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A Review of Technology Application and Benefits in Comprehensive Facilities Management for Housing Quality Assurance

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Abstract

The role of technology in housing delivery has been highlighted in recent research. This study explored technologies and their benefits to housing quality and delivery, especially during the development and operational stages. A desktop study based on a semi-systematic review from Scopus, Google, Google Scholar, Science Direct and Academic Search Ultimate was employed. Thematic analysis was used to analyse the data to extract relevant information from the sampled studies. The identified technologies used in post-construction (facilities management) processes include building information modelling (BIM), autonomous robots, laser scanning and remote sensors, blockchain, radio frequency identification (RFID) technology, drones and mobile devices. While some challenges to adopting new technologies could be associated with the costs, resistance to change, management capacity, and delays in the process flow, the study revealed that the benefits of adopting technology outweigh the challenges. Such benefits include improved speed, accuracy, consistent and complete data, reduced carbon emission, improved collaboration and efficiency and productivity. The study adds to the knowledge on technology adoption in housing quality management.

Keywords

Buildings, Facilities Management, Housing, Maintenance, Quality, Real Estate, Technology.

1. Introduction

Cities are realizing the need for adequate housing and quality management of existing infrastructure and housing stock. Habitat III in 2016, adopted the New Urban Agenda, requiring 'the promotion of housing policies that support the progressive realization of the right to adequate housing for all' by 2030 (World Economic Forum (WEF), 2019). An estimated three billion people will require adequate and affordable housing by 2030 (United Nations (UN), 2019). Adequate housing is a multi-dimensional concept consisting of elements of the residential environment that are both quantitatively and qualitatively sufficient in meeting users' needs, expectations, and aspirations (Mazur et al., 2022). According to the World Health Organisation's Housing and Health Guidelines, housing can be structurally deficient due to poor construction or maintenance (WHO, 2018). In addition, under the Right to Adequate Housing, housing is not affordable if its costs (including the rent, operation, and maintenance) threaten or compromise the occupants' enjoyment of other human rights (ibid.). This suggests that the adequacy of housing is partly a quality issue. Therefore, in addition to the way housing is constructed, the building materials used, operations, maintenance and management are critical to support habitable housing and contribute to guaranteeing the safety and satisfaction of the housing consumer (Mazur et al., 2022).

In addition to the burden of supplying sufficient housing to clear housing backlogs (over 2 million in South Africa), economies are faced with inadequacy and poor quality or unsustainable housing (Eggers and Moumen, 2013; Fuller Centre, 2014). Poor housing quality results in enormous costs (Rotimi et al., 2015). The impasse of good quality

real estate development is evinced in the extant literature, which reveals that the quality of housing delivered globally and in Africa is poor (Iddi et al., 2022). This is partly because of technology-related issues, poor facilities management viz-a-viz poor information flow and collaboration among project teams, and reduced productivity (Zainul Abidin et al. 2013). In South Africa, although there are requirements, regulations and guidelines in terms of national standards and policies set by governments to manage housing quality (for example, the National Housing Act and the National Building Regulations, as well as Agrément Certification), the homes are still poor (WEF, 2019; Iddi et al., 2022). More attention should be paid to the end-user or dweller who experiences the function and performance of the house after building, to ensure satisfaction with housing and built environment quality (Mabasa, 2017). Therefore, the observed trends, demand and complaints regarding poor housing quality give rise to the need to continue to explore ways to improve housing quality and ensure the achievement of real estate development objectives. Further, with urbanization, the demand for mass/social housing, housing estates, and high-rise buildings to accommodate middle and low-income households should match efforts to provide new affordable units and maintain the existing stock (Lai, 2011).

Literature advocates incorporating facilities management processes during the project development and implementation stages (Mewomo et al., 2022). Facilities management processes can identify hazards and reduce the risks of health problems such as lead poisoning, asthma, and unintentional injuries and accidents, thus improving indoor environmental quality and the general state of buildings (Korfmacher and Holt, 2018). Adequate management of workflows, risks and adverse events, training and tracking policies and procedures, and managing corrective actions allows for improved housing quality management (ETQ, 2023). A comprehensive quality management system enables facilities and facilities managers to operate at optimal efficiency while meeting required regulations; thus, facilities are a hidden influence on quality (ibid.). Such functions should therefore be included during the planning, installation and maintenance of services within a building (construction and post-construction processes), a view shared by Mewomo et al. (2022) in their study of public facilities. Olanrele et al. (2014) argued that facilities management can relate to business activities and environment (business/commercial properties) but also residential buildings, especially high rise. Nielsen et al. (2012) advocated attention to facilities management functions in social housing delivery, focussed on process management to improve support for sustainable living. Therefore, facilities management functions are critical in public and private buildings, as this study covers.

In addition, the adoption of innovative technologies can improve housing delivery and management (post-construction) processes. This view was supported in previous studies. For example, Okoro et al. (2020) and Calitz and Wium (2022) investigated the application of technology in facilities management, but with a focus on only BIM. Likewise, Gunasekara et al. (2022) examined the use of blockchain technology for facilities management procurement processes, while Marocco and Garofolo (2021) examined research trends on disruptive technologies in facilities management but focused on BIM and its association with the digital twin.

Therefore, ways to improve the status quo through facilities management, which has received limited attention, warrant consideration. The risk of housing deterioration will continue to increase if innovative solutions are not explored. Therefore, this study's objectives were to explore technologies that can be adopted to improve facilities management processes, their applications and associated benefits. Facilities managers need to embrace digital transformations and adapt new technologies to fulfil organisations' core business requirements (Gunasekara et al., 2022). Staying up to date with the latest technologies enables company growth and increases productivity as cost-effective decisions and faster turnaround are possible.

2. Housing Quality Assessment and Management Systems

Housing is a basic human need, which evolves with time. Changes in housing needs have made it necessary to constantly assess housing quality to ensure that it meets users' needs (Brkanić, 2017). However, quality can be subjective and objective. Housing quality assessments are carried out to maximize design quality, ensure the healthy housing quality of apartments, assess apartment safety, and ensure high indoor thermal and acoustic comfort (Brkanić, 2017). These include various subjective and objective aspects based on various perspectives – end users, experts, clients, and potential buyers. In the US, housing quality has entailed appraisal of structures and apartments, overcrowding and physical neighbourhood environment (Brkanić, 2017), and the impact of structural features and physical amenities (James, 2007). Research among selected countries in EU-OECD, Asia-Pacific, Africa, Latin America and Western Asian viewed housing quality assessments in terms of dwelling size and amenities (Heston, 2018). Research conducted in Croatia assessed housing quality on different aspects including the unit, the building, neighbourhood, and socio-economic criteria such as hazards, size, services, amenities, and condition (Brkanić, 2017).

In South Africa, housing quality has been assessed based on user satisfaction with size, services and amenities (Moolla et al., 2011), as well as client satisfaction (CIDB, 2011). However, it is arguable that user satisfaction is the most important measure of housing quality since the end users have to dwell in the structure and experience the functioning and performance while in use (Brkanić, 2017; Mabasa, 2017). Related to this, service quality (facilities) and the condition of the structure are paramount to ensure user satisfaction (Sibiya, 2018). Value for money, which is the most essential element in residential facilities management, dictates the performance of buildings in economic terms and contributes to the effectiveness of housing schemes (Olanrele et al., 2014). Therefore, attempting to address quality for the consumer should be at the forefront of housing policies. Over the years, effort has been made to address some of these challenges through quality management and assurance.

Quality assurance systems have been the most common forms of quality principles applied to housing projects, including document control, audits, non-conformance tracking, Corrective and Preventive Action (CAPA) and Management Review (Sibiya, 2018). The international standards applied to construction is the ISO 9000 family of standards, which includes technical guides, reports and specifications related to quality management systema (Letsbuild, 2020). In the UK, Building Control Bodies ensure that provisions of the Building Regulations are met in all building projects to which the regulations apply, to maintain and improve quality and performance (Baiche et al., 2006). In South Africa, the National Housing Act and the National Building Regulations, as well as Agrement Certification, allow the designs produced by a 'competent person' to be deemed appropriate for a location in terms of health and safety standards (Fuller Centre, 2014; Jackson, 2015). Visible efforts by the government to provide an acceptable level of quality viz-a-viz safety, health and welfare during construction and use of buildings have been made (NHBRC, 2020).

Further, with technological advancement, online systems for quality assessment have been designed and used. For instance, the Housing Quality Indicators (HQI), used in the UK, from 2008 to 2015 for the measurement, evaluation, and improvement of design quality; the Housing Assessment System in Switzerland, developed to aid in the design, evaluation, and comparison of residential buildings (Brkanić, 2017) and the NHBRC's inspection processes during construction in South Africa (NHBRC, 2020). However, more avenues to improve housing quality need to be explored, such as the adoption of technology, especially in the post-construction phase, which receives limited attention in research.

3. Methods

A semi-systematic review in Scopus, Google, Google Scholar, Science Direct and Academic Search Ultimate were used to identify contextual issues regarding housing quality and improvement efforts globally. The search keywords contained keywords including the following, inputted in different permutations: housing, quality, buildings, technology, post-construction, maintenance, and facilities management. The subject areas of Engineering, Environmental Sciences, Business, Management and Accounting and Social Sciences. Most of the articles were focused on inspection and technology use at the maintenance and management stage, construction site management and quality of temporary structures. Some articles contained technology in relation to housing quality and were thus included. Thematic analysis was used to analyse the selected materials. This enabled examining of different researchers' perspectives to highlight similarities and differences regarding technology use in post construction processes (Nowell et al., 2017).

4. Findings

The summary of the study findings is presented in Table 1, covering the technologies identified from the sampled literature, for building and facilities management functions. Their applications in improving operations and maintenance management functions and associated benefits are highlighted and discussed. The table shows that there are ten main technologies, mainly the digital (including the emerging) ones such as augmented reality, digital twin and blockchain technology. The application of these technologies cut across construction and post construction; however, the post-constriction processes are the focus of this paper. The table also covers the benefits which are not limited to improved fast, accuracy, consistent and complete data; reduce carbon emission, improved collaboration, and productivity.

Table 1. Identified technologies, application and benefits in building and facilities management functions

Results	Results	Results	
Autonomous robots	- The autonomous robot is equipped with sensors for navigation, map building, and obstacle avoidance algorithms. - For detection of wall defects - Processes data using computer-vision-based techniques (e.g., using cameras, laser sensors, and infrared thermography (IRT) and codes	- Reduced labour - Improved productivity - Inspection accuracy - Complete data	Wang & Luo (2019) Yan et al. (2018)
BIM, digital twin and augmented reality	- Enables organising of multiple workflows and information - Clear presentation and management of information - Automated spatial data processing workflows	- Complete data - Accuracy - Improved efficiency - Reduces omissions - Easily accessible information - Management of information - Automatically recognise data points - Faster fix	Tang & Pradhan (2012) Kim et al. (2013) Tsai et al. (2014) Ma et al. (2016) Mirshokraei et al. (2019) Kubicki et al. (2019) Khanzadi et al. (2020) Marocco & Garofolo (2021) Sarkar (2021)
Upgrading of software on mobile devices or tablets (eg. Virtual Reality Modelling Language, iObserver Interface, etc.)	- Easy approach to data capturing and inputting information - Automatic generation of observation reports	- Prompt information delivery - Improved efficiency - Increased efficiency	Kim et al. (2013)
Blockchain	Distributed ledger	- Data verification - Ease of data recording, handling and accessibility - Long-term record keeping for maintenance and management	Gunasekara et al. (2022)
Drones and GPS-enabled devices (smartphones and cameras) and network cameras	- Data capture and photogrammetric modelling - uses simple photographs to make intelligent 3D models of objects and structures	- Quick and accurate data capture	Kim et al. (2013) Featherston & Maclachlan (2018) Guyton (2020)
Laser scanning and remote/mobile sensors, eg Lidar	- Data acquisition and post processing	- Data consistency and accuracy - Interoperability	Puente et al. (2013) Yan et al. (2018)
Thermal cameras	- Captures thermal images after heating the assessed environment for a short time	- Data accuracy	Yan et al. (2018)
Radio frequency identification (RFID) technology	- Tracks location and status of hidden components	- Direct visual feedback - Quick data capture	Kim et al. (2013) Li and Burcin Becerik-Gerber (2011)
Wireless routers	- For connectivity	- Improved network and efficiency	Tsai et al. (2014)
Wireless communication devices and programs such as Bluetooth, memory devices and PDAs	- To assist the less skilled	- Improved communication and assistance	Kim et al. (2008) Miller et al. (2016)

4.1 Autonomous Robots

High-quality, complete and more accurate data can be collected with the use of automated data collection systems such as autonomous robots, as opposed to manual inspections (Wang and Luo, 2019). A test performed on a real case study in Budapest, to assess the effectiveness of the BIM system in the recording of building process data revealed improvements in information accessibility, reporting, fault deduction and decision-making (Mirshokraei et al., 2019). With BIM, professionals can import, browse and operate 3D model to help them quickly locate the target and tasks, and generate a plan or standard documentation (Ma et al., 2016). Further, with a corresponding BIM model of the facility to be constructed, a manager can determine all major information, and retrieve them easily offline (Tsai et al., 2014). In addition, the shared environment and update-to-date information provided by BIM is beneficial (Mirshokraei et al., 2019). Similarly, blockchain technology enhances data and information flow, and access for later stages for maintenance and management (Gunasekara et al., 2022).

Furthermore, a robotic system that has the capability of simultaneously assessing different types of defects in constructed buildings such as hollowness, evenness, or cracks can be used (Yan et al., 2018). A thermal camera is used to capture a thermal image after heating the assessed environment for a short time (Yan et al., 2018). However, thermal cameras are ideal for finding objects with a certain temperature, but they do not deliver distance information, while 2D laser scanners deliver distance measurements, and thus a fusion of the two works best (Gleichauf et al., 2017). Other computer-aided applications can be used for facilities management functions (Sarkar, 2021).

4.2 Radio Frequency Identification (RFID) Technology

The findings show that this can be used to locate underground or hidden services on sites and constructed buildings such as utility lines and laid-in pipes. By tracking the location and status of the components, early detection of delays and timely decisions on corrective measures is possible (Li and Burcin Becerik-Gerber, 2011). With the implementation of an RFID-based system, reports are availed to all users and progress of functions can be monitored in real time with reference to specifications (ibid.).

4.3 Wireless and Mobile Computing Devices

Additionally, the findings show that other wireless and mobile computing devices such as routers and editing programs can be useful (Miller et al., 2016). Personal Digital Assistant (PDA) and wireless web-integrated Quality Inspection and Defect Management System (QIDMS) have also been advocated to collect defect data at a site in real time, and effectively manage the status and results of the corrective works (Kim et al., 2008). This view was supported by Marocco and Garofolo (2021) opining that visualisation systems or applications can be utilised to facilitate more effective and efficient processes, and collaborative systems that allow multiple maintenance teams to perform their tasks in real time is desirable.

5. Discussion

Quality control is critical on a construction project as it guarantees compliance with requirements, standards and regulations during and post construction, at least to some extent. Using electronic systems can improve inspections (Sibiya, 2018) which is consistent with the findings of the current study (Table 1). Extant literature discussion the implications of adopting technology in construction and post construction should. For example, in addition to flexibility, improved collaboration and increased productivity (Delaney and D'Agostino, 2015), it can afford benefits such as improved communication and information flow, improved accuracy, reduced costs and time in post construction stages (Delaney and D'Agostino, 2015; Guo et al., 2020; Okoro et al., 2020, Sarkar, 2021).

Adopting new technologies will go a long way in ameliorating the status quo with regard to rate and quality of housing. However, the use of electronic systems, gadgets and new technologies may come with challenges, for example, it may be costly for some organisations to purchase or obtain special licensing, efforts should be made to gradually implement (Okoro et al., 2020). Other challenges in adopting new technologies such as conflicts,

management capacity to implement, resistance to change and generational concerns, may also be faced by organisations making the effort (Delaney and D'Agostino, 2015; Marocco and Garofolo, 2021). However, the benefits of adopting new technologies outweighs the challenges. The processes need to be managed in an organisation's work, in the steps of project development, and customised to suit their functions and in line with standard operating procedures (Tsai et al., 2014; Kubicki et al., 2019).

6. Conclusion

The study set out to investigate the technologies for improving facilities management processes, their applications and associated benefits towards housing quality enhancement. New technologies such as BIM, drones and sensors as well as autonomous robots were identified as beneficial. The benefits of adopting these new technologies were also highlighted. These include data consistency and accuracy, time savings, increased efficiency and productivity, better data storage, transfer and management and generally, improved organisational processes. Therefore, adopting these technologies is worth considering given the backlog of housing and the need to deliver on quality.

The findings are envisaged to encourage housing quality assurance entities and managers in devising strategies to adopt new technologies. Policymakers and regulators can consider various technologies to make decisions on which ones will best suit their functions and goals. This is especially important in developing countries where adoption and implementation of various technologies are still developing, and the contexts do not adequately support them. Further studies could be performed on the experiences of real estate professionals in using these technologies to perform specific functions, as well as the wellbeing implication given the interactions between quality environment, people and technology. Also, the factors identified in the current study can be empirically validated through a survey questionnaire and qualitative research methods such as semi-structured interviews can provided a deeper insight into the discourse.

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