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DOI
10.1108/F-04-2022-0053

Publication date
2023

Document Version
Final published version

Published in
Facilities

Citation (APA)
Hassanain, M. A., & Hamida, M. B. (2023). AEC/FM performance in adaptive reuse projects: investigation of challenges and development of practical guidelines. *Facilities*, *41*(7-8), 477-497. https://doi.org/10.1108/F-04-2022-0053

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https://www.emerald.com/insight/0263-2772.htm

AEC/FM performance in adaptive reuse projects: investigation of challenges and development of practical guidelines

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Received 4 April 2022
Revised 9 October 2022
26 December 2022
Accepted 9 January 2023

Abstract

Purpose – This paper aims to provide architecture, engineering, construction and facilities management (AEC/FM) practitioners with a guiding tool for overcoming the challenges affecting their performance in adaptive reuse project.

Design/methodology/approach – Literature review was conducted to comprehend the challenges affecting the AEC/FM performance during the implementation of adaptive reuse projects. A case study was conducted on an adaptively reused building, located in Saudi Arabia. The case study building was converted from a bookstore into an amusement center. Document review of the as-built drawings, and a structured interview with the project manager were conducted. The study concluded with the development of AEC/FM practical guidelines, pertaining to the different involved domains.

Findings – This study indicated that the potential challenges are interrelated among the three domains. These challenges pertained to the spatial, legislative, technical, administrative and operational aspects. The findings emphasized the vital role of the integration among the AEC/FM domains, at the early project planning phases. Based on the findings, three sets of AEC/FM guidelines were developed.

Research limitations/implications – Theoretically, to the best of the authors' knowledge, this is the first study that provides a case-specific investigation of the challenges affecting the AEC/FM performance in adaptive reuse projects.

Practical implications – The developed practical guidelines could potentially enhance the AEC/FM performance in future adaptive reuse projects.

Originality/value – This study contributes to the practice of adaptive reuse projects through providing practical guidelines for mitigating the challenges that affect the AEC/FM performance in these projects.

Keywords Adaptive reuse, AEC/FM, Challenges, Lessons learned, Property development

Paper type Case study

The authors thank King Fahd University of Petroleum and Minerals for the support and facilities that made this research possible.

0263-2772
DOI 10.1108/F-04-2022-0053

1. Introduction

Adaptive reuse of the built environment has been viewed as a sustainable strategy for communities, due to its capacity to provide multiple ecological, economic and social benefits (Hassan *et al.*, 2020; Langston *et al.*, 2008; Mehr and Wilkinson, 2018, 2020; Remøy, 2010; Wilkinson and Remøy, 2015, 2018; Yoon and Lee, 2019). The practice of adaptive reuse is in line with the oldest conceptualizations of sustainable development, such as the Brundtland Report (UN, 1987), as adaptive reuse contributes to eliminating the depletion of non-renewable resources. In addition, adaptive reuse has also been considered to be a practice that contributes to the achievement of the sustainable development goals (SDGs), as it can align the economic, cultural, societal, environmental and urban considerations in the context where the built-asst is located (Dell'Ovo *et al.*, 2021). In this context, numerous adaptive reuse projects were implemented worldwide during the 20th and 21st centuries, to preserve and refunction obsolete premises in an efficient manner (Douglas, 2006; Wilkinson *et al.*, 2014). From a business development perspective, building adaptive reuse represents a viable approach for workplace and property development, as it provides time and cost savings for property investors (Remøy *et al.*, 2011; Remøy and van der Voordt, 2014; Wilkinson and Remøy, 2017). From the perspective of urban redevelopment, adaptive reuse is an attractive strategy for regulators and developers due to its potential to provide environmental and social benefits, despite some regulatory and building-related concerns (Wilkinson *et al.*, 2014).

Building adaptive reuse entails the involvement of different stakeholders (Li and Tsai, 2017), including owners, business developers, investors, regulators and occupiers. Investors have a long-term perspective of the property use, and thus, tend to invest in adaptive reuse projects, when the project is structurally and economically feasible. Investors would usually involve professional consultants to decide on the technical and economic feasibility of the project (Wilkinson *et al.*, 2014). In this context, there are key other parties who are involved in the majority of the technical and managerial aspects of adaptive reuse projects. These parties are mainly actors of the architecture, engineering, construction and facilities management (AEC/FM) industries (Hamida *et al.*, 2022). Several challenges may impact upon the performance of the AEC/FM in adaptive reuse projects (Hamida and Hassanain, 2022b). The review of the relevant literature revealed the fragmented investigations on the AEC/FM performance in these projects, including the potential challenges, during the design (Kurul, 2007; Yaldiz and Asatekin, 2013), construction (Danso *et al.*, 2015; Hein and Houck, 2008) and the operation and maintenance (O&M) phases (Al-obaidi *et al.*, 2017; Günçe and Misirlisoy, 2019; Hamida and Hassanain, 2022a). This entailed undertaking a comprehensive investigation of the AEC/FM performance to comprehend the encountered challenges during the implementation of adaptive reuse projects.

In light of the lack of availability in the documentation of lessons learned in adaptive reuse projects, the aim of this paper is to provide AEC/FM professionals with a guiding tool that can assist them to overcome the challenges affecting their performance in adaptive reuse projects. Thus, the focus of this study is twofold: investigate the challenges facing the AEC/FM performance based on the lessons learned by a property owner; and thus develop practical guidelines to eliminate the adverse effect of these challenges in future adaptive reuse projects. The study encompassed multiple data collection techniques, including document review of the as-built drawings and a structured interview with the project manager. The study holds theoretical and practical implications for the related domains involved in adaptive reuse projects. In essence, the study documents and discusses the acquired knowledge from the industry and the literature, in the context of adaptive reuse projects.

2. Research methodology

To achieve the research objective, a stepwise case study approach was followed. Case study research is a useful approach to explore or understand a contemporary matter of study in the real world, for the sake of knowledge expansion or even addressing the matter under study (Meyer, 2001). In this research, the case study assisted in understanding the challenges that affect the performance of AEC/FM in adaptive reuse projects, and thus, developing practical and applicable guidelines that will help practitioners to overcome these challenges in practice. The design of the followed approach consisted of four-stepwise activities, namely, literature review, data collection, synthesis and development of guidelines for AEC/FM practitioners, as illustrated in Figure 1. Methodologically, the design of this research represents an integrative approach that bridges the gap between theory and practice, as it uses the existing theory to explore its extent in real-world settings (Groat and Wang, 2013). In this study, the followed approach contributed to defining the challenges affecting the AEC/FM performance using the existing literature, and hence, explored their emergence and influence in the real practice context to develop practical guidelines.

2.1 Literature review

This study is thematically interconnected, covering two areas of literature, namely, professional AEC/FM practices in buildings and adaptive reuse projects. Accordingly, the authors reviewed the relevant sources from each area of literature.

First, the authors reviewed the role of AEC/FM practitioners in the built environment with an indication of the contribution of integrating the three professions in building

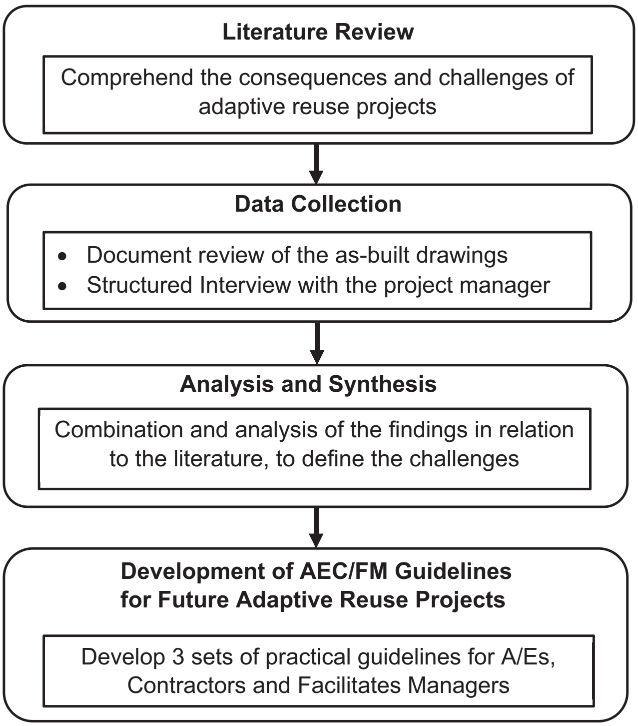

Figure 1. Research methodology

projects (Camposano and Smolander, 2019; Deng *et al.*, 2021; Zeb and Froese, 2011; Zhang *et al.*, 2022). In addition, the authors also concluded with a reflection on the necessity of such an integration in adaptive reuse projects, as these projects undergo new life cycle and complex processes (Hamida and Hassanain, 2022a, 2022b).

Second, a review of the relevant literature on building adaptive reuse was conducted, to comprehend the various aspects pertaining to the encountered challenges in these projects (Douglas, 2006; Langston *et al.*, 2008; Remøy, 2010; Wilkinson and Remøy, 2015; Al-obaidi *et al.*, 2017; Mehr and Wilkinson, 2018; Wilkinson and Remøy, 2018; Günçe and Misirlisoy, 2019; Yoon and Lee, 2019; Hamida and Hassanain, 2022a; Hassan *et al.*, 2020; Mehr and Wilkinson, 2020). The literature review served to provide insights into the possible challenges that might be encountered by the AEC/FM practitioners. Owing to the fragmentation of the relevant literature on AEC/FM practices in building adaptive reuse, the reviewed studies were sorted under three categories, corresponding to the AEC/FM domains and the key project phases in adaptive reuse projects, namely, design, construction and FM.

Conceptual models serve as a representation or an abstraction that coherently brings the components or variables of a research problem together; thus, resulting in a better understanding of a real-world problem (Nelson *et al.*, 2012). The components of this research are: adaptive reuse, challenges facing professionals' performance, AEC/FM integration. Thus, the reviewed literature resulted in the synthesis of a conceptual model that summarizes the key challenges that may affect the AEC/FM performance in adaptive reuse projects.

2.2 Data collection

The case study used document review and structured interview as the main data collection methods. The criterion for selecting the case study project considered exploring an adaptive reuse project that incorporated the three interrelated AEC/FM professional domains, where all processes had to be performed by one organization.

2.2.1 Document review. Two sets of as-built drawings of the case study building were collected from the client project department of the property owner. These drawings comprised the as-built blueprints of the previous, as well as the new uses. This activity aimed at acquiring a record of the key alterations that were implemented in the adaptive reuse case study project.

2.2.2 Structured interview. Interviews constitute a useful research method that can be combined with other methods to get a deeper understanding of an explored or observed phenomenon in the built environment (Groat and Wang, 2013). In the adaptive reuse domain, several authors combined interviews with other data collection methods to get a deep dive in several aspects pertaining to this practice. For instance, Hein and Houck (2008) combined field observation during construction with interviews to understand the construction challenges in adaptive reuse projects. In addition, Kurul (2007) combined interviews with archival research in a case study, which intended to explore and map the processes involved in adaptive reuse projects.

As this study focused on exploring a certain issue in a particular context, a structured interview was conducted to investigate the challenges affecting the AEC/FM performance in adaptive reuse projects. Structured interviews represent a standardized data collection tool, with pre-established questions which can be used to obtain and elicit knowledge on factual information, and thus, objectively generalize the outcomes (Qu and Dumay, 2011). The following five aspects were the components of the interview form which was used as a guide for structuring the interview:

(1) The building profile.
(2) The reasons for selecting and adapting the case study building.
(3) The challenges that were encountered during the planning and design phase.
(4) The challenges that were encountered during the construction phase.
(5) The challenges that were encountered during the O&M phase.

Accordingly, the main criterion for selecting the interviewee was the involvement in all the AEC/FM processes. The key informant in this study is the project manager, who was approached through the investor organization. This project manager has worked in the engineering department of the investor organization. This project manager is acquainted with the entire process of adapting the case study building, owing to being involved in the entire project life cycle, starting from the property acquisition till its operation, on a daily basis. The interviewed project manager was involved during the entire AEC/FM processes in the adaptive reuse project. The project manager had a diverse experience, over 10 years, with different types of building projects, including new construction as well as major alterations. These projects included hotel, recreational, residential and corporate facilities.

2.3 Analysis and synthesis

The findings from the document review and the structured interview were analyzed and triangulated, in light of the structure of the synthesized conceptual model, which is based on the reviewed literature (Figure 2). This approach is known as "directed content analysis" approach. This approach is a theory-led procedure that uses conceptual or theoretical frameworks to guide the analysis by focusing on certain variables, and thus, can contribute to expanding the models being used (Hsieh and Shannon, 2005). As the conceptual model maps the potential challenges per the professional domains and the relevant project phase, the observed challenges were clustered and discussed in a profession- and phase-oriented context as follows:

- Challenges encountered by architecture, engineering (A/E) practitioners during adaptive reuse design.
- Challenges encountered by contractors during adaptive reuse construction.
- Challenges encountered by FM practitioners during adaptive reuse O&M.

The discussions were supported by observations and findings derived from the relevant literature. This activity aimed at interpreting the findings in a comprehensive context, and thus, indicating the lessons learned from the perspective of the AEC/FM practitioners.

2.4 Development of architecture, engineering, construction and facilities management guidelines for future adaptive reuse projects

Guidelines for future adaptive reuse projects were developed based on the lessons learned from the research findings. Based on the structured interview findings, the observed challenges were listed in a profession- and phase-oriented context. Based on the observed challenges through the statured interview and documented solutions through the document review and statured interview, the practical guidelines were proposed and formulated, accordingly. The guidelines were individually directed to each profession, as follows:

- Guidelines for the A/E practitioners.
- Guidelines for the construction practitioners.
- Guidelines for the FM practitioners.

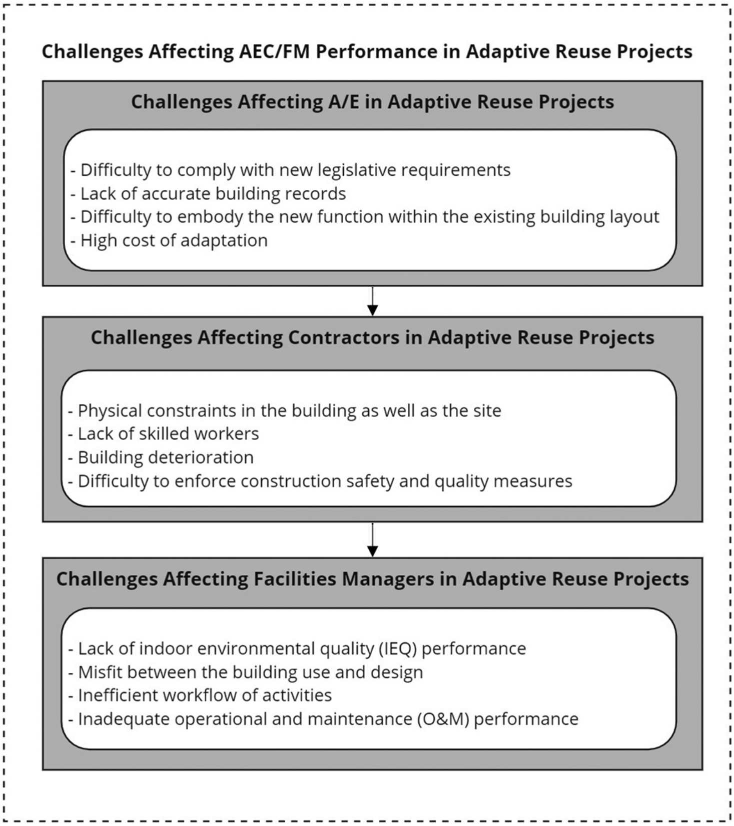

Figure 2.
A conceptual model for the challenges affecting the AEC/FM performance in adaptive reuse projects

The guidelines were mapped and tabulated against each of the identified challenges. These guidelines aimed at facilitating the potential challenges affecting the practices of AEC/FM in adaptive reuse projects.

3. Literature review

3.1 Role of architecture, engineering, construction and facilities management practitioners in buildings and adaptive reuse projects

Buildings undergo a sequential life cycle that consists of planning, design, construction and operation and maintenance phases, respectively. Thus, the development of buildings tends to be a piecemeal process, where different practitioners contribute to the project's development in a certain phase within its life cycle (Kartam, 1996). Typically, the A/Es are involved in the planning and design phase, contractors in the construction phase and facilities managers in the O&M phase (Deng *et al.*, 2021). Different challenges might be encountered in each of the phases, owing to the fragmentation of the project's components and professional AEC/FM practices (Zhang *et al.*, 2022). Accordingly, the integration of AEC/FM practices would contribute to mitigate the presence of several challenges and enhance the performance of the involved practitioners through proper communication and alignment of activities in each of the different phases of the project life cycle (Camposano and Smolander, 2019; Zeb and Froese, 2011).

As adaptive reuse projects undergo a new life cycle, AEC/FM processes will be practiced as a typical building project (Hamida and Hassanain, 2022b). Hence, integrating the AEC/FM domains contributes to the effective implementation of these projects as well as the mitigation of potential challenges that may hinder the performance of each profession (Hamida and Hassanain, 2022a). Relevant studies to the context of the research were reviewed, to comprehend the potential challenges affecting the AEC/FM practices in adaptive reuse projects. These studies were clustered under three domains, namely design, construction and O&M of adaptive reuse projects. The following subsections discuss the findings of these studies, respectively.

3.2 Design, construction and facilities management of building adaptive reuse

3.2.1 Previous studies on the design of adaptive reuse projects. Numerous studies have explored the various aspects pertaining to adaptive reuse design. Kurul (2007) explored the processes that are carried out during the design of adaptive reuse projects. Case studies-based approach was followed in the exploration of the design processes, using interviews with project representatives and review of archived documents. The study concluded that adaptive reuse projects are surrounded by common interfering activities and complex issues among the stakeholders and professions, which entails the integration and coordination of the design processes.

Eyüce and Eyüce (2010) discussed the context of the adaptive reuse design, from the design professional perspective. The study highlighted that adaptive reuse projects entail the implementation of substantial changes in the space configuration, as reconfiguring the building layout efficiently to embody the new functional requirements is one of the key challenges in these projects. In this context, the authors highlighted the necessity and the vital role of developing the architectural program and design scheme at the early design phase, to satisfy the project requirements in a comprehensive manner.

Yaldiz and Asatekin (2013) proposed a design process for adaptive reuse of historic buildings, based on a literature review. The proposed approach entails the implementation of an architectural program for the new use, considering the functional, environmental and technical requirements, to overcome the legal, structural and functional issues. The proposed process incorporates the implementation of an assessment of the project feasibility, in terms of spatial capacity, environmental performance, economic viability, regulatory compliance and technical considerations.

3.2.2 Previous studies on the construction of adaptive reuse projects. Few studies have explored the context of the adaptive reuse projects, from the perspective of the construction profession. Hein and Houck (2008) investigated the challenges affecting the process of implementing adaptive reuse projects, with a focus on historic premises. Field observations in four projects were noted, as a data collection method. The investigation focused on exploring the challenges pertaining to three main aspects, namely, feasibility, construction and structure. The study revealed that feasibility assessment of the adaptation, considering the costs and budget of all managerial and site activities, is among the significant aspects that need to be satisfied to avoid all financial constraints. Further, the study indicated that an adequate level of site accessibility and compliance with the applicable regulations need to be fulfilled for overcoming all the technical challenges that may impact upon the smooth flow of the field construction processes. The study also concluded that a condition assessment of the foundation system is a fundamental task that needs to be carried out, to investigate its structural integrity, at the beginning of adaptive reuse projects. This is owing to its vital role in overcoming the technical challenges associated with the stability of the building during and after the implementation of the change of use.

Oppong and Masahudu (2014) explored the challenges associated with the process of implementing adaptation and retrofit projects. The study used case studies as a data collection method. The study highlighted the legal challenges that could face the stakeholders involved in the implementation of these projects. These challenges focus mainly on compliance with the legislative and municipal laws related to construction safety and quality.

Danso *et al.* (2015) explored the obstacles encountering the contractors' enforcement of an adequate level of health and safety during the implementation of adaption projects, and the mitigation measures to eliminate such obstacles. The study used a mixed approach for understanding these obstacles, to determine potential measures, using knowledge from the literature, as well as the Delphi technique. The Delphi technique used questionnaire surveys as a data collection technique for a twofold exploration: first judging the importance of the observed obstacles in the literature; and second judging the importance of the applicability of the defined mitigation measures from the literature. The study indicated that lack of structural integrity, presence of unobservable hazardous material and implementation of a huge number of labor-based activities are the common obstacles that could hinder the enforcement of safety measures, in adaptive reuse projects.

3.2.3 Previous studies on the facilities management of adaptive reuse projects. Different studies were conducted to investigate the challenges affecting adaptive reuse projects during their O&M phase. Al-obaidi *et al.* (2017) assessed the performance of two adaptively reused buildings, which were converted from shophouses into hotels, in Malaysia. The study used different assessment tools, including interviews, physical observations and environmental measurements of the indoor environmental quality (IEQ). The study revealed that the two case study buildings have fulfilled the recommended performance criteria, despite some operational shortcomings. The study emphasized the necessity of considering the technical and functional aspects during the early design phases of these projects, to avoid any operational shortcomings in the IEQ performance.

Günçe and Misirlisoy (2019) investigated the success of adaptively reused buildings, in terms of their functionality to suit the new use, from the occupant perspective. The selected case study buildings were originally used as dwelling units. These buildings have undergone different forms of transformations, including residential, commercial, educational, cultural and religious. The study used different methods of investigation, including field observation and questionnaire surveys. The study indicated that the buildings that were converted to public uses have performed well, in terms of socioeconomic achievements for the communities. The study highlighted the necessity of considering the physical, operational cost and social aspects during the use of these premises for the continuity of their functionality.

Hamida and Hassanain (2020) conducted a post occupancy evaluation on an adaptively reused building, to assess its performance after the change of use. The case study building was converted from being a student housing to an office building. The study used different investigation techniques, including a walkthrough, interviews and a questionnaire survey. The study concluded that adaptive reuse projects can satisfy the performance requirements for the new occupancy, which entails careful consideration and fulfillment of the project requirements, on a life cycle basis, from the planning stage till the operation stage.

The review of literature indicated that several studies have explored the context of adaptive reuse projects from different professional perspectives, including design, construction and O&M. These studies have presented different challenges, which were encountered during the life cycle of adaptive reuse projects. These studies have also indicated the interrelation amongst the different professions. Nevertheless, these studies were fragmented, in the sense that they focused only on a particular project phase, at the time, as well as a particular profession within the life cycle of adaptive reuse projects. This necessitates the need for exploring these projects, in a comprehensive context, to comprehend the challenges that may impact upon these projects throughout their life cycle.

3.3 A conceptual model for the challenges affecting the architecture, engineering, construction and facilities management performance in adaptive reuse

The review of literature has revealed the availability of numerous challenges facing the AEC/FM performance in adaptive reuse projects. Figure 2 illustrates a conceptual model for the challenges affecting the AEC/FM performance in adaptive reuse projects.

During the planning and design phases, A/Es may experience difficulty with obtaining accurate building records, including drawings and specifications (Hein and Houck, 2008). Design wise, those professionals could face challenges in complying with new legislative requirements, as well as embodying the new function program within the layout of the existing building, owing to spatial and physical restrictions (Eyüce and Eyüce, 2010). Economically, the cost of adapting the building may increase to a large extent, especially when the building is in a deteriorated condition (Yaldiz and Asatekin, 2013).

During the construction phase, the contractor may face interrelated challenges when adapting an existing building for a new purpose. For instance, limited spaces for storing the building materials as well as performing the adaptation work constitute a physical challenge, which may impede the contractor's performance in adaptive reuse projects (Hein and Houck, 2008). In the same context, the deterioration of some building systems and components contributes to the economical and physical challenges, which contractors usually face. These challenges could result in the difficulty to enforce the quality and safety measures during the implementation of the adaptive reuse (Danso *et al.*, 2015; Oppong and Masahudu, 2014).

During the O&M phase of adaptively reused buildings, facilities managers may face different managerial and technical challenges in operating these buildings. For instance, the provision of the required performance of the IEQ may be one of the challenges that frequently take place during the O&M phase (Al-obaidi *et al.*, 2017). In addition, the misfit between the building function and its appearance could be one of the shortcomings that could be faced in adaptively reused buildings. Finally, the efficient flow of the operational activities may be hindered in these projects, due to the ineffective space allocation (Hamida and Hassanain, 2020).

4. Case study

A case study was conducted on a commercial building in Khobar city, the Eastern Province of Saudi Arabia. The building is a three-story building, with a gross area of 2,100 m^2, and a footprint area of 680 m^2. The building was built using cast in place concrete. The building was constructed in 1982 and used as a bookstore for 32 years. The building was converted by a new business investor into an amusement center in 2017. Table 1 summarizes the profile of the case study building. Figure 3 illustrates the floor plans of the previous use of the building.

The new business investor rented the facility in 2015, as it is located in a touristic location within the city, near to the seafront, which represented a strategic destination for a high profit margin. As the building was previously used as a bookstore facility, the investor

Table 1.
Profile of the case study building

Parameter	Value
Location	Khobar city, the Eastern Province of Saudi Arabia
Construction date	1982
Date of conversion	2017
Conversion period	2 years (2015 and 2017)
Previous use	Bookstore
New use	Amusement center
Gross area	2,100 m^2
Footprint area	680 m^2
Number of stories	Three-story building
Type of structure	Cast in place concrete
HVAC system	Central

Figure 3.
Floor plans of the previous use (bookstore)

endeavored on a change of use, to align the spatial layout of the facility with the new function.

The space planning for the new use was facilitated by the availability of the open floor plan, as the previous use of the building entailed the provision of large halls and showrooms. To meet the functional and spatial requirements of the new use, an architectural program was prepared by the engineering department of the business investor. Thus, the architectural layout of the spaces was developed. These spaces comprised play areas, catering facilities, dining and seating areas, office room and public toilet. A relocation of the elevator was undertaken, to efficiently use the usable spaces. Figure 4 illustrates the floor plans of the new use.

The entire process of reusing the building, starting from the rental of the property till the operation of the new business, took a period of 23 months, from August 2015 to July 2017. The major AEC/FM processes were implemented by the engineering department of the business investor, which enabled the authors to document the challenges that impacted upon the adaptive reuse project in a holistic manner.

Figure 4. Floor plans of the new use (amusement center)

5. Findings and discussion

The findings of the case study were analyzed and presented corresponding to the conceptual model, as shown in Figure 2, that links the challenges that may affect the AEC/FM performance with the corresponding phase.

5.1 Challenges encountered by A/E practitioners during adaptive reuse design

The A/E team of the engineering department of the organization, encountered several challenges, during the planning and design phase, for adapting the building into an amusement center. These challenges are described as follows:

5.1.1 Acquirement of accurate digital blueprints of the building. The acquirement of the digital blueprints of the building, in a complete and accurate manner, was the first challenge that encountered the A/E team of the organization. Owing to the building age, these documents were not updated to the recent condition of the building. This entailed the A/E team to contact all the stakeholders for the acquisition of these documents. The digital blueprints of the floor plan were availed by the real estate agency which leased the building. However, these blueprints were not identical to the current layout of the building, as they did not reflect the recent configuration of the building, and thus, the A/E team was in need to update and edit the blueprints accordingly. This challenge corroborates with findings concluded in the relevant literature (Alauddin, 2014; Conejos *et al.*, 2016; Remøy and van der Voordt, 2007; Wilkinson *et al.*, 2014).

5.1.2 Fulfillment of the functional requirements of the new architectural program within the building boundaries. The project manager indicated that the A/E team was challenged with satisfying the spatial requirements of the new business. This was mainly attributed to the diversity of functions that need to be accommodated and provided within the allowable space, including administrative, services and recreational spaces. These challenges were highlighted through different studies in the relevant literature (Arge, 2005; Eyüce and Eyüce, 2010; Remøy and van der Voordt, 2014; Wilkinson *et al.*, 2014). This prompted the A/E team to define the spatial requirements, and accordingly, identify their corresponding locations and distribution in the floor plans. In this context, the new design solution of the building has allocated the main correlated functions in a floor plan, as a functional zone, as follows:

- The ground floor was planned to include a recreational space, accommodating mechanical games, a dining area and catering facilities. Some services were provided on the ground floor, including storage rooms as well as a workstation.
- The first floor was planned to provide a space for soft play, besides offices for the administrative staff.
- The second floor was planned to provide spaces for the various amenities, as well as the games arcade.

This zoning entailed the provision of additional services. These additions comprised the provision of a kitchen in the ground floor, in addition to further public toilets in each floor, as illustrated in Figure 3. Furthermore, a secondary entry to the building was provided in the northern side, to meet code requirements for safety.

5.1.3 Coping with the condition and layout of the mechanical, electrical and plumbing systems. The condition and layout of the original mechanical, electrical and plumbing (MEP) systems have affected the new design solution, as the A/E team had to install new systems to fulfill the indoor environmental requirements, based on the new architectural layout. The A/E team concluded that it was better to install new MEP systems throughout the building. This was mainly attributed to the obsolescence of the existing systems, as well as the substantial impact of the change on the architectural configuration and the technical layout of the building systems. Furthermore, due to the new layout of the building, the existing elevator was shifted to a new location, besides the northern entrance. A similar challenge was mentioned by Bullen and Love (2010).

5.1.4 Reconfiguration of the building in accordance with the applicable regulations. Challenges pertaining to compliance with the applicable regulations have also influenced the architectural design of the building, as additional fire safety requirements were demanded to obtain the legislative permit, on the design documents. Particularly, the A/E team was required to provide two fire exits, to fulfill the recommended level of occupational safety during emergency conditions. A similar challenge was indicated in different sources in the relevant literature (Bullen and Love, 2011; Conejos *et al.*, 2016; Danso *et al.*, 2015; Olivadese, 2017; Remøy and van der Voordt, 2014; Wilkinson *et al.*, 2014). Consequently, this fire safety requirement has prompted the A/E team to develop an effective solution, without compromising the space use. The installation of a fire rated structural-steel-stairs, adjacent to the northern side of the building, was concluded to be the most feasible option, as illustrated in Figure 3.

5.1.5 Accommodation of the building's loads within its structural capacity. The distribution of the recreational machines was the main structural challenge that influenced the design of the adaptation, as the weight of these equipment exceeded the allowable live load on the building structure. Accordingly, the A/E team had to avoid installing these equipment on the upper floors, and thus, all of these equipment were installed in the ground floor. In fact, issues pertaining to the structural integrity of the adapted building are among the common challenges that impact upon the A/E performance in adaptive reuse projects, as indicated in the relevant literature (Bullen and Love, 2011; Conejos *et al.*, 2016; Douglas, 2006; Kincaid, 2002; Watson, 2009).

5.1.6 Alignment of the building appearance with its new use. The alignment of the building appearance with its new use have prompted the A/E team to use attractive, alternative finishes that can be installed at the elevations for publicizing the recreational identity of the building. Colorful cladding panels were installed over the main building elevations, which are fronting the main roads.

5.2 Challenges encountered by contractors during adaptive reuse construction

There were several physical and spatial restrictions, which impacted upon the performance of the construction team of the organization. In fact, these physical and spatial restrictions are among the critical challenges that contractors may encounter in adaptive reuse projects, as revealed in the relevant literature (Douglas, 2006; Eray *et al.*, 2019; Hein and Houck, 2008; Oppong and Masahudu, 2014). These challenges are described in the following sub-sections.

5.2.1 Physical restrictions of the building layout. The project manager indicated that the challenges pertaining to the physical restriction of the building layout were observed in two situations, mainly associated with the installation of the MEP systems. The first physical challenge pertained to the net floor height. The building has a net finish to finish height of 3.6 meters. The developed design documents aimed at providing a ceiling depth of 0.9 meter to facilitate the allocation and distribution of the new MEP systems. This design outcome resulted in a shorter finish-to-finish height, of about 2.7 meters for the occupied spaces. The construction and A/E teams of the business investor encountered this shortcoming during the construction phase. Accordingly, the design documents were revised. The revised design provided a ceiling depth of 0.8 meter, and a net floor height of 2.8 meters. The project manager indicated that this revision resulted in delaying the construction process, for about a month.

The second physical challenge pertained to the implementation of the wiring and piping activities through the only vertical, services shaft in the building. As the new function entailed the installation of new and additional MEP systems, the contractors faced a challenge in extending the cables, pipes and ducts through that shaft without causing any clashes among them. Thus, the A/E and construction teams decided to extend the drainage pipes externally across the back side of the building, to maintain an appropriate distance with the other services within the vertical, services shaft.

5.2.2 Lack of loading space due to the site configuration. The project manager indicated that the construction team faced spatial and technical difficulties pertaining to the site configuration. As the project was located within an already built area, assigning a loading space was a challenge that encountered the performance of the construction team. Thus, the contractor decided to schedule the material delivery periodically during non-peak hours, to avoid blocking the street.

5.2.3 Lack of a designated space for material storage. Specifying a space for storing the construction material within the project site was also among the challenges that faced the construction team. Due to limitations in the available space for providing a temporary structure for storing the materials at the project site, the construction team had to store the material within the building and appoint a security guard during the off hours work periods. These actions were taken to ensure and secure the availability of the frequently used construction materials, such as cement.

5.3 Challenges encountered by facilities management practitioners during adaptive reuse operation and maintenance

There were several challenges faced by the FM team and building administrator during the operation of the amusement center. The review of the relevant literature indicated the potential of these challenges to face the occupant and operators of adaptive reuse projects, as being consequences of implementing not well-thought out planning and design decisions (Brown and Cresciani, 2017; Bullen, 2007; Günçe and Misirlisoy, 2019; Hinks and Puybaraud, 1999). Two challenges were observed and described as follows:

5.3.1 Inadequate number of car parking. The management of the amusement center noticed the inadequate number of car parking for the visitors, specifically during the weekends. This shortcoming was observed immediately after the operation of the amusement center. The project manager indicated that the organization is currently considering to rent and develop a neighboring parcel as a car parking, to resolve this shortcoming.

5.3.2 Lack of protection measures against risky children' behavior. The project manager indicated that the implemented design solution lacked the provision of an appropriate level of protection against risky children' behavior. This was mainly attributed to the accessibility and location of the main entrance, which was fronting the main road. The door was accessible and transparent, where many children were able to exit the building to the main road. This shortcoming prompted the building administrators and the FM team to close that door, and limit the entry to one entrance to restrict the building accessibility.

6. Architecture, engineering, construction and facilities management guidelines for future adaptive reuse projects

Based on the investigated challenges that encountered the AEC/FM performance, 18 practical guidelines were developed for enhancing the entire process of designing, constructing, operating and maintaining adaptive reuse projects. Table 2 provides a mapping of these guidelines against the corresponding challenges and adopted measures/solutions in the case study. These guidelines were directed to each profession.

6.1 Guidelines for the A/E practitioners

The following guidelines are recommended for enhancing the A/E performance during the planning and design of adaptive reuse projects:

- Check the completeness and accuracy of the as-built drawings, and collect all the technical specifications pertaining to the building components and systems.
- Update and digitize the as-built drawings of the building according to the recent conditions.
- Investigate the structural integrity of the building against the possible live loads.
- Define and document all functional, spatial and economic needs of the new project.
- Survey all the mandated legislative requirements and technical criteria pertaining to the new use and municipal procedures.
- Identify all the technical and physical restrictions present in the facility.
- Reconfigure the space layout in line with the spatial, physical and technical restrictions present at the building.
- Evaluate the reliability and capacity of the MEP systems, against the recommended performance criteria.
- Align the building appearance with the visual considerations of the new use.

6.2 Guidelines for the construction practitioners

The following guidelines are recommended for enhancing the performance of the contractor during the implementation of adaptive reuse projects:

- Survey the building, considering all possible physical and spatial restrictions, at the beginning of the mobilization process.

Table 2. Mapping of the guidelines against the encountered challenges and adopted masseurs/solutions by the AEC/FM practitioners

Phase	Challenge faced in the case study	Adopted solution//measure in the case study	Proposed practical guideline
Planning and design	Acquirement of accurate digital blueprints of the building	Development of new as-built blueprints	– Check the completeness and accuracy of the as-built drawings, and collect all technical specifications pertaining to the building components and systems – Update and digitize the as-built drawings of the building according to the recent conditions
	Fulfillment of the functional requirements of the new architectural program within the building boundaries	Development of a brief of the new architectural and technical requirements and redesign of the building in line with these requirements and building layout	– Define and document all functional, spatial and economic needs of the new project – Identify all technical and physical restrictions present in the facility – Reconfigure the space layout in line with the spatial, physical and technical restrictions present at the building
	Coping with the condition and layout of the MEP systems	Replacement of the old MEP systems with new ones	– Evaluate the reliability and capacity of the MEP systems, against the recommended performance criteria
	Reconfiguration of the building in accordance with the applicable regulations	Provision of additional systems and increment of the capacity of existing systems	– Survey all recommended legislative requirements and technical criteria pertaining to the new use and municipal procedures
	Accommodation of the building's loads within its structural capacity	Redistribute the new architectural configuration per the floor plans according to the structural capacity of the floors	– Investigate the structural integrity of the building against the possible live loads
	Alignment of the building appearance with its new use	Redesign of the building elevations by using another façade materials	– Align the building appearance with the visual considerations of the new use

(*continued*)

Phase	Challenge faced in the case study	Adopted solution//measure in the case study	Proposed practical guideline
Construction	Physical restrictions of the building layout	Revising the building design to optimize the ceiling height and relocate the place of extending the MEP systems vertically	– Survey the building, considering all possible physical and spatial restrictions, at the beginning of the mobilization process
	Lack of loading space due to the site configuration	Reschedule the time of material delivery to be during non-peak hours	– Analyze the workflow of the construction processes and material delivery, considering the influential communal aspects, such as the peak time of transportation – Plan the layout of the construction site in line with the potential restrictions and construction workflow – Define and schedule the construction activities and their resources, corresponding to the project restrictions and construction workflow
	Lack of a designated space for material storage	Storing the construction materials and products within the building and recruitment of a security guard	– Manage and control the construction workflow, material delivery and labors' performance in line with the defined restrictions, project schedule and communal considerations – Allocation of a space for material storage
O&M	Inadequate number of car parking	Renting and developing a neighboring parcel as for car parking	– Document all functional and technical shortcomings in the facility
	Lack of protection measures against risky children' behavior	Limiting the building accesses to one entrance	– Develop an operational plan of the facility, comprising the soft, functional, managerial and technical considerations of the new use – Keep an ongoing appraisal of the condition and performance of the building, considering the soft, functional, managerial and technical indicators

Table 2.

- Analyze the workflow of the construction processes and material delivery, considering the influential communal aspects, such as the peak time of transportation.
- Plan the layout of the construction site in line with the potential restrictions and construction workflow
- Define and schedule the construction activities and their resources, corresponding to the project restrictions and construction workflow.
- Manage and control the construction workflow, material delivery and labors' performance in line with the defined restrictions, project schedule and communal considerations.
- Allocation of a space for material storage

6.3 Guidelines for the facilities management practitioners

The following guidelines are recommended for enhancing the FM performance during the operation of adaptively reused buildings:

- Document all functional and technical shortcomings in the facility.
- Develop an operational plan of the facility, comprising the soft, functional, managerial and technical considerations of the new use.
- Keep an ongoing appraisal of the condition and performance of the building, considering the soft, functional, managerial and technical indicators.

7. Conclusion

Adaptive reuse of the built-environment is a sustainable strategy for preserving communal and environmental resources, through re-functioning underutilized facilities to meet the market demands (Wilkinson *et al.*, 2014). Adaptive reuse is an ongoing practice, which will be implemented more frequently in the near future in light of the call for achieving the SDGs (Dell'Ovo *et al.*, 2021). Business and property developers view building adaptive reuse as a viable strategy, which provides time and cost savings, simultaneously. Building adaptive reuse entails a substantial re-engineering of all the AEC/FM processes, to suit the new project requirements. In this regard, it is important to get a better grasp on the technical challenges that may affect the AEC/FM practice, whereas understanding such challenges would contribute to develop practical guidelines for enhancing the performance of such technical domains.

This paper aimed to provide AEC/FM practitioners with a guiding tool that assist them to overcome the challenges affecting their performance in adaptive reuse projects. Thus, the paper focused on investigating the potential challenges that could affect the AEC/FM performance in adaptive reuse projects, and hence, developing practical guidelines to overcome these challenges and their effect based on the lessons learned by a business investor.

A review of the relevant literature was conducted to comprehend the potential challenges. A case study was conducted to document the challenges that affected the AEC/FM performance, and thus, formulate practical guidelines based on the lessons learned. Two data collection methods were conducted, including document review of the as-built drawings, and a structured interview with the project manager, respectively. The findings were analyzed against the synthesized conceptual model based on the literature review.

These findings were used to develop practical guidelines for enhancing the AEC/FM performance in future adaptive reuse projects.

The findings indicated that the majority of the challenges were present due to the inadequate project planning and coordination of the interrelated functional and technical considerations. Accordingly, a series of practical guidelines were developed based on the lessons learned.

The study contributes to the theory and practice of building adaptive reuse, through documenting and discussing the challenges affecting the AEC/FM performance based on knowledge acquired from the industry and linkage to the relevant literature. Theoretically, this paper is the first study that provides a case-specific investigation of the challenges that affect the AEC/FM performance in adaptive reuse projects. The study concludes with a set of practical guidelines for improving the AEC/FM performance in future adaptive reuse projects. However, the conceptual model of this research was limited to the traditional paradigm of phasing the life cycle of building projects, namely: planning, design, construction and O&M (Kartam, 1996). Future studies can expand the findings of this study by using RIBA plan of work 2020 (RIBA, 2020). This standard categorizes the life cycle of building projects into seven phases, namely, project briefing, conceptual design, spatial coordination, technical design, manufacturing and construction, handover and use. This model explicitly considers the overlap across the phases, such as the overlap between technical design phase and manufacturing and construction phase, also handover and use.

References

Alauddin, K. (2014), "The development of an intellectual capital framework for successful adaptive Re-Use", Doctoral Dissertation, School of Property, Construction and Project Management, RMIT University, Melbourne, Australia.

Al-Obaidi, K.M., Wei, S.K., Ismail, M.A. and Kam, K.J. (2017), "Sustainable building assessment of colonial shophouses after adaptive reuse in Kuala Lumpur", *Buildings*, Vol. 7 No. 4, p. 87.

Arge, K. (2005), "Adaptable office buildings: theory and practice", *Facilities*, Vol. 23 Nos 3/4, pp. 119-127.

Brown, L.A. and Cresciani, M. (2017), "Adaptable design in Olympic construction", *International Journal of Building Pathology and Adaptation*, Vol. 35 No. 4, pp. 397-416.

Bullen, P. (2007), "Adaptive reuse and sustainability of commercial buildings", *Facilities*, Vol. 25 Nos 1/2, pp. 20-31.

Bullen, P. and Love, P. (2010), "The rhetoric of adaptive reuse or reality of demolition: views from the field", *Cities*, Vol. 27 No. 4, pp. 215-224.

Bullen, P. and Love, P. (2011), "Factors influencing the adaptive re-use of buildings", *Journal of Engineering, Design and Technology*, Vol. 9 No. 1, pp. 32-46.

Camposano, J. and Smolander, K. (2019), "Inter-organizational integration in the AEC/FM industry", in Giorgini, P., Weber, B. (Eds), *Proceedings of the 31st International Conference on Advanced Information Systems Engineering*, Rome, Italy, June 3–7, pp. 64-79.

Conejos, S., Langston, C., Chan, E.H.W. and Chew, M.Y.L. (2016), "Governance of heritage buildings: Australian regulatory barriers to adaptive reuse", *Building Research and Information*, Vol. 44 Nos 5/6, pp. 507-519.

Danso, F.O., Badu, E., Ahadzie, D.K., Nani, G. and Manu, P. (2015), "Towards a framework for the management of health, safety and well-being on adaptive-retrofit projects in Ghana", in Edinburgh. (Ed.), *Proceedings of the ARCOM Doctoral Workshop – Health, Safety and Wellbeing*, February 11, University of Edinburgh, Association of Researchers in Construction Management, pp. 73-83.

Dell'Ovo, M., Dell'Anna, F., Simonelli, R. and Sdino, L. (2021), "Enhancing the cultural heritage through adaptive reuse: a multicriteria approach to evaluate the Castello Visconteo in Cusago (Italy)", *Sustainability*, Vol. 13 No. 8, p. 4440.

Deng, M., Menassa, C. and Kamat, V. (2021), "From BIM to digital twins: a systematic review of the evolution of intelligent building representations in the AEC-FM industry", *Journal of Information Technology in Construction*, Vol. 26, pp. 58-83.

Douglas, J. (2006), *Building Adaptation*, 2nd ed., Butterworth-Heinemann, Oxford.

Eray, E., Sanchez, B. and Haas, C. (2019), "Usage of interface management in adaptive reuse of buildings", *Buildings*, Vol. 9 No. 5, p. 105.

Eyüce, Ö. and Eyüce, A. (2010), "Design education for adaptive reuse", *International Journal of Architectural Research*, Vol. 4 No. 2, pp. 419-429.

Groat, L. and Wang, D. (2013), *Architectural Research Methods*, Wiley, NJ.

Günçe, K. and Misirlisoy, D. (2019), "Assessment of adaptive reuse practices through user experiences: traditional houses in the walled city of Nicosia", *Sustainability*, Vol. 11 No. 2, p. 540.

Hamida, M.B. and Hassanain, M.A. (2020), "Post occupancy evaluation of adaptively reused buildings: case study of an office building in Saudi Arabia", *Architecture, Civil Engineering, Environment*, Vol. 13 No. 1, pp. 29-40.

Hamida, M.B. and Hassanain, M.A. (2022a), "A framework model for AEC/FM knowledge in adaptive reuse projects", *Journal of Engineering, Design and Technology*, Vol. 20 No. 3, pp. 624-648.

Hamida, M.B. and Hassanain, M.A. (2022b), "Investigation of AEC/FM practices in adaptive reuse projects", *International Journal of Building Pathology and Adaptation*, Vol. 40 No. 4, pp. 636-660.

Hamida, M.B., Hassanain, M.A. and Al-Hammad, A. (2022), "Review and assessment of factors affecting adaptive reuse of commercial projects in Saudi Arabia", *International Journal of Building Pathology and Adaptation*, Vol. 40 No. 1, pp. 1-19.

Hassan, N., Khalifa, M.A. and Hamhaber, J. (2020), *Adaptive Reuse as a Revitalization Tool: The Case of Downtown Cairo Post Relocation of Governmental Buildings to the New Administrative Capital, Architecture and Urbanism: A Smart Outlook*, Cham. Springer, pp. 289-301.

Hein, M.F. and Houck, K.D. (2008), "Construction challenges of adaptive reuse of historical buildings in Europe", *International Journal of Construction Education and Research*, Vol. 4 No. 2, pp. 115-131.

Hinks, J. and Puybaraud, M.C. (1999), "Facilities management and fire safety during alterations, changes-in- use, and the maintenance of building facilities – a management model for debate", *Facilities*, Vol. 17 Nos 9/10, pp. 377-391.

Hsieh, H.-F. and Shannon, S.E. (2005), "Three approaches to qualitative content analysis", *Qualitative Health Research*, Vol. 15 No. 9, pp. 1277-1288.

Kartam, N. (1996), "Making effective use of construction lessons learned in project life cycle", *Journal of Construction Engineering and Management*, Vol. 122 No. 1, pp. 14-21.

Kincaid, D. (2002), *Adapting Buildings for Changing Uses: Guidelines for Change of Use Refurbishment*, 1st ed., Spon, London.

Kurul, E. (2007), "A qualitative approach to exploring adaptive re-use processes", *Facilities*, Vol. 25 Nos 13/14, pp. 554-570.

Langston, C., Wong, F.K.W., Hui, E.C.M. and Shen, L.Y. (2008), "Strategic assessment of building adaptive reuse opportunities in Hong Kong", *Building and Environment*, Vol. 43 No. 10, pp. 1709-1718.

Li, H.-W. and Tsai, T.-C. (2017), "Revitalization strategies for abandoned sugar factory sites in Taiwan", *The International Journal of Organizational Innovation*, Vol. 10 No. 1, pp. 229-237.

Mehr, S.Y. and Wilkinson, S. (2018), "Technical issues and energy efficient adaptive reuse of heritage listed city halls in Queensland Australia", *International Journal of Building Pathology and Adaptation*, Vol. 36 No. 5, pp. 529-542.

Mehr, S.Y. and Wilkinson, S. (2020), "The importance of place and authenticity in adaptive reuse of heritage buildings", *International Journal of Building Pathology and Adaptation*, Vol. 38 No. 5, pp. 689-701.

Meyer, C.B. (2001), "A case in case study methodology", *Field Methods*, Vol. 13 No. 4, pp. 329-352.

Nelson, H.J., Poels, G., Genero, M. and Piattini, M. (2012), "A conceptual modeling quality framework", *Software Quality Journal*, Vol. 20 No. 1, pp. 201-228.

Olivadese, R., Remøy, H., Berizzi, C. and Hobma, F. (2017), "Reuse into housing: Italian and Dutch regulatory effects", *Property Management*, Vol. 35 No. 2, pp. 165-180.

Oppong, R. and Masahudu, M. (2014), "Exploration of building adaptations and retrofitting challenges in Ghana: the case of selected rural bank projects", *Structural Survey*, Vol. 32 No. 5, pp. 349-364.

Qu, S.Q. and Dumay, J. (2011), "The qualitative research interview", *Qualitative Research in Accounting and Management*, Vol. 8 No. 3, pp. 238-264.

Remøy, H. (2010), "Out of office: a study on the cause of office vacancy and transformation as a means to cope and prevent", Doctoral Dissertation, Department of Real Estate and Housing, Delft University of Technology, Delft, The Netherlands.

Remøy, H. and van der Voordt, T. (2007), "A new life: conversion of vacant office buildings into housing", *Facilities*, Vol. 25 Nos 3/4, pp. 88-103.

Remøy, H. and van der Voordt, T. (2014), "Adaptive reuse of office buildings: opportunities and risks of conversion into housing", *Building Research and Information*, Vol. 42 No. 3, pp. 381-390.

Remøy, H., Jong, P. and Schenk, W. (2011), "Adaptable office buildings", *Property Management*, Vol. 29 No. 5, pp. 443-453.

RIBA (2020), "RIBA plan of work 2020", Royal Institute of British Architects (RIBA), London, UK, available at: www.architecture.com/knowledge-and-resources/resources-landing-page/riba-plan-of-work (accessed 25 December 2022).

UN (1987), "Report of the World Commission on Environment and Development: Our common future", Report of the World Commission on Environment and Development, United Nations, available at: www.are.admin.ch/are/en/home/media/publications/sustainable-development/brundtland-report.html

Watson, P. (2009), "The key issues when choosing adaptation of an existing building over new build", *Journal of Building Appraisal*, Vol. 4 No. 3, pp. 215-223.

Wilkinson, S. and Remøy, H. (2017), "Adaptive reuse of Sydney offices and sustainability", *Sustainable Buildings*, Vol. 2 No. 6, pp. 1-10.

Wilkinson, S. and Remøy, H. (2015), "Building resilience in urban settlements through conversion adaptation", *RICS COBRA AUBEA 2015: The Construction, Building and Real Estate Research Conference of the Royal Institution of Chartered Surveyors, The Australasian Universities' Building Educators Association Conference, Sydney, Australia*, July 8-10, Royal Institution of Chartered Surveyors (RICS), *Sydney, Australia*.

Wilkinson, S. and Remøy, H. (2018), *Building Urban Resilience through Change of Use*, Wiley, Chichester.

Wilkinson, S., Remøy, H. and Langston, C. (2014), *Sustainable Building Adaptation: Innovations in Decision-Making*, Wiley, Chichester.

Yaldiz, E. and Asatekin, N.G. (2013), "Definition of a new design process for the reuse of monumental buildings", Central Europe towards Sustainable Building (CESB 2013): Sustainable Refurbishment of Existing Building Stock, Prague, available at: www.cesb.cz/cesb13/proceedings/1_refurbishment/CESB13_1353.pdf

Yoon, J. and Lee, J. (2019), "Adaptive reuse of apartments as heritage assets in the Seoul station urban regeneration area", *Sustainability*, Vol. 11 No. 11, p. 3124.

Zeb, J. and Froese, T. (2011), "Design and management of transactions in the AEC/FM industry using an ontological approach", *Proceedings of the CSCE 3rd International/9th Construction Specialty Conference*, *Ottawa, ON, Canada*.

Zhang, F., Chan, A.P., Darko, A., Chen, Z. and Li, D. (2022), "Integrated applications of building information modeling and artificial intelligence techniques in the AEC/FM industry", *Automation in Construction*, Vol. 139, p. 104289.

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