Bibliometric and content analyses of research on technology use in real estate facilities management

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Abstract

Purpose – Technological change drives transformation in most sectors of the economy. Industry 4.0 technologies have been applied at different stages of a building's lifecycle. However, limited studies exist on their application in real estate facilities management (REFM). This study aims to assess the existing knowledge on the topic to suggest further research directions.

Design/methodology/approach – Scopus-indexed literature from 2013 to 2023 was examined and visualised using VOSviewer software to output quantitative (descriptive) results. Content analysis was used to complement the quantitative findings.

Findings – Findings indicated a concentration of research in China, Norway and Italy. The knowledge areas included three clusters: lifecycle integration and management, data curation and management and organisational and management capabilities. The benefits, challenges and support strategies were highlighted.

Research limitations/implications – More collaboration is needed across countries and territories on technology integration in REFM. Future research using alternative methodologies is recommended, with a focus on adopting and non-adopting REFM organisations. Further, implications for facility managers, employees, technology suppliers or vendors, training, organisations and management exist.

Practical implications – Further, implications for facility managers, employees, technology suppliers or vendors, training, organisations and management exist.

Originality/value – The study reveals the knowledge base on technology use in REFM. It adds to the evidence base on innovation and technology adoption in REFM.

Keywords Facilities management, Innovation, Real estate, Sustainability, Technology, 4IR, 5IR, Industry 4.0

Paper type Literature review

Introduction

Facilities management (FM) practices affect organisations' functions, profitability and image (Potkány *et al.*, 2021). Despite contributing 5%–10% to the gross domestic product in developed countries, FM is the costliest phase of a facility's lifecycle, as operation and maintenance functions account for about 80%–85% of capital project costs (Ensafi and Thabet, 2021). This extended phase of buildings' life cycle is exacerbated by limited quality drawings and historical data, resulting in more complicated information flow and inefficient FM (Duong and Lin, 2022). Two-thirds of the estimated loss in the capital facilities industry

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in the USA is due to operations and maintenance inefficiencies (Li *et al.*, 2019). Effective FM is, therefore, critical to ensure cost savings and improved quality (Potkány *et al.*, 2021).

Modern FM considers physical, environmental and social interests and is applicable in various fields, including manufacturing, hospitality, housing/real estate, health and general infrastructure (Beckers *et al.*, 2015; Macarayan *et al.*, 2019; Nota *et al.*, 2021). Its focal areas have evolved over the years, from hard services, total FM, value-driven design, intelligent buildings, workplace management, sustainable workspace and customer satisfaction (Nota *et al.*, 2021). Consequently, changing circumstances and focus demand a move with technological advancements to align with organisations' changing needs.

In Industry 4.0 scenario, FM is evolving because of new technologies that can enhance the capabilities of roles devoted to the management of structures post-construction (Nota *et al.*, 2021). Research into technologies in various economic sectors has increased exponentially. The fourth industrial revolution (4IR) era features ubiquitous connectivity of machines, people and devices and yields unlimited but augmented information in appropriate ways. In addition, organisations' stakeholders are realising the possibility of a fifth industrial revolution (5IR) future, where humans and machines are expected to act in synergy (Noble *et al.*, 2022). Recent 5IR talks have sparked research interest in ways to ensure "harmonious human-machine collaborations, focusing on the wellbeing of multiple stakeholders (society, companies, employees, customers)" (Noble *et al.*, 2022), suggesting an increased focus on impacts on stakeholders' well-being and liveability since they contribute to organisational performance. Understanding how to obtain benefits from new developments with a minimal negative impact on costs or efficiency (Huisman *et al.*, 2021). Digital technologies are aligned with FM's well-being and innovation goals and provide opportunities for the management of operations for greater efficiency and cost reduction (Ensafi and Thabet, 2021). Organisations are increasingly turning to innovative workplaces to offer employees more collaborative workspaces to improve productivity and the optimal utilisation of space (De Bruyne and Gerritse, 2018; Valks *et al.*, 2019; Sim, 2022). Recently, PropTech companies have introduced digital technologies in operation and maintenance to improve effectiveness, service efficiency and asset performance (Pomè and Signorini, 2023). Thus, the role of technology in ensuring efficient and sustainable FM practice is critical.

Although research on technology in FM exists, few studies have focused on real estate. Studies exist on digital technologies in FM (Nota *et al.*, 2021), advancements and trends in FM research (Li *et al.*, 2019) and FM challenges and gaps in data management processes and quality control (Mourtzis *et al.*, 2020; Ensafi and Thabet, 2021). Further, Valks *et al.* (2019) assessed the use of smart campus tools to improve the use of campus buildings and space using interviews among Dutch universities and other organisations. Likewise, Evjen *et al.* (2020) examined the effectiveness of integrating Internet of Things (IoT) and building information modelling (BIM) for real-time monitoring of building condition. Other studies undertook reviews on the use of smart technologies for urban spatial integration, sustainable land use and value creation (Temeljotov *et al.*, 2015) and cloud applications in the field of real estate (Mladenow *et al.*, 2015). Also, Adama and Michell (2018) explored the influence of technology adoption on the well-being of FM professionals, but with a focus on social sustainability impacts, including job security, work-life balance, feelings of alienation, networks and overwork. Therefore, it appears that limited bibliometric studies exist on technology use and application areas in real estate facilities management (REFM) practice. It is essential to track research on this topic to identify hotspots and gaps to make future decisions and policies, especially in 4IR times where digital technologies are ubiquitous.

Moreso, given the recent COVID-19 pandemic, technology adoption was heightened in all sectors. Organisations had to adapt to the changing circumstances quickly (Nota *et al.*, 2021).

Continuous research on using revolutionary technologies is needed to ensure that related concerns are clearly and consistently mapped, intellectualised and contextualised to gauge the impact of FM processes and practices and devise suitable sustainable strategies. Moreover, although much research has been conducted on technology use within organisations, limited studies exist that link to real estate FM, a view supported by Valks *et al.* (2019) and Carbonari *et al.* (2018).

Therefore, the current study uses bibliometrics and content analyses to map existing research and suggest future trends, focusing on REFM. The objectives were to:

- map the research trajectory on technology use in REFM;
- analyse the knowledge structure based on co-authorship among authors, organisations and countries; and
- establish existing themes on technologies used, associated benefits and areas of application in REFM.

Future research on technologies in REFM is suggested, and practical implications are proffered. The findings are envisaged to inform further research on technology use in FM practice and engender more support for innovation and adoption by REFM organisations.

Literature review

Real estate facilities management

Real estate encompasses land and improvements, including buildings, fixtures, infrastructure and utility systems. Thus, FM is a function within real estate. Thus, in addition to managing the property portfolio of an organisation, how the physical structure and other business processes and resources are managed are encompassed in FM functions. Therefore, supporting the primary activities and business purposes efficiently and effectively is a key issue (Van der Voordt, 2017).

Facility management is "an integrated approach to operating, maintaining, improving and adapting buildings and infrastructure of an organisation to create an environment that strongly supports the primary objectives of that organisation" (Nota *et al.*, 2021:2). It entails an "integration of processes within an organisation to maintain and develop the agreed services which support and improve the effectiveness of its primary activities" (Temeljotov *et al.*, 2015; 150). It aims to streamline support processes, harmonise employees, work activities and environment, incorporating business administration principles, architecture, humanities and sciences to reduce costs and improve efficiency and quality of life (Janošková, 2016).

FM focuses on health and productivity, integrated services and work environment in the UK (Li *et al.*, 2019), facilities managers' skilling and commitment towards a sustainability agenda in Australia (Elmualim *et al.*, 2010; Kamarazaly *et al.*, 2013), process quality *viz-a-viz* cost savings in Poland (Potkány *et al.*, 2021), management of public facilities in Ghana (Macarayan *et al.*, 2019) and technology integration in South Africa (Okoro and Musonda, 2019). According to Philbeck and Davis (2019), such technologies and systems as robotics, autonomous vehicles, artificial intelligence (AI), machine visions, augmented reality (AR) and advanced applications are being integrated into organisational processes and spaces, thus altering behaviours, relationships and meaning. Therefore, this bibliometric research is warranted, especially in this Industry 4.0 era, which focuses on the relationship between digitisation, organisational transformation and productivity enhancement.

Application of technology in real estate facilities management

Different technologies have been applied in various fields and spheres. In the real estate industry, technology has been used in the valuation and management of high-rise buildings.

While there is some evidence of the benefits of technology application in REFM, such as in data management, risk management, cost control and strategic planning, there is marginal evidence in the current knowledge on how various new technologies can be applied in REFM (Carbonari *et al.*, 2018; Valks *et al.*, 2019), especially to ensure cost reduction and value creation, which are broad concerns in FM (Temeljotov *et al.*, 2015).

Data management. The handling of complex information, which is sometimes vast, creates a seemingly insurmountable problem in terms of data management. According to Munawar *et al.* (2020), big data is the concept of enormous amounts of data being generated daily in different fields due to the increased use of technology and internet sources. It emerged as an amalgam of intersecting fields, including statistics, storage, technology, data hosting and computing, data management, data refining, data patterns and machine learning (Munawar *et al.*, 2020). In addition, innovative and smart technologies can improve the way information is classified, giving the opportunity to aggregate data and visualise results to effectively communicate complex information (Temeljotov *et al.*, 2015). Technologies like BIM can help facilitate real-time data access during maintenance and management processes (Carbonari *et al.*, 2018).

Strategic planning and cost control. Through strategic leveraging of FM, it is possible to collect, organise, visualise and communicate data as a means for strategic planning and budgeting (Temeljotov *et al.*, 2015). Knowledge of what it would entail to build and manage a resultant structure and services therein is relevant at the beginning to reduce costs. These are possible with BIM applications (Smith *et al.*, 2016). New technologies like BIM can be used in planning and studying the feasibility of non-capital construction and controlling and monitoring energy use in buildings (Róka-Madarász *et al.*, 2016; Carbonari *et al.*, 2018). Further, telemanagement and light emitting diode (LED) technologies can be used to monitor electricity consumption, as revealed by Cerezo-Narváez *et al.* (2022) in their Spanish study. These technologies provide wireless data communication systems, which can be remotely controlled via handheld devices, including smartphones and tablets, to monitor electricity (Sung and Lin, 2013). Other than that, the IoT, which uses smart and non-smart mobile devices (object tags and beacons), can be used to position and track objects, providing a smart approach to managing facilities (Evjen *et al.*, 2020). Other information technology (IT) systems, such as integrated workplace management systems (IWMS) and energy management systems (EMS), are beneficial in monitoring and reporting environmental building performance (Maslesa, 2019). Further, better cost management and control can be using computer-aided FM during operation and maintenance (Róka-Madarász *et al.*, 2016).

Task efficiency. Task efficiency can be improved using technologies such as BIM and automation. In a study that aimed to implement a BIM model for existing buildings, Carbonari *et al.* (2018) found that including information that would support the management of a single facility/portfolio can be easily performed in such a model. The study identified tasks that are typically performed inefficiently during a building's operational phase. According to the authors, the implementation of new technologies to support business needs during the occupancy phase of buildings has been lagging compared with other fields or stages in the construction and building process. The identified areas where BIM can be used in management processes include locating building components, managing space, visualising and marketing, checking maintainability, creating and updating digital assets and personnel training and development. Task efficiency can be improved in these aspects using technology. These views are supported by Tarek and Marzouk (2022), who developed and examined the usability of a smart app for utility maintenance and asset management. Furthermore, the use of cloud computing systems and machine learning could improve network service in real estate property management (Mladenow *et al.*, 2015; Ye *et al.*, 2022).

Risk management. New technologies can be used to manage emergencies (Carbonari *et al.*, 2018). Munawar *et al.* (2020) developed a merger framework for smart real estate and disaster risk management. The authors demonstrated that big data generated from smart real estate in the form of occupant data, FM and building integration and maintenance can be shared with the disaster risk management and emergency response teams to help prevent, prepare, respond to or recover from the disaster. Further, technology usage can help to identify systemic challenges in the quality, access and management of data (Shaw *et al.*, 2023). This avoids delays in the design of maintenance considerations and risk management plans. Additionally, these help to reduce uncertainties and costs in the operational phase (Smith *et al.*, 2016).

Therefore, the benefits of incorporating technology in REFM functions are many-fold. These include cost management, value-add, data or information management, risk management, task efficiency and productivity improvement, as further highlighted in the literature.

Challenges of technology adoption in real estate facilities management

The real estate sector presents unique challenges with its static, long lifespan (at least 50 years) and cost-intensive nature (Valks *et al.*, 2019). Consequently, the advancements in technology and ever-changing technical requirements and business ecosystem exacerbate concerns regarding innovation (Xu *et al.*, 2019). New types of work and work processes are appearing in the FM space and need to be accommodated (Evjen *et al.*, 2020). However, although the prospect of adopting technology is promising in many organisations, some entities are sceptical and face challenges regarding this.

According to Ullah and Sepasgozar (2019), information technologies in property management fails due to lack of attention to the governance dynamics in implementing technologies. On their part, Zhang *et al.* (2015) opined that property management companies are hesitant to adopt green technologies because of the large investment involved and their lack of experience. The lack of experience was also highlighted by De Bruyne and Gerritse (2018). Adaptive capabilities to keep up with new trends are required by organisations. In addition, the increased autonomy of end-users with working with new technologies could result in more independence and, in turn, less visibility within the organisation (De Bruyne and Gerritse, 2018).

Further, digitalisation of the work process requires specific attention in terms of office space, behaviour and work environment. This will then require digital tools and monitoring of the work-life balance (De Bruyne and Gerritse, 2018). Other studies suggested sharing the risks involved to cushion the impact of the large investment, upskilling and training of FM professionals, appropriate relationship and change management structures (De Bruyne and Gerritse, 2018; Ullah and Sepasgozar, 2019; Musonda and Okoro, 2022). The relationship between management and employees also need to change to accommodate change management issues while implementing new technologies. Moreover, capabilities and upskilling are, therefore, critical in technology adoption, a view supported by Koch *et al.* (2019).

Although the above challenges may exist, the benefits outweigh the problems. Moreso, given the ever-changing world of work, business objectives and globalisation, FM organisations need to continuously adapt and find ways to mitigate the challenges and any adverse impacts of adoption.

Gaps in related empirical literature

Studies concur that technology is adaptable by facilities managers for related real estate activities. For example, Sarkar (2021) undertook a multi-case study of BIM and the application of other digital technologies in REFM services in the UK built environment (BE).

Ruan *et al.* (2022) applied spatial data-driven approaches for research using remote sensing technologies and data on public facilities' locations to analyse the impact on housing prices in China. Further, Shaw *et al.* (2023) undertook an interview among six facilities managers and three data managers and found that effective information management can help real estate operators improve asset performance, reducing environmental impact. These are most useful considering lifecycle thinking and asset management. This view was supported by Hoeft and Trask (2022), who undertook mixed-method research to examine BIM-based platforms and barriers in buildings' lifecycle and stakeholder management among Swedish construction and real estate practitioners; however, the study focused on the applicability of one technology at all lifecycle stages.

Similarly, Vigren *et al.* (2022) explored innovation capabilities and ecosystems in the Swedish real estate sector among 32 estate owners, associations and digital technology suppliers. Although the efficacy of digitalisation was demonstrated, the study findings were silent on the technologies examined and did not include FM professionals. The results, therefore, only contribute to the understanding of technology integration in real estate management. Further, review studies used either semi-systematic or integrative approaches (Ensafi and Thabet, 2021; Mourtzis *et al.*, 2020), which either focused on the applications/mechanisms of the Industry 4.0 technologies in smart real estate (Ullah *et al.*, 2018), cloud applications in real estate (Mladenow *et al.*, 2015) or broadly, on urban spatial integration (Temeljotov *et al.*, 2015). Moreso, Smith *et al.* (2016) study was from a design and planning perspective; however, the authors acknowledged that all decisions concerned with cost, quality, time, value or sustainability are interrelated. Hence, various actors' values should be coordinated before designing the project to ensure that their needs/requirements are addressed (Temeljotov *et al.*, 2015).

Therefore, although there have been contributions to an overview of the current research status in the FM field, little is known concerning technology use focusing on REFM from bibliometric and content analyses perspectives. This study, therefore, uses co-occurrence descriptive and interpretive analysis to uncover the knowledge structure and progress of research based on the matrices of networks and clusters. Co-word analysis was used to explore conceptual work and knowledge trends across the REFM arena. As revolutionary technologies evolve and research interests increase, a higher level of critical thinking about future directions must be conducted (Li *et al.*, 2019); thus, identifying REFM research and future directions is crucial.

Methods

In undertaking this study, a systematic review approach was adopted. This involved multiple review techniques to combine study findings from multiple literature reviews and stages. According to Low-Choy *et al.* (2021), literature reviews can be structured as a multi-method or mixed method. This process entailed selecting studies through scoping, systematic review, clarifying eligibility by means of qualitative, narrative or model-centric review; and ending with realist review, interpreting and adjusting review findings as necessary. The preferred reporting items for systematic reviews and meta-analyses 2020 guidelines in Page *et al.* (2021) were followed. The rationale and study objectives were identified in the existing knowledge context, and the methods (information sources, eligibility criteria, outcomes, risks/biases and control) were specified. The results and limitations are also presented in line with systematic reviews in the BE and multidisciplinary fields where FM is applicable (Parida and Brown, 2018; Núñez-González *et al.*, 2020; Page *et al.*, 2021). The use of a semi-systematic approach was considered;

however, the data obtained through such reviews may have repetitions and inconsistencies (Li *et al.*, 2019).

Based on a systematic search, bibliometric and content analyses were used to elicit quantitative and qualitative patterns and boundaries, revealing insights into a research area. This measured research outputs and in-depth underlying meaning of concepts while providing a framework of extant knowledge, as was done by Okoro (2023). This three-step science mapping approach was also used by Tezel and Giritli (2021) in mapping knowledge in the BIM-FM domain. The data collection and analysis procedures are described further.

Selection of database

The Scopus database was used to identify materials for the study. This database was selected because it contains over 69 million abstract and citation records of peer-reviewed literature in a wide variety of disciplines (Campedelli, 2020). Records from Scopus can be generated and exported in a standardised format containing the title, author, year, keyword, affiliations and citations (Song and Wang, 2020). Therefore, relevant and current literature was accessible.

Further, although an alternative could have been used, for example, Web of Science, as it includes important research papers and provides built-in analysis tools to produce similar exportable files for further analysis, one database was deemed sufficient (Yu *et al.*, 2020). The "simultaneous use of other databases does not increase the number of relevant documents due to duplications" (Aparicio *et al.*, 2019). Scopus can give search results that can be exported to VOSviewer for further analysis and has a similar content coverage as Web of Science.

Search strategy and eligibility

The initial scoping searches were undertaken for materials in July 2022 using various databases, including Google, Google Scholar and Scopus. Articles were considered if they contained the relevant keywords, including real estate, FM and technology. To refine the search scope and rationale, the researcher included other words related to technology and innovation in REFM practice. The use of other relevant groups of terms in the innovation and FM areas, for example, property management, integrated management systems, cloud computing and computer-aided returned more articles. These were then incorporated in a follow-up search in Scopus in May 2023.

One hundred and twenty-two documents were obtained for the period 1985–2023. Search filters were applied to select the most current and relevant articles. The inclusion and exclusion criteria included publications from 2013 to date. Ten years were considered to give the most up-to-date evidence and thus an idea of the trajectory of knowledge. In addition, the current year was included as it had gone halfway and could provide relevant insights into the knowledge status. To evaluate the direction and maturity of the field, documents including articles, conference papers and book chapters were included, as supported by Hoeft and Trask (2022). There were no limitations on the "open access" nature, country/territory, keywords emerging and funding structure. All articles were in the final publication stage. Documents in the English language were then selected. Title and abstract screening resulted in the removal of 25 documents that were full conference proceedings and not directly related to technologies or FM, for example, housing investment and purchase and urban planning. The remaining 46 documents were used for the bibliometric analysis. The entire search string is below:

TITLE-ABS-KEY ("real estate" AND "facilities management" OR "property management" AND "technology" OR "proptech" OR "smart" OR "digital" OR "innovative technologies" OR

"industry 4.0" OR "4IR" OR "industrial revolution" OR "integrated management" OR "cloud computing" OR "computer-aided") AND (LIMIT-TO (PUBYEAR, 2023) OR LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019) OR LIMIT-TO (PUBYEAR, 2018) OR LIMIT-TO (PUBYEAR, 2017) OR LIMIT-TO (PUBYEAR, 2016) OR LIMIT-TO (PUBYEAR, 2015) OR LIMIT-TO (PUBYEAR, 2014 OR LIMIT-TO (PUBYEAR, 2013) AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp") OR LIMIT-TO (DOCTYPE, "ch") AND (LIMIT-TO (LANGUAGE, "English").

The search procedure is presented in Figure 1. The export options of Scopus produced detailed bibliometric information about the documents, which were thereafter exported into comma-separated values format for further analysis (Campedelli, 2020; Yu *et al.*, 2020).

Visualisation techniques

VOSviewer (version 1.6.16) software package, which has been widely used in bibliometric analysis, was used. The networks of scientific publications, researchers, organisations, countries and keywords were visualised and analysed through text-mining to identify relevant noun expressions in coalition with a unified clustering approach, without additional plugins in VOSviewer, as opposed to other software like Gephi, Pajek or Cytoscape (Cherven, 2015).

The characteristics of and links between a set of items (network), such as keywords co-occurrence, co-citation and co-authorship among authors, sources and organisations, were analysed (Hosseini and Erfanmanesh, 2015). Such a network is represented as a set of nodes and links with strength (indicating the strength of the co-authorship links) (Van Eck and Waltman, 2021). The total link strength (TLS) attribute, which indicates the links of an item with other items, for example, researchers, countries and institutions, was applied (Yu *et al.*, 2020). The density (node ties and nature of clustering or extent of relativity) was also viewed (Hosseini and Erfanmanesh, 2015).

Further, keyword co-occurrence and cluster analyses were used to identify the research status/trends among the same group of documents (Li *et al.*, 2019). The co-occurrence

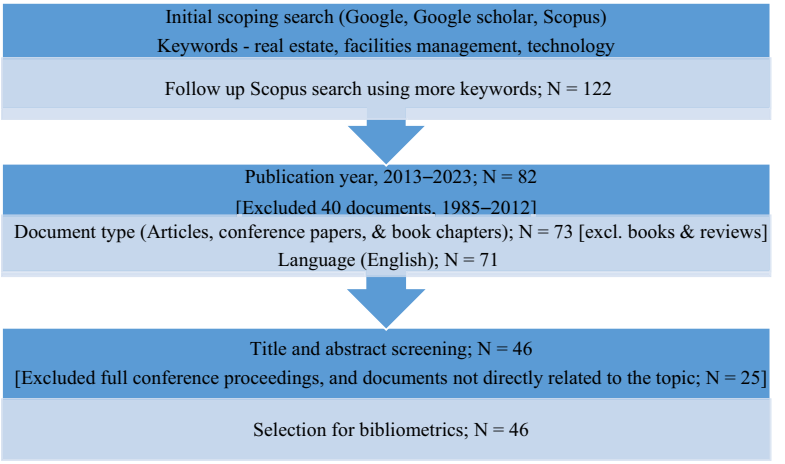


Figure 1.
Search procedure adopted

Source: Author's work

network analysis is based on a mixed method of clustering and network mapping built for data set mining and the selection of keywords (Okoro, 2023). The clustering technique enables highlighting gaps and key findings and keyword ranking to characterise the research directions and frontiers (Liu *et al.*, 2018). Additionally, the distance-based approach indicated the nodes' relatedness; the smaller the distance, the higher their relatedness (Van Eck and Waltman, 2014).

Content analysis

Content analysis was used to analyse the most cited studies as identified within the selected documents. Content analysis is a systematic procedure used to examine recorded textual information through the content, making valid inferences or conclusions (Elango and Kumaravel, 2022). This provided underlying and in-depth explanations of the concepts identified in the literature review and consensus in extant studies. The analysis at this phase was related to the themes or clusters emerging from the study. Although using the most cited papers may favour older papers, that is, those published more than five years ago having accrued a smaller number of citations, highly cited ones are important nodes in the dissemination and scientific information network and show the opinions over the selected time (Ioannidis *et al.*, 2014). A similar approach was adopted by Okoro (2023). The process entailed sampling (establishing the criteria and identifying the documents, in this case, the ten most cited documents), coding (reading and re-reading the selected documents and grouping of common themes) and quantification or subjective description of features (Okoro, 2023). The integration of findings from both phases was done at the discussion stage.

Results and discussion

Productivity over the years

Figure 2 presents the publication trajectory (frequency) of the retrieved literature. It shows the level of attention garnered each year (Li *et al.*, 2019). The number of publications on the use of innovative technologies in REFM fluctuated over the years. The increase in the number of publications from 2018 suggested enlightenment on other ways of doing things (culture) in FM at the time, as supported in van Rensburg's (2018) book review, which revealed that client satisfaction (not innovation or technology) was a major focus in 2017. Thus, FM keeps evolving and shifting to accommodate changing environments and

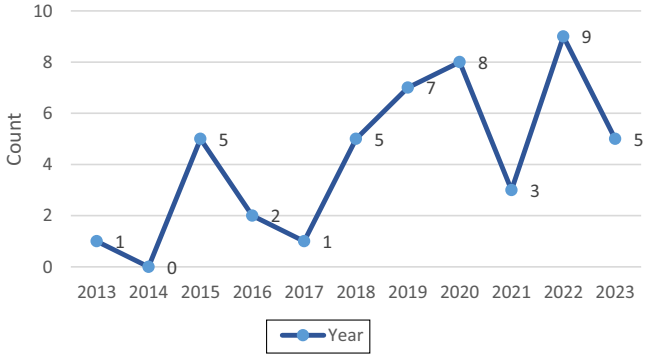


Figure 2.
Trend of publications over the years

Source: Author's work

circumstances (Li *et al.*, 2019). The significant drop in publications in 2021 is surprising since one would have thought the debate on technology would be at its peak given the incidence of the COVID-19 pandemic then. However, the awareness of the role of technology in REFM peaked again in 2022.

Notably, publications on this topic were not indexed in Scopus in 2014, and only one study was recorded in 2017. This is surprising since housing contributes to meeting the basic physiological needs, according to Maslow's hierarchy of needs. Providing a suitable living environment through FM is important to sustain the physiological need for shelter (Zavei and Jusan, 2012). However, the five publications so far, halfway through 2023, may signify sustained interest in technology use in REFM. More papers will likely be published on this topic before the end of the year.

Geographical distribution of research

In bibliometric analysis, geographic perspectives show the spatial distribution and country links in scientific publications. The location variation and connectedness reflect the country's contribution and demonstrate where the most significant research interest exists. Based on the data, researchers from different countries have contributed to the studies over the selected period.

With at least four documents per country, the most productive countries were China (four documents, 65 citations), Norway (four documents, 36 citations) and Italy (nine documents, 19 citations). However, there was no collaboration with any other countries, as indicated by the TLS of zero. Notably, there is a dearth of studies in the African continent.

Document type and source

Out of the 46 documents, most publications were in journals (20 articles), followed by conference papers (19) and book chapters (seven). Research articles are a notable source of information dissemination. Conference papers and book chapters were also included as they provide research ideas and trends on a topic.

The documents' sources were further analysed using bibliographic coupling to reveal the number of pairs of cited references in documents that have the same match key (Van Eck and Waltman, 2021).

Out of 38 sources, the top documents with the highest links emerged. The threshold was set at two documents and one citation per source. The top five sources were:

(1) Facilities (three documents, 38 citations, TLS = 2);

(2) Journal of Corporate Real Estate (two documents, 37 citations, TLS = 1);

(3) International archives of the photogrammetry, remote sensing and spatial information sciences (two documents, three citations, TLS = 1);

(4) International Multidisciplinary Scientific Geoconference (two documents, one citation, TLS = 0); and

(5) Lecture Notes in Civil Engineering (two documents, three citations, TLS = 0).

The TLS of 2.0 for facilities indicated cross-referencing with another journal; the others had little or no links on the topic.

Analysis of prominent authors and organisations

The analysis of the authors' documents and citations indicated their prominence. With the occurrence threshold set to at least two documents and 12 citations per author, the top four

authors out of 122 were A. Mladenow, N. M. Novak, C. Strauss and S.M.E. Sepasgozar. The strength of the co-authorship network was stronger (TLS = 4) for the first three authors. The last author had no links with authors (TLS = 0), albeit with 21 citations.

The top four organisations out of 76, with at least one document and 25 citations per organisation were the:

(1) Department of Building and Real Estate, Hong Kong Polytechnic University;

(2) Department of Public Policy, City University of Hong Kong;

(3) School of Construction Management and Real Estate, Chongqing University; and

(4) Department of Built Environment, University of Greenwich, United Kingdom.

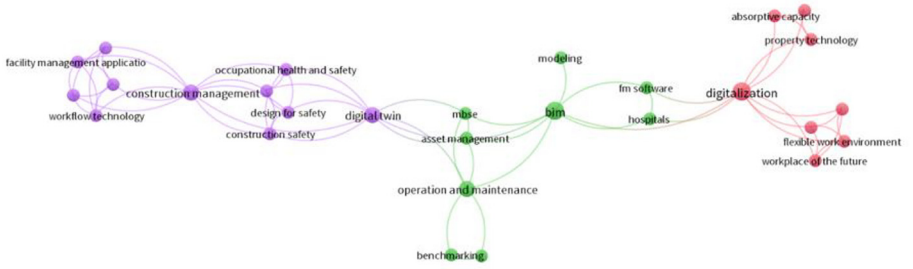
The network visualisations showed little links between these organisations. The greatest TLS was 2.0 among them. An examination of the citation distance (network visualisation) also revealed little interlinkages outside of the established research groups or organisations. Industry collaboration is needed as technology adoption is key to business organisations' functions.

Co-occurrence of keywords

The keyword co-occurrence analysis showed the scope and content of the research on REFM. An occurrence threshold of two was set to identify the most relevant author keywords. Out of 167 keywords, 28 were linked. The keywords with the greatest TLS were collaboration, business models, cloud computing, cloud product, integration and software as a service, with an occurrence of two and TLS of 14, respectively.

Figure 3 presents the grouping of the keywords) into clusters – purple, green and red. These showed the relationships between the keywords; The relative importance of each item is reflected in the circle's size or weight (Van Eck and Waltman, 2021). These included the following:

- Cluster 1 – Eleven items, including building life cycle, construction management, construction safety, design for safety, digital twin, enterprise resource plan, FM applications, facility managers, greenhouse gases, occupational health and safety and workflow technology.
- Cluster 2 – Six items, including asset management, benchmarking, BIM, computer-aided facilities management (CAFM), FM software, hospitals, model-based systems engineering (MBSE), modelling, operation and maintenance.



Notes: Colour codes: purple – Cluster 1 (life cycle integration and management); green – Cluster 2 (data curation and management); red – Cluster 3 (organisational and management capabilities)
Source: Author's work

Figure 3.
Network of author keywords (visualisation results from VOSviewer)

- Cluster 3 – Five items, including absorptive capacity, digitisation, flexible work environment, future of work, innovation, property technology, work support infrastructure and workplace of the future.

These are named and discussed with the findings from the content analysis.

Content analysis of the most cited documents

The most cited documents were analysed using content analysis to reveal in-depth findings regarding the authors' perceptions and consensus on the emerging themes from the bibliometric analysis. The findings from the top ten, with at least eleven citations, are summarised in Table 1. The key objectives, methods used and findings regarding the technologies used, applications areas, benefits and challenges are highlighted.

There was agreement on the role of technology in REFM. From the table, the technologies explored in the most cited studies and thus the most relevant in REFM were IoT, smart tools (data sensors and devices), AR, CAFM, blockchain, BIM, industry foundation classes (IFC) data models, green building technology (photovoltaic-LED lighting system), AI applications, digital twins, digitalisation and IT, indoor positioning systems and cloud environments and systems. The application areas and benefits of technology adoption in REFM were highlighted as enhanced data integration, management and transfer, risk and disaster management, improved building condition assessment and monitoring, improved task efficiency, cost planning, management and monitoring, improved energy management, smart building and effective space management.

Challenges to the use or adoption of technologies in REFM were also revealed. These include the large investment and long payback period involved, incompetence or inadequate know-how for digitalisation and innovations, managerial concerns about implementation and monitoring, system incompatibility and poor integration between departments and actors, data ownership, a lack of good examples or referrals on the appropriate usage and implementation, incomplete information, poor/inadequate infrastructure and inappropriate applications/systems and the time spent in collecting information for further processing. Strategies suggested to alleviate the above challenges include sharing of the risks involved in the investment, training and upskilling of relevant professionals, structured approaches for monitoring the condition of existing buildings and updating of relevant infrastructure and environments (cloud and digital tools) for specific operations and purposes. Others include national standards, contracts and specifications, involving organisations in the planning processes for implementing new technologies, implementation structure and dynamics (flexibility and change management), multidisciplinary and open-oriented approach (involving all relevant stakeholders in the value chain), combining multiple and similar functions in one smart tool to improve compatibility and integration, regular follow-up to evaluate priorities and functionality.

These findings are further discussed and integrated with the clusters emerging from the quantitative bibliometric phase. This is done in relation to other literature identified from the initial scoping review.

Discussion and integration of findings

The findings from bibliometric clusters and content analysis are discussed hereunder. The challenges in the related application areas are also discussed.

Cluster 1 – life cycle integration and management. The first cluster contained items relevant to the entire lifecycle of a building, including operations and maintenance aspects. This suggests that technology use in the design of buildings impacts FM functions.

Table 1. Summary of findings from the most-cited documents

	Document	Citations	Key findings: Objectives and methods	Technology identified	Benefits	Challenges	Suggested strategies
1	Zhang *et al.* (2015)	63	Explored the use of green technology contracting framework in implementing a PV-LED lighting system in China's real estate industry Interviews with representatives from a real estate developer, property management company and energy service company and case study	PV-LED lighting system	Application of green technologies in energy efficient system retrofit and new construction projects Economic benefits and environmental benefits for the project stakeholders and society	Large investment is involved, facilities management professionals' lack of experience and long payback period	Proposed strategy – sharing of the risks involved Training
2	Carbonari *et al.* (2018)	25	Investigated tasks and data needs for an integrated BIM and IFC model Focused on understanding how the information included in the integrated model can improve task efficiency Questionnaire survey; 752 responses form Facilities management professionals in national and multinational organisations	BIM and Industry Foundation Classes (IFC) data models	Improved task efficiency during operations and maintenance BIM can be used to support building operations and maintenance, and respond to short-term and long-term strategy needs and managing day-to-day operations	Some entities within the model need supporting information, for example, external information like market analysis Barriers to the uptake of BIM in FM – knowledge, software compatibility, data ownership and reliability of information	Strategy – structured approach for existing buildings

(*continued*)

Table 1.

				Key findings			
	Document	Citations	Objectives and methods	Technology identified	Benefits	Challenges	Suggested strategies
3	Koch *et al.* (2019)	21	Investigated the role of digital FM in new hospital projects in Scandinavia Interpretive qualitative approach using literature review, document analysis and two case studies; consultancy reports and handbooks	Digital FM in general (IoT, data sensors, AR, CAFM, Blockchain and BIM)	Integration between technical digitalisation, competences, organisation and management of digital FM. Information can be imported with data for future digital operation and maintenance Re-use of object definitions and acceleration of later processes (avoiding delays)	Problems with aligning BIM models from design and construction to the FM system Lack of competences for digitalisation Lack of good examples or referrals on the use of BIM regarding documentation for operation and facilities management Incompatibility of systems, for example, different software will communicate, and clients and the organisation do not necessarily have the same systems Time spent in collecting information on management and operation and inputting into relevant software (for example, from EXCERL to TIDA), which is not done in a seamless manner	BIM models and other digital systems should be integrated to align with operations and management National standards as well as contracts and specifications could help Upskilling of professional who use them Organisations must be involved in the planning processes of new build

(*continued*)

Table 1.

	Document	Citations	Objectives and methods	Key findings: Technology identified	Benefits	Challenges	Suggested strategies
4	Róka-Madarász *et al.* (2016)	20	To assess how to gather and access data in computer aided facility management (CAFM) system during operation and maintenance management phase Questionnaire survey among Hungarian corporate real estate companies on facility management factors, sites ($n = 76$) and buildings on the sites ($n = 207$); descriptive and inferential (correlation analysis, one-way ANOVA and Box Plots)	CAFM	Cost management and monitoring Benchmarking – organisations can collect benchmark data from their own buildings Benchmark information available in an easy-to-understand form Opportunity to observe the differences of building's performance Easy planning and tracking of activities and costs (equipment and tasks including regular and cyclical)	–	–
5	Ullah and Sepasgozar (2019)	20	Developed a system dynamics model for adoption of real estate websites Examined perceived usefulness, user satisfaction and behavioural intention to use Literature review	IT	Three quality components including system, information and service quality can be improved	Information technologies in property management fails Dynamics that govern the adoption are ignored	Attention to the implementation structure and dynamics

(*continued*)

Table 1.

	Document	Citations	Key findings: Objectives and methods	Technology identified	Benefits	Challenges	Suggested strategies
6	Xu *et al.* (2019)	15	Explored the use and need for a user-oriented digital service ecosystem and business model in the smart building sector A multi-method, interpretive case study, real estate and facility management operators in Northern Europe (Finland) The case was VirpaD research project – a Finnish national digital service and innovation project	AI applications	Smart building is enabled	The development of AI applications often follows a traditional, closed and product-oriented approach, which is not suitable in an evolving and ever-changing digital business ecosystem The delivery of digital information is currently experiencing limited improvement in time, expenditure or performance	Multidisciplinary and open-oriented approach Study proposed an extended comprehensive framework of the 5 C – connection, content, computation, context and commerce A need for new value-chain-and ecosystem-oriented AI development and big data platforms in the future
7	Valks *et al.* (2019)	14	Assessed the use of smart campus tools to improve the effective and efficient use of campus buildings and spaces Compared findings from a two-stage research process among 13 Dutch universities and other organisations Interviews with structured and semi-	Smart tools (Wi-Fi, Bluetooth and wearable infrared sensors)	Smart tools support users, improve the use of buildings and reduce the energy footprint Real-time space use can help users to make better use of spaces Better decision-making and space management	Integration concerns among tools	Unified approach – combining multiple and similar functions in one smart tool

(*continued*)

Table 1.

	Document	Citations	Objectives and methods	Key findings: Technology identified	Benefits	Challenges	Suggested strategies
			structured questions, 27 cases				
8	Evjen *et al.* (2020)	12	Assessing the effectiveness of using IoT for data collection and real-time monitoring of building condition Case study using one hospital in Norway	IoT, which uses smart and non-smart mobile devices (object tags and beacons) with the aim of positioning and objects tracking that lead to a smart approach in FM Indoor positioning systems are key to IoT applications when integrated with BIM (Enterprise BIM – where the virtual building and building processes are used throughout the lifetime of the building, and the outdoor environment is combined with sensors and the companies' own work processes	IoT can be integrated with BIM to monitor the condition of buildings and plan for performance improvement Enables effective data collection for FM as an organisational function in large and complex buildings Improves quality, cost-effectiveness and client satisfaction	Implementation and monitoring concerns	Systematic review of results and regular evaluation to maintain functionality/ relevance
9	De Bruyne and Gerritse (2018)	12	Explored the future workplace in The Netherlands' large organisations Focus groups with office end-users and employees of 11 organisations (public and private	Digitalisation, automation and IT	Increased efficiency of organisations Organised and dynamic work processes; reduced time to conduct admin tasks	Capabilities to accommodate new work ways and complex systems Digitalisation of the work process requires specific attention in terms of behaviour, office and	Upskilling Joint priorities for support services Providing functional, compatible and reliable IT infrastructure

(*continued*)

Table 1.

	Document	Citations	Objectives and methods	Key findings: Technology identified	Benefits	Challenges	Suggested strategies
			partners). Follow-up Delphi study applied to a multidisciplinary expert group. Results were further developed in a "pre-design" workshop Included knowledge-based and administrative organisations with functions including facilities management			work environment, digital tools and monitoring of the work-life balance Adaptive challenges to keep up with new trends Increased autonomy of end-users makes them more independent and less visible in the organisation	Strategic flexibility Relationship management with employees
10	Mladenow *et al.* (2015)	11	Analysed the use of various (types of) cloud applications in the field of real estate review	Cloud applications (advanced cloud environments such as pervasive cloud and intercloud infrastructures)	Flexibility – cloud usage may be quickly adjusted to fluctuating demand in resources, users are in control over both performance and costs Efficiency of processes; enhanced speed and scalability Information is accessible to project members Web-based platforms are independent from operating systems and compatible with almost every properly programmed browser	Poor programming Poor infrastructure Inappropriate applications	The improvement of cloud infrastructure and cloud environments Integration of advanced clouds and cloud-based services with customised solutions

Source: Author's review

According to Zavei and Jusan (2012), the disconnection between designers and eventual users is a dimension of the modern era that has resulted in a lack of attention to traditional know-how and its associated skills and innovations. The incorporation of FM requirements at the design, configuration and visualisation stage is critical to support operations and maintenance plans, as well as achieve long-term building performance and enterprise resource planning in terms of health and safety. Additionally, according to Manganelli and Tataranna (2020), who developed and tested a software for estimating the depreciated reproduction costs over time, BIM environments can be used to monitor the service life, maintenance cost or optimal periodicity of maintenance and enable those involved in REFM to adequately plan and monitor the costs of maintenance work, renovation or eventual demolition.

However, in this aspect, infrastructure requirements pose a major concern, as identified by the ninth and tenth most cited studies (Mladenow *et al.*, 2015; De Bruyne and Gerritse, 2018). For example, intelligent and innovative modern access control systems, recreational facilities and security systems will require more codification, frequent updating and monitoring to ensure that the functionality and relevance of the systems are maintained (Evjen *et al.*, 2020). As opined by these studies, providing functional, compatible and reliable IT infrastructure and updating applications with programmes relevant to specific tasks within an organisation or department are essential to obtain the benefits from technology adoption (De Bruyne and Gerritse, 2018).

Other barriers that could threaten the implementation of digital tools (like digital twins) relevant for use throughout a building's lifecycle are the incompleteness and unreliability of information, as identified by Carbonari *et al.* (2018), the second most cited study. Moreso, the lack of examples or reference projects where digital and other technology solutions were successfully implemented was highlighted by Koch *et al.* (2019). These can be mitigated by the direct involvement of facilities managers and technology experts in the design stage, which has the potential to enhance knowledge transfer and reduce maintainability problems during the operational phase of a facility. Furthermore, structured approaches for monitoring the condition of existing buildings and for phasing in the implementation of new technologies can ensure familiarity with tools and efficiency of tasks at the various stages in a building's lifecycle.

Cluster 2 – data curation and management. The second cluster revealed items related to software and applications for data curation and management in FM, such as BIM, CAFM, and MBSE. As opined by Munawar *et al.* (2020), data curation is at the intersection of data analysis, refining, management and hosting, and the enabling technologies to improve these processes. Likewise, findings from Temeljotov *et al.* (2015) reiterate the critical role of innovative and smart technologies in improving information classification and visualisation, thus enhancing REFM processes. In another study by Pogorelskiy and Kocsis (2023), data management was found to be critical in improving the profitability and efficiency of organisations.

According to Koch *et al.* (2019), the third most cited study, with digital platforms like BIM and CAFM, information can be imported for future digital operation and maintenance. BIM models and other digital systems can be integrated to align with operations and management. This also alleviates the problems with aligning BIM models from design and construction to the FM system; thus, reducing system incompatibility and poor integration between departments and actors (Koch *et al.*, 2019; Valks *et al.*, 2019). These views are consistent with the views expressed in Róka-Madarász *et al.* (2016), the fourth most cited study, which assessed how to gather and access data in CAFM system during the operation and maintenance management phase. According to the study, the use of technologies allows

organisations to collect benchmark data from their building easily, thus enabling efficient planning and tracking of activities and costs for equipment as well as regular and cyclical or scheduled maintenance. This provides an opportunity to observe the differences in a building's performance over time.

Moreover, managing facilities failure using technologies could help to identify recurring issues, unregistered assets, weaknesses in disposal and maintenance, as well as misappropriated and functionally depreciated assets (Aziz *et al.*, 2016). These views were consistent with findings by Naticchia *et al.* (2020) and Duong and Lin (2022), who developed reality model-based frameworks to enable semantic information input and real-time updating of data in the digital models for existing building without historical data using point cloud model. Machine learning and other technologies can also be integrated into real estate property management to improve the network service of intelligent communities (Ye *et al.*, 2022).

Further, building management systems help to improve efficiency at the FM stage. Formalised data systems could be put in place to connect centres from the design to operational stages and keep employees and stakeholders (Aziz *et al.*, 2016). This will also allow for the creation of scheduled maintenance and preparation for emergencies. A robust planning management system that incorporates innovation and new technologies in delivering expected productivity levels cannot be over-emphasised. Since FM entails streamlining processes for increased productivity and quality at minimal cost, integrating new technologies benefits organisations (Potkány *et al.*, 2021).

Therefore, preparation for the proper operation of data centres and the implementation of any new technology is essential (Pogorelskiy and Kocsis, 2023). According to Sporsem *et al.* (2021), facilities managers must ensure that such data curation processes influence how data comes to be (quality and availability) and the degree of access to the people who need the information to fulfil their various functions and needs. This ensures that data flow is maintained and information reaches all the parties or stakeholders involved in the REFM life cycle.

Cluster 3 – organisational and management capabilities. This cluster contained aspects relating to an organisation's systems and relevance of technology in the processes and products within an organisation, given new or recent developments that could impact the future workplace. The items included absorptive capacity, digitisation, flexible work environment, future of work, innovation, property technology, work support infrastructure and workplace of the future.

Absorptive capacity refers to a firm's capability to recognise the value of innovation, which influences its propensity to adopt innovative technologies in its products and processes (Sancho-Zamora *et al.*, 2021). Organisations increasingly recognised the need for computerised support during the COVID-19 pandemic. Computerised support improves how facilities are operated and maintained, thus improving decision-making and management. For example, adopting BIM in mainstream FM functions that encompass multiple disciplines ensures higher functionality of the BE by integrating people, places, processes and technology (Aziz *et al.*, 2016). Innovative methods are particularly of interest in BE organisations, where intricate cross-disciplinary problems necessitate collaboration and unified solutions are drawn from various disciplines (Parida and Brown, 2018). According to Naticchia *et al.* (2020), manual retrieval of technical specifications and features of building components and their performance assessment leads to increased cost and time and efficiency reduction, especially during the FM stage. For example, BIM and cloud computing tools enable communication and real-time updating of data with repositories in digital

models, which are sharable and accessible via a cloud platform by various actors involved in FM. These views were supported in the tenth most cited study (Mladenow *et al.*, 2015).

Furthermore, IT systems like IWMS and EMS can be used in benchmarking and monitoring environmental building performance (Maslesa, 2019). These views align with findings by De Bruyne and Gerritse (2018), which investigated the future of the workplace using focus group discussions among office end-users and employees of 11 organisations and the Delphi study. The study found that digitalisation, automation and IT increase the efficiency of organisations. Management can use workflow technologies and other database-driven software for space planning (Head, 2018).

Additionally, cloud environments like online databases and computerised methods are flexible, fast and scalable and provide integrated design and documentation processes that are relevant to FM at present and in the future. However, these may differ across the real estate value chain. In keeping with Mladenow *et al.* (2015) views, advanced cloud environments such as pervasive cloud and intercloud infrastructures are still in their infancy but promising for REFM. Thus, the more advanced environments may be difficult to adopt but should be introduced in certain FM spheres. This implies that training at different levels is required for different FM needs and functions, a view supported in four of the most cited studies (Zhang *et al.*, 2015; Carbonari *et al.*, 2018; De Bruyne and Gerritse, 2018; Koch *et al.*, 2019).

This theme also relates to operational knowledge to work with technologies. Operational knowledge is crucial during the planning and installation of the technologies and management should be involved. In Sancho-Zamora *et al.* (2021) view, assimilating external knowledge from outside the organisation also helps to improve routines and procedures for analysing, processing, interpreting and understanding information (Sancho-Zamora *et al.*, 2021).

As opined by Okoro (2023), sustainability is becoming increasingly relevant in FM today. Investing in technologies helps in cost-effective FM and project management, avoiding substantial repetitive work that could be costly and time-consuming and enhancing environmental and energy management (Makosinski, 2023). Therefore, implementing technologies with a futuristic focus and intent are critical to ensure sustainability of organisations in terms of cost-effective processes, quality products and time savings.

Implications for future research

Given the dearth of literature indexed in Scopus in African countries, more research is needed thereof. Also, transdisciplinary research to design innovative workplaces that are adaptable to economic, social, technological and organisational drivers of change is needed, as opined by Sim (2022). In addition, only one study, Adama and Michell (2018), was found through Google Scholar that focused on the adverse impacts of technology adoption on FM professionals. More studies are needed as the social sustainability of REFM could be threatened by job insecurities, feelings of alienation and poor work-life balance, a view supported by Adama and Michell (2018).

Although studies demonstrate the efficacy of these technologies, for example, Valks *et al.* (2019) and Evjen *et al.* (2020), there are no studies on the degree of learning from the experience of use, that is, from the end-users' perspectives. This could be the focus of future studies. In addition, as supported by Nota *et al.* (2021) and Guerin and Slember (2021), given the incidence of the COVID-19 pandemic, the need to reevaluate business priorities and constantly monitor performance, the introduction of new technologies and identify opportunities and areas of technical requirements are now more critical. Organisations will not only benefit from responding optimally to changing needs but will increase value-add to

end users, occupants, and employees. As opined by Bakker and Veuger (2021), the value-add from FM is difficult to measure, except in cost reduction and risk aversion terms. Therefore, a move with the times towards technological advancement will contribute to delivering optimal services and experience at lowered costs to relevant stakeholders in line with changing needs. Moreover, the world is evolving towards a synergy between humans and machines in the 5IR era, a view supported by Noble *et al.* (2022). The possibility that organisations' stakeholders will realise a future where humans and machines act in synergy is becoming greater, and the FM sector should not be left behind.

Future research could be undertaken to assess the level of use in FM organisations and for what purposes using primary research techniques. Real estate firms use some form of technology, but there may be challenges regarding its use. Consequently, a focus on non-adopting organisations to assess the technology requirements and reasons for lack of (or low level) of adoption irrespective of the need in business operations will be beneficial in devising strategies to support such organisations and the FM industry in moving with the times. As supported by De Bruyne and Gerritse (2018) and Bakker and Veuger (2021), the future is digital and data-driven, and there are limited studies in this area in the FM arena.

Additionally, quantitative techniques could be used to evaluate the impact of the identified technologies and benefits on the performance of technology-adopting FM firms. Previous studies revealed technology adoption influencers among management-level professionals, for example, Okoro *et al.* (2023), which identified the determinants of immersive (advanced) technology acceptance in the construction industry. However, this was focused on activities in the construction stage. Hence, future studies could deal with employees' intention to use and usage attitude in the post-construction (operation and maintenance) stage.

Practical implications

Digitisation and innovation are key inputs in business processes to ensure continued operations and management (Fadzil, 2019). Congruent to those, the future of FM requires expertise in building, installing and applying algorithms and the necessary protocols at an advanced level (Sarkar, 2021). New technologies are essential in tackling evolving business challenges and needs in the Industry 4.0, post-COVID-19 and 5IR era. Therefore, the concern is no longer that of awareness but how to use and integrate the technologies in REFM activities. Organisations need to understand the impact of the usage or lack thereof on business objectives, values and competitive advantage going forward, as concurred by Janošková (2016). More so, introducing technologies can be done in an integrative and responsive manner, integrating high and low technology solutions and easing the employees into it as they familiarise themselves with the new systems in response to their needs, a view shared by Arabshahi *et al.* (2017). This is crucial because employees' behavioural intention and usage attitude, as well as organisation readiness, can influence innovation diffusion and technology implementation, and with specific users' evolving work requirements, complex and generic solutions may take time to implement in different contexts and practices (Greenhalgh *et al.*, 2017; Okoro *et al.*, 2023).

Further, since the FM practice is evolving in the light of recent occurrences and technological advancements, employees in various FM roles should be capacitated to use technology through training by vendors on the appropriate usage. Moreso, because there might be difficulties or disillusionment regarding its usage; technology vendors should guide organisations in appropriate ways to adopt new technologies to their benefit. Other than that, they should be organisation of usability challenges and choose homogenous

products for similar and adaptable functions, for example, training in technologies for data centre curation and management and information transfer.

Management should introduce new technologies in phases or by degrees. This is important because the levels of difficulty for individual users and companies may differ. It is also important for organisations to deliberate on who will use various tools or technologies while planning to adopt to ensure relevance and achieve cost reduction, task efficiency and risk management. These are critical areas in FM (Carbonari *et al.*, 2018; Munawar *et al.*, 2020; Tarek and Marzouk, 2022). In addition, adopting new technologies may not be well received by the intended users, a view supported by Okoro *et al.* (2023). Consequently, attention to how employees perceive changes in the workplace and change management systems is critical as this may affect adoption, a view supported by Musonda and Okoro (2022) and Sim (2022). Intended or new users should embrace new learning opportunities to increase capabilities in their roles in the management of buildings and structures and ultimately improve productivity.

On the government's part, cost-sharing avenues could be provided to support real estate firms in implementing new or innovative technologies for specific FM functions. Supportive regulations, standards and specifications are critical to encourage technology integration and ensure sustainability (Koch *et al.*, 2019).

Construction stakeholders and consortiums should involve facilities managers in the project initiation stage as they are critical to post-construction successes like maintenance and knowledge transfer. In turn, the sustainability of structures, the BE and FM practice will be ensured.

Conclusion

The study set out to consolidate information from published research on the use of technology in FM, with a specific focus on real estate. Relevant information about the connections and grouping of studies published by various authors, organisations and countries were produced from bibliometric and content analyses. An author-based bibliographic co-occurrence analysis, organisation knowledge networks yielded three clusters of keywords. The emerging themes include lifecycle integration and management, data curation and management and organisation and management capabilities. These highlighted the significance of technology adoption, albeit in varying degrees, to ensure appropriate and assured behavioural intention and usage and sustenance of the FM workplace in the future. The key stakeholders are facility managers, property owners, real estate managers and the government, who aim to organisation and improve future practices in REFM. The findings will also be beneficial to technology suppliers and vendors to appropriately train organisation personnel according to business objectives and requirements to improve task efficiency and risk management.

Broadly, the study findings contribute to the dialogue on the subject by using bibliometrics for the analysis of networks, such as the trends of research work, how these studies build on each other's knowledge via co-citation, and the evolution over time. The authorship or productivity was mostly in China, Norway and Italy, with little collaboration among the authors. The study also identified the core journals and authors in the investigated area, which can help future researchers on this topic to locate relevant materials for gap analysis and critical literature review. They can draw on these findings to further identify hotspots and collaborative opportunities for real estate innovation and sustainability research.

Further, based on the findings, more research is needed in other territories or regions, including Africa. The world is moving on to the 5IR, and no industry, country or economy

should be left behind. Additionally, enhancing facilities managers' capabilities to use technology could be the focus of future research. This is especially important in policymaking in developing countries (Global South), where the adoption and implementation of various technologies are still developing, and the contexts do not adequately support awareness and training of facilities managers.

The first research limitation lies in using one database (Scopus) to identify the documents included in the analysis. However, the search filters applied helped to ensure that a broad range of articles could still be analysed and organisation for reliable results. The mixed methods (quantitative bibliometric and qualitative content analyses) also provided useful insights on the technologies used in various REFM areas, the benefits and challenges thereof. Future studies using primary research approaches could elicit useful qualitative and quantitative information to promote increased adoption of technology in REFM organisations. In addition, the use of the most cited papers, thus favouring older papers, may have unintentionally introduced an element of bias. Future studies may apply another metric, such as the most recent publications, to espouse meaning regarding the bibliometric themes and trends.

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