Review

Current Status and Emerging Trends on the Adaptive Reuse of Buildings: A Bibliometric Analysis

Oluwatobi Mary Owojori [1,*], Chioma Sylvia Okoro [1] and Nicholas Chileshe [2]

1   Department of Finance and Investment Management, University of Johannesburg, P.O. Box 524, Johannesburg 2006, South Africa; chiomao@uj.ac.za
2   UniSA STEM, Scarce Resources and Circular Economy (ScaRCE), University of South Australia, Adelaide 5001, Australia; Nicholas.Chileshe@unisa.edu.au
*   Correspondence: tobiowojori@gmail.com

Abstract: The emerging demand for sustainable development and the need for efficient use of resources across the built environment have stirred research efforts globally. The construction sector is often regarded as one of the major world consumers of resources, so many international establishments are trying to create a sustainable environment through adaptive reuse of existing building stocks, a concept which has been receiving momentous recognition by reason of its richly diversified applicability for circular economy. Thus, profound knowledge of the topic and research trends is requisite to promote scholarship. For this analysis, the global research developments in adaptive reuse are assessed according to published documents, co-authorship, geographical distribution and keyword- co-occurrences. From the Scopus directory, 227 journal articles published from 2006 to 2021 were retrieved. Results showed that from 2006, published documents rose by 221 articles. About 29% of the publications were from Italy and the United Kingdom. Among the articles, 110 were from the subject area of environmental science (48.5%), while the subject area of engineering represents 104 publications (45.8%). Recent progress in adaptive reuse in building and construction includes, but not limited to: (i) component and materials reuse and technology, (ii) life cycle assessment, (iii) economic assessment and multi-criteria decision making and (iv) regulatory policies and stakeholders' analysis. The findings are important to furnish all relevant personnel in the academic and industries with a broad perception of the status and potential emerging trends on the adaptive reuse of buildings.

Keywords: adaptive reuse; bibliometrics; building reuse; sustainable development; heritage reuse; re-purposing

1. Introduction

From the perspective of a more sustainable development, the building and construction industry is facing significant challenges regarding the adaptability of buildings. These challenges include reduction in cost of construction management, cutting down of new constructions, efficient use of resources, socio-environmental impact [1]. These challenges related to the sustainable use of buildings, call for discourse in response to the United Nations SDGs, SDG 11 (Sustainable Cities and Communities) on the built environment and communities recognized as advantaged places for revolution and technical development, to initiate probable measures and resolutions in the direction of greater inclusiveness, safety, resilience and sustainability [2]. Further, the achievement of the SDG 11 targets can be facilitated through the sustainability protocols [3].

Change is inevitable throughout the lifecycle of a building, in terms of the socio-economic condition, physical environment and the requirements and prospects of occupants [4]. Socio-spatial segmentation and radical decline in value are characteristic reasons prompting the vulnerabilities of existing buildings alongside the forfeiture of functionalities

and abandonment [5]. The ability of structures to be subjectable to significant transformation which can imply flexibility or allowing slight shifts in space design through conversion, or by permitting alterations of use within the building for an extension.

Ultimately, adaptive reuse offers an improved resolution to a myriad of existing concerns and challenges in the built environment against demolition and new structures. When a structure cannot survive with contemporary style and requirements while lacking efficiency in technical and economical facets, such structure signifies a "maladaptive building" [6], bearing in mind that the built environments represent significant evidence of the culture, economy and social layering of settlements [7]. Thus, the responsibility to reuse is receiving an important role within theoretical debates [8], which is more necessitated by the current environmental crisis and emerging societal and economic challenges.

The benefits of adaptive use of buildings transcend the benefits attached to climate mitigation and efficient resource utilization but include constructive contribution to the social and economic plan motivated by heritage and communal benefits, increasing the commercial viability of buildings and decreasing their cost of maintenance [9]. These benefits also extend to heritage buildings such as serving well the needs of the local community and leads to sustainable economic, social and environmental development [10]; plays a pivotal role in regenerating the built environment [11,12]; and a means to achieving sustainability [13].

Researchers have worked on the adaptive reuse of buildings in many aspects. A study [14] proposed physical, economical, functional, technological, social and legal obsolescence criteria to understand the issue; [15] explored the Adaptive reuse of office buildings into housing by investigating the opportunities and risks; [16] addressed the need to re-use the spaces based on the lack of ability of urban space to meet daily needs, economic factors and environmental factors in particular. On their part, [17] explored the potential of the adaptive re-use by examining the differences between urban and non-urban projects; [18] explored and assessed the adaptive reuse practices through user experiences; [19] examined the implementation challenges to the adaptive reuse of heritage buildings; while [20] reviewed the literature to collect pertinent information in a single place and to critically examine whether adaptive reuse incorporates the three Es of sustainability.

This study conducts further research by providing an integrated bibliometric analysis of published research on adaptive reuse of buildings through a bibliometric analysis adopting multiple methods such as evolution analysis, citation network and co-occurrence network of keywords. The contributions of this study differ from previous studies as example of the work of [21], which presented the bibliometric analysis of multi-criteria decision-making methods in heritage buildings as it represents an extensive range of systematically selected literature to reflect the current research status on the subject. The findings from the bibliometrics can potentially provide researchers and industry practitioners with a comprehensive insight into intellectual status-quo, and potential research areas on adaptive reuse in the construction industry and built environment.

The remaining sections of the paper are structured as follows: An overview of adaptive reuse and the contribution of this bibliometric research are presented in the succeeding sub-sections. Section 2 presents the materials and methods adopted including the parameters employed choice of database and selection of document types. The results of the bibliometric analysis in line with the objectives of the paper are presented in Section 3. The study presents a comprehensive evaluation and discussion of the results of each research step with implications in Section 4. This section further recognized and highlighted the gaps in research and the limitation of the study by suggesting further potential research areas. Finally, in Section 5, the paper presents a concluding part to provide a summary of the previous sections and how the research questions of the study have been answered.

1.1. Brief Overview—Adaptive Reuse of Buildings

Unanticipated forces and emerging circumstances have compelled change in construction for ages and the reuse of different types of buildings for new purposes has been an

age-long response to these unanticipated changes. Since history, in many societies, old buildings are rarely pulled down but instead; they are adapted to meet the needs of a succession of users through expansion, conversion, restructuring and other processes of physical change [22].

Around the world, the conservation and re-use of buildings are regarded as vital to the preservation of legacy resources and environmental sustainability. Through building adaptation, existing public infrastructures are efficiently reused, cost reduced, energy and resources conserved and time saved, compared to the construction of new buildings. Furthermore, well-managed and preserved buildings could lower the number of vacant buildings; create workable business localities and employment, as well as attracting visitors [23]. A number of applications for adaptive reuse of buildings have also emerged in both developed and developing countries. These have ranged from preserving global architectural heritage [24]; cultural heritage [25–27]; and transitioning to the circular economy [28,29].

The adaptive reuse of buildings for new purposes is categorized into two uses, the active and the passive use. Active use represents a new activity that produces enough income to encompass the cost of restoration and maintenance in the adaptive reuse program, such as hospitality (eateries, resorts) and commercial (stores and other retails) business. The passive use does not produce significant revenue to cover the cost of restoration as well as the maintenance, however, it offers social benefits to the society through libraries, museums, welfare housing, amongst others. [30].

A successful adaptive reuse building takes into consideration the building's heritage significance through the inclusion of a contemporary development that guarantees long-term value. Many organizations are coming to the awareness that building adaptation signifies a key part of a renewal system [31]. However, a lot of freeholders, developers and construction professionals perceive the adaptability and reuse of heritage buildings as an unattractive decision based on various challenges such as restrictive policies, planning and zoning regulations.

The research questions for the study were formulated using the neglect gap-spotting mode defined in [32]. Such an approach has been used previously by [33] in off-site construction-related research. Our study builds on that and is supported by the approach undertaken by [34] in generating research questions in educational artificial intelligence research development. Our emphasis however is on adaptive reuse of buildings, and the following research questions emerge:

- What is the current state of adaptive reuse of building publication outputs globally?
- What are the cooperation trends among countries over the last 15 years?
- What constitutes as recent progress of adaptive reuse of buildings research?
- How has adaptive reuse of buildings research evolved from 2006 to 2021?

Nowadays, many scientific papers are committed to studying the practicability of adaptive reuse of vacant, obsolete and underused buildings as a stratagem for preserving both the legacy of the urban fabric and finding solutions to their implementation challenges, through the transformation and adaptation to new uses as per their architecture style and construction properties. It is imperative to provide a comprehensive review of building reuse and adaptability by assessing research activity on the subject and identifying the global research on this field, the trending themes discussed by researchers and knowledge gaps in the field evidence from the literature.

1.2. Contribution of the Research

This study contributes to the ongoing discourse and demand for sustainable development in the built environment by focusing on the efficient and sustainable use of resources. This is in line with sustainable development goals on sustainable cities and communities (SDG 11). The study has practical implications for the adaptability of existing building stocks (through reuse) by providing the state of research and development in this field over the past 15 years. This evolutional analysis is highly resourceful and contributes to

empirical knowledge by conceptualizing the emerging areas of research and identifying the research gap in the field. It contributes to the education and awareness of professionals in the built environment on the status quo on building reuse and further research opportunities. It further contributes to knowledge and societal needs by bringing into light the evolutionary needs of our cities to adaptively reuse the underused and unused spaces as forced by the pandemic and environmental transitions. This prompts a review of strategies and support needed from the policymakers for more practical-based actions and methods.

2. Methods

Analysis by bibliometrics is widely employed in quantitatively analyzing of academic works to illustrate the hotspots, developments and contributions of researchers, journals and globally/territories [35]. Bibliometrics is a statistical analysis tool of publication that provides quantitative awareness into academic literature [36]. The bibliometric analysis technique has also been used to study areas such as wastewater treatment costs [37]; sustainable and responsible tourism (SRT) [38], and Reverse logistics with a focus on collection systems [39]. Co-word analysis, devised in the late 1970s [40] as an essential bibliometric technique, can detect the most important themes, explore hot-spots and identify knowledge gaps in research. It has also been used in sustainable supply chain management (SSCM) related research [41]. Therefore, bibliometrics can give substantial insight by tracking and examining the evolution and pattern of academic reports [42] and can be used to accurately analyze a wider depth of information within a period of time.

2.1. Publication Search and Indexing Strategy

The Scopus database is reputably known for its depth and extensive exposure and hence the selected choice of database for the study [43]. It is regarded as an eminent research database and considered as a fast-growing repository based on its efficiency in offering researchers knowledge on the very renowned academic publications in any scientific domain [44]. A search of "keywords" was carried out to identify all related publications from the Scopus database from the period of 2006 to 2021. The following keywords—"Adaptive reuse" OR "Building reuse" OR "Heritage reuse" OR "Repurposing were used for the search. The literature selection focused on published works related to the specific research string (keywords). The search for relevant publications was initialized with no period boundaries. However, after entering the search key words and applying the inclusion criteria to English language only, the results of the search produced publications from 2006 and thus influenced the period of search to start from 2006 to 2021. The search produced a result of 1776 documents published within this period. Further screening of the title, abstract and keywords was conducted from all the publications to choose the studies relevant to this study and objectives. After the screening, a total of 227 publications met the criteria, which included 148 journal articles (65.1%) and 62 conference papers (27.3%).

2.2. Selection of Tools for Analysis

Several tools for visualization such as VOSviewer, Cite-Space, Gephi, Hite-Space and Bib-Excel exist for data visualization [45]. However, to analyze statistical data retrieved from the data source for this study, the VOSviewer software was utilized. VOSviewer is an application utilized for the technical construction and imaging of pictorial and bibliometric charts which has gained popularity in the review of construction literature and is very much adopted in bibliometrics study due to its accessibility and user-friendly interface [46]. The application offers the functionality necessary for displaying significant bibliometric systems in an understandable way [47]. In comparison to several other similar software, the VOSviewer is easier to use, readily accessible and offers distinct attributes such as network plotting and normalization [47].

2.3. The Bibliometric Maps Citation

References of authors and associated keywords of 227 publications was exported to VOSviewer for the visualization and bibliometric mapping. Maps comprise items created with the VOSviewer. The items could be a link between any pair of items connection or affiliation connecting two items. Each connection has a strength that signifies a positive value of numbers. The greater the value, then the greater the level of relationship [48]. The minimum number of keyword occurrences analysis is five in VOSviewer which is as utilized for the study. The study selected the overlay mode of visualization in illustrating the keywords and the count of occurrences. Figure 1 below shows the research framework detailing the bibliometric procedure employed for the study.
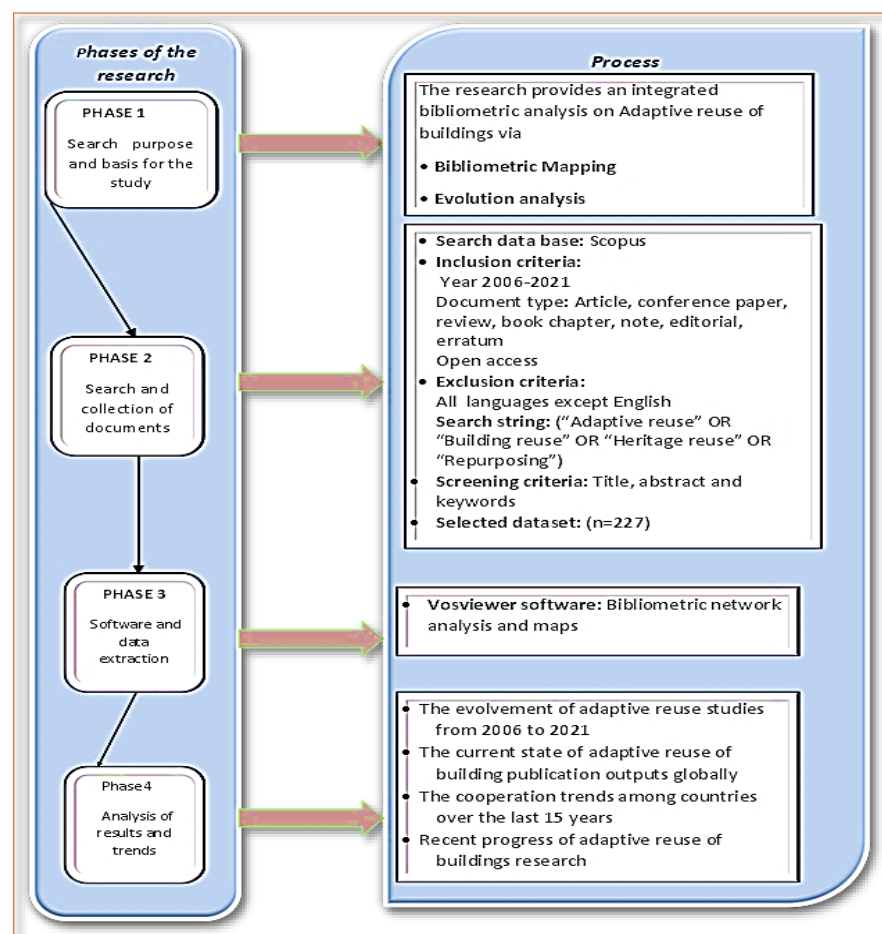

Figure 1. The research framework.

3. Results of Data Analysis

This section presents the result of the Bibliometric analysis. The first phase presents the analysis of the yearly publication, types of publication and the most prolific journals with the most cited articles. This displays the evolutionary field of the research topic, to answer the research question on "What is the current state of adaptive reuse of building publication outputs globally"? It was thus possible to perform an interpretation of the conceptual evolution. In the second phase (Period I), the analysis presents the bibliometrics of the Institutional affiliation of the authors, the Co-Authorship citation, Distribution by region and the most prolific authors in the field of Adaptive reuse research to answer the objective on "What are the cooperation trends among countries over the last 15 years". The third phase responds to the third objective by focusing on "what constitutes as recent progress of adaptive reuse of buildings research"? through the analysis of the Subject area of published documents, the Keyword clusters and keyword trends, thus making it

possible to establish the status quo and emerging trends. Finally, the fourth phase presents a discussion to consolidate the findings and results of the previous phases on "How has adaptive reuse of buildings research evolved from 2006 to 2021"? The implications of the findings were discussed with the limitations of the study highlighted and schema for future research suggested. The analysis is as presented below:

3.1. Evolution Analysis of Yearly Publications

The yearly publications from 2006 to 2021 are presented in Figure 2. Before the year 2016, the output of related publications annually was in the range of 5 publications. A substantial growth is apparent from the year 2016 with 13 publications which is an increase of 8 publications compared to the preceding year. In 2016, 13 publications were registered with 8 publications higher than in 2015. The number of publications for subsequent years rose steadily, but a little decline was experienced in 2018, however, the publication grew more than double the number of the previous year in 2019 with 36 publications and an increasing trend has been recorded in the following year also, with the total publications documented for 2020, and 2021 being 60 (26.4%) and 49 (21.6%), respectively. The 49 publications recorded for 2021 is based on the time of this study which is July 2021 (mid-year), therefore a lot more publication is expected to be added to the database by the end of the year. Previous studies suggested that with sustainable development gathering a great deal of recognition over the past years, there is an expected upsurge in studies concerted on circular economy and the application of adaptive reuse in the building and construction industry [49,50].
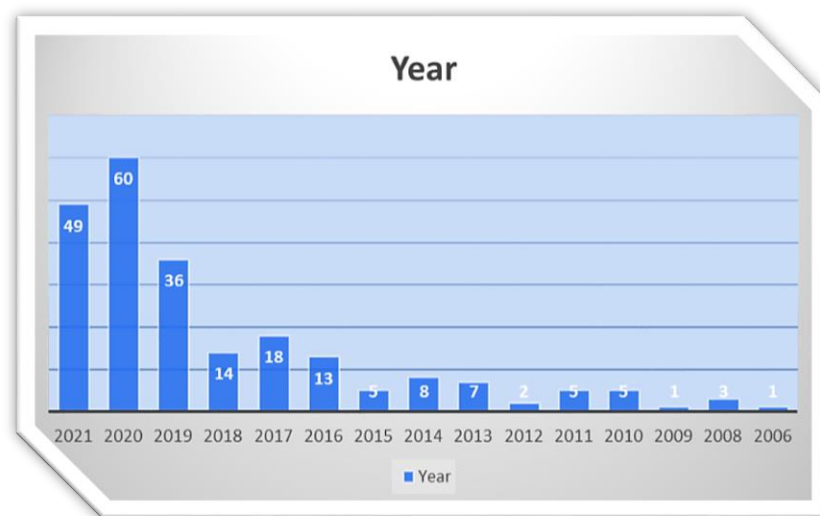

Figure 2. Annual publication.

3.2. Type of Publication and Source Analysis

Figure 3 presents a break-down of the 227 documents published within 2006 to 2021, which includes 148 journal articles and 62 conference papers. There are lesser published book reviews and editorial articles on this subject. This could be due to the longer time involved in publishing books. Table 1 presents the 10 most prevalent journals in adaptive reuse alongside the number of publications and most cited publications. Sustainability journal (MDPI) and the IOP Conference Series (Earth and Environmental Science) represent the most popular journals with the highest publications of 51 and 24, respectively, while sustainability and International Journal of Strategic Property Management have the most cited document of 35 and 26 citations, respectively.
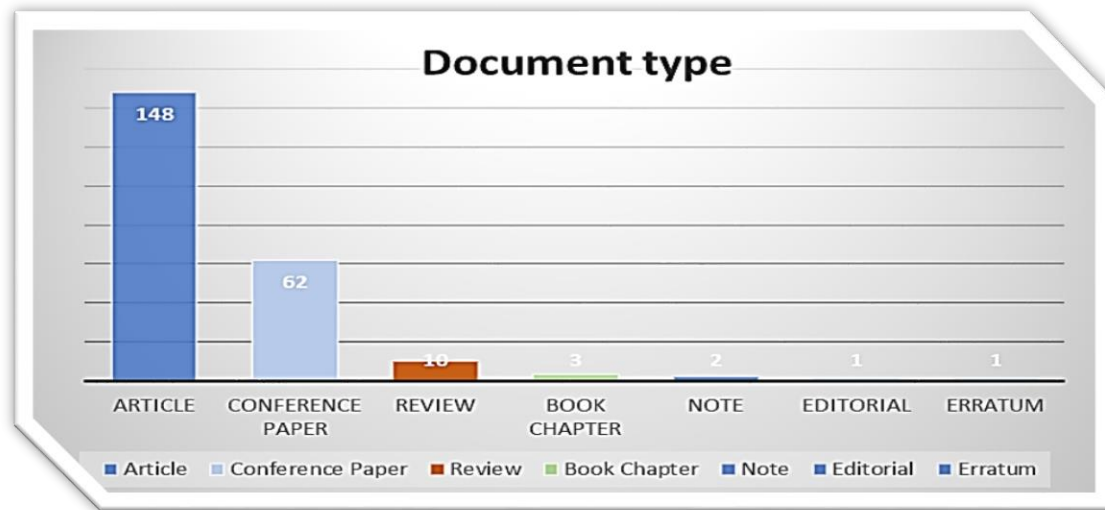
Figure 3. Document type.

Table 1. The top 10 most productive journals on adaptive reuse with their most cited article.

	Journal Source	Number of Documents	Cite Score	Most Cited Article	Times Cited
1	Sustainability	51	3.9	"Ranking of adaptive reuse strategies for abandoned industrial heritage in vulnerable contexts: A multiple criteria decision aiding approach"	35
2	IOP Conference Series Earth and Environmental Science	24	0.5	"The Centrum-Bandung Adaptive Reuse at Heritage Building as Sustainable Architecture"	3
3	IOP Conference Series Materials Science and Engineering	9	0.7	"The application, benefits, and challenges of retrofitting the existing buildings"	8
4	Wit Transactions on Ecology and The Environment	8	0.6	"Adaptive reuse as an effort to preserve a historical district: A case study of the Braga corridor in the city Centre of Bandung, Indonesia"	2
5	Wit Transactions on The Built Environment	8	0.6	"Technical detailing principles for the design of adaptable and reusable construction elements in temporary dwellings"	3
6	Buildings	6	4.2	"Sustainable building assessment of colonial shophouses after adaptive reuse in Kuala Lumpur"	15
7	International Journal of Building Pathology and Adaptation	5	2.4	"A critical review of the developments in building adaptability"	21
8	International Journal of Strategic Property Management	4	3.6	"A fuzzy approach for adaptive reuse selection of industrial buildings in Hong Kong"	26
9	Matec Web of Conferences	4		"The Criteria for Decision Making in Adaptive Reuse Towards Sustainable Development"	9
10	Procedia Engineering	4	4.0	"Regenerative Design of Existing Buildings for Net-Zero Energy Use"	22

Table 1 presents the 10 most prevalent journals in adaptive reuse alongside the number of publications and most cited publications.

As regards institutional affiliations, the subject of adaptive reuse has also been affiliated with key institutions. The Università Degli Studi di Napoli Federico II ranked highest with 10 publications affiliated to it. It is a public university in Naples, Italy specifically prominent for research; was ranked in 2015 among the topmost hundred institutions in the world based on citations per paper and one of the best universities in Italy globally [51]. This is followed closely by the Delft University in the Netherlands, which is steadily ranked as one of the best universities in the Netherlands, and as of 2020 ranked by QS World University Rankings among the top 15 engineering and technology universities in the world [52]. The Politecnico de Milano is the largest technical university in Italy and is ranked in 2020 as the 20th best globally according to the ranking by the QS World for the field 'Engineering & Technology' [52]. Analysis showed that the authors' institutional affiliations are mostly from universities compared to polytechnics and others. This could be due to research publication emphasized as a prerequisite for major Universities. Further analysis on the co-citation links between authors showed the strongest for the citations of Foster [49] and Wilkinson [53].

3.3. Distribution by Region

The distribution of publications across countries globally is presented in Figure 4 on the subject of adaptive reuse and its contribution to the growth of research activity in building and construction. Countries were recognized alongside the number of publications. The analysis shows that Italy represents the leading country, contributing about 19.8% of the global publications with 45 publications, followed by the UK with 22 publications (9.6%). On the other hand, Jordan, Mexico and Brazil represent the countries with the lowest number of publications with just a single publication each in the database.
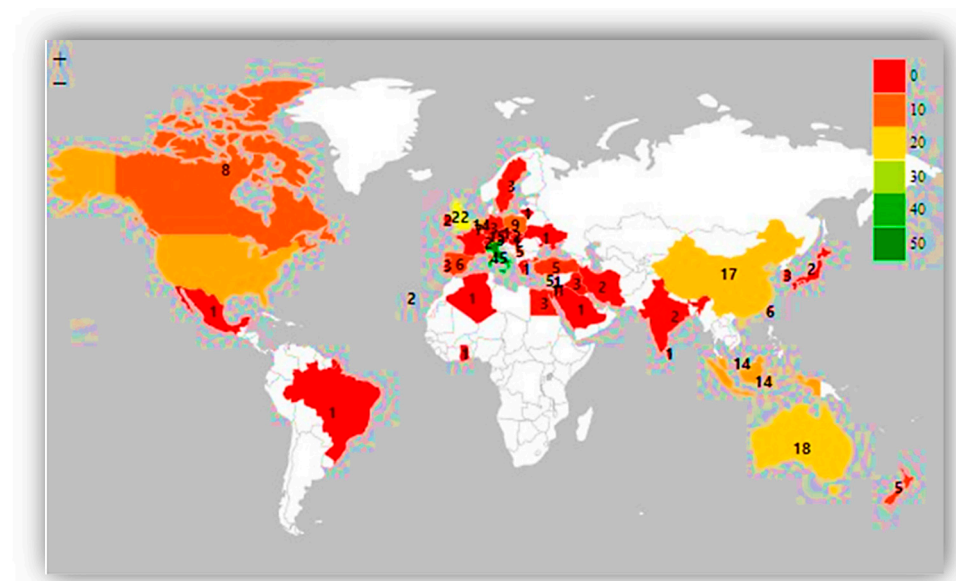

Figure 4. Geographical distribution of publications.

The European countries are well represented in terms of publication distribution, for example, Italy, UK and the Netherlands with 45, 17 and 14 publications, respectively. This is attributed to their various programs targeted at fast-tracking the sustainability agenda [49]. Particularly after the European year of cultural heritage 2018 (EYCH), adaptive heritage reuse has gained more prominence in the respective countries' agenda [54]. Furthermore, the commitment of the European funding on adaptive heritage reuse projects is strong, and more importantly, reuse projects could profit from a wide range of funds, for example, the EU-social fund, cohesion fund and the regional development fund, which co-funds related projects [55].

In Italy, the high number of studies in adaptive reuse is a reflection of the country's duty to take care of heritage as part of its Constitution. During the last two decades, some programs have been launched, partly to accelerate interventions in urban areas and to support initiatives of urban redevelopment. Thus, heritage is afterward realized as a blend between landscape and historical heritage and is recognized as a vital ingredient of democracy, fairness and independence [56]. Historical building preservation is listed among the social responsibilities to be engaged by the government. In the UK, the large research interest in the field of adaptive reuse is prompted by the supporting national planning policy on conservation, accessibility of building regulations, flexible requirements, financial incentives and disincentives that influence the adaptive reuse of heritage buildings [55].

Australia's high publication record in the field is largely influenced by its legislation which inspires mutual government and public coalition in issues concerning heritage preservation. The present legislation gives flexibility to the local planning authorities as regards the building specifications to encourage the adaptive reuse of heritage for example, through the transfer of development rights. There are also many tax concession planning incentives provided by the government to encourage heritage conservation. In addition, the dynamic involvement of the private sector is required for investment in adaptive projects [57]. Results also reflected that Africa is still lagging in the field of adaptive reuse and circularity in building and construction as only Ghana was found with one publication. This finding is hardly surprising as relatively little attention has been given to the concept of circular economy in many low-income and middle-income countries [58].

3.4. Prolific Authors and Subject Area

The identified top prolific authors in adaptive reuse were Langston CA, Gunce K and Pintossi N. Out of the 10 most prolific authors, three are from Italy and two are from Australia. Italy also represents the country with the highest publication as earlier mentioned in the analysis. Figure 5 presents the subject area of the published documents.
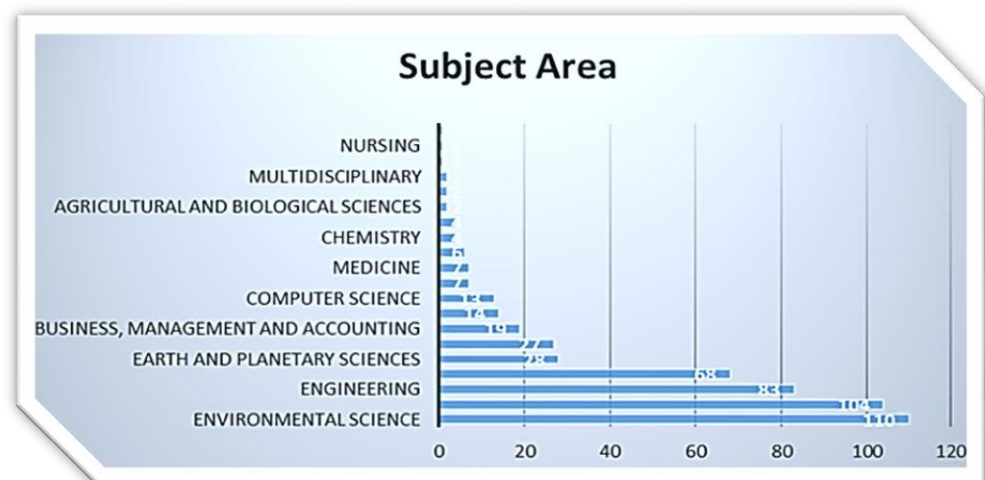

Figure 5. The subject area of published documents.

The most publication was found in the subject area of Environmental science with a total publication of 110 documents (48.4%), followed by Engineering having a publication of 104 (45.8%). Publications on adaptive reuse in the field of medicine and nursing are also springing up, with Medicine having 7 publications (3%). This is expected to increase more given that the increasing awareness and need to adaptively reuse buildings for hospitals, especially in recent times where there is a shortage of spaces in clinics and hospitals during the pandemic.

3.5. Keyword Clusters and Keyword Trends

To determine the basic structure and clusters from the retrieved documents, a keyword co-occurrence analysis was performed. A co-occurrence network was obtained from an aggregate of 1577 keywords through the VOSviewer software. Set at a minimum number of 5 co-occurrences of keywords; 76 keywords co-occurred and 4 significant keyword clusters were found. Results revealed that the most associated keyword with adaptive reuse are "sustainable development" and "cultural heritage" with a strength link of 295 and 240 and occurrences of 55 and 40, respectively. The analysis also identified some characteristics, substratum, Process and configuration used to name "adaptive reuse". Examples of substrate/mechanism related were 'repurposing' (5 occurrences), 'refurbishment' (6), 'retrofitting (8)'. Similarly, heritage conservation (17), historic preservation (27) and other multiple words were used. Figure 6 presents the keyword clusters.
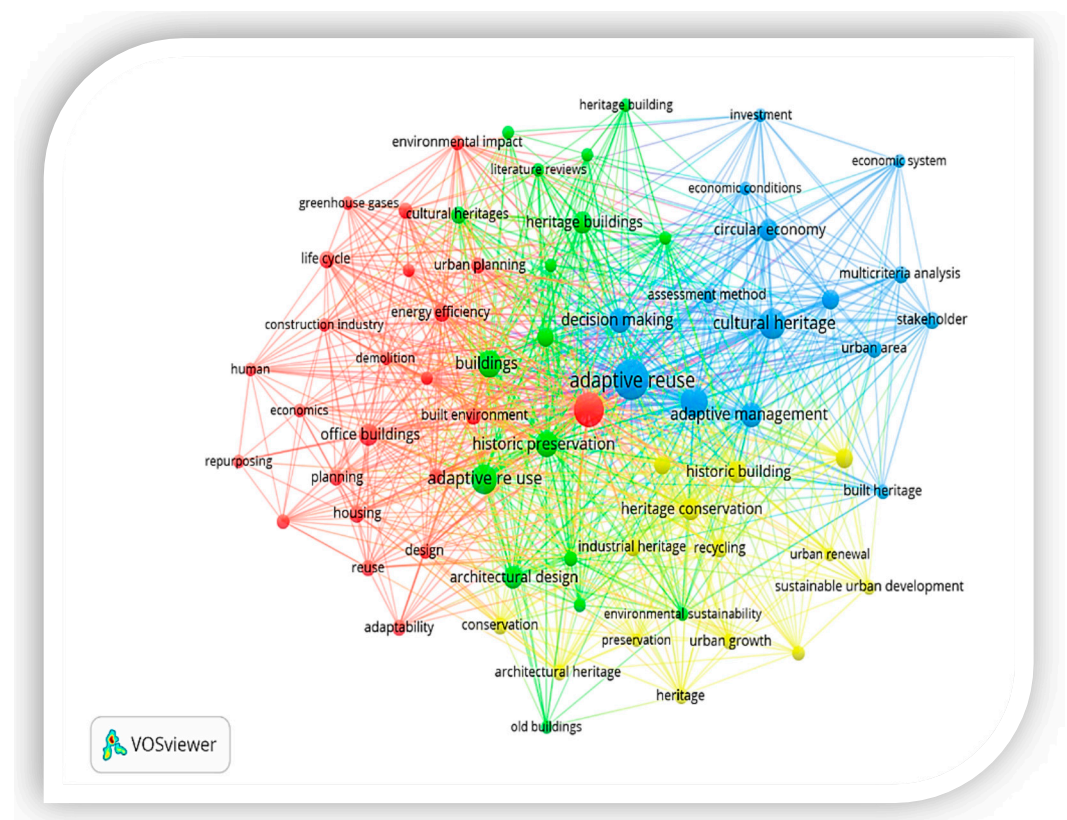

Figure 6. A bibliometric chart created according to author key-words co-occurrence with overlay visualization mode. The least occurrences of a keyword were set at 5.

The first cluster (red) comprised 25 items and concentrated on these themes arranged chronologically which includes but is not limited to adaptability, building, construction industry, demolition, energy efficiency, greenhouse gases, housing, reuse, repurposing, urban planning. The second cluster (green) contained 15 terms and concentrated on these topics listed alphabetically which include, Architectural design, built heritage, conservation, historic building, multi-criteria analysis. The third cluster (blue) consists of 11 items and is centered on the following subjects which include but are not limited to assessment methods, circular economy, economic systems, economic conditions, decision making, investment and stakeholder. The fourth cluster (yellow) included 11 terms which include: adaptive management, conservation, environmental sustainability, heritage, heritage conservation, industrial heritage, historic building, preservation, recycling, sustainable urban development, urban growth, urban renewal.

Drawing on the results of the cluster analysis, the keywords in adaptive reuse articles can be classified into four broad research themes. Keywords are crucial subjects of articles,

playing a key role in uncovering the development of research subjects. The clusters are Cluster (1) Adaptability to mitigate the environmental impacts of construction activities; Cluster (2) Multi-criteria decision tool for sustainable reuse of buildings; Cluster (3) Theoretical frameworks, stakeholder study and assessment techniques in the adaptive reuse of buildings, and Cluster (4) Sustainable urban development and neighborhood revitalization.

Cluster (1): Adaptability to mitigate the environmental impacts of construction activities

The first cluster is associated with the environmental impacts of construction activities and the importance of adaptive reuse which received substantial awareness from the built environment, and environmental discipline. According to the keywords identified in the cluster analysis (Figure 6), studies in this cluster attempted to resolve three main questions: (1) what are the environmental implications of construction and demolition activities? (2) how does the issues of greenhouse gases, energy efficiency and resource depletion impact the built environment? and (3) what are the sustainable mitigation of the environmental impacts of construction activities obtainable through adaptive reuse?

The studies identified that construction and demolition activities generate lots of waste which contains multiple pollutant compositions such as greenhouse gases. Adaptive reuse signifies an alternative to traditional demolition and reconstruction; it is innately sustainable as it entails less energy and waste [59]. Adaptive reuse is recommended to be relevant to the current climate change adaptation agenda due to its ability to recycle resources in place. The studies identified existing buildings that have been upgraded to achieve substantial cuts in greenhouse gas emissions (GGE) as those buildings are considered a more climate-friendly strategy than producing new energy-efficient buildings [60].

Cluster (2): Multi-criteria decision tool for sustainable reuse of buildings

The second cluster is structured around the discussion on decision tools for sustainable reuse of buildings mostly conducted from the perspective of heritage conservation. Following the keywords associated with the cluster analysis (Figure 6), studies under this cluster are directed on the following problems: (1) what decision tools can be made for the conservation of heritage buildings? (2) what situations are the tools applicable for adaptive reuse? and (3) how to test the performance of the decision tools on reuse projects?

Studies in this cluster identified the need and development of criteria decision-making tools to guide investment choices which is advantageous in lowering the risk associated with investing in building adaptation. The studies were important in supporting several building re-use cases that rejuvenate economic development and recognized the value of sustainable urban development. Some aspects of models focused on by the studies regarding this theme are (1) PAAM—"The Preliminary Adaptation Assessment Model" used by a non-professional in making a preliminary valuation of a building's overall appropriateness for modifications and extensions for adaptations [61], (2) AHP multicriteria decision-making technique (3) DFAHP method (Delphi-Fuzzy-AHP) risk assessment model for restoring derelict public buildings [62], (4) Fuzzy logic theory which is suitable for evaluating complex and cumbersome decision-making problems [63]. The studies identified the need for and proposed some evidence-based decision-making tools essential for managing the reuse of built properties.

Cluster 3: Theoretical frameworks, stakeholder study and assessment techniques in the adaptive reuse of buildings

The third cluster is about the theoretical frameworks, assessment factors and models in the adaptive reuse of buildings. Given the keywords associated with the cluster analysis (Figure 6), studies within this cluster were pertinent about these concerns: (1) what are the theoretical frameworks underpinning adaptive reuse studies, (2) what factors inform the adaptive reuse projects and 3) how can adaptive reuse projects be improved through the collaboration of various stakeholders?

The clusters on the theoretical frameworks of adaptive reuse identified that the financial, material, governmental and utilitarian criteria can have a positive impact on adaptation if properly monitored [64,65]. However, it was reported that contributions of these criteria to achieving viable solutions can be disproportionate and it is, therefore,

important to run through a multi-criteria framework and examine the overall picture constantly to ensure success of the heritage [66]. The studies under this cluster propose a combined evaluation model, established on multi-criteria analysis, with an economic model to strengthen the decision of alternative reuse of the building and the engagement of stakeholders. Amongst these include the (PESTEL-CA) framework for the allocation and classification of factors and related policy tools for adaptive reuse [67], the use of a multi-procedural approach founded on decision tests and social multi-criteria assessment in adaptive reuse [68], multi-stakeholder decision analysis (M-SDA) developed to support stakeholders in selecting appropriate use to activate circularity developments [69,70].

Cluster 4: Sustainable urban development and neighborhood revitalization

The fourth cluster is about adaptive reuse from the standpoint of urban development and renewal. According to the characterization of the keywords, studies in the cluster made effort to respond to the questions of (1) what are the insights to revitalize an obsolete building? (2) what is the role of adaptive reuse in urban heritage reconstruction?

The clusters addressed possible issues that can arise in the adaptation of the historic building to a new use from a broader perspective, as a significant element in the course of the reconstruction of community identity, rejuvenation of urban fragments and development in the quality of living. The clusters identified, sustainable urban development using adaptive reuse is not only a tool that appeals to external personnel while increasing their financial and social benefits, but it is also an instrument for expansion and management of the urban area [22]. Furthermore, due to the physical environmental heritage, consideration is given to the construction of spatial events relying on indigenous knowledge and properties of the urban cores [4,49]. The studies under the clusters evidenced the adaptive reuse of historic buildings as a sustainable resource over time which advances the four pillars of sustainable urban growth [22,31].

Emerging areas of the sustainable revitalization of the historic areas include identifying the role of stakeholders in adaptive reuse of spaces; interdisciplinary collaboration; and indigenous social models in sustainable revitalization of urban cores.

4. Discussion

4.1. Summary of Findings

This section presents a summary of the discussion on the findings on the evolvement of adaptive reuse from 2006 to 2021 according to each objective, with implications, and highlights the possible research areas for future studies as follows:

4.1.1. The Current State of Adaptive Reuse of Building Publication Outputs Globally

Based on the findings, adaptive reuse studies have gained momentum in both scientific and popular discourse since 2016, the prime cause being that adaptation could be less costly than new constructions and usually results in quicker project completion times [53] and the drive for sustainable development is another important motivation. Recent studies have also highlighted among the advantages of adaptive reuse of vacant buildings as that of bringing environmental, social and economic benefits towards an urban strategy based on circular economy principles by generating useful values to support innovative development dynamics [29].

In terms of the progression of scientific knowledge in the adaptive reuse of buildings, the findings of this study revealed that the field of adaptive reuse exhibits an exponential knowledge advancement process. The 227 documents archived at the Scopus database on the topic of study database are more concentrated in the *Sustainability*-MDPI journal and also are largely from the countries—Italy, United Kingdom, Australia, China, the US and the Netherlands.

4.1.2. The Cooperation Trends among Countries over the Last 15 Years

In terms of geographical distribution, broadly, the study indicates that the field has evolved considerably in different regions of the world over time; in addition, there is an

established cooperation trend among different countries over the years, however, there is considerable low research on the field emanating from the developing countries. Overall, the field has maintained an interdisciplinary orientation from the perspective of the environmental sciences, engineering, arts and humanities, social sciences, earth and planetary, business and management, computer science and health sciences.

4.1.3. Recent Progress of Adaptive Reuse of Buildings Research

Concerning the trends on knowledge creation through adaptive reuse literature, topics in the first period of scholarly work begin with a focus on assessment of building reuse and principles of adaptive reuse such as principles for the design of adaptable and reusable construction elements in temporary dwellings, building reuse assessment for sustainable urban reconstruction, adaptive reuse potential and evaluation of designs for reuse [71,72]. At this point, the concept of adaptive reuse models started to emerge in the literature such as the ARP model using icon CUR, AdaptSTAR model, DFAHP multicriteria risk assessment model, fuzzy approach [62,63]. In the most current period, the evolution of adaptive reuse has shifted its focus to design for sustainability and innovative technologies [49,73]; and also, the considerable amount of policy-driven studies in the field has been progressively growing and the policy sciences have gained greater traction. Scholars are more interested in understanding how governmental policies, government priorities and actions impact the dynamics of adaptive reuse and its effects on adaptive projects [4,25].

Finally, this study is not without its limitations, thus the limitations are highlighted as follows: First, the study made use of a single database which is Scopus and did not consider other databases that are used in the research world such as the Web of Science (WOS). However, the study presents a detailed methodology for the selected documents and the choice of a database regarded reliable among researchers globally. Secondly, only the documents published in English were selected and analyzed, given that the English language is universal and widely extensive in scope. However, some publications are published in the field of adaptive reuse outside the English language which if considered would also be a great contribution to the perspective of the study. Therefore, based on the foregoing, this study draws suggestions for potential research in adaptive reuse as presented in the section below.

4.2. Schema for Future Research

Despite recent advancements in literature, much more research is needed about adaptability on the scale of existing buildings. Considering the current universal challenges presented by the pandemic amidst other social, economic and environmental problems, there is the need to direct future research to the potential of reuse of abandoned or underused buildings or infrastructures, as direct changes in use could set off opportunities for innovation, urban contribution and redevelopment by pursuing novel and innovative solutions.

It is expected that exploring and co-building the shared spaces that have been left underused during this pandemic will take a different role in the cities in the future. Moreover, the opportunity is presented to increase research into policies, regulations and stakeholder's involvement in the industry to explore the possibility for adaptation across all the lifecycle of the building because sometimes intentions to building reuse for new purposes might be challenged by local building regulations, zoning and codes with other legal requirements which might obstruct the reuse potential [74].

Moreover, the choice of repurposing a building requires a logical framework to evaluate the diverse viable options and ample information to detect the best solution, or the most outstanding negotiated solution [75]. Therefore, given the difficulties and constraints in the application of adaptive reuse, there is a need to review policies and supportive systems need to be well applied into practical-based actions and approaches.

Hence, it is imperative to evaluate the operation of adaptive reuse practices according to sustainability values to induce forthcoming policies. However, the evaluation procedure

has to deal with the dilemma compositely by viewing from diverse perceptions, objectives, participants and values in an extensive approach as such a procedure might enhance the value of public decisions [76]. Further, there is a need for more research into the technologies and design of adaptable buildings pre-construction as it is established that the design of an adaptive reuse or reconstruction project entails all the typical or more architectural design deliberations for the new construction [77].

The disproportionate distribution in the global distribution of publications signifies a great need for further, comprehensively, cross-sectorial and multi-disciplinary research that would reveal the influence of cultural heritage on various spheres of life across countries, particularly collaboration in middle and low-income countries due to the relatively low research with limited scope in the African context. Finally, there is a need to strengthen collaboration between the developed and the developing countries on the subject of adaptive reuse to foster and develop more research from the developing regions.

5. Conclusions

This study presented bibliometrics of the research progress in adaptive reuse through a comprehensive review of 227 related publications from the Scopus repository during the period of 2006–2021. Visualization analysis and interpretation were carried out using 227 literature. Given that framework, the following conclusions are drawn.

Globally, the concept of adaptive reuse is gaining rapt attention. Frequency and co-occurrence analyses were performed to characterize publication trends based on geographical distribution, yearly publications, type and source. The evolution of research subjects was presented through a cluster of keywords offering researchers with a trend of current study directions to drive potential research about adaptive reuse in building and construction. The findings revealed that over the past five years, publication progress has been impressive and further advancement is anticipated.

It is apparent from the study that research on the application of adaptive reuse in Africa is under-represented in comparison with other regions which connotes that research is infantry at this time. The potential area for further research is established. Given that research is an incessant process, then the citation network map, co-word network map and the evolution chart are not static but subject to changes over time, therefore future studies are recommended to trail the changes that take place. Considering that the Scopus directory was utilized as the source of data for this study and only the documents published in English were retrieved and analyzed, further studies are therefore recommended using a mix of other databases including documents that are not only published in English.

References

1. United Nations. Global Status Report: Towards a Zero-Emission, Efficient, and Resilient Buildings, and Construction Sector. 2017. Available online: https://www.worldgbc.org/sites/default/files/UNEP%20188_GABC_en%20%28web%29.pdf (accessed on 24 July 2021).
2. United Nations. *Transforming Our World: The 2030 Agenda for Sustainable Development*; Department of Economic and Social Affairs: New York, NY, USA, 2015.

3. Abastante, F.; Lami, I.; Gaballo, M. Pursuing the SDG11 targets: The role of the sustainability protocols. *Sustainability* **2021**, *13*, 3858. [CrossRef]

4. Pintossi, N.; Kaya, D.I.; Roders, A.P. Assessing cultural heritage adaptive reuse practices: Multi-scale challenges and solutions in Rijeka. *Sustainability* **2021**, *13*, 3603. [CrossRef]

5. Viola, S.; Diano, D. Repurposing the built environment: Emerging challenges and key entry points for future research. *Sustainability* **2019**, *11*, 4669. [CrossRef]

6. Russell, P.; Moffatt, S. *Adaptability of Buildings, IEA Annex 31, Energy-Related Environmental Impact of Buildings*; International Energy Agency (IEA): Paris, France, 2001.

7. Butina-Watson, G.; Bentley, I. *Identity by Design*, 1st ed.; Routledge: London, UK, 2007. [CrossRef]

8. Grin, J.; Rotmans, J.; Schot, J. *Transitions to Sustainable Development: New Directions in the Study of Long Term Transformative Change*; Routledge: London, UK, 2010.

9. Gosling, J.; Sassi, P.; Naim, M.; Lark, R. Adaptable buildings: A systems approach. *Sustain. Cities Soc.* **2013**, *7*, 44–51. [CrossRef]

10. Abdulameer, Z.A.; Abbas, S.S. Adaptive reuse as an approach to sustainability. *IOP Conf. Series Mater. Sci. Eng.* **2020**, *881*, 012010. [CrossRef]

11. De Silva, G.; Perera, B.; Rodrigo, M. Adaptive reuse of buildings: The case of Sri Lanka. *J. Financ. Manag. Prop. Constr.* **2019**, *24*, 79–96. [CrossRef]

12. Wijesiri, W.M.M.; Devapriya, K.A.K.; Rathnasiri, P.; Karunaratne, T.L.W. A framework to implement green adaptive reuse for existing buildings in Sri Lanka. *Intell. Build. Int.* **2021**, 1–25. [CrossRef]

13. Zulkanain, M.I.; Jaafar, M.; Salim, N.A.A. Exploring the adaptive reuse concept and benefits in managing public building quarters in Malaysia. *Malays. Constr. Res. J.* **2021**, *12*, 258–270.

14. Langston, C.; Wong, F.K.W.; Hui, E.C.M.; Shen, L.-Y. Strategic assessment of building adaptive reuse opportunities in Hong Kong. *Build. Environ.* **2007**, *43*, 1709–1718. [CrossRef]

15. Remoy, H.; Voordt, T.J. Adaptive reuse of office buildings into housing: Opportunities and risks. *Build. Res. Inf.* **2014**, *42*, 381–390. [CrossRef]

16. Çevik, S.; Vural, S.; Tavşan, F.; Aşık, Ö. An example to renovation–revitalization works in historical city centres: Kunduracılar Street/Trabzon-Turkey. *Build. Environ.* **2008**, *43*, 950–962. [CrossRef]

17. Shen, L.; Langston, C. Adaptive reuse potential. *Facilities* **2010**, *28*, 6–16. [CrossRef]

18. Günçe, K.; Mısırlısoy, D. Assessment of adaptive reuse practices through user experiences: Traditional houses in the walled city of Nicosia. *Sustainability* **2019**, *11*, 540. [CrossRef]

19. Kalaci, E.; Dervishi, S. Implementation challenges to the adaptive reuse of a heritage building in Tirana, Albania. In Proceedings of the 2nd ICAUD International Conference in Architecture and Urban Design, Tirana, Albania, 8–10 May 2014.

20. Mohamed, R.; Boyle, R.; Yang, A.Y.; Tangari, J. Adaptive reuse: A review and analysis of its relationship to the 3 Es of sustainability. *Facilities* **2017**, *35*, 138–154. [CrossRef]

21. Morkūnaitė, Ž.; Kalibatas, D.; Kalibatienė, D. A bibliometric data analysis of multi-criteria decision making methods in heritage buildings. *J. Civ. Eng. Manag.* **2019**, *25*, 76–99. [CrossRef]

22. Plevoets, B.; van Cleempoel, K. *Adaptive Reuse of the Built Heritage*; Routledge: London, UK, 2019.

23. Bullen, P.A. Adaptive reuse and sustainability of commercial buildings. *Facilities* **2007**, *25*, 20–31. [CrossRef]

24. Li, Y.; Zhao, L.; Huang, J.; Law, A. Research frameworks, methodologies, and assessment methods concerning the adaptive reuse of architectural heritage: A review. *Built Herit.* **2021**, *5*, 1–19. [CrossRef]

25. Farjami, E.; Türker, Ö.O. The extraction of prerequisite criteria for environmentally certified adaptive reuse of heritage buildings. *Sustainability* **2021**, *13*, 3536. [CrossRef]

26. Foster, G.; Saleh, R. The adaptive reuse of cultural heritage in European circular city plans: A systematic review. *Sustainability* **2021**, *13*, 2889. [CrossRef]

27. Gravagnuolo, A.; Micheletti, S.; Bosone, M. A participatory approach for "circular" adaptive reuse of cultural heritage. Building a heritage community in Salerno, Italy. *Sustainability* **2021**, *13*, 4812. [CrossRef]

28. Joensuu, T.; Edelman, H.; Saari, A. Circular economy practices in the built environment. *J. Clean. Prod.* **2020**, *276*, 124215. [CrossRef]

29. Marika, G.; Beatrice, M.; Francesca, A. Adaptive reuse and sustainability protocols in Italy: Relationship with circular economy. *Sustainability* **2021**, *13*, 8077. [CrossRef]

30. Pimonsathean, Y. Current issues concerning adaptive reuse in the conservation of urban cultural heritage. *RC Rev. Cult. Rev. Cult.* **2002**, *4*, 45–51.

31. Bullen, P.A.; Love, P.E.D. Adaptive reuse of heritage buildings. In *Structural Survey*; Emerald Group Publishing Limited: Perth, Australia, 2011; Volume 29, pp. 411–421.

32. Sandberg, J.; Alvesson, M. Ways of constructing research questions: Gap-spotting or problematization? *Organization* **2011**, *18*, 23–44. [CrossRef]

33. Mostafa, S.; Chileshe, N.; Abdelhamid, T. Lean and agile integration within offsite construction using discrete event simulation: A systematic literature review. *Constr. Innov.* **2016**, *16*, 483–525. [CrossRef]

34. Song, P.; Wang, X. A bibliometric analysis of worldwide educational artificial intelligence research development in recent twenty years. *Asia Pac. Educ. Rev.* **2020**, *21*, 473–486. [CrossRef]

35. Ahmadvand, A.; Kavanagh, D.; Clark, M.; Drennan, J.; Nissen, L. Trends and visibility of "digital health" as a keyword in articles by JMIR publications in the new millennium: Bibliographic-bibliometric analysis. *J. Med. Internet Res.* **2019**, *21*, e10477. [CrossRef]

36. Benckendorff, P.; Zehrer, A. A network analysis of tourism research. *Ann. Tour. Res.* **2013**, *43*, 121–149. [CrossRef]

37. Gallego-Valero, L.; Moral-Parajes, E.; Román-Sánchez, I. Wastewater treatment costs: A research overview through bibliometric analysis. *Sustainability* **2021**, *13*, 5066. [CrossRef]

38. Mihalic, T.; Mohamadi, S.; Abbasi, A.; Dávid, L. Mapping a sustainable and responsible tourism paradigm: A bibliometric and citation network analysis. *Sustainability* **2021**, *13*, 853. [CrossRef]

39. Alkahtani, M.; Ziout, A.; Salah, B.; Alatefi, M.; Elgawad, A.E.E.A.; Badwelan, A.; Syarif, U. An insight into reverse logistics with a focus on collection systems. *Sustainability* **2021**, *13*, 548. [CrossRef]

40. Agarwal, A.; Durairajanayagam, D.; Tatagari, S.; Esteves, S.C.; Harlev, A.; Henkel, R.; Roychoudhury, S.; Homa, S.; Puchalt, N.G.; Ramasamy, R.; et al. Bibliometrics: Tracking research impact by selecting the appropriate metrics. *Asian J. Androl.* **2016**, *18*, 296–309. [CrossRef]

41. Su, Z.; Zhang, M.; Wu, W. Visualizing sustainable supply chain management: A systematic scientometric review. *Sustainability* **2021**, *13*, 4409. [CrossRef]

42. Li, F.; Li, M.; Guan, P.; Ma, S.; Cui, L. Mapping publication trends and identifying hot spots of research on internet health information seeking behavior: A quantitative and co-word biclustering analysis. *J. Med. Internet Res.* **2015**, *17*, e81. [CrossRef] [PubMed]

43. Hosseini, M.R.; Maghrebi, M.; Akbarnezhad, A.; Martek, I.; Arashpour, M. Analysis of citation networks in building information modeling research. *J. Constr. Eng. Manag.* **2018**, *144*, 04018064. [CrossRef]

44. Olawumi, T.O.; Chan, D.W.M.; Wong, J.K.W. Evolution in the intellectual structure of bim research: A bibliometric analysis. *J. Civ. Eng. Manag.* **2017**, *23*, 1060–1081. [CrossRef]

45. Cobo, M.; López-Herrera, A.; Herrera-Viedma, E.; Herrera, F. Science mapping software tools: Review, analysis, and cooperative study among tools. *J. Am. Soc. Inf. Sci. Technol.* **2011**, *62*, 1382–1402. [CrossRef]

46. Vigneshkumar, C.; Salve, U.R. A scientometric analysis and review of fall from height research in construction. *Constr. Econ. Build.* **2020**, *20*, 17–35. [CrossRef]

47. Van Eck, N.J.; Waltman, L. Visualizing bibliometric networks. In *Measuring Scholarly Impact: Methods and Practice*; Ding, Y., Rousseau, R., Wolfram, D., Eds.; Springer: Cham, Switzerland, 2014; pp. 285–320.

48. Van Eck, N.J.; Waltman, L. *VOSviewer Manual. Manual for VOSviewer Version 1.6.7*; Leiden University: Leiden, The Netherlands, 2018.

49. Foster, G. Circular economy strategies for adaptive reuse of cultural heritage buildings to reduce environmental impacts. *Resour. Conserv. Recycl.* **2020**, *152*, 104507. [CrossRef]

50. Vecchio, M.; Arku, G. Promoting adaptive reuse in Ontario: A planning policy tool for making the best of manufacturing decline. *Urban Plan.* **2020**, *5*, 338–350. [CrossRef]

51. University of Naples—Federico, II. Top Universities. Available online: https://www.acadimat.com/a-brief-look-at-federico-ii-medicine. (accessed on 10 September 2021.).

52. QS World University Rankings—Engineering and Technology 2020. Top Universities. *Retrieved September 2021.* Available online: https://www.topuniversities.com/university-rankings/university-subject-rankings/2021/engineering-technology. (accessed on 30 August 2021).

53. Wilkinson, S.; James, K.; Reed, R. Delivering sustainability through the adaptive reuse of commercial buildings: The Melbourne CBD challenge. In Proceedings of the Pacific Rim Real Estate Society 15th Annual Conference, Sydney, Australia, 18–21 January 2009; pp. 1–19.

54. Macknight, E.C. Introduction, Historical Reflections/Réflexions Historiques. 2021. Available online: https://www.berghahnjournals.com/view/journals/historical-reflections/47/1/hrrh470101.xml. (accessed on 20 August 2021).

55. Veldpaus, L.; Krajewska, O.; Miah, J.; Szemzö, H.; Adaptive Heritage Reuse. Learning from Policy and Governance Frameworks across Europe. 2020. Available online: https://eprints.ncl.ac.uk/file_store/production/275351/D191E448-5281-404A-AE65-EB9B5FA1638A.pdf. (accessed on 20 August 2021).

56. De Medici, S. Italian architectural heritage and photovoltaic systems. matching style with sustainability. *Sustainability* **2021**, *13*, 2108. [CrossRef]

57. Department of Environment. The Australian Government Department of Environment. 2015. Available online: https://www.researchgate.net/deref/http%3A%2F%2Fwww.environment.gov.au%2Fheritage (accessed on 20 August 2021).

58. Halog, A.; Anieke, S. A review of circular economy studies in developed countries and its potential adoption in developing countries. *Circ. Econ. Sustain.* **2021**, 1–22. [CrossRef]

59. Douglas, J. *Building Adaptation*, 2nd ed.; Butterworth-Heinemann: Oxford, UK, 2006.

60. Thornton, B.J. The greenest building (is the one that you don't build!): Effective techniques for sustainable adaptive reuse/renovation. *J. Green Build.* **2011**, *6*, 1–7. [CrossRef]

61. Wilkinson, S. The preliminary assessment of adaptation potential in existing office buildings. *Int. J. Strat. Prop. Manag.* **2014**, *18*, 77–87. [CrossRef]

62. Hsueh, S.-L.; Lee, J.-R.; Chen, Y.-L. DFAHP multicriteria risk assessment model for redeveloping derelict public buildings. *Int. J. Strat. Prop. Manag.* **2013**, *17*, 333–346. [CrossRef]

63. Tan, Y.; Shen, L.-Y.; Langston, C. A Fuzzy approach for adaptive reuse selection of industrial buildings in Hong Kong. *Int. J. Strat. Prop. Manag.* **2014**, *18*, 66–76. [CrossRef]
64. Tu, H.-M. The attractiveness of adaptive heritage reuse: A theoretical framework. *Sustainabilty* **2020**, *12*, 2372. [CrossRef]
65. Dewiyana, E.; Ibrahim, N.; Hidayah, H.N. The green aspects of adaptive reuse of Hotel Penaga. *Procedia—Soc. Behav. Sci.* **2016**, *222*, 631–643. [CrossRef]
66. Parpas, D.S.; Savvides, A.L. On the determinants of a successful, sustainable-driven adaptive reuse: A multiple regression approach. *Int. J. Sus. Dev. Plann.* **2020**, *15*, 1–13. [CrossRef]
67. Kaya, D.I.; Dane, G.; Pintossi, N.; Koot, C.A. Subjective circularity performance analysis of adaptive heritage reuse practices in the Netherlands. *Sustain. Cities Soc.* **2021**, *70*, 102869. [CrossRef]
68. Oppio, A.; Bottero, M.; Ferretti, V. Designing adaptive reuse strategies for cultural heritage with choice experiments. In *Energy Performance in the Australian Built Environment*; Springer: Cham, Switzerland, 2017; pp. 303–315.
69. Della Spina, L. Adaptive sustainable reuse for cultural heritage: A multiple criteria decision aiding approach supporting urban development processes. *Sustainability* **2020**, *12*, 1363. [CrossRef]
70. Salerno, E. Identifying value-increasing actions for cultural heritage assets through sensitivity analysis of multicriteria evaluation results. *Sustainability* **2020**, *12*, 9238. [CrossRef]
71. Wilkinson, S.J.; Reed, R. Examining and quantifying the drivers behind alterations and extensions to commercial buildings in a central business district. *Constr. Manag. Econ.* **2011**, *29*, 725–735. [CrossRef]
72. Laefer, D.F.; Manke, D.F. Building reuse assessment for sustainable urban reconstruction. *J. Constr. Eng. Manag.* **2008**, *134*, 217–222. [CrossRef]
73. Shao, D.; Nagai, Y.; Sosa, R. Design for sustainability and innovation: A kansei engineering evaluation of the adaptive reuse of old buildings. *Proc. Des. Soc. Int. Conf. Eng. Des.* **2019**, *1*, 3221–3230. [CrossRef]
74. Hsu, Y.-H.; Juan, Y.-K. Ann-based decision model for the reuse of vacant buildings in urban areas. *Int. J. Strat. Prop. Manag.* **2016**, *20*, 31–43. [CrossRef]
75. De Medici, S.; Pinto, M.R.; Senia, C.; Fabbricatti, K.; de Toro, P. Building reuse: Multi-criteria assessment for compatible design. *Int. J. Des. Sci. Technol.* **2017**, *22*, 165–193.
76. Bottero, M.; D'Alpaos, C.; Oppio, A. Ranking of adaptive reuse strategies for abandoned industrial heritage in vulnerable contexts: A multiple criteria decision aiding approach. *Sustainability* **2019**, *11*, 785. [CrossRef]
77. Lombardi, A.; Murphy, J., Jr.; Iannarelli, A.; Ciranna, S.; Montuori, P.; de Leon, E.G. Case studies of environmental the quality of buildings damaged by earthquakes, prior to adaptive reconstruction: Palazzo moscardelli in ofena and ex-colonia ix maggio at Monteluco Di Roio, L'aquila, Italy. *WIT Trans. Ecol. Environ.* **2017**, *226*, 59–72. [CrossRef]