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Making the 'Available Desirable' Using Adaptive Reuse (AR) In Sustainable Construction: A Systematic Review and Directions from case studies

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Abstract
The future of construction will take a different look from the past considering that the conventional system of "take, make, and dispose of" appears more and more insecure in a resource-constrained future calling for more sustainable construction. Alternatively, the system becomes more attractive, in contrast to demolition and new construction projects given that the real estate resources are kept in use and their value retained resulting in increased efficiency. To guarantee resources for future generations, adaptive reuse and thus the reduction of waste, recycling, and efficient use of spaces is essential to ensure the prolonged life of developments. The study examined the role of adaptive reuse to identify critical indicators for sustainable development through adaptive reuse. A systematic review from the Scopus bibliographical database was used to identify the indicators of sustainable development. Subsequently, multi-case studies were used to explore the application of adaptive reuse in line with the sustainable development indicators. The progress made towards adaptive reuse as a tool for sustainable development in construction. Findings revealed that adaptive reuse can be applied to achieve economic, environmental, social, and cultural pillars of sustainable development. The paper recommends that practical actions and tools seem to be the optimal way of making sustainable construction more concrete and understandable for the construction sector, therefore it is of significance to look in the directions of the modeled cities and implements the lessons learned to promote sustainable development.

Keywords
Construction, Adaptive reuse, Systematic review, Sustainability, Sustainable development

1. Introduction

Over the years sustainability has been the core concern of various organisations including the construction industry and the topic has been gaining global spread in literature (Winans et al., 2017), involving also diverse industries and policymakers (Suarez-Eiroa et al., 2019). Building and construction generate close to half of all greenhouse gas emissions thus prompting the subject of sustainable construction as a major driver for adaptation. Researchers and various organisations try to find effective and efficient means of lowering the contribution of cities to climate change and building adaptation appears to offer a practical means of lowering building-associated emissions (Wilkinson & Reed, 2011).

Constructing a new building produces a lot more waste materials than modifying a pre-existing building for a new use, and thus Bullen (2011) suggests that existing building stock should be regarded as a recyclable source and not as a -product because most products become waste eventually after being utilised for consumption. With adaptive reuse, buildings are being environmentally responsible while integrating socio-economic factors as well enhancing the environment that the building is sited (Richardson, 2013).

In line with the United Nation's sustainable development goals (SDG11), Adaptive reuse is a vital tool that is important for guaranteeing resources for future generations, based on the 3 R (reuse, recirculation, recycling), and prolonging the lifecycle of products. Adaptive reuse (AR) in the construction sector is majorly characterised by the need to improve the use of available and existing resources, through the reduction of waste, recycling, and efficient use of spaces which is an important factor in the development of sustainable cities (Strumillo, 2016).

However, the concept of adaptive reuse has somewhat remained elusive in the building and construction industry as evidenced in the prioritisation of new construction over adaptively reusing existing constructions. There is a need to examine the concept of adaptive reuse as a major proponent of sustainability. Studies on adaptive reuse have focused on showing the potential of the adaptive reuse of buildings but not as a direct function of the pillars of sustainable development. For instance, Strumillo (2016) investigated adaptive reuse of Buildings as an important factor of sustainable development but did not relate the case studies based on the sustainable pillar (social, economic, environmental, and cultural).

Langston (2011) investigated the benefits associated with adaptive reuse and explored how to enhance those benefits while Langston et al. (2008) assessed the factors affecting local sustainable development but did not directly examine the case studies as a contributor to sustainable development. Further, Yung & Chan (2012) investigated implementation challenges focusing on carbon emissions in heritage buildings; while Yung et al. (2014) identified community initiatives in adaptive reuse of historic buildings but the relation of the initiative in terms of the socio-cultural, environmental, and economic contribution to the community was not incorporated. Although studies have been undertaken on adaptive reuse, few studies have related it to a wider range of sustainability outcomes. This study, therefore, reviews existing knowledge by identifying the indicator of sustainable development and analyses case studies to establish the critical role of the adaptively reused buildings in contributing to the pillars of sustainable development.

The paper maintains that adaptive reuse should be treasured and applied more practically beyond the theory in the construction industry as this corresponds to the idea of recycling and is a crucial step towards sustainable development. The paper adopts a qualitative and exploratory approach to identify adaptive reuse as a tool for sustainability using the lessons from case study examples to promote the sustainability vision using. Starting from these approaches, the paper identified from the literature the indicators of the four pillars of sustainable development and analysed the contribution of adaptive reuse from selected case studies to sustainable development.

1.1. Pillars of sustainable development in construction: Overview

The term sustainability (SD) is often used to signify projects, schemes, and activities targeted at the conservation of a specific resource. However, it comprises four distinct parts which are: human, social, economic, and environmental, referred to as the four pillars of sustainability (Kolk, 2016; Zhai & Chang, 2019). The principle of the four pillars of sustainability states that for complete sustainability, problems need to be solved and maintained concerning all four pillars of sustainability.

Schaefer and Crane (2005) define "Sustainable development as a development that meets the needs of the current generation without compromising the ability of future generations to meets their own needs". Evers (2018) further relays the notion to the organising principle for providing human development goals and also sustaining the capacity of natural systems to provide the natural resources and ecosystem services upon which the economy and society depend. Considered from this perspective, sustainable development aims at attaining social development, environmental stability, and economic development. The four pillars are briefly described below:

- Economic sustainability: this recognises that as a population increases, human needs such as food, clothing, and shelter also increase, but the available resources in the world cannot meet up with the requirements endlessly (Retchless & Brewer, 2016). Economic sustainability, therefore, requires that decisions be made in the most reasonable and economical possible way while taking into regard the other aspects of sustainability (Zhai & Chang, 2019)
- Social sustainability: this aims at delivering enabling conditions for everyone to have the capacity to realize their needs, ensuring that everyone's needs are met. Whatever impedes this capacity is deemed a barrier, and needs to be addressed for persons, organizations, or communities to be progressive (Kolk, 2016). It also comprises other issues such as human rights, gender justice and impartiality, community involvement, and the rule of law all of which are aimed at promoting harmony and societal stability for sustainable development (Zhai & Chang, 2019).
- Cultural sustainability: encompasses the sense of wellbeing, creativity, diversity, and innovation that should be treated as one of the basic requirements of a healthy society. It refers to a broader definition of culture that is not limited to arts and heritage but encompasses the whole complex of distinctive spiritual, material, intellectual and emotional features that characterize a society or social group (Zhai & Chang, 2019).

- The notion of environmental sustainability is about the natural environment and its ability to remain beneficial and resilient in supporting human life. Environmental sustainability relates to ecosystem integrity and the carrying capacity of the natural environment (Kolk, 2016).

This section has summarised the four pillars of sustainable development as reviewed from literature namely, economic, social, environmental, and cultural sustainability. These four pillars are an essential consideration for sustainable development and therefore construction projects must build on these pillars to deliver sustainability. This paper further identified indicators of adaptive reuse as a tool for sustainable development and reviewed case studies of adaptive reuse to show their contribution to sustainable development in the construction industry. The methodology adopted is as described in section 3.0.

2. Materials and Method

This study employs a systematic literature review. Search on Scopus database was conducted to review relevant articles. Denyer & Tranfield (2009) proposed a five-step process to a systematic literature review. This process involves formulating question(s), locating, and identifying relevant studies, selection, and evaluation of studies, analysis or synthesis, and results reporting. Denyer and Tranfield's (2009) procedure was adopted in this research.
The search question string used was TITLE-ABS-KEY ("adaptive reuse " AND "sustainable development" OR "sustainable construction") AND (LIMIT-TO (DOCTYPE, "ar") OR LIMIT-TO (DOCTYPE, "cp")) AND (LIMIT-TO (EXACT KEYWORD, "Sustainable Development") OR LIMIT-TO (EXACT KEYWORD, "Adaptive Reuse") OR LIMIT-TO (EXACT KEYWORD, "Adaptive Re-Use") OR LIMIT-TO (EXACT KEYWORD, "Sustainability") OR LIMIT-TO (EXACT KEYWORD, "Buildings") OR LIMIT-TO (EXACT KEYWORD, "Circular Economy")) AND (LIMIT-TO (LANGUAGE, "English"))

No date restrictions were imposed on the search as priority was given to the relevance of the materials in terms of their substantial contribution to the ongoing discourse on adaptive reuse and sustainable development, irrespective of the age of the material. Attempts, however, were made to capture as much recent literature as possible to reflect the currency and increasing relevance of the topic. The initial search criteria identified a total of 109 references. However, applying the screening and eligibility processes stated above, 64 articles were identified for full-text retrieval, out of which 26 were identified as meeting the final inclusion criteria, more additional 14 materials were sourced using snowballing as shown in Figure 2.

Three case studies on adaptive reuse were also examined to provide practicality. The selection of the three cases is from countries considered as frontiers in circular economy and adaptive reuse of buildings. As a research approach, case studies offer insights along multiple fronts for exploratory stages of a project (Rowley, 2002). The study considered countries from both developed and developing countries who are frontiers in sustainable development and transition to circularity. The Netherlands is regarded as the World Capital of circular economy and adaptive reuse based on the move to become a circular city by 2050 through her government-wide program and projects, which makes it suitable for a model case, and the case selected was chosen because of its peculiarity in terms of size and the use of sustainable local materials through the construction. Also, France is recognised as one of the frontiers in circular economy and adaptive reuse, and the case study was selected based on the reuse of materials in the project. Egypt was also chosen in Africa based on its listing among the 6 "Grow countries" accelerating transition to a circular economy in the 2020 circularity gap report. Furthermore, Egypt is well known for its historical and heritage buildings which are suitable for adaptive reuse studies.

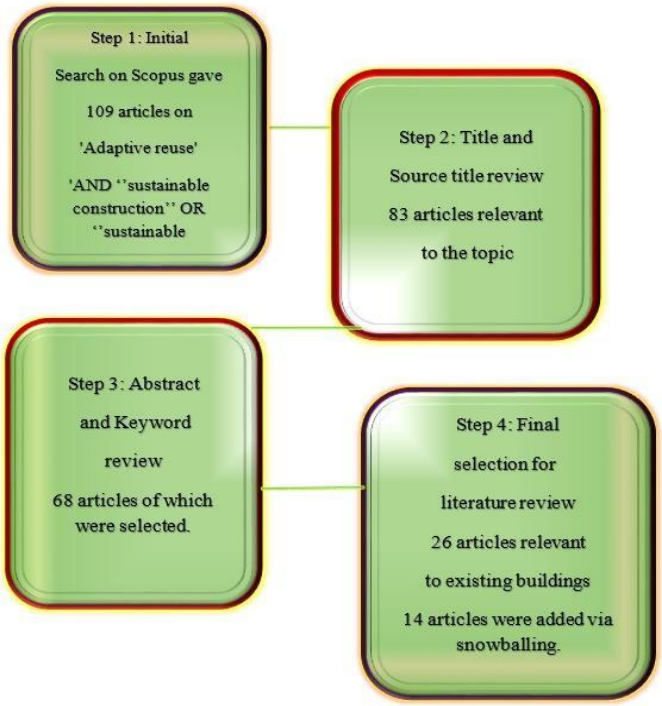

Fig. 2. The systematic review search procedure

3. Results

3.1 Adaptive reuse as a tool for sustainable development

Adaptive Reuse is 'to re-use a building or structure to give it new life through a new function' (Odasa, 2014) and it is described as developing the potential of further use for functionally obsolete buildings. It is fundamentally the recycling of a building (Ijla & Brostrom, 2015). Literature has shown that adaptive reuse can benefit both the local community and the existing built fabric as it possesses socio-economic, ecological/environmental, and cultural characteristics which are considered to constitute the pillars of sustainability, and so adaptive reuse is a potential tool for sustainability.

Furthermore, adaptive reuse can contribute to sustainable development, economically, environmentally, socially, and culturally, establishing values such as giving a sense of place and new income flows (Girard, 2019). Adaptive reuse of buildings has been successfully engaged in several places and thus played a key role in the sustainable development of many communities.

Adaptive reuse can pull new visitor attractions, which have an impact on economic development, this is for the reason that new use may inspire new public and private investors sponsoring the expansion of interrelated activities and the establishment of funding services in the zone in which the reuse project is carried out (Douglas, 2002). Therefore, economic benefits, comparable to all contributions, could exist at different scales (owner, community, urban scale). When adaptive reuse is considered more frequently in building construction, it presents numerous opportunities as a viable solution to achieving sustainable development. The next section presents the three case studies and their adaptive reuse scenarios.

3.2 Indicators of sustainable development in adaptive reuse in building projects

The results on the indicators of adaptive reuse as a tool for sustainable development and case studies of adaptive reuse as well as their contribution to sustainable development in the construction industry are presented in this section. Table 1 describes the indicators of sustainable development, indicators are necessary to assess the case studies against outcomes and performance rather than outputs (Ness & Xing, 2017). The indicators were identified based on the four pillars of sustainability, the indicators for social sustainability are social engagement, community empowerment, quality of life, and Improvement. The indicator for economic sustainability includes economic development and technological invention. Further, the indicators for environmental sustainability are mirrored in environmental control and land preservation, while the indicators for cultural sustainability are reflected in community environmental awareness, education and preservation of cultural heritage, local value enrichment, tourism, and economic development (Bullen & Love, 2011; Tam 2018). The next section presents the three case studies.

Table 1. The indicators of sustainable development in adaptive reuse of building project

Sustainable Pillars	**Elements**	**Descriptors**	**Literature**
Social	Social engagement And community empowerment	• Revenue Growth • Neighborhood/Environmental Quality • liveliness & Hospitable community	Bullen & Love (2011), Yung et al. (2014), Ijla & Broström (2015), Yung, Chan & Xu (2014), Langston et al. (2008), Mitoula et al. (2013)
	Quality of life Improvement	• Increased welfare • Increased vacation or leisure • Robust and resilient city	
Economy	Economic development	• increased investment/investors •Increased market /business opportunities • job opportunities • improved tax • increasing Property Values	Ijla & Broström (2015), Tam, Fung & Sing, (2016), Agaliotou (2015), Wang (2011), Mitoula et al. (2013)
	Technological invention	• Technical Invention Integration • Recovering Local Traditional Construction Methods • Aesthetically Smart Cities	
Environment	Environmental Control and Land preservation	• Climate Change Alleviation • Eco-Building • Energy Efficient building • building life cycle extension Reuse of Buildings, Materials and resources • Reduced landfill and demolition Waste •Decreased GHGs emissions • decreased consumption of resources • increased recycling • Decreased Urban Sprawl	Bullen & Love (2011), Langston et al. (2008), Vardopoulos (2018) Lewin & Goodman, (2013), Mitoula et al. (2013)
Culture	Community environmental awareness education	• Contribution to education, cultural skills, and knowledge • community environmental awareness	Bullen & Love (2011), Tam et al. (2016) Lewin & Goodman (2013), Papalou (2015), Plevoets & Cleempoel (2012), Tsilika (2014)
	Preservation of cultural heritage Local value Enrichment	• Preserve Local Memory and identity •Diversity and vitality • Aesthetic Enhancement	
	Tourism (cultural) Economic development	• Safeguard the words' cultural and natural heritage • • Promoting cultural and tourism	

3.3 Case studies from selected cities

The analysed case studies in Table 2 demonstrated the contribution of all the three case studies to the listed indicators of sustainable development. This has been reflected in the communities through increased revenue growth and technological innovations, promotion of eco-efficient buildings, and sustainable building materials. Increased culture and tourism also increased property values and investment (IJla & Bostrom, 2015).

Table 2: Contribution of the cases to sustainable development

Sustainable pillars	Elements	Descriptive contribution	Case study 1	Case study 2	Case study 3
Social	Social engagement and community empowerment	• Revenue growth	x	x	x
		• Neighbourhood/environmental quality	x	x	x
		• Liveliness & hospitable community	x	x	x
	Quality of life Improvement	• Increased welfare			x
		• Increased vacation or leisure		x	x
		• Robust and resilient city		x	x
Economy	Economic development	• Increased investment/investors	x	x	x
		• Increased market /business opportunities	x	x	x
		• Job opportunities	x	x	x
		• Improved tax		x	x
		• Increasing property values	x	x	x
	Technological invention	• Technical invention integration			
		• Recovering local traditional Construction methods	x	x	x
		• Aesthetically smart cities	x	x	x
			x	x	x
Environmental	Environmental Control	• Climate change alleviation	x	x	x
		• Eco-Building	x	x	x
		• Energy efficient building	x	x	x
		• Building life cycle extension	x	x	x
		• Reduced landfill and demolition waste	x	x	x
		• Decreased GHGs emissions	x	x	x
		• Reuse of building materials	x	x	x
		• Increased recycling	x	x	
	Land preservation	• Decreased urban sprawl	x	x	x
Culture	Community environmental awareness and education	• Contribution to education, cultural skills, and knowledge	x	x	x
		• Community environmental awareness	x	x	x
	Preservation of cultural heritage	• Preserve Local Memory and identity		x	x
		•Diversity and vitality		x	x
	Local value enrichment	• Aesthetic Enhancement	x	x	x
	Tourism (cultural) Economic growth	• Preservation of cultural and natural heritage	x	x	x
		• Promoting culture and tourism		x	x

3.3.1 Case study 1: The Werkspoorkwartier project Netherlands

The city of Utrecht is close to 45 miles west of Arnhem and there lies a large ex-industrial area around its harbor area. During the 20th century, steam trains, railroad parts, and other large-scale fittings were manufactured there, but by the 1970s and '80s, those activities began to diminish and a collection of companies primarily auto repair and renovation workshops occupied the vacant buildings.

The adaptive reuse: By 2012, the municipality determined to convert the Werkspoorkwartier (named after the Werkspoor company, the former Dutch state company that built and maintained the train network) into a center for future-oriented cultural and creative industries. The two largest buildings were selected out to be rehabilitated into highly visible examples of the desired change. Thus, the Werkspoorkathedraal became a venue attracting up to 20,000 was to adapt light manufacturing, such as 3D printing.

The materials used in the project were all recycled and eco-efficient, for example, the use of traditional local materials in the project black and white walls mix with the new wooden structure, creating a lively and comfortable working environment, Photovoltaic elements on the roof and new insulation are further sustainable elements of the project, this also increased business and job opportunities.

3.3.2 Case Study 2: Bayt al-Kritliya, Cairo, Egypt

Bayt al-Kritliya is in Darb al-Asfar, Cairo, Egypt, is regarded as one of the most magnificent residential Ottoman edifices. The building was originally built in 1540 AD and was expanded afterward in 1632 AD. The building mirrors the social patterns of the Ottoman era with divided public and private areas referred to as salamlik and haramlik, respectively. Additionally, it comprises other features such as mashrabiyas and maq'ad. Bayt al-Kritliya is considered as a world heritage that combines both tangible and intangible heritage features. Aga Khan Award for Architecture (2007). The adaptive reuse: The house was contracted for reuse into a museum in 1999 and followed by many phases. The museum was named "The Gayer-Anderson Museum" after his last declared name and is considered as a well-preserved example of the domestic architecture of Cairo during the seventeenth century. The house comprises an array of furniture, carpets, and other collections. The project was directed at protecting the house and its various collections as well as its exceptional setting of having two houses connected. Thus, the building was adaptively converted into a museum. The project involved the construction of new preservation, establishing new display spaces, and landscaping the gardens to produce an open-air area for cultural events and other amenities (Othman & Elsay, 2018).

3.3.3 Case study 3: The Rehafutur Engineer's House (France)

Rehafutur Engineer's house is an ancient mining house in the Northern France UNESCO heritage site and is among the sites incorporated in the EU's project CAPEM (Cycle Assessment Procedure for Eco-impacts of Materials) targeted at evaluating the efficacy of renewable materials for insulation. The major intervention realised in the course of adaptive reuse comprised of enhancing the building thermal insulation.

The adaptive reuse: now transformed into offices, due to its heritage significance, making use of bio-based (e.g., wood fiber, sheep wool), and recycled (e.g., recycled textiles) insulating materials, high standards of energy efficiency were achieved. Furthermore, to preserve the heritage value of the original construction, materials were reused. For example, marble fireplaces were used as adornments in public rooms, and cement tiles were also reused. Rehafutur Engineer's House is an important illustration of the application of circular economy principles (adaptive reuse) in the construction industry for the use of renewable insulation materials, high energy efficiency standards, and recycling of materials (Mangialardo & Micelli, 2018). The study approaches the selected case studies in adaptive reuse of buildings to examine their contributions to the pillars of sustainable development (economic, social, cultural, and environmental) identified as a system of interconnected relationships. It is however necessary to specify that all three cases have been analysed through a desk exploration.

4. Summary and suggestions for the construction industry

Literature review and analysis of the case studies showed the importance of adaptive reuse of buildings to achieving sustainable development. The three case studies showed that the various adaptive reuses contributed to the four pillars of sustainable development reviewed in their respective applications. Re-using existing built materials provides several environmental benefits. These include decreased demolition waste, decreased utilisation of resources as against the demolish-and-rebuild development, and the preservation of the initial building's embodied energy. It alsomaintains the uniqueness and cultural identity of the building, creating further jobs than new construction and providing significant tourism pull and attracting and investment. The research comes to the following recommendations for the construction sector for sustainable development:

- The adaptive reuse of buildings should be used as an essential approach to achieve sustainable construction.
- Leverage on expanding the life cycle of buildings to increase cost-effectiveness.
- Seek to prioritise reuse of existing stock before new construction.
- Embrace technological innovations for building adaptability and sustainable construction.

With the foregoing, through practical and applied adaptive reuse of buildings, the global building and construction sustainability is achievable.

5. Conclusions

Adaptive reuse as a tool for sustainable construction has gained recognition in literature over the years. Nonetheless, practice and application in achieving sustainable development have not measured par with theory. The construction industry has continuously focused on new constructions which is a good development but contradictory to the principles of sustainable development and waste hierarchy. Notwithstanding, the time to act towards sustainable construction is now. This study provides an adapted, systematic literature review cum case study review to provide evidence of adaptive reuse as a tool for sustainable development in the construction industry. Based on the review, despite recent advancements in literature, much more practicality is needed about adaptive reuse in construction projects.

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