Bibliometric Analysis of Facility Management Research Field

Shuyi Tong*

School of Management, Shanghai University, Shanghai 200444, China

Abstract

This study aims to assess the current development and trends of studies on facility management through bibliometric analysis. To achieve this goal, we reviewed the 612 papers published during the period spanning 2000–2020 in the field of facilities management. The articles were downloaded from Web of Science, and quantitative analysis was conducted by using CiteSpace, a visualization analysis tool to find out which journals published the most frequently, and from which journals the most research topics originated. Finally, the hottest trends and most popular topics of the last two decades were examined to provide guidance for researchers in the field of facilities management.

Keywords

Facility Management; Bibliometric Analysis; Research Topic.

1. Introduction

With the development of China's economic quality and efficiency and social transformation, facility management (FM) activities in the built environment of a large number of industrial and technological parks, commercial office buildings and public infrastructure in the urbanization process are facing huge development needs and challenges. FM is a system engineering that uses multidisciplinary theories and methods from management, behavioral, and engineering sciences to effectively plan, integrate, and control production, living, and ecological spaces in built environments by integrating people, space, processes, and technology to meet the core business and strategic needs of organizations [1, 2]. However, for a long time, the FM industry in China has been more focused on the practical operational level and lack of systematic knowledge on the topic of this research area [2]. Although domestic scholars have analyzed the progress of facility management from multiple dimensions or perspectives on the origin, value, performance, maturity, and informatization of FM [3-7], systematic identification of FM research themes and frontiers based on bibliometric quantification to construct a theoretical research framework for FM is still lacking, which is an important reason why the FM profession is relatively lagging behind practice and even unable to locate and expand [8,9]. Based on the above analysis, this study intends to adopt the scientometric analysis method to explore the distribution of journals and the characteristics of research themes of papers in the field of FM qualitatively and quantitatively through the visualization software CiteSpace, so as to provide theoretical guidance and content reference for the construction of the theoretical system of FM discipline.

2. Methodology and Data

As a visual bibliometric method, CiteSpace [10,11] constructs and visualizes different types of knowledge networks for various elements, such as cited references, collaborating authors, co-occurring keywords, based on the information extraction of authoritative Chinese and English databases, so as to discover the developmental veins or emerging themes in a specific research field. CiteSpace has been widely used by scholars in the fields of life science, information science,

environmental science, technology science and management to discover hotspots and trends in research topics in the respective disciplines. In the knowledge network generated by CiteSpace, nodes represent the object elements of analysis, such as authors, institutions, countries, journals, and keywords. A link in a co-cited network indicates how often two elements are cited together by other elements. The size of the node reflects the occurrence frequency or cited times of the studied element. The larger the node, the higher the frequency or more cited times. The color change of nodes (from cold color to warm color) represents the time of studying elements from far to near. In addition, individual nodes in the network are clustered into groups, and each cluster represents a different field or topic [12]. Betweenness centrality reflects the influence of a node on other nodes in the knowledge network. The greater the betweenness centrality of a node, the higher its influence on other nodes in the network, and it is more likely to become a key node. Burst detection is used to track the sudden changes in the frequency of the nodes in different time intervals, so as to identify several terms that represent the frontiers of research.

In this study, we searched the papers whose titles or keywords were facility management from 2000 to 2020 in the core collection of Web of Science, that is, "facility management" or "facilities management" (author keywords) or "facility management" or "facilities management" (title) and "articles" or "review articles" (document type).After eliminating 30 unrelated research directions such as medicine, biology, history, and instrumentation science, a total of 612 literatures on topics related to FM research were obtained to construct a knowledge network in the field of FM research and analyze its characteristics using the corresponding parameters mentioned above.

3. Analysis and Results

3.1. Analysis of Journals

In order to reveal the core and active journals in the field of FM, the study generated a journal co-citation network through journal co-citation analysis, with 2346 nodes and 8462 links, as shown in Figure 1. Journal co-citation analysis was developed from the basis of literature co-citation. The object of the study was the journals to which the cited literature of the aforementioned 612 documents belong. If two documents appeared in the same cited literature, the journals to which these two documents belong established connections. Therefore, in the journal co-citation network, the nodes represent the source journals of the cited literature, the size of node circle and label represent the level of citation frequency of the journals, and the link between the nodes represents the documents from different journals appearing in the same cited literature at the same time. The top 10 journals in the field of FM research in terms of citation frequency and betweenness centrality are shown in Table 1.
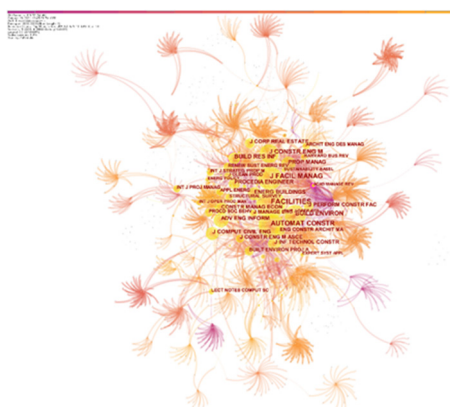
Figure 1. Journal co-citation network

Table 1. Journals according to frequency and betweenness centrality

| Freq	Journals	Centrality	Journals
293	Facilities	0.31	Academy of Management Review
176	Automation in Construction	0.14	ACM Transactions on Information Systems
161	Journal of Facilities Management	0.11	Building Research and Information
127	Building and Environment	0.09	Advanced Engineering Informatics
121	Journal of Construction Engineering and Management	0.09	Communications of the ACM
91	Building Research and Information	0.09	Advances in Engineering Software
83	Advanced Engineering Informatics	0.08	American Psychologist
82	Energy and Buildings	0.07	Facilities
80	Property Management	0.07	Construction Management and Economics
72	Journal of Computing in Civil Engineering	0.06	Journal of Computing in Civil Engineering

(1) Top 10 co-cited journals according to frequency. High citation frequency means that highly cited journals contain literature with an important knowledge base in one or more fields. The top 3 journals according to frequency were Facilities, Automation in Construction, and Journal of Facilities Management, all of which were cited more than 150 times, indicating that the above 3 journals have established literature citation or cited relationship with more than 150 journals. These journals were also the core journals in the FM field. The top 10 journals were all active journals in engineering, structure and management, or interdisciplinary computer applications, except for the journals on FM, whose topics covered environmental, health, energy, and information research directions. This situation reflected the cross-cutting nature and the active publication of FM research.

(2) Top 10 co-cited journals according to betweenness centrality. Betweenness centrality refers to the ratio of the shortest paths passing through a node in the network and connecting these two nodes to the total number of the shortest path links between these two nodes. It depicts the node establishing a bridge between 2 unrelated nodes. So it can discover the connecting points of different disciplines or the pivot points of disciplinary evolution. Nodes with betweenness centrality over 0.1 are called critical nodes and were represented as purple ring nodes in Figure 1. The top 10 journals according to betweenness centrality were shown in Table 1. The key node journals were Academy of Management Review, ACM Transactions on Information Systems, and Building Research and Information, which means that the papers published in these journals are cited in the cited literature from numerous journals. So it represented the high average quality of papers in these journals, which have a significant impact on the study of FM. Further analysis showed that the top 10 journals can be divided into four main categories. The first category was focused on FM itself, such as Building Research and Information, Facilities, and Construction Management and Economic. The second category wass concerned with computer information science, such as ACM Transactions on Information Systems, Advanced Engineering Informatics, and Communications of the ACM, etc., which mainly introduces information system applications, data integration and management, and related information technology in the field of FM. The third category was Academy of

Management Review, which focuses on facility strategic planning for business and corporate organizations. The last category was American Psychologist, which analyzes the impact of facility settings on personnel mental health.

3.2. Analysis of Keywords

High-frequency keywords were used to establish research topics in the field of facilities management, and keyword co-occurrence analysis was performed on the cited literature through CiteSpace. Since the keywords FM, Facility Management and Facilities Management all express facilities management, the study merged the three words into FM when constructing the keyword co-occurrence network. The keyword co-occurrence network with 633 nodes and 2693 links is shown in Figure 2. The nodes represent keywords, and two keywords have links connected if they appeared in the same cited literature. The study further applied knowledge mapping parameters such as frequency, betweenness centrality, burst detection and cluster analysis to systematically analyze hotspots and trends in FM research.
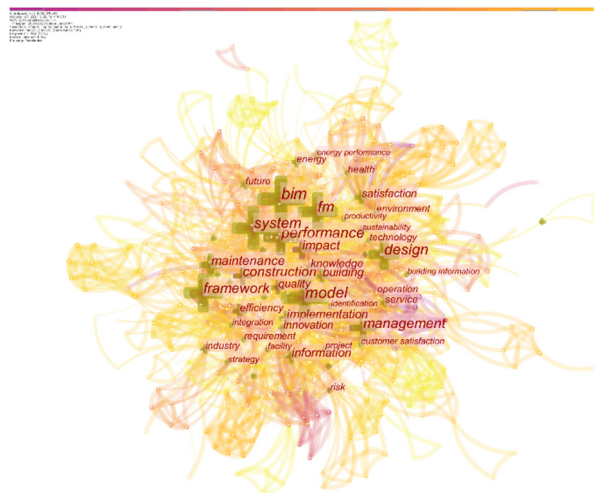
Figure 2. Network of cooccurring keywords

Table 2. Top 20 co-occurring keywords according to frequency

Freq	Centrality	Keywords	Freq	Centrality	Keywords
65	0.02	BIM	25	0.04	Maintenance
57	0.07	Model	22	0.07	Information
45	0.16	Performance	22	0.09	Building
43	0.09	design	19	0.07	Implementation
43	0.03	FM	18	0.09	Quality
41	0.08	System	18	0.03	Innovation
37	0.08	Framework	15	0.08	Satisfaction
35	0.14	Management	15	0.08	Knowledge
28	0.12	Construction	14	0.13	Efficiency
26	0.22	Impact	13	0.03	Service

(1) Keyword frequency and betweenness centrality analysis. The top 20 keywords according to frequency and their centrality are shown in Table 2. These keywords reflected the main research topics of FM in the past two decades. The most frequent keyword was 'BIM'. Relevant research focused on how to apply BIM Technology in the whole life cycle of engineering projects, especially in FM. Keywords such as 'performance', 'quality', 'satisfaction' and 'efficiency' focused on the research of FM service quality and evaluation. Keywords such as 'information',

'innovation' and 'knowledge' focused on FM information, innovation and knowledge management. In addition, the top 5 keywords of betweenness centrality (the bold part of Table 3) were 'impact' (0.22), 'performance' (0.16), 'management' (0.14), "efficiency" (0.13), and "construction" (0.12). These keywords can be used as intermediary connectives for many research topics, which had a significant impact on the cross development and integration innovation in the FM field. For example, the paper with 'impact' as the keyword involves the cross themes of impact and evaluation in environmental sustainability, personnel, innovation and informatization.

Figure 3. Top 25 co-occurring keywords with the strongest citation bursts
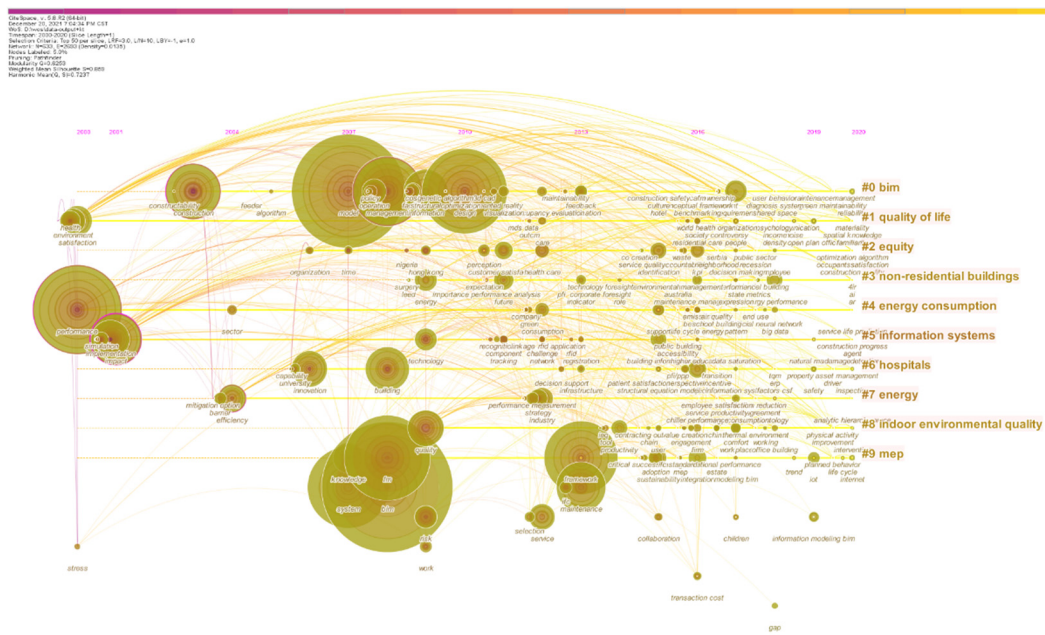

Figure 4. Timeline visualization of cooccurring keywords

(2) Burst detection. Keywords with the strongest citation burst can be used to identify hotspots in a specific period, reflecting the development trend of the research field in that time period. The keywords with the strongest citation bursts are shown in <u>Figure 3</u>. The burst strength is mainly used to measure the frequency of keywords in the cited literature. A keyword is defined as a burst keyword if it increases sharply in a certain period of time. Firstly, the keyword with the highest strength was 'Information' (2.46), which indicated that the cited literature in 2018-2020 concentrated on information flow in FM and other processes throughout the life cycle of construction projects, focusing on visualization applications and information management methods. The top 25 keywords were all between 1 and 2.5, and there was no particularly high strength which indicated that there were many topics and disciplines and not concentrated in a particular subject area. Second, The keyword with the long period were 'Policy' (2008-2017) and 'Decision' (2009-2016), reflecting the research trend of policy and organizational decision making in the FM industry over a long period of time. In addition, the three keywords still bursting were 'Information', 'Visualization', and 'Big Data' (2018-2020). This reflected the hot research trend in the field of FM on informatization, visualization and big data under the background of the current information age and driven by technology.

Table 3. Summary of the largest 10 clusters for co-occurring keywords

Cluster ID	Size	Label (LLR)	Mean Year	Critical Keywords	Representative Literatures
#0	74	BIM	2013	BIM; interoperability; data transfer; space management; property management	[13,14]
#1	51	Quality of Life	2015	Quality of life; elderly people; private domestic buildings; individual behaviour	[15,16]
#2	48	Equity	2016	Equity; financial barriers; building service robots; environmental behaviour; expectation	[17,18]
#3	47	Non-residential Buildings	2015	Non-residential buildings; principal component; artificial intelligence; augmented reality	[19]
#4	47	Energy Consumption	2015	Energy consumption; energy consumption drivers; predictive maintenance; operational	[20,21]
#5	42	Information systems	2011	Information systems; artificial intelligence; personnel management; knowledge gap; transition	[22]
#6	41	Hospitals	2014	Hospitals; facilities management; factor analysis; fm services; management model	[23]
#7	41	Energy	2013	Energy; HVAC system repair; measurement; service diversification; occupancy	[24,25]
#8	41	Indoor environment quality	2017	Indoor environmental quality; wireless sensor networks; occupant productivity	[26]
#9	37	MEP	2016	MEP; BIM; information requirements; operation and maintenance	[27]

The representative literature is the cited literature with multiple important keywords (including additional keywords) and high citation frequency.

(3) Keywords cluster analysis. The clusters were determined by calculating the similarity between the nodes. The visual clustering timeline of keywords is shown in Figure 4. The time point corresponding to each node is the year in which the keyword first appeared. The modularity was 0.6253 (> 0.3), and the Silhouette was 0.853 (> 0.7), indicating that the clustering structure was significant. The ID, size, labels, mean year, critical keywords and representative literatures of the top 10 clusters are shown in Table 3. Among them, the size of each cluster was more than 37, and the largest cluster contained 74 member keywords, indicating that each research topic formed a large research population represented by a label. The analysis shows that the themes clustered by research topic keywords are in the following order: using BIM in FM, FM impact on quality of life, FM service equity, FM in non-residential buildings, facility operation and maintenance energy management, BIM information system, hospital FM, FM energy system, facility indoor environment, and electromechanical equipment management. The above large aggregation keywords reflected the hot clustering of current FM research, and can guide scholars on relevant research topics to carry out cooperative research.

4. Conclusion

The study applied scientometric method and visualization software CiteSpace to construct the knowledge network map in the field of FM research, then systematically analyzed the international journals and subject characteristics in the field of FM research with relevant parameters. The findings of the study are as follows. (1) In addition to professional core journals such as Facilities and Journal of facilities management, FM research journals also cover interdisciplinary application journals such as engineering technology, structure and management, and computer, reflecting the intersection and activity of FM research journals and their concerned contents. (2) The subject keywords of high-frequency papers in the field of FM research include BIM and technology application, service quality and evaluation, innovation and knowledge management. At the same time, the research on FM informatization, visualization and big data has become hotspots in recent years. (3) FM research field has formed a number of important topic keyword clusters, such as using BIM in FM, impact of FM on quality of life, fairness of FM services, etc., which can guide scholars on relevant research topics to carry out in-depth cooperative research.

Studying and clarifying the hotspots and trends in the research field of FM will contribute to the systematic development and professional practice of FM concepts, methods and technologies. As a professional field integrating multi-disciplinary theories, methods and technologies, the research field of FM urgently needs to provide theoretical and implementation method support of sustainable strategy for national economic transformation, social transformation, urban renewal, park operation, and enterprise operation through innovative theoretical system construction and research theme design.

References

[1] C. Coenen, D. Felten: A Service-oriented Perspective of Facility Management, Facilities, Vol. 32 (2014) No.9 /10, p.554-564.

[2] J.M. Cao, L.L Miao: Analysis of Current Implementation Situation and Restricting Factors of Facility Management in China, Construction Economy, (2008), No.3, p.100-103.

[3] J. M .Zhang: The Future of BIM for Facility Management: the Impact of IoT and AI, Journal of Information Technology in Civil Engineering and Architecture, Vol. 10(2018), No.6, p.10-20.

[4] J.M. Cao, L. Liu and L.L. Miao, et al: Facility Management Maturity Model for Public Buildings, Journal of Engineering Management, Vol. 31 (2017), No.2, p. 59-63.

[5] Z.H. Wang, W.H. Qiu and W. Zhan: Facility Management and Its Future Development in China, Modern Management Science, Vol. 2 (2006), p. 27-29.

[6] Z.H. Wang, W. Zhan and W.H. Qiu: Research on the Theoretical System Framework of Facility Management, Modern Management Science, Vol. 4 (2008), p.86-88.

[7] Z.S. Ding, N. Zhao: Facility Management and Its Development Tendency in Chian, Construction Economy, (2007), No.7S, p.23-26.

[8] P. McLennan: Service Operations Management as a Conceptual Framework for Facility Management, Facilities, Vol. 22 (2004), No.13/14, p.344-348.

[9] Z.H. Wang, W.H. Qiu and W. Zhan: The Development of Facility Management Research, Journal of Engineering Management, Vol. 3 (2006), p.5-8.

[10] C. Chen: Searching for intellectual turning points: Progressive Knowledge Domain Visualization, Proceedings of the National Academy of Sciences of the United States of America, Vol. 101 (2004), No.S1, p.5303-5310.

[11] C. Chen, I.S. Fidelia and J.H. H: The Structure and Dynamics of Co-citation Clusters: A Multiple-perspective Co-citation Analysis, Journal of the American Society for Information Science and Technology, Vol. 61 (2010), No.7, p.1386-1409.

[12] C. Chen, R. Dubin and M.C. Kim: Orphan Drugs and Rare Diseases: A Scientometric Review (2000-2014), Expert Opinion on Orphan Drugs, Vol. 2 (2014), No.7, p.709-724.

[13] E.M. Wetzel, W. Thabet: A Case Study Towards Transferring Relevant Safety Information for Facilities Maintenance Using BIM, Electronic Journal of Information Technology in Construction, Vol. 23 (2018), p.53-74.

[14] S. Matarneh, M. Danso-Amoako, S. Al-Bizri, et al: BIM-based Facilities Information: Streamlining the Information Exchange Process, Journal of Engineering, Design and Technology, Vol. 17 (2019), No.6, p.1304-1322.

[15] M.Y. Leung, J.Y. Yu and M.L.A. Chong: Impact of facilities management on the quality of life for the elderly in care and attention homes - Cross-validation by quantitative and qualitative studies, Indoor and Built Environment, Vol. 26 (2017), No.8, p.1070-1090.

[16] M.Y. Leung, I.O. Famakin and K. Ahmed, et al: Comparison of facilities management in private domestic buildings among different elderly groups in Hong Kong, Facilities, Vol. 36 (2018), No.7/8, p.386–402.

[17] A.E. Palchik, M.W. Winstons and H.D. Kiwanuka, et al: Health facility management and access: a qualitative analysis of challenges to seeking healthcare for children under five in Uganda, Health Policy and Planning, Vol. 32 (2017), No.7, p.934-942.

[18] B. Mantha B, K.J. Min and B. Soto, et al: Generalized task allocation and route planning for robots with multiple depots in indoor building environments, Automation in Construction, Vol. 119 (2020), p.103359.

[19] R. Bortolini, N.R. Forcada: Facility managers' perceptions on building performance assessment, Frontiers of Engineering Management, Vol. 5 (2018), No.3, p.10.

[20] N. Brown, A.J. Wright and A. Shukla A, et al: Longitudinal analysis of energy metering data from non-domestic buildings, Building Research and Information, Vol. 38 (2020), No.1, p.80-91.

[21] F. Ling, D. Wong: Redesigning facility management operatives' jobs to increase work outcomes, Journal of Facilities Management, Vol. 14 (2016), No.1, p.50-68.

[22] S.P. Thor, J.R.R. Antonio and B. Henrik, et al: Spatio-temporal facility utilization analysis from exhaustive WiFi monitoring, Pervasive and Mobile Computing, Vol. 16 (2015), p.305-316.

[23] D.I. Ikediashi, S.O. Ogunlana, I.A. Odesola: Service quality and user satisfaction of outsourced facilities management (FM) services in Nigeria's public hospitals, Built Environment Project and Asset Management, Vol. 5 (2015), No.4, p.363-379.

[24] H.K.L. Joseph: Energy use and maintenance costs of upmarket hotels, International Journal of Hospitality Management, Vol. 56 (2016), p.33-43.

[25] W. Yan, S. Li: Understanding occupancy and user behaviour through Wi-Fi-based indoor positioning, Building Research and Information, Vol. 04 (2017), p.725-737.

[26] M. Mohamed, A. Ahmed: Monitoring thermal comfort in subways using building information modeling, Energy and Buildings, Vol. 84 (2014), p.252-257.

[27] Z.Z. Hu, J.P. Zhang and F.Q. Yu, et al: Construction and facility management of large MEP projects using a multi-Scale building information model, Advances in Engineering Software, Vol. 100 (2016), p.215-230.