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TITLE PAGE

Heritage building maintenance management (HBMM): a bibliometric-qualitative analysis of literature

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Abstract

Heritage buildings (HBs), which are unique landmarks across the world, have special cultural significance. However, many of the HBs, in lack of proper maintenance management, have become deplorable. Whereas a myriad of studies have been conducted on the general aspects in the heritage building maintenance management (HBMM) domain, it is lacking a detailed and systematic study on the state-of-the-art of HBMM research and its significant trend. . To provide a better understanding of this underexplored area, a study was initiated. Using keywords in the HBMM domain, 944 articles published between 2000 and 2020 were identified through a bibliometric search from the Scopus databases. The "VOSViewer" software was utilized to carry out a scientometric analysis of the articles, which revealed the rising trend of research in HBMM, distribution of articles across the reviewed journals, number of citations of the journals, and strength of connections between the journals based on mutual citations. Then, a qualitative review of the key articles identified that the focuses of investigation of the previous research in HBMM fall into five areas: i) decision-making frameworks, ii) integration of digital technologies and HBMM, iii) building condition and maintenance practice, iv) sustainability and HBMM, and v) new technologies for HBMM. Based on these areas, a framework of directions for future research in HBMM was established. The methodology of this study and the study results, especially the future research directions, can serve as a useful reference for researchers, practitioners, and policymakers in making future effort for the betterment of HBMM.

Keywords: Bibliometric analysis; Facilities management; Heritage buildings; Literature review; Maintenance; Science mapping

1. Introduction

Heritage buildings (HB s), which are iconic buildings with cultural, historical, economic, and political values [72], are of high importance and global significance. To preserve these values for the benefit of future generations, HBs should be managed sustainably; in particular, effective management of the maintenance for HBs is crucial [103].

There has been a myriad of publications that advocate the importance of maintenance for HBs. As [138] mentioned, maintenance is essential to the survival of any building - heritage or non-heritage. In a broader sense, maintenance is pivotal to environmental sustainability, as it limits the usage of new materials and at the same time harmonizes old and new development [6]. Application of appropriate maintenance strategy (e.g. reuse and revitalization) to HBs, also, will minimize land consumption and reduce the built environment's ecological footprint [45].

To ensure sustainable maintenance management of HBs, it is imperative to properly implement heritage building maintenance management (HBMM) - with practical and managerial steps taken to ensure HBs are put to sustainable uses, thereby reducing cases of building dilapidation, demolition, and loss of social and economic benefits attributed to HBs [60]. Despite the well-recognized importance of maintenance, HBs around the world are still confronted with the unending problem of unsatisfactory maintenance management [6]. To address this issue, many studies have been conducted over the years [21,108], resulting in notable contributions to the HBMM domain [72,104].

Nevertheless, anecdotal shreds of evidence depict the existence of knowledge gaps that have not been sufficiently addressed in previous studies [108]. To identify clearly and fully the knowledge gaps in

HBMM, it is indispensable to conduct a comprehensive review of the relevant literature. Yet, most of such review studies in the past adopted a qualitative approach to manually appraise the literature. For instance, [104] conducted a review of the maintenance factor of HBs based on a manual review of the selected articles. A similar review, made by [21] on decision-making models for HBs, exhibited similar limitations. Recently, [108] completed a bibliometric study on Multi-Criteria Decision Making (MCDM) in HBMM, but the scope of this study is limited to quantitative discussions only of methodologies adopted, it overlooked qualitative discussions on the content of the articles.

Purely qualitative literature reviews may have been influenced by a subjective bias and thus are weak in reliability [78]. Literature reviews with limited scopes could only portray part pictures of the status quo and hence some vital areas in research and practice may have been omitted. In either of these cases, there may be an omission of important research focus or hindrance in the identification of future research directions [152].

To address the above limitations, it is imperative to conduct a detailed and systematic study on the state-of-the-art of HBMM research to identify any needs for future research [73]. As such, a study was initiated to systematically search and review the existing literature in HBMM. In the next section, how the literature was searched for this review study and what methods were used to review the literature are recounted. After reporting the series of scientific, quantitative analyses made on the searched literature, a section is dedicated to in-depth discussions on the literature reviewed. The outcomes of the discussions, exposing five main knowledge gap areas, were taken to formulate a framework of research directions for HBMM. At the end is the conclusion section, which points out the implications of the study on stakeholders including users, practitioners, policymakers, and future researchers in the sector of HBs.

2. Materials and Methods

This research primarily utilized the “mixed-method systematic review” approach, which is a combination of scientometric analysis and qualitative analysis of articles, involving both qualitative and quantitative methods for integration and analysis of available literature on a topic [69]. As a systematic review is an effective method for identifying literature gaps in a research domain [101] while a manual review is prone to bias and subjective judgment [73], a mixed-method systematic review can address the shortcoming of the manual review method [76].

This review-based study investigated the existing literature on HBMM from 2000 to 2020 contained in Scopus. Being a major database of academic research outputs, Scopus covers more recent publications than other digital sources such as Web of Science [3]. The workflow of the literature review, as illustrated in Figure 1, is described below.

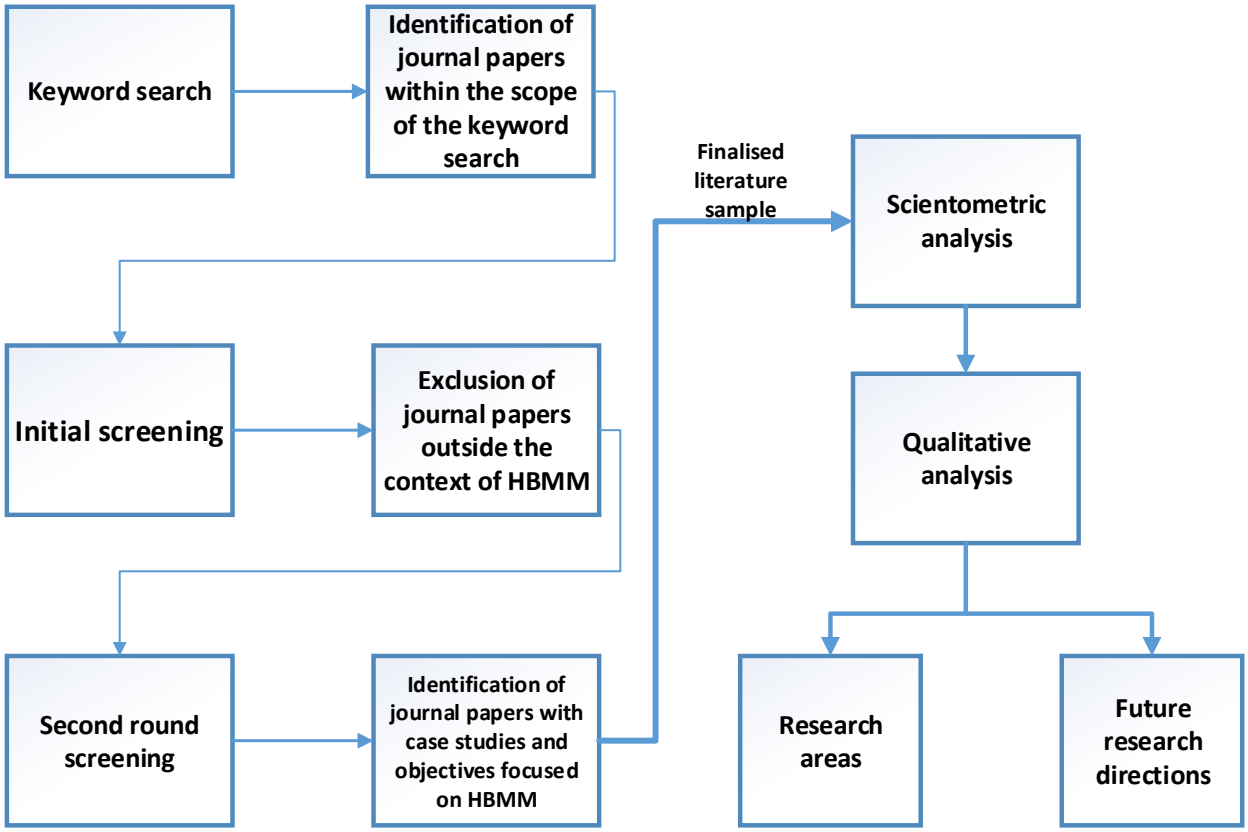


Figure 1. The workflow process of reviewing HBMM literature

2.1 Bibliometric search

The bibliometric search of HBMM was conducted using keywords that were selected based on related existing studies in the research domain [107, 116]. A list of keywords related to HBMM thus created were input to Scopus as follows: TITLE-ABS-KEY ("Heritage building" OR "historic building" AND "maintenance " OR "decision making" OR " building condition" OR "decision-making" OR "facilities management" OR "facility management" OR "Maintenance challenges" OR "heritage building reuse" OR "conservation" OR "Adaptive reuse"). The “AND” connector was used in the keyword search to identify articles that focused on the maintenance of HB.

The language of the publications searched was confined to English and the publication sources were journals. Conference papers, which provide less information than journal articles [33], were excluded from the review process. After the bibliometric search of journal publications, two more steps of analysis were conducted to screen out publications that are either out of the scope of this study or with a focus not falling on HBMM.

2.2 Science mapping

Scientometric analysis has been established to form part of the science mapping approach [151]. Science mapping emphasizes the existing relationship among disciplines, fields, and individual publications in a

spatial approach [136]. It displays the expression of the dynamic and structural aspects of a research domain [44].

Science mapping tools such as CiteSpace [40] and Gephi [22] could be used for a literature review. In this study, VOSviewer, which is a text-mining tool developed by [147] was used. Providing a user-friendly platform that offers basic functionality for providing, visualizing, and exploring bibliometric data.

Also, the VOSviewer software has comprehensive capabilities for displaying large bibliometric maps in a comprehensible manner and its compatibility with the literature database makes it accessible and convenient for users. It has been widely used in other review-based analyses in the field of construction engineering and project management. Such studies include those on building information modelling [116], off-site construction research [78], building environmental control [120], construction and demolition waste management [81], and public-private partnership [139]. However, the use of VOSviewer for scientometric analysis may not have been considered in heritage building-related reviews, thus, its application is worth considering for this study

This study used VOSviewer to perform the following steps: (i) downloading journals from Scopus; (ii) visualizing, computing, and analyzing the influence of journals, authors, publications, and countries in the research domain of HBMM; and (iii) analyzing mainstream keywords and their interrelatedness.

2.3 Qualitative analysis

After the bibliometric search and scientometric analysis, a qualitative analysis of the selected publications was undertaken in the last stage of this review study. The three objectives of this analysis process are to identify: the past/recent research focuses; the past/recent research areas; and future research directions in the context of HBMM.

3. Analysis of findings

3.1 Scientometric analysis

The process of keyword search in Scopus resulted in 1,144 publications. Removing journal articles that are beyond the scope of HBMM reduced the number of publications to 1,011. Articles like those of [7, 62, 95, and 96] were excluded because their fields of study are not management-related; they are in scientific areas such as chemistry and physics (e.g. thermal properties and composition of building materials).

The second-round screening was specific in that it selected articles that focus on HBMM topics and articles that report on case studies of HBs. Studies such as [25, 35, 100], with a focus on condition assessment, management, and/or decision making, were selected. Eventually, a total of 944 articles were included in the scientometric analysis.

3.2 Overview of the literature sample

Of the literature sample, the numbers of publications per year from 2000 to 2020 (up to February) are shown in Figure 2. Generally, the trend of publications over the two decades was on the rise, with an obvious increase in the number of published articles starting from 2012. This supports the submission of [94] that research in the domain of HB management has become a growing necessity, for addressing the concern of decaying HB [52]. The rising trends of related disciplines such as Historic Building Information Management (HBIM) and Facilities Management (FM), amongst others, could also be an influence on the rise in the publications in recent years [119]. As pointed out earlier, the literature search

process was up to February 2020. Consequently, publications featured on Scopus afterward may not have been captured, leading to the reduced number of publications in 2020.

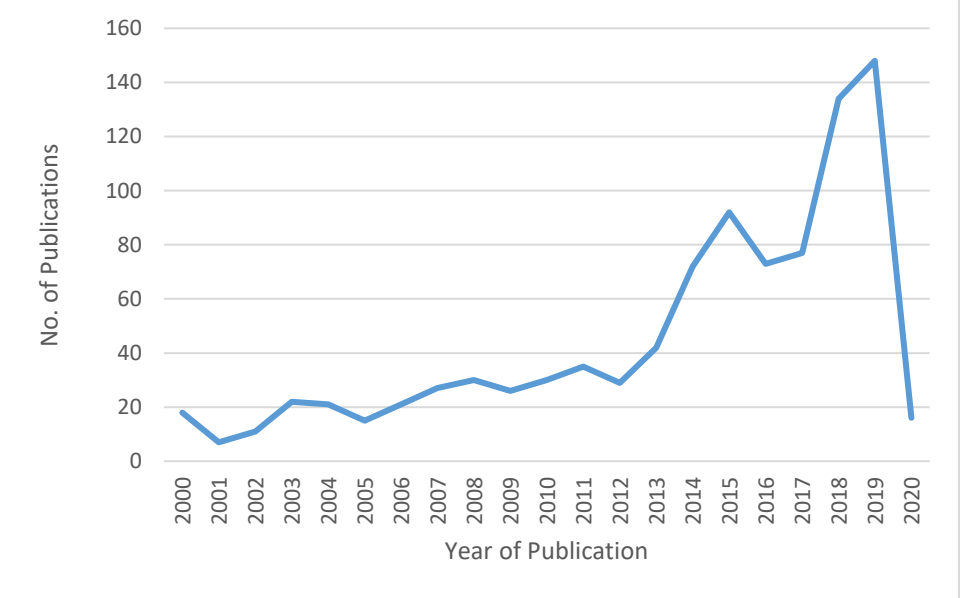


Figure 2. Yearly publications from 2000 to 2020 (up to February)

3.3 Science mapping of publication sources

Journals that published articles on HBMM related issues were identified, visualized, and analyzed using VOSviewer. Following the default setting of this software, the minimum number of papers published is 5 and the minimum number of citations is 20. Of the 357 sources identified from the search process, 27 journals met these thresholds. Figure 3 displays the various journal clusters, with an indication of their sources and interrelationships. The connection lines represent mutual citations between the journals within a cluster and inter-cluster connections. The node and font sizes reflect the numbers of publications accrued to the respective journals: a larger node and a bigger font size indicate a larger number of journal publications and vice versa. Different clusters are represented by different colors and the connection lines are a function of the relationship or closeness between journals concerning mutual citations. This can be seen in figure 3.

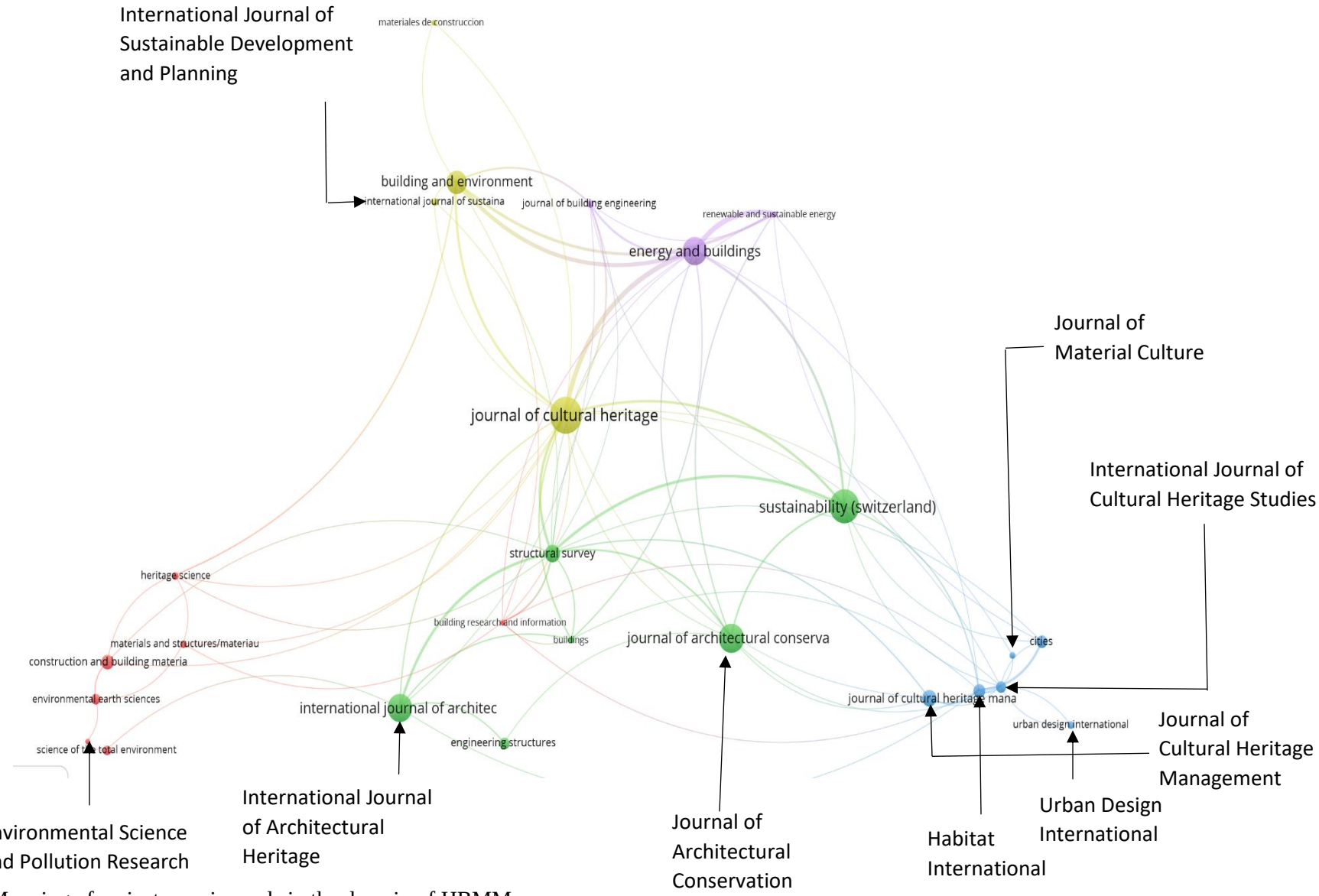


Figure 3: Mapping of mainstream journals in the domain of HBMM

Figure 3 shows that the *Journal of Cultural Heritage*, with the largest node and font size, is the most prominent in terms of research publications in the HBMM domain. With a multidisciplinary scope, the journal covers fields such as safeguarding and conservation of cultural heritage, and heritage management and economic analysis, which match with the focus of this study. Interested in papers that present multidisciplinary research and/or deal with issues of wide/global interest, the journal publishes review papers presenting an up-to-date "state of the art" of specific topics - a kind that the current paper belongs to.

Taking a closer examination of the publication sources, five measurement indicators were computed, as summarized in Table 1: number of publications, total link strength, total citation, average citation, and average normalized citation. "Number of publications" represents the total number of articles published by a journal within a specified period, which is a year (for this study). "Total link strength" indicates the connections between journals based on clusters and mutual citations: the thicker the connection lines between journal nodes, the higher their link strength, and vice versa. "Total citation" represents the total number of times an article in a journal was cited as a reference in another article, and this is also an indication of scientific impact. "Average citation" represents the average number of citations received by an article in which a keyword or a term occurs, or the average number of citations received by the article published by the respective source. "Average normalized citation" is calculated by dividing the total number of citations by the average number of citations per year. The normalization corrects the misinterpretation that older documents gain more time to receive citations than more recent publications [148]. Note that the average normalized citation measurement may not have a significant relationship with the number of publications and the number of citation measurements of a given journal. A journal may rank higher in terms of the number of publications and total citations but may rank lower according to average normalized citation; this does not mean that the journal has a lower influence.

Table 1 Quantitative measurements of journals publishing HBMM research

Source	Number of publications	Total link strength	Total citation	Average citation	Average normalized citation
Journal of Cultural Heritage	43	48	740	17.21	1.98
Sustainability (Switzerland)	38	25	154	4.05	1.04
Energy and Buildings	31	55	704	22.71	2.31
Journal of Architectural Conservation	32	14	99	3.09	0.26
International Journal of Architectural Heritage	31	15	264	8.52	1.32
Building and Environment	25	29	693	27.72	2.71
Structural Survey	17	35	317	18.65	1.21
Journal of Cultural Heritage Management and Sustainable development	16	8	28	1.75	0.32
Construction and Building Materials	14	5	176	12.57	1.68
Habitat International	13	17	227	17.46	1.68
Cities	12	9	175	14.58	1.63
Engineering Structures	11	3	131	11.91	1.61
Environmental Earth Sciences	10	4	82	8.20	0.84
Science of The Total Environment	9	2	283	31.44	2.13
International Journal of Sustainable development and planning	7	3	21	3.00	0.64
Journal of Building Engineering	7	14	122	17.43	2.28
Urban Design International	7	2	64	9.14	0.76
Heritage Science	7	6	35	5.00	1.11
Material and Structure/ Materiaux et Constructions	7	4	145	20.71	1.77
Buildings	6	11	31	5.17	1.24
Journal of Material Culture	6	2	54	9.00	1.00
Building Research and Information	5	10	40	8.00	1.46
Materials de Construccion	5	2	70	14.00	0.99
Renewable and Sustainable Energy Reviews	5	27	110	17.98	3.60

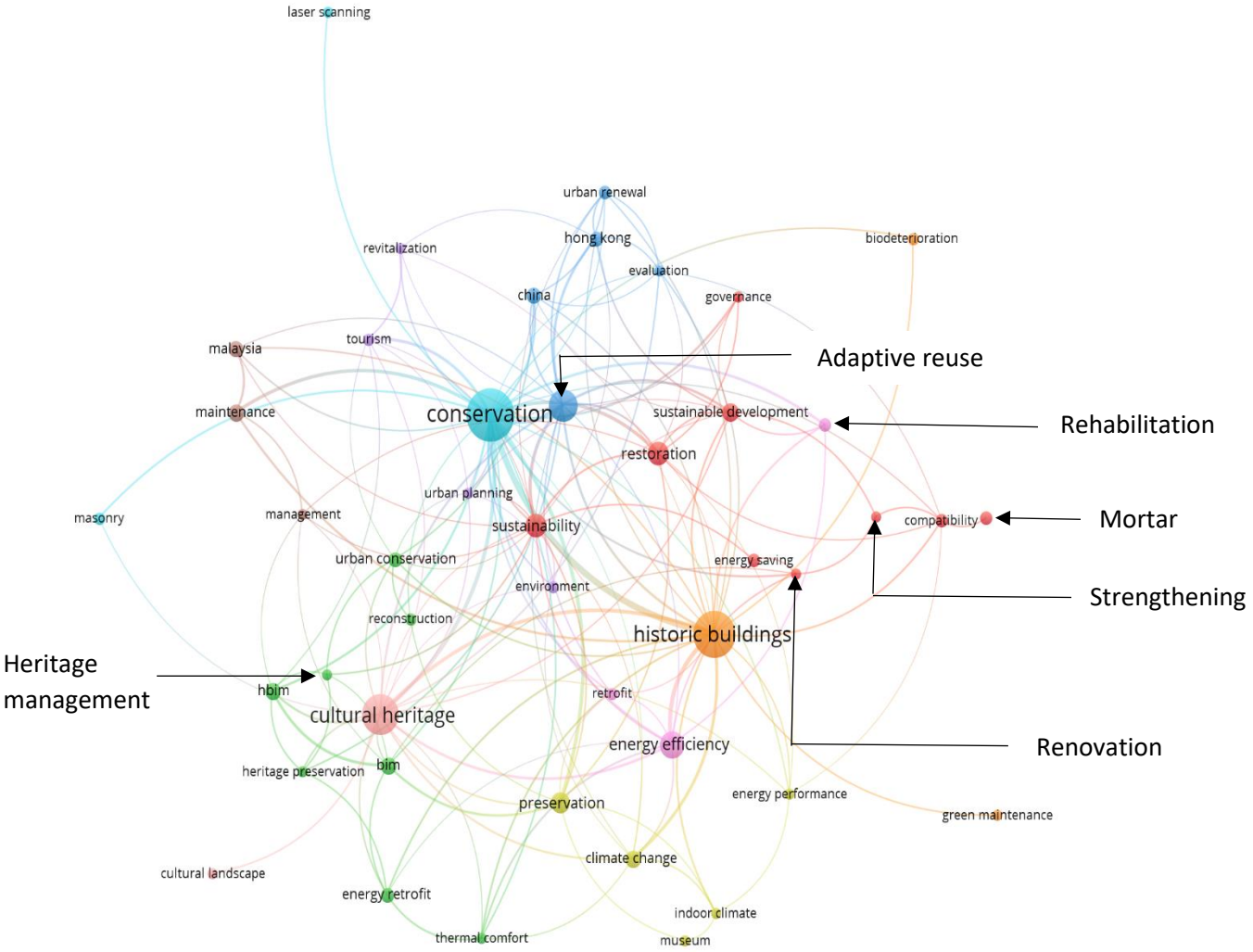
Some journals, such as *Sustainability (Switzerland)* and *Journal of Architectural Conservation*, were found with a high number of publications but a small number in the average citation or average normalized citation. The low citation of these journals could be due to their scope, relatively short history, or a small number of articles published per year. For instance, the scope of *Sustainability (Switzerland)* broadly covers sustainable issues, not confined to the sustainability of HB. On the other hand, *Building and Environment* were found with fewer publications but high total citation, high average citation, and high average normalized citation. Other journals with a similar performance include *Science of the Total Environment* and *Habitat International*.

3.4 Co-occurrence of keywords

To explore and provide a knowledge base of the contents covered in articles associated with HBMM, an analysis of keywords occurrence was conducted using VOSviewer. Keywords give an understanding of the main ideas and focus of research content [73]; a link of keywords represents knowledge among their relationships and intellectual organization of the research domain [147]. In line with the widely accepted suggestions [78, 116, 140, 147], "Author Keywords" and "Fractional Counting" were used for keyword analysis in VOSViewer. "Author Keywords" are lists of words given by authors, giving insight into the central focus of the study reported in the respective publications [140]. "Fractional Counting", as opposed to full counting, is used to reduce the influence of documents with many authors. When it is applied, the strength of a co-authorship link between two authors is determined not only by the number of documents co-authored by the authors but also by the total number of authors of each of the co-authored documents. When an author has co-authored a document with *n* other authors, this yields a strength of 1 / *n* for each of the *n* co-authorship links. The total strength of the *n* co-authorship links equals 1.

The keywords taken for analysis were derived from the articles filtered in the above literature search process. The minimum occurrence of keywords was set at 5, which is the default setting of the analysis software. Of the 2751 keywords analyzed, 85 met the threshold and they were further filtered for removing some words that have the same semantic meaning or some words that have their singular and plural words appearing as keywords. Keywords like "historic buildings" and "heritage buildings" with the same semantic meaning were removed, with only one of the similar words retained. And keywords such as "stone" and "lime", which are not relevant to the study, were deleted. After the analysis, a total of 45 keywords were shortlisted, with different clusters shown in different colours (Figure 4).

249


laser scanning
urban renewal
hong kong
revitalization
biodeterioration
evaluation
china
governance
tourism
malaysia
Adaptive reuse
maintenance
conservation
sustainable development
Rehabilitation
restoration
urban planning
masonry
management
sustainability
compatibility
Mortar
urban conservation
energy saving
environment
Strengthening
reconstruction
historic buildings
Heritage management
hbim
retrofit
cultural heritage
energy efficiency
Renovation
heritage preservation
bim
energy performance
preservation
green maintenance
climate change
cultural landscape
energy retrofit
indoor climate
thermal comfort
museum
VOSviewer

250

Figure 4. Co-occurrence of keywords in HBMM research

The frequency of occurrence of the keywords is reflected by the size of their nodes. Keywords with stronger links between each other are connected by thicker lines. The clusters of keywords were categorized based on the areas of focus of the articles reviewed. For instance, articles that focus on maintenance practices and decision-making for HB maintenance were grouped. Thus, three main clusters, as discussed below, were identified:

a. *Heritage governance and decision making*

Decision-making is one focus of research in HBMM. The maintenance of HB has been limited due to a lack of reliable decision-making tools [125]. Many authors have employed Multi-Criteria Decision Making (MCDM) and Artificial Intelligence (AI) to guide decision-making as such techniques are believed to be more accurate and less biased than decisions made solely based on human knowledge (e.g. experience). MCDM tools used to enhance decision making include the Analytic Hierarchy Process (AHP), Step-Wise Weights Assessment Ratio Analysis (SWARA), and Weight Aggregated Sum Product Assessment-Single-Valued Neutrosophic Set (WASPAS-SVNS) methods for making contractor selection decisions (Morkunaite et al., 2019); AHP for adaptive reuse decision making [77]; and AHP and Evamix for making conservation decisions [123]. AI tools used for decision making in HB management, for example, are Fuzzy Logic [124], and Genetic Algorithm [47].

Some studies have been conducted on the role of governance and public decision-making in HB management [45,129,156]. To achieve a better decision-making system, factors that influence decision-making in maintenance have been studied [61]. As maintenance practices adopted in HB management is dependent on multiple stakeholders involved, some studies investigated HB maintenance from the perspectives of different stakeholders: owners [157], managers [68], users [117], professionals [158], and the general public [156]. However, studies of [30, 60] show that despite the clamour to practice good maintenance culture, some HB buildings remain in a deplorable physical state.

b. *Heritage and sustainability*

Studies have revealed that there is a link between HBMM and sustainability. In particular, [58] highlighted the challenges and solutions for retaining historic centres to enhance sustainability. Instrumental in reducing the impact of climate change on the environment, proper management of HB can be achieved through various means, such as retrofitting strategies for achieving energy efficiency [5, 47,109], building refurbishment, and sustainable designs [87], refurbishment as a means of reducing greenhouse gas (GHG) emissions [67], retrofitting [115], and adaptive reuse [77].

c. *New technologies for HBMM*

New research directions are being geared towards taking advantage of new technologies to optimize HB maintenance and usage. [26] recommended the use of Heritage Building Information Modelling (HBIM) for decision making on material selection. Similarly, [82,150] emphasized the importance of HBIM in heritage conservation. Other applications of technology to HBMM include the use of

Structural Health Monitor (SHM) to monitor maintenance work [131], and wireless sensors to monitor building damage [102].

More quantitative measurements of the keywords analyzed are summarised in Table 2. “Occurrence” represents the number of documents in which keywords have occurred in the selected HBMM publications. “Total link strength” indicates the interrelationship between keywords in different articles. “Average year published” indicates the average publication year of the article in which a keyword appeared, published by the respective source. “Average citation” represents the number of citations received by the documents in which a keyword occurred. “Average normalized citation” is calculated by dividing the total number of citations by the average number of citations per year.

Keywords	Occurrence	Total link strength	Average year published	Average citation	Average normalized citation
Conservation	113	77	2014	5.71	0.96
Historic buildings	91	58	2014	10.07	1.37
Cultural heritage	68	33	2015	12.69	1.78
Adaptive reuse	42	35	2015	8.95	0.9
Energy efficiency	30	21	2016	9.27	1.93
Sustainability	24	19	2014	9.08	0.96
Restoration	22	15	2013	3.68	0.56
Preservation	19	12	2015	3.21	0.34
Historic preservation	14	7	2012	8.43	2.72
Sustainable development	14	14	2015	18.21	1.87
HBIM	13	8	2018	4.69	1.17
BIM	12	9	2018	3.00	1.00
Urban regeneration	13	7	2012	11.46	1.26
Maintenance	12	10	2013	8.42	1.07
Climate change	12	9	2016	11.5	1.18
Malaysia	11	7	2014	4.73	0.40
China	11	8	2013	10.82	0.97
Urban conservation	10	6	2009	13.50	1.06
Refurbishment	10	8	2017	5.50	1.29
Hong Kong	10	8	2014	18.40	1.74
Energy retrofit	9	4	2018	13.33	4.36
Rehabilitation	8	6	2012	6.75	0.60
Urban renewal	8	7	2013	10.12	1.20
Compatibility	8	5	2013	12.38	0.88
Energy saving	8	4	2016	20.88	2.14
Retrofit	7	5	2016	15.57	1.64
Biodeterioration	7	2	2015	12.00	1.14
Reconstruction	7	3	2015	5.29	0.35
Environment	7	4	2014	4.86	0.69
Masonry	7	3	2013	15.71	1.67
Tourism	7	7	2008	8.86	0.67
Evaluation	6	5	2013	9.33	1.24
Renovation	6	5	2015	2.00	0.39
Laser scanning	6	2	2016	7.83	0.77
Cultural landscape	6	2	2013	2.33	0.28
Governance	6	6	2016	3.67	0.43
Heritage management	6	4	2016	2.67	0.59
Museum	6	5	2016	8.33	0.94
Thermal comfort	6	6	2018	3.00	3.04

Urban planning	6	5	2011	7.00	0.46
Revitalization	6	5	2009	6.50	0.48
Strengthening	5	3	2014	1.40	0.17
Management	5	3	2016	4.60	1.16
Indoor climate	5	4	2015	16.00	1.62
Earthquake	5	5	2014	5.40	0.68

The most frequently-found keywords based on average citation are: “energy-saving”, “Hong Kong”, “sustainable development”, “retrofit”, “reuse”, “built heritage”, “China”, “urban conservation”, “urban renewal”, implying that they received more attention in the domain of HBMM. The analysis also showed the existence of a strong link strength between these keywords. On this basis, HBMM can be regarded as important for achieving sustainability of the built environment through energy saving, adaptive reuse, retrofit, and conservation. Researchers in places such as China, Hong Kong, and Malaysia have been active in this research domain.

“Average year published” is an indication of the recent attention given to the keywords in the field of HBMM. Based on this indicator, it can be deduced that studies focusing on HB sustainability and maintenance management were largely published from 2014 upwards. This attention gained by HBs may be due to the need to have sustainable cities and communities as indicated in the United Nations (UN) Sustainable Development Goals (SDG). The analysis also shows that studies related to HBIM, climate change, energy retrofit, laser scanning, and biodeterioration were published between 2015 and 2018, which indicates that research in these areas has become popular and they have more ground to be explored.

There are cases where keywords with high occurrences did not receive have high citations. For instance, “sustainable development” had a relatively high average citation of 18.21 but only a moderate occurrence of 14. This high average citation could be because studies with such keywords were conducted in earlier years.

3.5 Scientific collaboration networks in HBMM (Co-authorship analysis)

Figure 5: Co-authorship analysis

The information on the existing scientific and academic collaboration connections within a research sphere increases expertise, specialties, and funding access and increases productivity [51, 53]. This may resultantly motivate research collaborations among scholars, increase communications and yield better research outputs. [78] asserted that co-authorship symbolizes the roadmap of academic teamwork and as such lack of scientific collaboration may be a signal of lower research output. Hence, co-authorship is evidence of research productivity. In cognizance of this, it is important to investigate the co-authorship network in the research domain of HBMM.

This analysis was conducted using the VOSViewer. The threshold limit for the number of documents of an author and citations were both set at '5'. 16 authors met the threshold as visualized in figure 5. The nodes are colored based on researchers' network links. Three sets of collaboration links can be seen, Yung and Chan with a link strength of 10; Henriques, F.M.A and Silvia, H.E, with a link strength of 5 and the largest cluster comprise of four authors; Alejandre F.J., Marcias, J.M., Prieto A.J, and Silva, A. These authors have the strongest network of all the authors in HBMM, with a total link strength of 16. The distance and connectivity among researchers further represent their influence on each other [145]. For instance, Yung, E.H.K, and Chan, E.H.W, are close to each other, indicating the strength of their connection, which is also evident in their research output. Of all the collaboration links, the authors produced 10 documents which is the highest number of documents produced in the analysis. This further buttresses the point that research collaborations enhance productivity. However, it is important to note that the overall network of collaborations of researchers in the HBMM domain, is relatively low and as such signals the need for authors to engage in teamwork to address the salient issues in HBMM. Table 3 also shows the top research scholars in HBMM

Table 3

Prominent researchers in HBMM

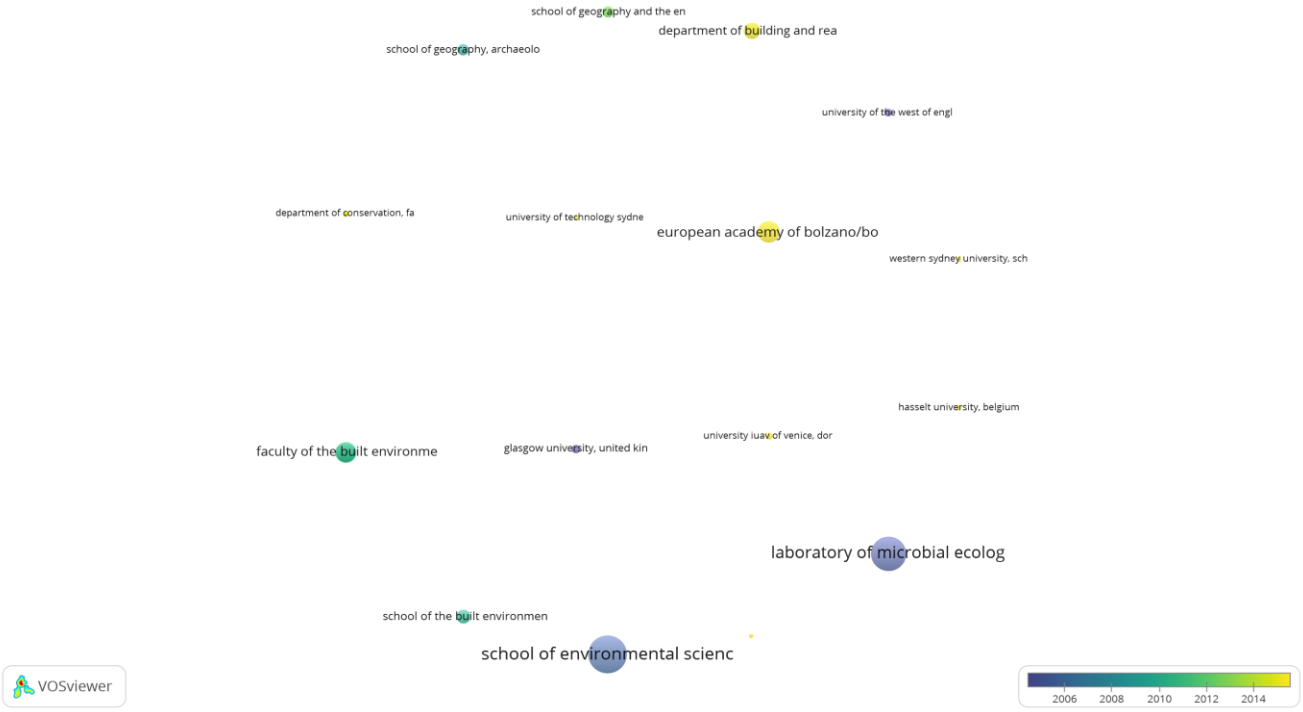
Authors	No. of Publications	Citations	Total link strength	Avg. Publication year
Yung, E.H. K	13	236	10	2014
Chan, E.H. W	12	235	10	2014
Forster A.M	8	141	0	2012
Lourenco, P. B	7	178	0	2013
Bonazza, A.	7	99	0	2013
Marcias-Bernaj, J.M	7	27	16	2018
Lucchi, E.	6	100	0	2016
Prieto, A.J.	6	26	10	2015
Ahmad, A.G.	6	18	0	2011
Fort, R.	5	83	0	2013
Henrique, F.M.	5	63	0	2016
Silva, H.E.	5	65	5	2016
Frazoni, E.	5	61	0	2015
Alejandre, F.J.	5	26	14	2017
Silva, A.	5	22	14	2018
Zhang, Y.	5	13	0	2017

3.6 Top Institutions in HBMM

Research collaboration among institutions is pertinent, as it aids research partnership and policy-making [53], thus it is important to identify the research collaborations of institutions having high investments and interest in HBMM. VOSViewer was used in the mapping of the institutions. The “minimum number of documents of an organization” and “minimum number of citations of an organization” were set at 2 and 10 respectively. 18 organizations met the threshold limit. Figure 6 shows the active institutions in HBMM research fields. The size of the nodes reflects the number of citations of the documents produced by the institutions. This implies that the larger the nodes, the higher the number of citations of the publications of the institution and vice versa. School of Environmental Sciences, University of East Anglia, UK has the largest node size with a citation of 159, Laboratory of microbial ecology, division of engineering and applied sciences, Harvard University has the second-highest citation of 140, and followed by European Academy of Bolanzo, Institute of renewable energy with 77 citations. It can be deduced from the analysis that the top institutions in the HBMM research domain are multi-disciplinary as it cuts across different disciplines such as applied sciences, computing and engineering, renewable energy, archaeology, conservation, building and real estate, and environmental sciences. This may signify that HBMM related issues have gained the attention of scholars from various scopes and as such contributions are made from different dimensions to enhance HB maintenance.

Based on the mapping results, it can be inferred that the institutions are faring well independently in terms of research output, however, there seem not to be any collaboration linkages among the research organizations. Hence, there is a need for researchers from different institutions to engage in a research partnership, as it fosters research productivity and enhances research output and quality.

375 Science mapping of institutions



376

377 Figure 6: Mapping of top institutions in HBMM research domain

378 Table 4

379 Top institutions in HBMM

Institution	No. of Publications	Total citations	Avg. Publication year	Norm. Citations
School of Environmental Sciences, University of East Anglia, UK	2	159	2006	7.46
Laboratory of microbial ecology, division of engineering and applied sciences, Harvard university	2	140	2005	7.85
European Academy of Bolanzo, Institute of renewable energy	2	77	2016	10.95
Faculty of built environment, University of Malaya, Malaysia	2	70	2010	3.65
Dept. of Building and Real Estate, Hong Kong Polytechnic University, Hong Kong	3	53	2014	4.84

380

381 3.7 Science mapping of Countries

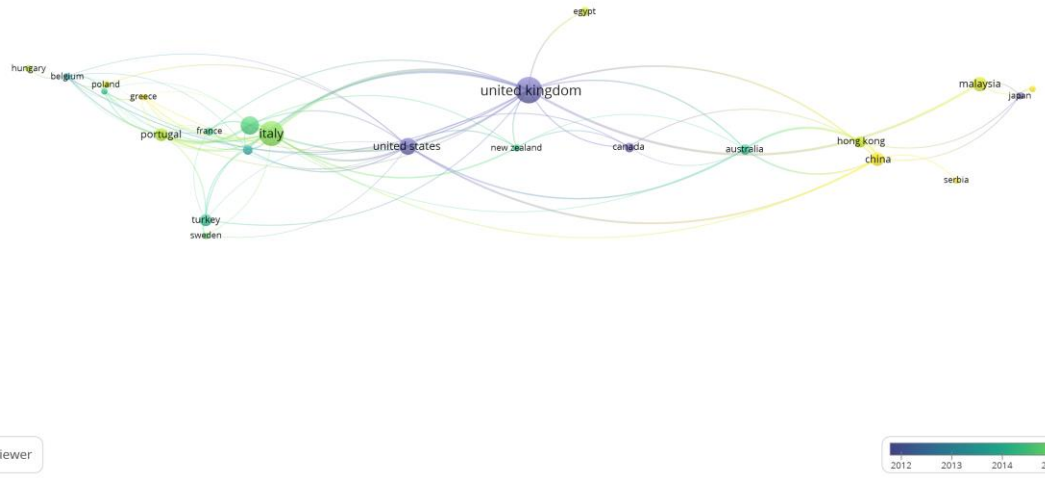
382 The information on prominent countries in a research domain may stimulate research collaborations,
383 access to grants, and study exchange among researchers [2,145]. Also, it helps to acknowledge diligent

384 countries in a research field. To identify, these countries, the VOSViewer was used for the analysis. The
385 "minimum number of documents of a country" and the "minimum number of citations of a country"
386 were both set at 10. 26 countries met the threshold limit. The result is shown in figure 7 below.

387 Based on the number of publications produced in a country, UK, Italy, and Spain ranked highest with
388 172, 153, and 80 publications respectively, implying that they are the largest contributors to HBMM
389 related research. This may be attributed to the high number of HBs within the country boundaries. Of
390 the three high-ranking countries, there exists linkage between UK – Italy, Spain – UK but the link
391 between Spain- Italy seems to be absent. Thus, research organizations in these active countries should
392 engage in policy formation and reformation to foster to encourage research partnerships and further
393 strengthen research output in the HBMM field.

394 About research linkages, UK has the highest link of 15, indicating it has collaborations with 15 other
395 countries (Italy, Germany, Turkey, Egypt, New Zealand, Canada, Malaysia, France, Portugal, Greece,
396 Netherlands, China, Spain, Belgium, and Australia). Afterward, Italy and the US with 13 and 12 links
397 respectively. Relating to the strength of links, the strongest links were among the paired countries;
398 France – Spain (21), UK – Italy (10.43), Hong Kong – China (7), UK- Malaysia (6). Other weak linkages
399 exist between US-China, Hungary- Belgium, Netherlands- Germany to mention a few. However, in
400 comparison to the total link strength of 129.5 in the network, there are limited strong links formed. This
401 may be in consequence of the insufficiency of cross-country benchmark studies in the existing HBMM
402 research field for findings and theories corroborations.

403 Concerning citations Italy has the highest number of citations which is 2253, even though it ranks
404 second in terms of document output. This may be because of the research outlet of the publication or
405 the scope and relevance of the document published. Also, emergent nations were inadequately
406 represented in the network analysis. This suggests the need to create platforms for researchers in these
407 regions to participate more actively in research collaborations to increase their visibility in the research
408 sphere. Figure 7 and 8 shows the visualization of top countries in HBMM research field and their
409 linkages, table 5 shows the contribution of countries based on publications.



410

411 Figure 7. Linkages of top countries in the HBMM research field.

412

413

414 Figure 8. Mapping of active countries in the HBMM research field.

415 Table 5

Top countries in the HBMM research domain

Countries	Documents	Total Link Strength	Citations	Links
UK	172	40	1740	15
Italy	153	36	2253	13
Spain	80	21	1087	10
US	73	19	638	12
Malaysia	53	8	218	3
China	45	20	240	7
Portugal	42	14	568	9
Turkey	37	7	257	7
Hong Kong	32	14	357	4
Germany	25	12	226	10

4. Discussions

This section provides in-depth discussions of the literature reviewed. The discussions are summarised by dividing mainstream research topics in HBMM into five broad categories concerning the research areas identified from the review, where each research area covers articles with a similar focus of the investigation.

4.1 Decision-making frameworks in HBMM

HBMM involves balancing the needs of various stakeholders' requirements to justify decisions regarding its maintenance options. Previous studies have noted the importance of cultural heritage as a driver and enabler of sustainable development [146]. However, its maintenance can be somewhat complicated due to numerous issues. The findings of [50] on the maintenance management of historic buildings, revealed issues related to decision making as a constraint to HBMM. A more robust study conducted by [154] on the problems of decision making in HB conservation in Hong Kong, identified problems such as lack of effective public participation mechanism and supportive government framework, inadequate knowledge for the public to evaluate historic buildings, and conflicts of interest from different stakeholders. [155] further explained that a large number of public administrations have abandoned underused HBs because of a lack of public resources or a lack of synergy on the importance of HBs among stakeholders. This has prompted researchers [98,146,149] to focus on proposing decision-making models that guide the selection of appropriate maintenance options and reduce bias that may be resulted from subjective judgments of stakeholders.

In the work undertaken by [55], it was recommended that MCDM methods should be applied in decision making regarding the grading of heritage sites as the methods provide a more transparent approach to minimizing disputes that could arise between policymakers and stakeholders. In the study of [70], the Analytic Hierarchy Process (AHP) - an MCDM tool – was utilized to guide decision making in selecting the most suitable reuse option for HBs in Egypt, and the result showed that the AHP method, when compared with human judgment, enables less biased decisions to be made. Some other research studies that have adopted MCDM tools in decision making in the HB research domain include [123,130].

[64] explained that an appropriate regulatory framework is necessary for the maintenance of HBs and advised that a methodological framework should be formulated jointly by various experts in the field of

HB conservation. Having identified the lack of an information database that hinders effective maintenance decisions, [80] developed a maintenance index framework to support decision making in the diagnosis of HB maintenance through building a robust database. Given that a simple and accurate method of estimating HB maintenance cost is essential for making a realistic maintenance budget and develop good financial maintenance plans, [98] developed a model that could help custodians and owners of heritage buildings to forecast maintenance costs easily and accurately, make realistic maintenance budgets, and develop a good financial plan for managing the maintenance works of their buildings.

A review study on the use of MCDM in HB decision making [107], however, revealed that despite the wide usage of MCDM in other areas, its application in HBMM was still limited. The main areas of its applications in the HB domain are selecting appropriate reuse alternatives, material selection, and appropriate refurbishment, among others. Other decision-making frameworks that have been proposed in the HBMM research areas include: monitoring HBs and digitization of structural information [112], investment decision for HBs [113], location decision [121], budget allocation [122], and best use selection [130]. To take advantage of technological advancement, Artificial Intelligence (AI) has also been adopted by some scholars as a tool to support decision-making in HBMM. Notable tools of this kind include Fuzzy Logic [124] and Genetic algorithms [47, 122]. In any case, decisions on HBMM need to be more transparent; hence, it is necessary to carry out more studies in this aspect.

4.2 Integration of digital technologies and HBMM

HBs are usually buildings that have existed for a long time. Due to the old nature of these buildings, there is a need to employ innovative ways to preserve them for optimum utilization. [1] suggested that the use of modern technology through the introduction of sophisticated elements that were not present at the time of initial construction (e.g. smart system technology and building management system) would contribute significantly to the sustainable reutilization of HBs, thereby ensuring their survival.

HBIM is a concept that has been widely used and globally accepted in HBMM [10]. As a means of preserving and maintaining the HB stock [9, 37, 56], HBIM is a process involving data capture, modeling, or simulation of building elements and subsequent communication of information to relevant stakeholders – all in all aiming at the efficient management of a historic building [99]. [82] proposed HBIM as a virtual model that would hold HB data to foster better management, with a simple and visual HBIM protocol developed and applied in a real case study. The protocol, named BIMlegacy, is divided into eight phases: building registration, determine intervention options, develop the intervention design, planning the physical intervention, physical intervention, handover, maintenance, and culture dissemination. Similarly, [150] developed a BIM-based asset management framework for heritage renovation projects, which comprises five key areas: value, significance, recording, data management, and asset management. This framework provides an overlay that could be used by practitioners and researchers to ensure that HBIM is fully exploited and a more standardized method is utilized in conservation heritage renovation projects.

The benefit of applying HBIM to HBMM has been demonstrated in practice. In applying HBIM to preserve historic buildings in Italy, [119] demonstrated the relevance of HBIM in heritage conservation by developing an information database using advanced visualization techniques based on augmented and virtual reality (AR and VR). Hence management decisions can be more accurate when relevant information is preserved. In another study, [63] revealed that technological solutions can be developed to convert HBIM into models suitable for portable devices, enabling Visual Tours (VT), Augmented Reality (AR) applications, and architectural heritage maintenance applications. While acknowledging the need for the adoption of technology for effective management of HBs, [99] highlighted that the process is not

efficient. A possible reason for this is the lack of technical know-how of HB maintenance practitioners on the application of technology to improve HBMM. In the same vein, [10] mentioned that its adoption within the Malaysian construction industry is relatively low due to the complexities associated with its use. Deducing on this basis, maintenance teams have yet to fully adopt HBIM in HBMM.

Geographic information system (GIS) is another technological advancement that has been incorporated into the domain of HBMM. For the assessment of neglect in the historic built environment, [114] developed a GIS-based framework. Also, [111] conducted a study that led to the development of an open-source GIS-based heritage site inventory and management system, which can facilitate better decision-making by heritage management officials. Laser scanning is another technological tool that has been employed in the field of HBMM. It has been used in creating a 3D navigation system for evacuation strategies during an emergency [75], HB cleaning [65], scanning for defects [74], and information sourcing [110].

4.3 Condition assessment and maintenance practice

Although the importance of maintaining HBs has been highlighted, a large number of HBs are still in poor physical condition [71]. [118] assessed the condition of wooden HBs and identified extensive degradation with most of the wood. In the study of [135], an assessment of traditional HB structures revealed that although most of the buildings were in fair physical condition, they were not well maintained, in need of repair works. A possible cause for this is related to the maintenance management strategy adopted or other factors in the economic, social, or environmental aspects that influence HBMM.

[60] asserted that ineffective maintenance strategies in organizations and financing often hamper efficient maintenance implementation. This often has a bearing on the physical conditions of buildings. As Lai (2010) revealed, ill budgets often arise from lack of proper operation and maintenance information, over-reliance on historical budget, and fear of underestimation of budgets. This indicates that apart from inadequate maintenance funding, improper budgeting techniques could hinder appropriate maintenance.

In Malaysia, [138] conducted a study on the maintenance management challenges of HBs. The study revealed that the maintenance team adopted a reactive maintenance approach. Other factors such as irregular inspections and lack of an existing database on maintenance records contributed to the poor conditions of the HBs. These findings were corroborated by [157], where factors that influence the maintenance of HBs, including limited finance, absence of maintenance guidelines, and ill-defined policies, were also identified.

To achieve better maintenance for HBs, various techniques have been proposed to enhance the assessment of the buildings. For instance, [127] developed an expert system for predicting the service life of buildings - Fuzzy Building Service Life (FBSL) – a process for evaluating and analyzing vulnerability and defects in HBs. In a more recent study, [106] proposed the use of unmanned aerial vehicles (UAVs), which enables more accurate results than manual observation, to assess the conditions of HBs.

Whereas efforts to promote and develop best practice maintenance systems for historic building conservation appeared to be wanting [49], there remains a gap between the current and best practices in maintenance for HBs. There is a need for more studies on the relationship between maintenance practice and condition assessment for HBs.

4.4 Sustainability and HBMM

Extant studies have shown the relationship between HBMM and sustainability [11, 36, 46]. Sustainability in HBMM can be achieved through several ways, which include adaptive reuse, refurbishment, and building retrofitting for energy savings. [46] asserted that adaptive reuse of buildings is significant in promoting sustainability in the built environment. The authors, additionally, explained that meeting the current needs of existing buildings and ensuring future adaptivity of new buildings contribute to global climate protection and emission reduction. These submissions align with the assertion of [8]: adaptive reuse of HBs can conform to requirements on indoor environmental conditions. Yet, [8] pointed out that the uses of natural light, natural ventilation, recycled materials have been neglected; instead, they should be prioritized to ensure a successful change of use. Other studies that highlighted the achievement of better indoor thermal comfort through the reuse of HBs include [19, 20].

For the successful implementation of adaptive building reuse, it is necessary to align the needs of various stakeholders. To address this, [35] conducted a robust study on assessing urban regeneration proposals by considering conflicting values; the evaluation process was structured combining different methodologies to address the need of various stakeholders from different pillars of sustainability (social, cultural, environmental, and economic). Further to explaining the need to develop an effective decision strategy to make choices on reuse decisions based on sustainability, [54] revealed that achieving sustainability is not a static process; instead, it is case dependent, relying on the primary characteristics of the buildings which determine the criterion that influences adaptive reuse. [83] developed a framework to guide the decision-making of sustainable preservation of modern built heritage using Life Cycle Assessment (LCA). The framework is meant to be beneficial in making a strategic decision in urban areas, making a nexus between preservation and environmental components of sustainability.

Other studies have also highlighted the benefits that can be achieved through the sustainable reuse of HBs. Such benefits include economic sustainability [86], environmental sustainability [97], real estate development [90], and tourism development [128]. However, [92] emphasized the need to develop a more socially sustainable future for cultural capital by integrating the notion of the cultural landscape with heritage conservation. While the benefits of achieving sustainability in HB management through adaptive reuse have been established in the literature, some barriers hinder its successful implementation. Such barriers include the inability to meet regulatory compliance, current design requirements [45], and technical barriers [153].

Energy-saving and retrofitting belong to an aspect that has caught the attention of many scholars in the pursuit of sustainability in HBMM [4]. The sustainability and efficiency of buildings represent a crucial issue since the building sector is responsible for more than 40% of energy consumption and hence carbon emissions. This concern is extended to HBs, as they have typically low-performance constructions, usually equipped with ineffective systems [13, 18, 36]. Also, [88] emphasized the need for maintenance practitioners to enrich their knowledge of operations and maintenance through attending continuing professional development (CPD) programs. The knowledge gained would help in achieving best practices towards improving sustainability, especially energy efficiency, of buildings.

Some studies have highlighted strategies for achieving better energy-saving agendas in HBMM. [4] mentioned that baseline project planning, periodic update, monitoring, and managing energy use could greatly facilitate better energy optimization and sustainable reuse of HBs. [23], besides emphasizing the importance of developing user-driven energy efficiency in historic buildings, proposed a bottom-up approach for energy refurbishment. The essence of the approach is that users and residents should play a key role in the decision-making process because the state of HBs depends on the activities of users and occupants.

Despite the increased efforts to reduce the energy consumption of the existing building stock, the HB sector still needs to improve its energy efficiency and reduce its greenhouse gas emissions [4]. Towards this goal, [36] developed an integrated approach for the preservation and energy upgrade of existing HBs by improving their energy performance and environmental quality while protecting their heritage value. The study proposed a Green Building Council (GBC) historic building rating system for evaluating the sustainability level of conservation of related activities in HBs. Similarly, [48] proposed a decision-making framework based on a cost-benefit analysis for preventive retrofit sustainability.

Achieving energy saving in HBs through retrofits usually encounter challenges. As [12] identified, the challenges to achieving energy efficiency in the reuse of existing buildings include: lack of understanding and implementation of building energy codes by officials, difficulty in managing interdependencies among the national policy of objective of energy efficiency, ubiquitous local planning objectives of downtown revitalization, and bureaucratic challenges of regulatory constructions in existing buildings. It was suggested that planners should bring code officials into adaptive reuse projects early. Furthermore, [13] asserted that the need to preserve cultural and architectural values poses challenges to retrofitting for HBs. [14] also opined that the selection of energy measures is a multi-objective optimization problem in HBMM. From the above discussions, it can be deduced that incorporating sustainable practices in HBMM is of utmost importance. Therefore, there is a need for practitioners, regulatory bodies, building users, and researchers to maintain a synergy to combat factors militating against sustainable use of HBs.

4.5 Emerging research trends in HBMM

Some new research areas have been identified in this review, and one of which is the introduction of modern strategic approaches to HBMM. [27], in advocating the concept of incorporating facilities management (FM) into HB maintenance, developed a framework for Cultural Heritage Management (CHM) that integrates the FM components (people, place process, and technology) in conserving HBs. A recent study by [79] further established that the role of FM in coordinating Heritage Building Revitalisation (HBR) projects is beneficial to stakeholders and the community at large, as the involvement of FM enables efficient decision making, creative facilities design, and effective public management.

[59] introduced the concept of "green" maintenance in HBMM. With maintenance identified as a mechanism through which carbon savings can be achieved, the study proposed a model for evaluating the efficacy of maintenance interventions. The model represents a framework for the selection of maintenance interventions about cost, philosophy, and carbon emissions. In this connection, [84] proposed a "Green Maintenance Model", using LCA to select repair options in HBMM. This model shows that the environmental maintenance impact generated from repair options relays the truly embodied carbon expenditure contextualized within the longevity of repair and its embodied carbon, thus enabling a rational appraisal of the repair option.

Incorporating inclusiveness into HBMM has also been a focus of research in recent years. [87] emphasized the need for sustainable designs in HB refurbishment to be more inclusive by giving preference to People with Disability (PwD). They mentioned the need for more research in this area as relevant literature was limited. [134] also asserted the need to have dementia-friendly HBs. Other emerging areas where only a paucity of studies have been conducted in the HBMM domain are sustainability education in HB management [93], business model development for HB management [28], and HB revitalization through a partnership [42]. As these research areas have not been fully explored, there is a need for more extensive studies to address the knowledge gaps there.

4.6 Recommended research directions

Based on the foregoing scientometric analysis and qualitative review of the literature, a framework consolidating the current research areas and the recommended future directions for HBMM is developed, as shown in Figure 9. Future research directions were suggested for bridging the research gaps identified in the review. Elaborations of the five research directions are as follows:

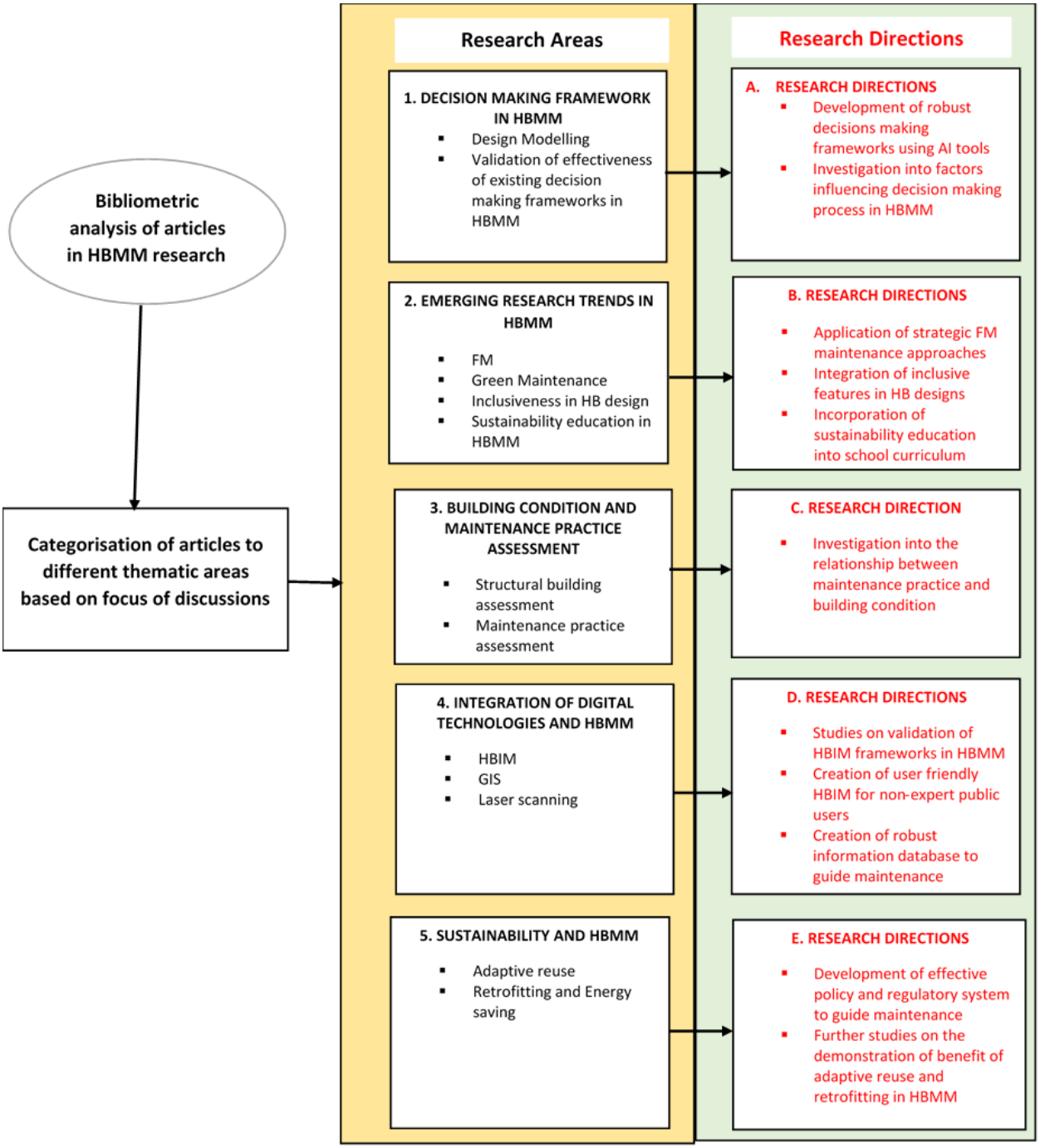


Figure 9. A framework of research directions for HBMM

a. According to Elements 1 and A, appropriate decision-making frameworks for HBMM should be further developed to incorporate stakeholders' concerns [55]. Decision-makers are often left making value-laden judgments of what to preserve, restore, and maintain in their best judgments,

which can leave them open to criticism for not protecting the cultural resources most important to diverse stakeholder groups [57]. More studies on the use of MCDM tools [66] and AI tools [122,126] would help eliminate subjective judgment, facilitating a more objective decision-making process.

b. As per Elements 2 and B, there are emerging trends in the research domain of HBMM that have not been sufficiently addressed in the literature. They include FM [79], Green Maintenance [85], HB design inclusiveness [87], and Sustainability Education [93]. There is a need to plug the research loopholes in these areas.
c. Elements 3 and C show that some studies have been centred on condition assessment of HBs [24,30]. However, some HBs remain in a poor state of repairs [137]. There seems to be an existing gap between the maintenance strategies and conditions of HBs. Investigations into the relationship between maintenance practices and building conditions need to be conducted.
d. Elements 4 and B highlight that technology could aid the sustainability of HBs. The benefits of HBIM application in HBMM have been established in some studies [82, 99]. [63] advised that the heritage interpretation of HBIM information should be less complex to enable the non-expert public to better understand architectural assets and their history. Also, there is a need for optimizing HBIM processes for heritage diffusion and public use management. Identifying the most efficient way of collecting and processing data to achieve the best HBIM technical information for dissemination is necessary. Further research studies, therefore, need to be conducted in these directions. Moreover, the use of GIS is effective in data collection for restoration works in HBMM [41]. This further underlines the need to conduct more investigative studies on the application of technological tools such as GIS and laser scanning in HBMM.
e. As Elements 5 and C indicate, for HBs to remain in a good physical and functional state, it is essential to incorporate sustainable practices. Research has been able to establish a link between HBMM and sustainable development [4, 46]. Adaptive reuse of HBs has been recorded as one of the means through which sustainability can be achieved in HBMM [54]. As few studies have validated the benefit of adaptive reuse in practical scenarios [91, 156], there is a need for further research in this area. Also, retrofitting for energy saving is a way to incorporate sustainability in HBMM [132, 133], but its application is invariably hindered by architectural, cultural, legal, and regulatory requirements. Hence, there is a need for more empirical research findings to justify that the architectural and cultural values of HBs can be preserved while achieving energy efficiency.

5. Conclusions

In this review study of HBMM, a holistic approach incorporating bibliometric literature search, scientometric analysis, and in-depth qualitative review of publications was conducted. A total of 944 journal articles published from 2000 to 2020 were selected for review. The growing trend of research in the HBMM domain is reflected by the increasing number of publications; in particular, the scientometric analysis revealed the following:

i. Influential journals that publications relatively large numbers of articles in the HBMM domain include: *Journal of Cultural Heritage*, *Sustainability (Switzerland*), *Energy and Building*, *Journal of Architectural Conservation*, and *International Journal of Architectural Heritage*.
ii. The main clusters of keywords of the reviewed articles lie in sustainability, energy efficiency, adaptive reuse, integrated technologies (e.g. HBIM, GIS), and decision making.

iii. The prominent scholars in the HBMM research field were identified apropos to their publications output and the collaboration links amongst them. Elicited from the analysis, Yung, E.H.K., and Chan, E.H.W have the highest number of publication output as well as the strongest collaboration link. However, Marcias-Bernaj, J.M, Silva, A., Alejandre, F.J, and Prieto, A.J have the largest collaboration links in the research domain.
iv. The top institutions or organizations leading in HBMM related research were also recognized based on publication output and impact. Of the 18 identified institutions, the School of Environmental Sciences, University of East Anglia has the highest number of citations on published documents.
v. The active countries in HBMM research were also pointed out, as it may be useful in elucidating the mainstream countries focused on the research area of HBMM. The top 3 countries leading in the research are publication based on publications output are UK, Italy, and Spain respectively, and
vi. The focuses of the reviewed articles can be categorized into heritage governance and decision making, heritage and sustainability, and new technologies for HBMM.

This study has also provided an in-depth analysis of the findings by summarising the key HBMM research areas into different categories: decision-making frameworks in HBMM, integration of digital technologies and HBMM, building conditions, and maintenance practice, sustainability and HBMM, and new technologies for HBMM. The research gaps identified are the application of a strategic maintenance approach to HBMM, investigating the relationship between maintenance practices and building conditions, inclusiveness in HB design, and incorporating sustainability education in the school curriculum. Based on these findings, a significant outcome is the establishment of a framework of future research directions for the betterment of HBMM.

The findings from this study have both theoretical and practical implications that may serve as a reference to practitioners, academics, and HB stakeholders in identifying ways to improve HBMM towards achieving sustainable use. Findings reveal that some research areas regarding maintenance management practices and approaches are yet to be fully explored. For example, the application of FM to HBMM has been identified as helpful to achieving sustainable use of HBs; however, FM practitioners still encounter challenges militating effective delivery of their duties. As such, more research needs to be focused in this direction to help identify the salient issues in HBMM and solutions for the issues. This is needful as the maintenance management approach adopted has a resultant effect on building performance, organizational performance, and maintenance programs. Focusing attention on the suggested research directions would help bridge the research gaps while illuminating the identified grey areas.

The research findings suggested the need to channel research focus on the application of strategic maintenance approaches to improve HBMM practices. As such, it is important to conduct studies on performance evaluation of maintenance practices in HBMM. This may be achieved through the identification of key performance indicators (KPIs) and critical success factors (CSFs) pertaining to HBs. This would help identify areas of improvement in maintenance practices and consequently enhance the functionality of HBs.

The importance of the usage of technological advancement to enhance building maintenance has been emphasized in the literature, thence its application in HBMM would be of immense benefit to ensuring optimum use of HBs. Thus, practitioners should make conscientious efforts towards

incorporating the use of technical tools and application of Information and Communication Technology (ICT) such as maintenance software tools to support maintenance procedures and processes. For instance, the use of technologies such as virtual reality (VR), photogrammetry, drones, GIS, and AI could assist in information gathering that may be useful for problem diagnostics and solution suggestions in HBMM. This may help improve productivity, problem-solving, and decision-making processes. Thus, it is suggested that studies should be conducted in this direction to facilitate innovativeness in the maintenance of HBs.

The research findings from this study can assist HB stakeholders such as governments in policy formulation - by identifying the areas of HBMM that can be strengthened through effective legislations. This would facilitate the protection and sustainable maintenance of HBs. However, the policies must be flexible and unambiguous to meet varying needs of the circumstances. Actions should also be put in place to facilitate the enforcement of such policies.

HBMM may also be improved through Public-Private Partnership (PPP) schemes; thus policies should be established to promote such participation. For instance, the provision of tax rebates, incentives, subsidies for HB maintenance-related activities may encourage PPP in HBMM, and resultantly improve maintenance conditions of HBs. Also, the economic, socio-cultural, and environmental potentials of HBs would be harnessed.

The level of knowledge and skills of HB maintenance personnel is vital towards achieving successful HBMM. Hence, professionals in the HB maintenance sector should be encouraged to participate in training programs to upskill themselves towards addressing the specific needs of HBMM. Efforts, too, should be geared towards increasing the number of training institutions to provide adequate training for HB maintenance practitioners. This is essential as the input of skilled practitioners would facilitate sound maintenance decisions and improved maintenance management practices. The academia should make efforts to include heritage education programs in the school curriculum, as this would foster heritage appreciation and maintenance consciousness among the youths, as some of them may eventually become future HB maintenance professionals.

To reduce the rate of abandonment and underutilization of HBs, adaptive reuse and revitalization of HBs should be encouraged. This would enhance the effective and efficient use of HBs. Where such projects are embarked upon, professionals need to take cognizance of ways in which inclusiveness can be incorporated into HB design to address the demands of individuals with special needs. For instance, making provisions for inclusive features such as ramps, elevators, braille, accessible and restrooms would improve the functionality of the buildings for people with disabilities.

The research reveals that there are weak collaboration links among researchers, institutions, and countries in the research domain of HBMM. Having emphasized the importance of research collaborations, it is essential for research institutions and funding agencies to create platforms and policies that would foster research partnerships among scholars. Also, researchers should be willing to partake in exchange programs to facilitate interdisciplinary research and collaborations. Focus group discussions should be encouraged among researchers and practitioners as it would synergize and channel research directions towards industry needs, leading to findings and innovations that would profer practicable solutions to challenges in the HBMM sector. Based on the foregoing, the issues in HBMM can be addressed through policy plan and enactment, training of HB maintenance personnel, use of technologies in maintenance practices, adaptive reuse, and strategic maintenance

approach to facilitate appropriate management of HBs. Thus, the outcome of this study can serve as a reference for researchers and practitioners in identifying a roadmap in the HBMM research domain.

Although this study has provided contributions to the body of knowledge in HBMM, it is not without limitations. First, the articles reviewed were only sourced from the Scopus database the keywords used in the search may have caused some limitations in the number of documents generated. Therefore, future studies may extend to review articles covered by other databases of literature and also increase the number of keywords inputted to cover a wider scope. Second, the literature sample of this study was confined to journal publications, which are oriented mainly from an academic research perspective; less emphasis has been placed on publications about the practical issues of the industry. Third, the usage of citations to conclude research output and productivity of scholars may be subject to criticism. Furthermore, the basis of parameter setting was based on the discretion of the researchers, which may affect the results generated based on the threshold set. Consequently, the constraints of this research should be considered when interpreting the results. Finally, this is a review study; the findings may require further validations with empirical studies to ascertain the implications of the research. Hence, to identify more clearly the prevalent maintenance practices among industry practitioners, the information should be elicited through, e.g., interviews, surveys, and case studies to probe the salient issues in the HBMM industry.

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Declaration of Competing Interest

The authors declare no conflict of interest

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