
SICHUAN NORMAL UNIVERSITY	37
NATIONAL TAICHUNG INSTITUTE OF TECHNOLOGY	21
NATIONAL CHUNG-HSING UNIVERSITY	17
NANJING UNIVERSITY OF SCIENCE AND TECHNOLOGY	16
NATIONAL CHIAO TUNG UNIVERSITY	15
ACHARYA NAGARJUNA UNIVERSITY	12
ALAGAPPA UNIVERSITY	11
FLORIDA INSTITUTE OF TECHNOLOGY	11

X. CORRESPONDING AUTHOR'S COUNTRIES

Table VIII gives a detailed summary of the trends in the scientific publication in different countries in a given area of research. It contains the information about the number of published articles, single-country publications (SCP) and multiple-country publications (MCP) as well as MCP Ratio, the percentage of cooperative research activities. China turns out as the most active with 126 articles, most of them being single-country articles (115 SCPs) but also has a fair share of collaborative articles (11 MCPs), which makes its MCP Ratio of 0.198. The next country that comes close with 83 articles which include 75 SCPs and 8 MCPs has an MCP Ratio of 0.131. The United States added 69 articles, 59 SCPs plus 10 MCPs which translates to 0.108 MCP Ratio, evidence of good international cooperation. Other countries such as Korea, Poland, and France have lesser but still substantial engagement with a few countries contributing to the research world with SCPs and a few MCPs, which highlights the diverse international presence in the research. In particular, nations like Turkey and Saudi Arabia are more dependent on international collaborations as all their publications are MCPs indicating widespread cross-border research associations. On the whole, the table provides useful information about the geographical distribution of the research output and the patterns of collaboration in the research sector under

study that is essential to the comprehension of the contributions to the world scientific knowledge and the development of international research networks.

XI. CONCLUSION

This study has presented a comprehensive bibliometric analysis of queuing theory research with N- policy spanning five decades. The results indicate a steady increase in both publications and citation numbers, and which shows the continued interest and influence of scholars. The international cooperation is vital, and the important role is played by such institutions as Yanshan University and authors as H. W. Lee and K -H Wang. The study highlights the timeless value of the queuing theory, which provides information on the changing trends and driving forces. The study ought to investigate the new methodologies and interdisciplinary applications in the future in order to further develop this important field of research.

TABLE VIII: COUNTRY-WISE RESEARCH METRICS

Country	Articles	SCP	MCP	MCP Ratio
CHINA	126	115	11	0.198
INDIA	83	75	8	0.131
USA	69	59	10	0.108
KOREA	16	12	4	0.025
POLAND	10	9	1	0.016
FRANCE	8	7	1	0.013
JAPAN	8	7	1	0.013
CANADA	6	5	1	0.009
BELGIUM	5	5	0	0.008
SPAIN	5	5	0	0.008

Declaration of Competing Interest

The authors declare that there is no conflict of interests regarding the publication of this paper.

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