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The Adaptive Reuse of Buildings as a Circular Economy Accelerator: A systematic review

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Abstract

Adaptive reuse of buildings plays a key role in achieving circularity in the built environment. Despite the number of studies that focus on the adaptive reuse of built environments on different scales, a limited focus has been given to conceptualizing the adaptive reuse of buildings as a circular economy accelerator. It is important to grasp how adaptive reuse aligns with circular economy in built environment. As the first step, this paper reviews the existing body of knowledge on adaptive reuse buildings as a circular economy accelerator. This study employed the Preferred Reporting Items for Systematic Review and Meta-Analysis (PRISMA) methodology to conduct the Systematic Literature Review (SLR). Scopus and Web of Science databases were utilized to search articles, and 60 peer-reviewed journal articles published between 2013 and 2024 were retrieved for further analysis. Descriptive analysis of selected studies revealed that the majority of the publications were from Italy (25%). This study classified three key research themes based on extant literature: (1) Policy and planning for adaptive reuse and circularity, (2) Sustainability attributes for circularity, and (3) multi-criteria decision and evaluation tools for circularity. This study provides insight into how circularity can be integrated into adaptive reuse building projects. As an emerging field, findings herein are significant for academics and industry practitioners to broaden the knowledge of current status, research gaps and emerging trends on the adaptive reuse of buildings as a circular economy accelerator.

Keywords
Adaptability, Adaptive Reuse, Buildings, Built Environment, Construction, Circular Economy.

1. Introduction
The growing emphasis on environmental crises and economic impact due to the excessive use of natural resources has provoked the topic of circular economy. In contrast to a linear economic model, which is characterized by extracting virgin materials, making them used and disposing at the end of the lifecycle of the product (Hossain et al., 2020), the circular economy helps to slow and close the resource loops by expanding the product life and minimizing the waste through reusing and recycling the material (Moraga et al., 2019). Recently, achieving a circular economy has become one of the prime focuses of many industries (Gamage et al., 2024). Nevertheless, the literature discovers that there is

a lack of consensus regarding a definition of circular economy, and it is difficult to set boundaries, as there are many broad definitions, abstract conceptualizations and perceptions (Hossain et al., 2020). According to the Ellen MacArthur Foundation (EMF), the circular economy can be defined as "*an industrial system that is restorative or regenerative by intention and design*" (Hossain et al., 2020).

The building sector is a major consumer of natural resources and a major contributor to greenhouse gas (GHG) emissions, hence the environmental crisis. The scarcity of primary resources, wastage and carbon footprint challenge builders and developers to adopt circular economy principles towards designing and managing the built environment (Illankoon & Vithanage, 2023). Various pathways and strategies are being implemented, including recycling building materials, passive and active design strategies through low-carbon retrofitting, waste reduction, design for adaptability and disassembly (De Silva et al., 2023). While new construction developments can significantly achieve resource efficiency through new designs and technologies, the existing building stock faces a number of issues in achieving circularity. Adaptive reuse of buildings is a significant initiative in favor of the application of circular economy in the existing building stock. Adaptive reuse of heritage buildings has been in discussion for many years or rather decades. With COVID-19 pandemic, followed by hybrid working arrangements, adaptive reuse of vacant offices gained light and became a centre of attention. Though there are many definitions on "adaptive reuse", Singh et al. (2022) defined it as "a building's ability to successfully fit the shifting demands of its setting, therefore maximizing value through time". As a core principle of the circular economy, adaptability offers a design of circular building to expand its lifespan through flexible and efficient use of resources (Marika et al., 2021, Ollár, 2024). Circular economy principles offer many advantages for optimal adaptive reuse projects (Sanchez et al., 2019b). However, the alignment of adaptive reuse and circular economy is still quite a new and emerging topic in the field (Hamida et al., 2024), and many policies do not identify the synergies between the two concepts to maximize the benefits (Hamida et al., 2023).

The first step in realizing the circular economy through the adaptive reuse of buildings is to grasp the current state of knowledge. A few studies have conducted literature reviews on the area of adaptive reuse buildings from the circular economic perspective. For instance, Hamida et al. (2022) conducted a review to analyze the definitions and determinants of the concept of circularity and adaptability to reconceptualize circular building adaptability. Foster & Kreinin (2020) reviewed the literature to identify the environmental impact indicators of adaptive reuse of cultural heritage buildings from a circular economy perspective. However, no review has evaluated worldwide research on the adaptive reuse of buildings from the circular economy perspective. Therefore, to address this knowledge gap, this research aims to conduct a systematic literature review to explore the current status of research on adaptive reuse buildings as a circular economy accelerator.

1.1 Objectives

In order to achieve the aim of this study, the primary objective is to provide a comprehensive overview of the current status of the field by analyzing countries, published years, publishing journals and co-occurrence network of keywords. The findings can provide extensive insight into the status quo, main research themes and guidance for adaptive reuse practices geared towards circular economy transition.

2. Adaptive Reuse of Buildings

Various challenges, including the depletion and scarcity of natural resources and virgin material for new construction, heritage and old building stock, and the housing crisis have compelled the need to reuse buildings for new purposes. Adaptive reuse of buildings can be identified as a process of changing an existing building to accommodate a different purpose from those originally intended (Mohamed et al., 2017). This process is different from the other building modifications, such as refurbishment, renovation and restoration, as they intend to extend the lifetime of the building for the same use (van Laar et al., 2024a). The concept of building reuse has been a notable area for years to address the issue of building obsolescence (Askar et al., 2021). However, there has been growing attention from governing bodies towards creating relevant policies, standards and protocols for standardizing this process.

Adaptive reuse of buildings has many benefits, including conserving resources and energy, reducing carbon emissions, preserving cultural heritage, and saving time and money compared to new construction (Owojori et al., 2021). This also has the potential to avoid premature demolition, extend the useful life of the building and play a decisive role in climate protection (Askar et al., 2021). Adaptive reuse building projects are mostly perceived as intrinsic to the circular economy and can greatly speed up the transition of the built environment to circularity (Hamida et al., 2024). A growing trend of adaptive reuse research has been noticed recently towards establishing the link between adaptive

reuse building and circular economy (Scialpi & Declercq, 2023, van Laar et al., 2024b, Marika et al., 2021). Both concepts, the circularity and adaptability in buildings, aim to preserve the prolonged and dynamic use of buildings (Ollár, 2024). As such, this review entails bringing this knowledge together to identify the current status of research in adaptive reuse buildings in transitioning to the circular economy of the built environment.

3. Methodology

The research methodology follows the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) (Moher et al., 2010). Accordingly, articles were retrieved from Scopus and Web of Science (WoS) databases as they contain a comprehensive collection of peer-reviewed journals in the field of study. An advanced search was conducted using Google Scholar to find any missing peer-reviewed journals. However, journals published in a non-English language, books, reports, grey literature and conference papers were excluded from the review. Accordingly, peer-reviewed journal articles published between 2013 and 2024 that discussed adaptive reuse in building projects as a driver for the circular economy were selected for the review. Keywords for searches were developed concerning the main domain of the research: (1) "adaptive reuse" and (2) "circular economy". A range of keywords that cover the main domains were used employing different combinations such as "Adaptive reuse" OR "Building reuse" OR "Heritage reuse" OR "building adapt*" OR "adaptable building" OR "adaptive building" OR "adaptability of buildings" OR "design for adaptability" OR "reuse of existing structures" AND "circular economy" OR "circularity" OR "circular".

The initial search of databases resulted in 306 total articles (Scopus = 176, WoS = 130). The documents were scanned to identify any duplications, and this reduced the total number to 218 articles. Thereafter, 163 articles were removed through three screening tests (title, abstract and full-text screening). These articles were removed because they were not related to adaptive reuse in buildings. Finally, 5 articles were added to the initial list through backward and forward screening. Sixty articles were carried forward for the analysis. Figure 1 presents the article retrieving and screening process for SLR in accordance with the PRISMA flowchart.

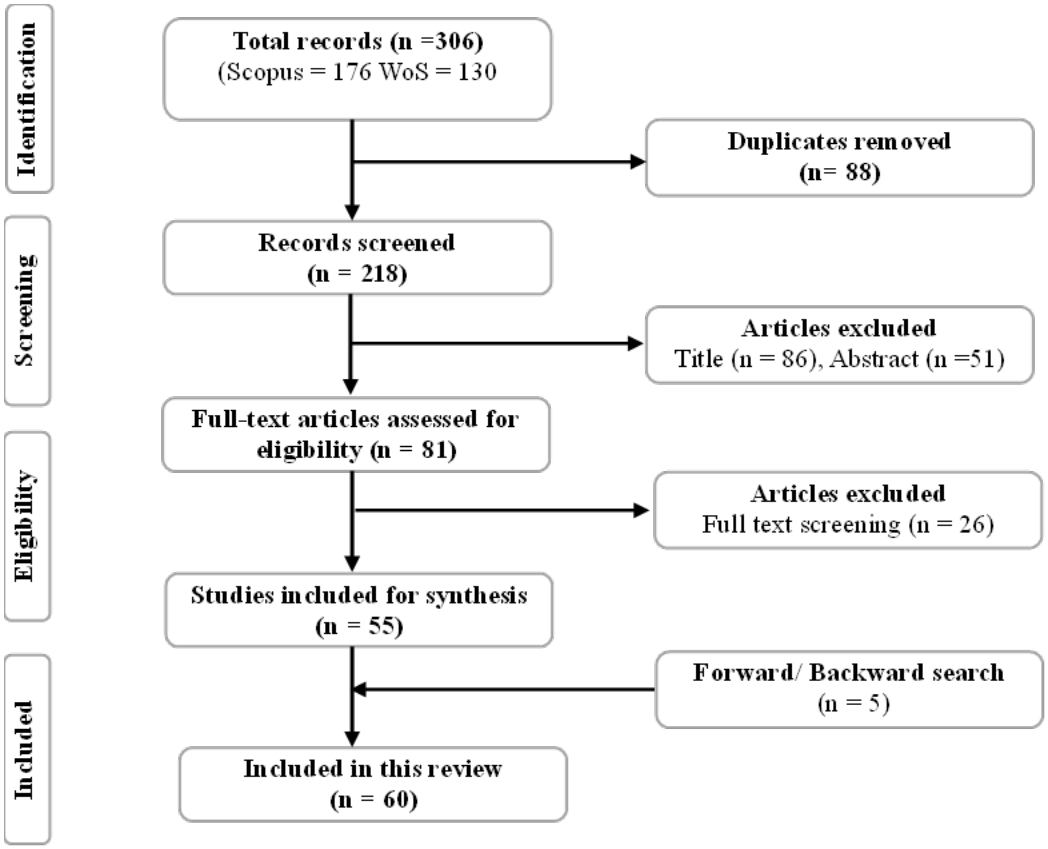

Figure 1. The screening process according to PRISMA

4. Results and Discussion

This section discusses the results of the systematic literature review. First, it provides insight into the summary of the selected articles. Second, it analyses the key research themes related to the adaptive reuse building as a circular economy accelerator based on the keyword co-occurrence.

4.1 Descriptive analysis of selected articles

The distribution of the selected articles was analyzed based on publishing time, study location and publishing journal. Figure 2 illustrates the publishing time frame of the circular economy studies in adaptive reuse building projects. Although peer-reviewed journals from 2013 to 2024 were included in the article screening process, the selected articles ranged from 2018 to 2024. The number of articles on the topic increased significantly after 2019, peaking in 2021. Changes to the working and social norms post COVID-19 supported adaptive reuse in buildings. For example, moving to remote and online work modes during and after COVID-19 left office spaces vacant which can be converted into residential buildings as a solution to the housing crisis (Kyrö et al., 2024). This can be one of the reasons for more focus on adaptive reuse and circularity during 2021.

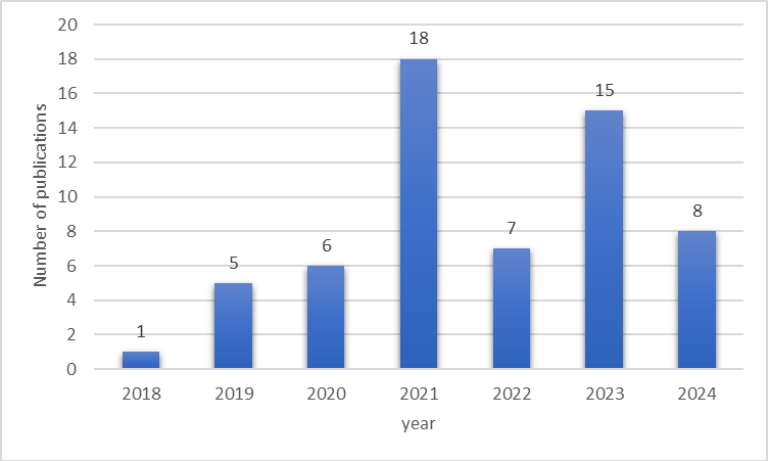

Figure 2. Publishing year

According to the analysis of published locations (Figure 3), the majority of studies were conducted in Italy, with 15 publications. This is followed by Canada and the Netherlands, which have five publications and the USA and UK, which have four publications. It is apparent that most of the studies were conducted in European countries, and seven studies focus on Europe as a whole. This can be due to the old and heritage building stock in Europe. Furthermore, there are various programs targeting sustainable built environments, such as the European Year of Cultural Heritage 2018 (EYCH) and associations, such as the European Union, promote the importance of a circular economy and responsible and cyclical use of resources (Moraga et al., 2019, Owojori et al., 2021). The European nations received quite a good amount of financial support for adaptive heritage reuse projects, such as the EU-social fund, which can also be a reason for the growing amount of research publications (Owojori et al., 2021). However, there is a recent development of adaptive reuse projects in non-European countries such as Australia due to the legislative requirements for preserving heritage buildings and as a solution for the housing crisis(Shehata et al., 2022, City of Adelaide, 2024).

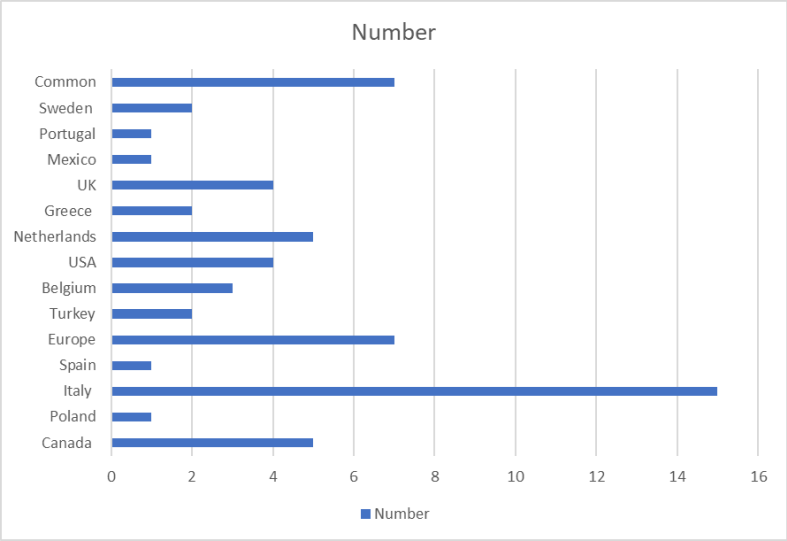

Figure 3. Analysis of the countries of origin of selected articles.

Figure 4 illustrates the journals in which the relevant articles have been published. Figure 4 presents the journals with more than two articles, and articles published in English were selected as per the selection criteria. "Sustainability" was the leading journal with the highest number of articles on circular economy and adaptive reuse in buildings.

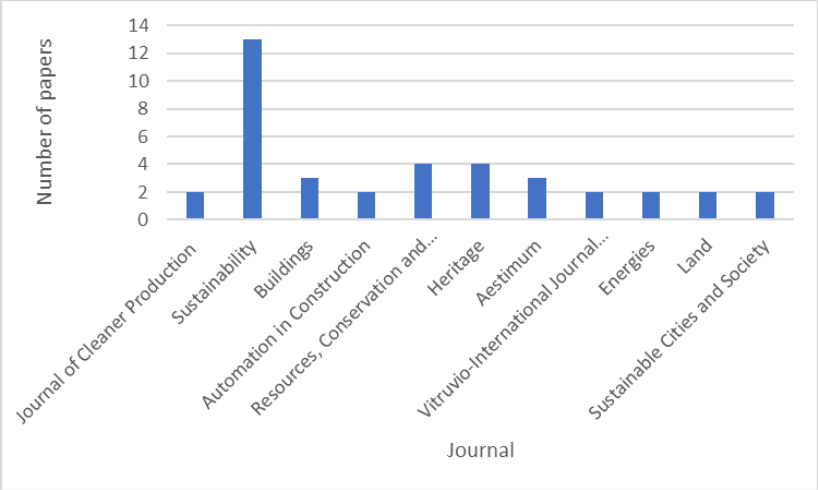

Figure 4. Journal paper distribution of selected articles

4.2 Research themes based on keywords co-occurrence

A keyword co-occurrence was carried out to determine the key research themes in the adaptive reuse of buildings from the circular economy perspective. VOSviewer software was employed to obtain the co-occurrence network through the keywords of each article. A minimum number of occurrences of keywords was set to two to obtain a broad view of the network. The keywords with similar meanings were merged to ensure the clarity of the network. For example, keywords such as "multi-criteria decision analysis" and "multi-criteria analysis". Further, some of the insignificant keywords, such as "management" and "Campus", were removed from the analysis. Of the 210 keywords, 43 keywords meet the threshold, and three main clusters were identified from the network. Figure 5 presents the keyword clusters.

The red cluster (cluster 1) consisted of 17 items, including but not limited to adaptability, barriers, building design, circularity, design for adaptability, construction, disassembly planning, enablers and policy. The green cluster (cluster

2) centred around the themes and contained 16 terms, including adaptable buildings, adaptive reuse, circular economy, circular construction, environmental impact, life cycle assessment, social sustainability and financial sustainability. The blue cluster (cluster 3) comprises 10 items and is arranged around key themes, including but not limited to the decision-making process, circular city, evaluation model, heritage, multi-criteria analysis and multidimensional indicators.

Keyword analysis of selected articles is crucial to uncover the development of key research areas in the field of analysis (Owojori et al., 2021). Drawing upon the results of cluster analysis, three research themes can be identified as follows: Cluster (1) Policy and planning for adaptive reuse and circularity; Cluster (2) Sustainability attributes for circularity, and Cluster (3) Multi-criteria decision and evaluation tools for circularity.

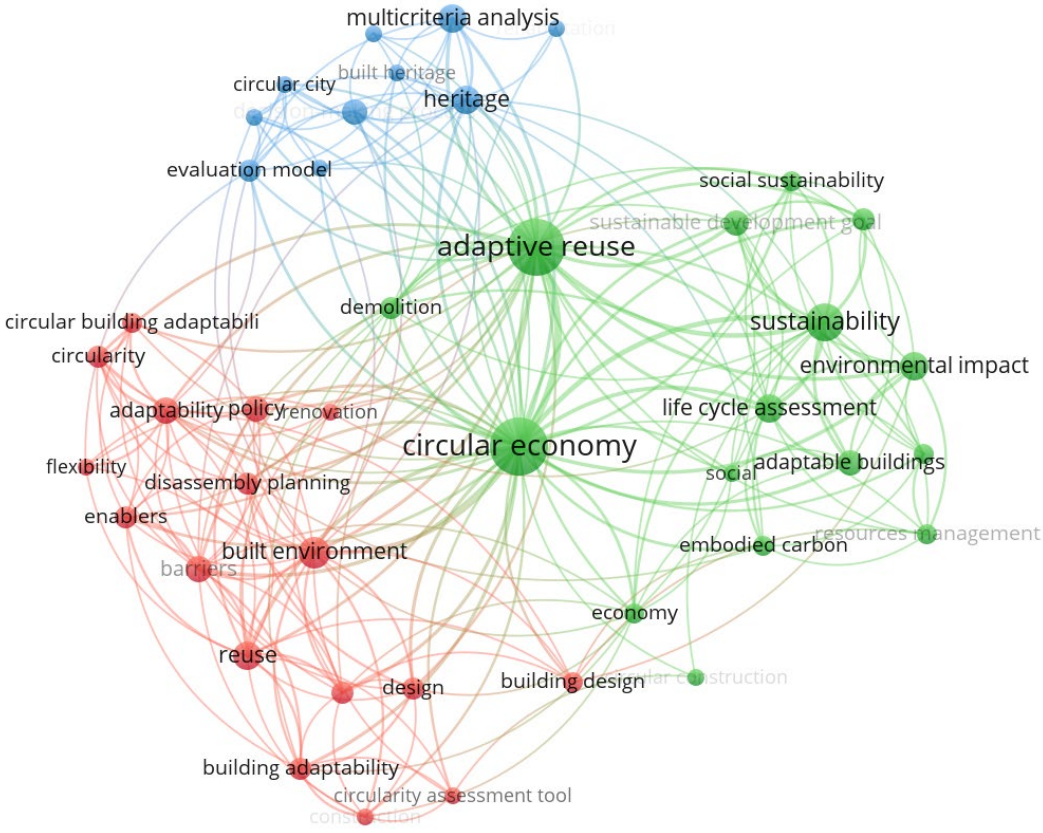

Figure 5. Keyword co-occurrence network

Cluster (1): Policy and planning for adaptive reuse and circularity

The first cluster highlights the importance of various policies, protocols and planning for adaptive reuse in accelerating the circular economy. Adaptive reuse of buildings has received important attention from governing authorities, and various policies and protocols on adaptive reuse have emerged in recent years to facilitate this process. However, the implementation of a circularity framework into adaptive reuse building is still quite new (Kaya et al., 2021). Kaya et al. (2021) have investigated enablers and policy instruments related to the adaptive reuse of buildings in the transformation towards circularity. Authors have revealed that these policies need substantial attention to incorporate circular economy action plans and highlight the need for communication and educational tools to promote them. This cluster also comprises studies that investigate the enablers, barriers and strategies for circular building adaptability (Hamida et al., 2023, Pintossi et al., 2023, Scialpi & Declercq, 2023). Among them, Hamida et al. (2024) highlight the most promising strategies for circular building adaptability as "provision of shareable facilities", "utilization of flexible and integrated installations", "utilization of renewable energy technologies", "application of material passports", "utilization of dismountable building components", and "alignment of the building design with the real

estate strategy". The design for Adaptability (DfA) principle in building reuse is also considered a key enabler for circularity and grabs substantial attention in research (Askar et al., 2022). In addition, project planning plays a critical role in achieving successful outcomes of adaptive reuse building projects, as well as creating closed-loop cycle building construction (Sanchez et al., 2019b). A few studies in this cluster focus on deconstruction programming and disassembly sequence planning for adaptive reuse projects to foster circular economy principles in the planning process of adaptive reuse building process (Sanchez et al., 2019b, Sanchez & Haas, 2018, Sanchez et al., 2020). This highlights the need for more research on deconstruction techniques for adaptive reuse projects to exploit more benefits from adaptive reuse projects to accelerate the circular economy.

Cluster (2) Sustainability attributes for Circularity

The second cluster is associated with environmental, social and economic attributes towards sustainability. Research on circular economy is increasingly paying attention to achieving sustainability. In particular, a large number of studies have focused on the environmental impact of circular building adaptability. Many countries are committed to achieving net zero carbon in the built environment, which can be greatly enabled through circular adaptive buildings. In the extant literature, Sanchez et al. (2019a) developed a method to analyze the net environmental impact of an adaptive reuse project. Similarly, Foster (2020) worked on a circular economy framework for heritage adaptive reuse building to reduce the environmental impact. Life Cycle Assessment (LCA) is also a popular approach among studies to evaluate the environmental impact of adaptive reuse buildings towards a circular economy (Gravagnuolo et al., 2020, Guidetti & Ferrara, 2023). Ferriss (2021) has evaluated total carbon savings from reuse building projects and discussed designing adaptability for optimizing carbon payback of reuse projects. Additionally, it is essential to develop a concrete assessment parameter to evaluate the degree of circularity in terms of environmental impact (Owojori et al., 2021). The current research has also attempted to develop sustainable financial models for adaptive reuse projects to enhance circular economy transitionary ambitions (Pickerill, 2021, Dell'Anna, 2022). However, circular economy research has paid less attention to social dimensions, and only a few studies have focused on the social sustainability of adaptive reuse building projects from a circular economy perspective. For instance, Lundgren (2023) adapted a social life cycle assessment to establish the social impact of adaptive reuse from a circular economy perspective. Research also evaluates the UN sustainable development goals that can be achieved through adaptive reuse projects (Lerario, 2022).

Cluster (3) Multi-criteria decision and evaluation tools for Circularity.

The third cluster is structured around the multi-criteria decision tools, multidimensional indicators and evaluation models for the adaptive reuse of building projects to accelerate the circular economy. Studies under this cluster mainly focus on integrating circularity principles in adaptive reuse projects, evaluating strategies for circular economy and focus on improving decision-making process of adaptive reuse of building projects from the perspective of circularity. For instance, Ikiz Kaya et al. (2021) developed a framework for examining the functional, financial, operational and circularity performance of the adaptive reuse of heritage buildings. van Laar et al. (2024b) highlighted the importance of unfolding specific criteria for decision-making throughout the different life cycle phases of adaptive reuse projects. The evaluation tools introduced in these studies support the participatory decision-making process to maximize the tangible and intangible values of building components, supply chains and assets from a circular economy perspective (Gravagnuolo et al., 2024, Dabbene et al., 2024, Munaro & Tavares, 2023, Della Spina et al., 2023). The circular business model is another approach suggested to achieve circularity in adaptive reuse projects (Lundgren et al., 2024). These tools and frameworks mostly provide guidance for the users on how to foster circular building adaptability in adaptive reuse buildings (Hamida et al., 2024).

Based on the findings, the involvement of adaptive reuse buildings as a circular economy accelerator has been taken into discussion since 2018. It is also evident that adaptive reuse projects in circular economy literature have concentrated on identifying policy, strategies, enablers and barriers for circularity, project planning incorporating circularity, achieving environmental, social and economic sustainability, developing multi-criteria decision-making tools and evaluation tools for achieving circularity in adaptive reuse buildings. This research also clarifies what constitutes an adaptive reuse building in the circular economy perspective to inform different pathways as well as standards and policies for circular building adaptability. It highlights the importance of broadening the current conceptualization of adaptive reuse within the standards and policies by integrating the circular economy principles. This signifies the need for further research to broaden the knowledge and understanding of the adaptive reuse of buildings as a circular economy accelerator.

5. Conclusion

Adaptive reuse of buildings has been identified as a promising approach for promoting a circular economy in the built environment. This study has explored the emergence of literature on the adaptive reuse of buildings as a circular economy accelerator. PRISMA protocol was employed for article selection, and 60 peer-reviewed journal articles spanning from 2013 to 2024 were selected for the analysis. Descriptive and bibliometric analysis of selected articles discover the trends and key themes in extant literature. Globally, adaptive reuse is a growing concept in the built environment. However, it has been revealed that most of the research was carried out in Europe, which opens up the debate about the need for more research on adaptive reuse building projects to accelerate the circular economy in other regions of the world. The keyword co-occurrence network revealed three clusters, which denote key research themes in the adaptive reuse of buildings research from a circular economy perspective. These clusters are Cluster (1) Policy and Planning for Adaptive Reuse and Circularity, Cluster (2) Sustainability Attributes for Circularity, and Cluster (3) Multi-criteria Decision and Evaluation Tool for Circularity.

This research contributes to the body of knowledge by providing a comprehensive overview of the current status of the research in the adaptive reuse of buildings from a circular economy perspective and provides valuable insight into adaptive reuse practices towards circular economy transition. The key research themes revealed in this study provide theoretical implications and future research directions. Accordingly, there are opportunities to develop future research on (1) developing policies and protocols to overcome barriers identified in these studies and for efficient transformation of adaptive reuse projects towards circularity, (2) integrating modern technologies and tools for achieving optimized circularity performance, (3) applying project planning approaches aside from disassembly sequence planning, (4) developing advanced approaches to verify the environmental and economic impact (5) simulating a regenerative capacity in order to achieve social sustainability and (6) establishing macro-level circularity indicators for adaptive reuse projects based on different geographical context. These observations can guide scholars, practitioners, and policymakers in understanding various aspects of the circular economy and promote adaptive reuse building projects as circular economy accelerators. This research has inherent limitations related to systematic literature reviews, such as being limited to two databases, Scopus and WOS. Since this is a growing research topic, future review studies are recommended to capture the evolving knowledge.

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Chethana Illankoon is a Scientia Lecturer at the School of Built Environment. Chethana focuses on life-cycle cost and carbon emission optimisation for green buildings circularity in buildings and embodied carbon in construction. Prior joining UNSW she worked at the University of Newcastle. She worked as a researcher at the University of Hong Kong engaging in many research projects. She has published a book, many scholarly articles in high impact refereed journals, refereed book chapters and refereed conference papers in leading conferences. Chethana has also received two awards from major conferences in Australia and New Zealand.