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APPLYING CHOOSING BY ADVANTAGES (CBA) DECISION-MAKING FRAMEWORK IN PROPERTY MANAGEMENT: A BIBLIOMETRIC ANALYSIS

Norbaizura Abu Bakar[a*], Siti Uzairiah Mohd Tobi[a]

[a] *Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, Kuala Lumpur Jalan Sultan Yahya Petra, 54100 Kuala Lumpur, Malaysia*
**Corresponding author's email: norbaizura86@graduate.utm.my*

ABSTRACT

The study explores the application of the CBA decision-making framework within the domain of property management, addressing a gap in the literature regarding structured decision-making methodologies in this field. Despite the increasing complexity of property management, there remains limited research on frameworks that aid in systematic decision-making, especially in areas like maintenance, resource allocation, and sustainability. This research conducts a comprehensive bibliometric analysis to map the trends, key contributors, and collaborative networks within CBA applications in property management. Using Scopus Analyzer and VOSviewer software, a dataset of 748 documents was gathered, spanning from 2004 to 2024. Scopus Analyzer provided insights into publication trends, identifying a sharp increase in CBA-related studies in recent years. VOSviewer was employed to visualize co-authorship patterns and popular keywords, revealing "Facility Management" and "Decision-Making" as dominant themes alongside emerging topics like "Building Information Modeling" and "Digital Twin," highlighting the integration of technology in decision-making processes. The analysis shows that countries such as the United States, United Kingdom, China, and Australia are key contributors with significant international collaborations. Findings indicate a rising trend in applying CBA in fields demanding structured evaluation, although property management remains underexplored, presenting further research opportunity. This study provides a foundation for understanding CBA's potential role in property management, suggesting that the framework could enhance decision-making processes in complex, asset-intensive environments, thereby paving the way for more efficient and sustainable property management practices.

***JEL classification**: C44, D81.*
***Keywords**: Choosing By Advantages; decision-making; property management; facilities management.*

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1. INTRODUCTION

Applying the CBA decision-making framework in property management offers a structured and systematic approach to navigate property-related decisions' complexities. CBA, a value-based decision-making method, emphasizes the advantages of decision alternatives rather than focusing solely on cost. This approach is particularly beneficial in property management, where decisions often involve balancing multiple criteria, such as financial constraints, sustainability, and stakeholder preferences. By considering the advantages of each alternative, CBA helps property managers make more informed and transparent decisions, ultimately leading to better outcomes in areas such as building maintenance, capital project planning, and resource allocation (Arroyo *et al.,* 2018; Besiktepe *et al.,* 2021, 2023).

Applying CBA in property management facilitates collaborative decision-making by involving various stakeholders in the process, helps minimize biases, and improves stakeholder consensus. This participatory approach ensures that the preferences and needs of different parties are considered, leading to more satisfactory and sustainable decisions. For instance, in building maintenance, CBA can help prioritize maintenance activities based on their advantages, thereby improving efficiency and resource utilization (Kpamma et al., 2018; Besiktepe et al., 2021). Additionally, CBA's ability to integrate multiple criteria and manage subjective trade-offs makes it a valuable tool for addressing the complex and often conflicting demands in property management (Arroyo *et al.,* 2018; Pérez *et al.,* 2021). By adopting the CBA framework, property managers can enhance decision-making processes, achieve greater consensus among stakeholders, and ultimately improve properties' overall management and performance.

Given the increasing interest in CBA's application within property management, this study employs a bibliometric analysis to explore the research trends and scholarly impact of CBA in this domain. Bibliometric analysis provides a systematic method to evaluate the body of literature, identifying key trends, influential authors, and collaborative networks. The following research questions guide the bibliometric analysis:

1. What are the research trends in CBA studies according to the year of publication?
2. Who are the most prolific authors in the field of CBA research?
3. Who are the top 10 authors based on citation counts?
4. What are the popular keywords associated with CBA in property management?
5. What are the patterns of international collaboration in CBA research?

Through this analysis, the study aims to uncover significant patterns and insights into the theoretical and practical evolution of CBA in property management. By addressing these questions, the findings will contribute to a deeper understanding of CBA's role in enhancing decision-making frameworks in this field and provide a foundation for future research and applications.

2. LITERATURE REVIEW

Applying the CBA decision-making framework in property management, specifically within the construction, maintenance, and operations domains, reveals a multifaceted

approach with various studies highlighting CBA's capacity for prioritizing sustainable options. Luong-Duc *et al.* (2024) demonstrate how CBA integrated with Building Information Modeling (BIM) enables the selection of sustainable materials by assessing energy consumption and CO2 emissions, thus supporting environmentally friendly decision-making. Similarly, Tuesta *et al.* (2024) emphasize CBA's advantage in optimizing subcontractor selection for multi-family housing projects, facilitating more informed decisions based on criteria such as financial stability and workforce capability. This body of work confirms CBA's versatility in addressing complex decision-making issues in sustainability-focused property management by enhancing transparency and reducing environmental impact (Bhuiyan *et al.,* 2022; Luong-Duc *et al.,* 2024; Tuesta *et al.,* 2024). Studies such as those by El-Kholy (2022) and Lopez De La Cruz *et al.* (2023) illustrate CBA's effectiveness in contractor and subcontractor selection, which is critical for minimizing risks associated with cost overruns and project delays. El-Kholy (2022) introduces a structured CBA framework for subcontractor selection, leveraging factors such as reputation and qualification, which improves decision-making efficiency and aligns with quality standards. Lopez De La Cruz *et al.* (2023) apply CBA to subcontracting in multi-family housing, demonstrating that quality and production capacity are key factors in optimizing project timelines and reducing labor costs. The findings across these studies underscore CBA's strength in reducing subjective biases, promoting a balanced approach, and facilitating quality-oriented decisions in project management (El-Kholy, 2022; Lopez De La Cruz *et al.,* 2023; Waleczko, 2024).

CBA's application extends to optimize decision-making tools in the Architecture, Engineering and Construction (AEC) industry, with Miranda-Quiñones *et al.* (2024) proposing a probabilistic adaptation of CBA to account for uncertainty in architectural and engineering projects. Their research shows how incorporating probabilistic models into CBA enhances stakeholder engagement and supports transparent decision-making under variable conditions, particularly in areas like energy efficiency in residential buildings. Similarly, Vázquez-Rowe *et al.* (2021) combine CBA with Life Cycle Assessment (LCA) in public procurement to address environmental impacts, showcasing CBA's adaptability to diverse criteria beyond cost efficiency. These applications reveal the ongoing evolution of CBA towards more comprehensive models capable of handling uncertainty and emphasizing sustainability within construction management (Vázquez-Rowe *et al.,* 2021; Besiktepe *et al.,* 2023; Miranda-Quiñones *et al.,* 2024;). Another area of interest is CBA's contribution to enhance facility management (FM) decision-making. According to Besiktepe *et al.* (2023), CBA assists in resource allocation, prioritization, and building maintenance by addressing cost constraints and evaluating long-term advantages. Their research identifies gaps, such as a need for improvements in the Importance of Advance (IoA) scale, which could refine CBA's consistency and objectivity. Furthermore, the study conducted by Ahmed & Jin (2024) explores the combination of CBA with the Fuzzy Analytical Hierarchy Process (FAHP) to improve material selection in the early stages of construction projects, offering a comparative analysis that enhances CBA's robustness. These contributions highlight CBA's potential to improve FM processes by providing structured, criteria-based evaluation tools in resource-constrained settings (Huarsocca *et al.,* 2022; Besiktepe *et al.,* 2023; Ahmed & Jin, 2024).

Despite CBA's benefits, challenges remain in achieving universal applicability across all areas of property management. Ahmed & Arocho (2022) point out that while CBA enables the evaluation of sustainable building materials like mass timber, construction practitioners still exhibit reluctance in adopting less conventional materials, indicating a gap in industry-wide acceptance. Tonetto & Saurin (2021) also identify limitations in using CBA for complex safety systems due to the inherent variability in construction hazards. This highlights a need for future research to improve CBA's scalability and adaptability in construction safety and material innovation contexts (Tonetto & Saurin, 2021; Ahmed & Arocho, 2022; Shah *et al.,* 2024). In conclusion, while CBA proves beneficial in promoting sustainability, efficiency, and transparency in property and construction management, several areas require further exploration. The method's adaptation to probabilistic contexts and integration with other decision-making frameworks represents a promising direction for addressing its current limitations. Additionally, more extensive applications in public procurement and FM practices could yield insights into enhancing its relevance in broader property management contexts. Future research may focus on refining CBA's quantitative capabilities, reducing subjective bias, and addressing industry-specific challenges in sustainable construction.

3. METHODOLOGY

Bibliometrics involves collecting, organizing, and analyzing bibliographic information from scientific publications (Verbeek *et al.,* 2002; Alves *et al.,* 2021; Assyakur & Rosa, 2022). This includes general descriptive statistics like publishing journals, publication years, and classifications of primary authors (Wu & Wu, 2017) and more advanced techniques such as document co-citation analysis. An effective literature review is an iterative process of identifying relevant keywords, searching the literature, and conducting detailed analysis to build a thorough bibliography and achieve reliable findings (Fahimnia *et al.,* 2015). With this in mind, this study focused on high-impact publications for valuable insights into the theoretical frameworks guiding this field's development. For data reliability, the SCOPUS database was used (di Stefano *et al.,* 2010; Khiste & Paithankar, 2017; Al-Khoury *et al.,* 2022), peer-reviewed academic journal articles including books and lecture notes were selected to ensure quality, intentionally (Gu *et al.,* 2019). Scopus, recognized for its wide-ranging database, provided publications from 2004 through December 2024 for analysis.

3.1 Data search strategy

An advanced search strategy in the Scopus database is a method of using detailed search parameters and logical operators to retrieve articles that match specific research criteria precisely. This approach is essential for conducting systematic reviews or bibliometric analyses, as it allows researchers to locate highly relevant literature within vast databases like Scopus by filtering out irrelevant results. Advanced search strategies typically involve the use of Boolean operators (AND, OR, NOT), specific field codes (such as TITLE, ABSTRACT, or KEYWORDS), date filters, and language restrictions to refine the search further. In the context of the provided tables, the advanced search strategy demonstrates a carefully constructed query designed to capture articles directly relevant to the study, titled *"Applying Choosing By*

*Advantages (CBA) Decision-Making Framework in Property Management: A Bibliometric Analysis."*The first table, titled "The Search String," outlines the specific keywords and filters used in Scopus to narrow down the literature relevant to this study. The search was performed on articles with titles, abstracts, and keywords, specifically using terms directly related to the research focus. These terms include "Choosing by Advantages" and "Decision-Making" to capture studies focused on the CBA decision-making framework, which is central to the research. To broaden the scope within the property management field, additional keywords like "Property Management," "Facilities Management," "Building Maintenance," "Property Maintenance," and "Facilities Maintenance" were included. This ensures that the search encompasses literature on decision-making frameworks and maintenance aspects in property and facilities management. Furthermore, a publication year filter was applied, limiting results to articles published from 2004 to 2024, thereby focusing on more recent and relevant literature. Additionally, the search was restricted to English-language publications to ensure the accessibility of the content for analysis.

The second table, labeled "The Selection Criterion," defines the inclusion and exclusion criteria applied to the search results to refine further and ensure relevance. The language criterion specifies that only English-language articles are included in the analysis, with non-English articles excluded to maintain consistency and accessibility in language. The timeline criterion was set to include articles published between 2004 and 2024, aligning with the search filter in Table 1. This range reflects a focus on relatively recent studies that could provide insights into contemporary practices and advancements in CBA and property management. Articles published before 2004 were excluded to avoid outdated information that may no longer be relevant to the current landscape of property management and decision-making frameworks. Together, these tables illustrate a well-defined and systematic approach to identifying pertinent research. The search string in Table 1 effectively captures studies aligned with the CBA framework, decision-making processes, and property management, while the inclusion and exclusion criteria in Table 2 further refine the results by focusing on language and publication year. This comprehensive search strategy ensures that the articles retrieved are relevant, accessible, and valuable for bibliometric analysis of applying the CBA framework in property management.

Table 1: The search string

Scopus	**TITLE-ABS-KEY ((("CBA" OR "Decision-Making") AND ("Property Management" OR "Facilities Management" OR "Building Maintenance" OR "Property Maintenance" OR "Facilities Maintenance"))) AND PUBYEAR > 2003 AND PUBYEAR < 2025 AND (LIMIT-TO (LANGUAGE, "English")).**

Table 2: The selection criteria.

Criterion	Inclusion	Exclusion
Language	English	Non-English
Timeline	2004 – 2024	< 2004

3.2 Data analysis

VOSviewer is an accessible bibliometric software developed by Nees Jan van Eck and Ludo Waltman at Leiden University in the Netherlands (van Eck & Waltman, 2010, 2017). Renowned for its use in visualizing and analyzing scientific literature, VOSviewer specializes in creating clear network visualizations, clustering related items, and producing density maps. This flexibility allows researchers to explore networks of co-authorship, co-citation, and keyword co-occurrence, offering a comprehensive view of research landscapes. Its interactive design and regular updates make navigating large datasets efficient and dynamic. VOSviewer's capabilities in metric calculation, visualization customization, and compatibility with multiple bibliometric data sources make it an invaluable asset for researchers seeking insights into complex research fields. One of VOSviewer's key strengths is its ability to convert complex bibliometric datasets into visually accessible maps and charts. Emphasizing network visualization, the software excels at clustering related items, analyzing keyword co-occurrence patterns, and generating density maps. Its user-friendly interface supports novice and experienced users in efficiently exploring research landscapes. With continuous improvements, VOSviewer stays at the forefront of bibliometric analysis, offering valuable insights through metric computation and adaptable visualizations. Its flexibility in handling diverse bibliometric data, including co-authorship and citation networks, establishes VOSviewer as a versatile and essential tool for scholars aiming to gain deep insights into their research areas.

Data sets containing details such as publication year, title, author, journal, citation count, and keywords in PlainText format were collected from the Scopus database, covering the period from 2004 to December 2024. These datasets were analyzed using VOSviewer software version 1.6.19. Through VOS clustering and mapping techniques, VOSviewer enabled the examination and generation of maps. Unlike the Multidimensional Scaling (MDS) approach, VOSviewer focuses on positioning items in low-dimensional spaces to ensure that the distance between items accurately represents their similarity (van Eck & Waltman, 2010). Although similar to MDS (Appio *et al.,* 2014), VOSviewer differs by utilizing a more suitable method for normalizing co-occurrence frequencies, such as association strength (AS_{ij}) as expressed by equation (1), calculated by Van Eck & Waltman (2007).

$$AS_{ij} = \frac{C_{ij}}{w_i w_j} \tag{1}$$

This measure is "proportional to the ratio between the observed number of co-occurrences of *i* and *j* and the expected number of co-occurrences of *i* and *j* under the assumption of statistical independence" (van Eck & Waltman, 2010). This index allows the VOSviewer to map items by minimizing the weighted sum of squared distances among all item pairs. According to Appio *et al.* (2016), LinLog/modularity normalization was applied. Through VOSviewer's visualization techniques, mathematical relationships in the data were identified, enabling analyses like keyword co-occurrence, citation analysis, and co-citation analysis. Keyword co-occurrence analysis helps explore the development of research areas over time (Zhao, 2017) and

effectively identifies popular topics across fields (Gu *et al.,* 2019). In contrast, citation analysis reveals key research issues, trends, and methodologies, as well as the historical significance of a field's primary focus (Allahverdiyev & Yucesoy, 2017). Document co-citation analysis, a widely used bibliometric method (Fahimnia *et al.,* 2015; Liu *et al.,* 2015; Appio *et al.,* 2016), produces maps based on network theory to uncover the relevant structure within the data (Liu *et al.,* 2015).

4. RESULTS AND FINDINGS

4.1 What are the research trends in CBA decision-making framework according to the year of publication?

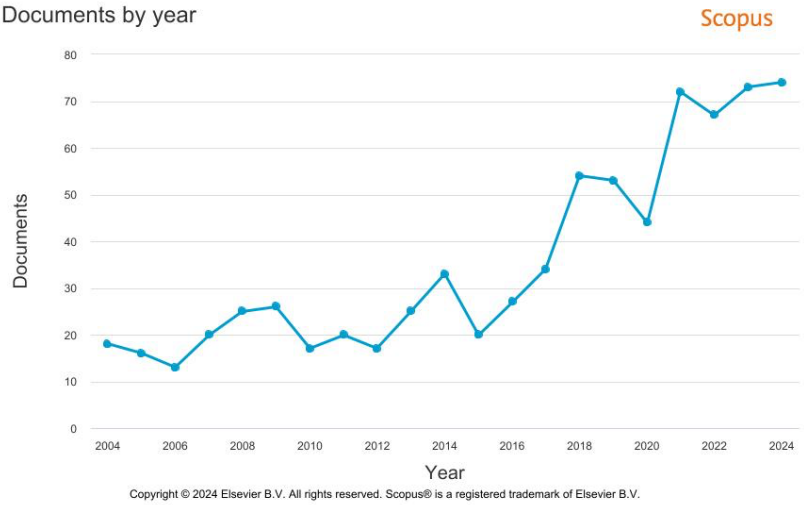

Figure 1: Document publication by year.

The figure illustrates a rising trend in the number of publications related to the CBA decision-making framework from 2004 to 2024, with a notable increase in recent years. Between 2004 and 2015, publications remained relatively stable, fluctuating between 10 and 30 documents per year, indicating limited research interest or applications during that period. However, beginning around 2016, there is a steady upward trend, suggesting growing recognition of CBA's value in various fields. This growth may be driven by the increasing complexity of decision-making in areas like environmental sustainability, construction, and engineering, where CBA offers structured, advantage-based evaluation.

From 2020 onward, there is a sharp rise in publications, peaking around 2022 with over 70 documents, which might be attributed to the global shift towards data-driven, value-oriented decision-making approaches. The significant jump in recent years suggests that researchers are exploring new and varied applications for CBA, although no specific literature exists on its use in property management. This trend highlights a promising gap: the potential for integrating CBA into property management frameworks, especially for maintenance decision-making, resource allocation, and strategic planning. By conducting this bibliometric analysis, this article aims to identify key authors, institutions, and research clusters, thereby establishing a

foundation for future work that bridges the CBA framework with property management practices.

4.2 Who are the most prolific authors in the field of research?

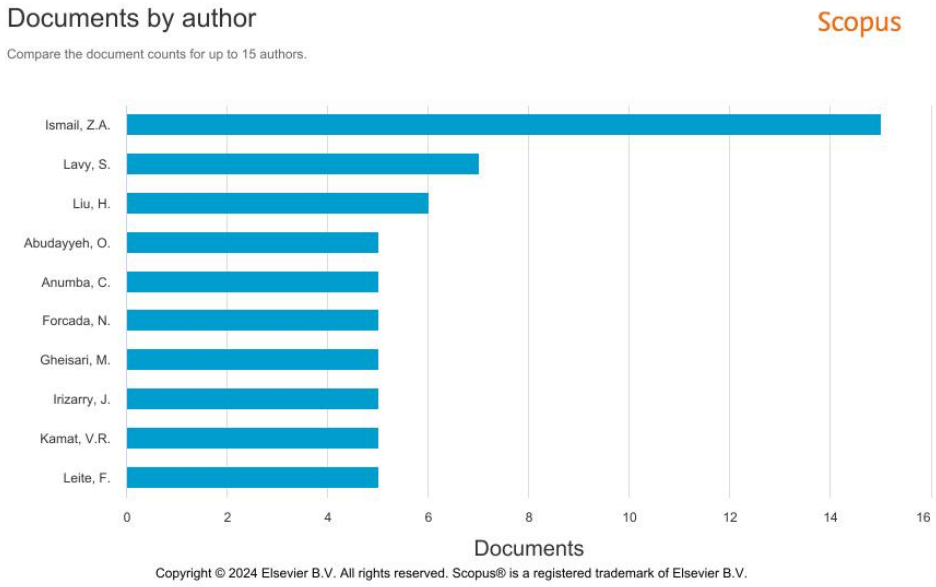

Figure 2: Top 10 most prolific authors.

Table 3: Top 10 authors with numbers of documents.

Author Name	Number of Document	Percentage (%)
Ismail, Z.A.	15	2.005
Lavy, S.	7	0.936
Liu, H.	6	0.802
Abudayyeh, O.	5	0.668
Anumba, C.	5	0.668
Forcada, N.	5	0.668
Gheisari, M.	5	0.668
Irizarry, J.	5	0.668
Kamat, V.R.	5	0.668
Leite, F.	5	0.668

The data, presented in both a bar chart and a table, reveals the most prolific authors in the field of CBA research, showing a distinct concentration of publications by a few key contributors. Z.A. Ismail stands out as the most productive author, with 15 documents contributing approximately 2.005% of the total literature, indicating a leading role in advancing the CBA framework. This dominance suggests that Ismail's work may include foundational studies or key innovations that are frequently referenced or built upon in subsequent research. Other notable contributors, such as S. Lavy and H. Liu, follow with 7 and 6 documents, respectively. Lavy's and Liu's substantial contributions underscore their roles in broadening CBA's application across various decision-making contexts, which may provide valuable insights and methodologies for expanding CBA into new fields such as property management.

Authors like O. Abudayyeh, C. Anumba, N. Forcada, and M. Gheitari, each with 5 documents (0.668% of the total), represent an essential tier of contributors that supports a collaborative research environment. This tier of authors contributes to the diversity of CBA applications, potentially covering specialized applications within fields such as construction, engineering, and project management. The relatively equal contribution among these authors may indicate the presence of small research clusters focused on exploring and validating CBA in specific industry practices, providing a basis for the interdisciplinary application of CBA. This kind of collaborative research is crucial for strengthening the CBA framework's adaptability and robustness across different domains.

The consistency among the top authors highlights a stable but narrow research base, implying that while the field has dedicated contributors, the exploration of CBA is somewhat concentrated within a limited number of experts. This situation suggests an opportunity for broader involvement and collaboration, particularly from researchers in underrepresented areas like property management. By analyzing the specific research outputs of these authors, especially those leading in publication volume, future studies can identify patterns, methodologies, and gaps in the literature. This analysis can ultimately guide researchers aiming to apply CBA in property management, fostering the development of decision-making frameworks that address unique challenges within property maintenance and management. This bibliometric analysis could, therefore, serve as a roadmap for emerging researchers looking to bridge CBA with property management practices.

4.3 Who are the top 10 authors based on citation by research?

The table provides data on the top-cited authors in CBA-related research, indicating their influence and the impact of their work. Among the top-cited works, the article by Xu S. *et al.* in 2021, titled *Computer Vision Techniques in Construction: A Review*, has received 227 citations. This high citation count suggests that Xu's work, although not explicitly about CBA, likely employs decision-making frameworks or related methodologies that resonate with CBA's structured approach. The prominence of computational and automation topics in highly cited works underlines the growing interest in integrating advanced technologies and decision-making frameworks in construction and project management. The study by Du J. *et al.* from 2018, with 224 citations, and Deng M. *et al.*'s 2021 study, with 236 citations, both focus on digital transformation topics, such as BIM and digital twins, which are critical to modern property and construction management. These studies contribute valuable insights into the data-centric decision-making processes, aligning well with CBA's approach of structuring decisions based on advantages. These high-impact publications highlight the interdisciplinary nature of CBA applications and demonstrate that influential research often incorporates digital solutions to support complex decision-making in engineering and construction.

The high citation counts of these publications reflect the research community's recognition of digital and computational advances in enhancing decision-making frameworks. This key aspect can be extended to property management. Examining the methodologies and frameworks used in these highly cited works can provide a foundation for adapting CBA within property management, particularly in areas like resource allocation and maintenance prioritization. This bibliometric analysis of top-cited authors helps to pinpoint influential research trends, showcasing opportunities

to integrate CBA with digital advancements, thereby fostering a more data-driven approach in property management applications.

Table 4: Top 10 of the most cited authors.

Authors	Title	Year	Source Title	Cited by
Xu S.; Wang J.; Shou W.; Ngo T.; Sadick A.-M.; Wang X.	Computer Vision Techniques in Construction: A Critical Review	2021	Archives of Computational Methods in Engineering	227
Du J.; Zou Z.; Shi Y.; Zhao D.	Zero latency: Real-time synchronization of BIM data in virtual reality for collaborative decision-making	2018	Automation in Construction	224
Deng M.; Menassa C.C.; Kamat V.R.	From BIM to digital twins: A systematic review of the evolution of intelligent building representations in the AEC-FM industry	2021	Journal of Information Technology in Construction	236
Wang Q.; Tan Y.; Mei Z.	Computational Methods of Acquisition and Processing of 3D Point Cloud Data for Construction Applications	2020	Archives of Computational Methods in Engineering	150
Brauers W.K.M.; Zavadskas E.K.; Turskis Z.; Vilutiene T.	Multi-objective contractor's ranking by applying the Moora method	2008	Journal of Business Economics and Management	160
Joshi S.; Arano K.G.	Determinants of private forest management decisions: A study on West Virginia NIPF landowners	2009	Forest Policy and Economics	146
Chen W.; Chen K.; Cheng J.C.P.; Wang Q.; Gan V.J.L.	BIM-based framework for automatic scheduling of facility maintenance work orders	2018	Automation in Construction	180
Golparvar-Fard M.; Peña-Mora F.; Savarese S.	Integrated sequential as-built and as-planned representation with D 4AR tools in support of decision-making tasks in the AEC/FM industry	2011	Journal of Construction Engineering and Management	175
Bhatla A.; Choe S.Y.; Fierro O.; Leite F.	Evaluation of the accuracy of as-built 3D modeling from photos taken by handheld digital cameras	2012	Automation in Construction	145
Wetzel E.M.; Thabet W.Y.	The use of a BIM-based framework to support safe facility management processes	2015	Automation in Construction	175

4.4 What are the popular keywords related to the study?

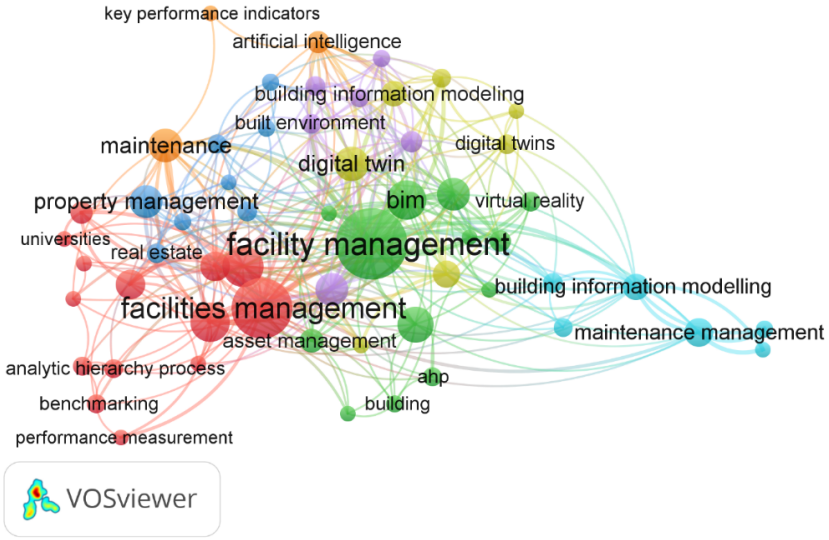

Figure 3: Network visualization map of popular keywords

The data generated from VOSviewer presents a comprehensive overview of popular keywords related to property management and the CBA (CBA) decision-making framework. The table highlights "Facility Management" and "Facilities Management" as highly recurrent terms, with occurrences of 99 and 72 and link strengths of 127 and 67, respectively. These terms serve as foundational concepts within the property management field and are central to the study of decision-making frameworks like CBA. Additionally, keywords related to decision-making, such as "Decision Making" (33 occurrences) and "Decision-Making" (31 occurrences), exhibit strong link strengths, indicating their high relevance and interconnectedness within this research area. This data suggests that decision-making is a critical theme within property and facility management, underscoring the importance of frameworks like CBA in optimizing processes and outcomes in this sector.

Technological advancements emerge as another significant theme, with keywords such as "Building Information Modeling" (BIM) and "Digital Twin" showing high occurrences and link strengths. For instance, BIM appears in multiple variations, including "BIM" (30 occurrences, 60 link strength), "Building Information Modeling" (21 occurrences, 35 link strength), and "Building Information Modelling" (14 occurrences, 29 link strength). Similarly, "Digital Twin" has 23 occurrences with a link strength of 47. These terms highlight the increasing role of technology in property management, suggesting that digital tools and models are frequently discussed within the literature as aids for enhanced decision-making and management efficiency. This technological trend could be relevant for studies exploring how CBA might interact with or benefit from such tools, as data-driven and simulation-based decision support systems are increasingly integral to property and asset management.

Maintenance and sustainability-related keywords are also prominently featured, reflecting key operational priorities in property management. Terms like "Building Maintenance" (26 occurrences, 19 link strength), "Maintenance" (22 occurrences, 33

link strength), and "Maintenance Management" (16 occurrences, 25 link strength) indicate a strong focus on maintaining the functionality and longevity of facilities. "Sustainability," with 21 occurrences and a link strength of 27, underscores the growing emphasis on sustainable practices within the field, aligning with global trends toward energy efficiency and environmental responsibility. Additionally, keywords like "Asset Management" (11 occurrences, 15 link strength) and "Outsourcing" (10 occurrences, 17 link strength) suggest a focus on resource management and operational efficiency. This data provides a holistic view of the themes within property management literature, which your study could explore further by examining how CBA supports or enhances decision-making in maintenance, sustainability, and asset management practices.

4.5 What are co-authorship countries' collaboration?

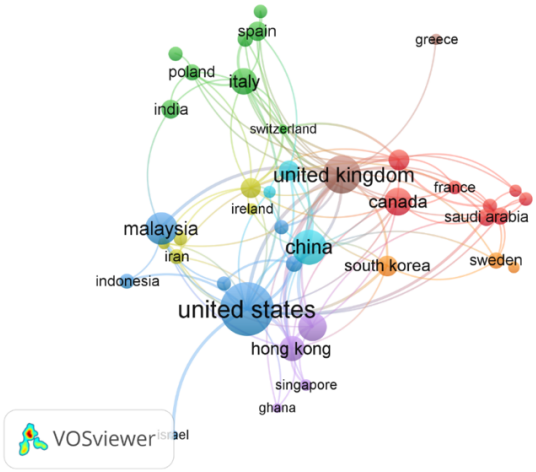

Figure 4: Co-authorship collaborations for countries involved in research

The data from VOSviewer on co-authorship collaborations for countries involved in research on *"Applying Choosing By Advantages (CBA) Decision-Making Framework in Property Management"* reveals key patterns of academic contribution and influence. The United States leads significantly, with 141 documents and 3,250 citations, indicating its strong involvement in this research area. Additionally, its total link strength of 44 suggests active international collaborations, although it remains lower than that of the United Kingdom. The United Kingdom also plays a crucial role with 71 documents, 1,280 citations, and a remarkable link strength of 55, indicating extensive global connections and a central position in international collaborations. The U.S. and U.K. demonstrate high productivity, impactful research, and openness to cross-border partnerships, suggesting they likely drive much of the discourse in property management and decision-making frameworks like CBA.

China and Australia also contribute significantly, with 60 and 41 documents, respectively. China stands out with the second-highest citation count of 1,137 and a total link strength of 28, showing a strong research output that is highly cited internationally. This suggests that Chinese research in this area is both prolific and influential. Australia, while having a lower citation count of 830 compared to China,

still shows substantial engagement in this field and a link strength of 18, indicating active collaboration within the global academic community. Similarly, Canada, with 38 documents and 711 citations, displays a solid research presence in this area, although with a lower link strength of 8, indicating fewer collaborative ties compared to China and Australia. These countries, along with the U.S. and U.K., represent core contributors to the research landscape on CBA in property management, bringing high citation counts and substantial contributions.

Among other nations, Malaysia's involvement is noteworthy, with 51 documents and 536 citations, which indicates its emerging role in property management research and its relevance within the context of this bibliometric study. Although Malaysia's total link strength of 11 is lower than some Western countries, its relatively high document count reflects growing research activity and interest in applying frameworks like CBA. European countries like Germany, Italy, and the Netherlands also show respectable contributions, with documents and citations indicating moderate impact and collaboration. Germany, with 20 documents and a link strength of 15, shows stronger connections than Italy and the Netherlands, suggesting Germany is more integrated within the international research network. Overall, this analysis shows that Western countries, particularly the U.S. and U.K., dominate in both output and collaboration. Still, countries like China, Australia, and Malaysia are increasingly contributing to the global research on property management and decision-making frameworks.

5. CONCLUSION

The bibliometric analysis reveals a steadily increasing trend in research related to the CBA decision-making framework from 2004 to 2024, with significant growth observed from 2016 onward. Early years reflect limited research interest. However, a consistent upward trend is visible as the framework gains recognition for its structured evaluation benefits, especially in fields like environmental sustainability, construction, and engineering. Notably, from 2020, there is a sharp rise in publications, peaking around 2022. This surge may correspond to a broader shift towards data-driven, advantage-based decision-making in complex sectors. Despite this growth, CBA's application, specifically within property management, remains unexplored, suggesting an opportunity for research that integrates CBA into frameworks for property maintenance, resource allocation, and strategic planning. Identifying key authors, institutions, and research clusters through this bibliometric analysis lays the groundwork for further studies that could bridge CBA and property management practices.

The analysis of prolific authors in CBA research shows a concentration of contributions by a few leading figures. The most productive authors have made substantial contributions, providing foundational studies or innovative applications that shape the field. These contributions indicate a somewhat narrow research base, where a select few authors drive the field forward. This limited pool of experts, while consistent, presents an opportunity for broader participation, particularly from researchers in underrepresented areas like property management. The influence of high-citation authors further reveals the impact of integrating digital advancements and computational methodologies in decision-making frameworks, which aligns with CBA's structured approach. By examining the work of these top-cited authors, this

study highlights a potential pathway for extending CBA applications, using digital tools to foster data-centric decision-making in property management. Such insights emphasize the interdisciplinary nature of CBA and its adaptability to emerging challenges in property management, encouraging future research to explore these underutilized connections.

The bibliometric analysis highlights two central themes in applying the CBA decision-making framework within property management: popular keywords and international research collaboration. The analysis of keywords, as generated by VOSviewer, indicates that terms like "Facility Management" and "Decision-Making" are foundational within the field, suggesting that these areas provide a significant basis for applying decision-making frameworks like CBA. Additionally, strong linkages are noted with terms related to decision-making itself, reinforcing the critical role of structured decision methodologies in property and facility management. Emerging technologies, such as "Building Information Modeling (BIM)" and "Digital Twin," also appear frequently, highlighting a trend toward digital solutions in property management that can support more data-driven and simulation-based decision processes. Moreover, the prominence of maintenance and sustainability-related keywords underscores the operational priorities in property management, emphasizing prolonging asset lifecycles and adopting environmentally responsible practices. These findings suggest that CBA can be particularly beneficial in scenarios where structured, advantage-based decision-making aligns with these priorities, providing potential for applications in maintenance planning and sustainable management practices.

The analysis of co-authorship collaborations reveals a concentration of research influence among a few leading countries, primarily the United States and the United Kingdom, which show high document counts and extensive international connections. The strong engagement of these countries suggests that they serve as central hubs in advancing the application of CBA in property management, likely shaping much of the discourse and methodological developments within this field. Other countries, such as China and Australia, also make substantial contributions, with China exhibiting high citation counts, which implies that its research is not only prolific but also impactful. Although emerging in this research area, Malaysia shows an increasing document count that reflects growing local interest in CBA applications, indicating potential for future growth in this region. The presence of European contributors like Germany and Italy further emphasizes the collaborative nature of this research, with countries establishing cross-border ties that facilitate the sharing of methodologies and insights. Overall, the data reveals a global landscape where leading Western countries dominate, yet significant contributions from Asia and other regions highlight a progressively collaborative research environment.

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