

# A Holistic and Systematic Assessment of Maintenance Approaches in Heritage Sites

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*Abstract:* - Maintenance approaches of heritage sites (MAHs) on heritage sites have become essential in both the industry and academia as construction projects grow increasingly complex. With a prime goal of increasing its productivity and safety, MAHs research has witnessed tremendous growth over the past three decades. With the increase in research grows the necessity to monitor the research growth of a research topic to identify its trends and gaps, and hence shed the light on research areas that warrant future research attention, there is a lack of systematic literature analysis in MAHs field. To fill this gap, this paper recruited a mixed-review method of scientometric and systematic reviews of research papers on MAHs published from 1990 to 2020 (as of mid of July). Its ultimate objective is to identify current trends, technologies, and techniques in the field of heritage site maintenance and layout their advantages and disadvantages. Additionally, country contributions are highlighted to identify which countries produce the most effective research in the field. Finally, the most cited articles are identified to highlight important topics in the selected time period. As a result, Journal of Destination Marketing & Management has the highest ranking across the different journals in the area of MAHs based on its number of published articles and their citations. In addition, the publisher Elsevier has the highest number of published articles with 58. Results also demonstrated that the collaboration between Ecuador and Spain accomplished the highest ranking, such that the strength link was estimated to be equal to 3. Moreover, the highest repetitive keywords were indicators with 20 times and cultural heritage cities with 19 times.

*Key-Words:* - Maintenance, heritage sites, architectural buildings, UNESCO, systematic review

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## 1 Introduction

World heritage sites are landmark pieces and strokes of genius that represent the story of humanity and the world we live in. It is essential that world heritage monuments and sites are kept protected and well maintained so that future generations can learn from their stories and be inspired by their wonder [1, 2]. Based on the UNESCO's classification of World Heritage, we have 3 main categories: (1) Natural, (2)

Cultural, and (3) Underwater Heritage. This article is mainly concerned with cultural heritage which is in turn divided into two main categories: (1) tangible and (2) intangible cultural heritage [3]. Tangible heritage represents the sites, monuments, and structures that were inherited from ancestors and have physical existence today, whereas the intangible cultural heritage represents the traditions and the habits that were inherited from ancestors and are

passed on throughout the generations [4, 5]. This article is mainly concerned with the maintenance techniques and approaches that help preserve tangible heritage sites in good conditions so that future generations may learn from them. Today, UNESCO has nearly 1200 world heritage sites inscribed by its state members. Figure 1 demonstrates the distribution of the inscribed sites per country. The graph shows that heritage sites are not localized and accordingly, human history is not localized. To keep those heritage sites serving their purpose, regular maintenance is required. The importance of regular maintenance lies in it being a pragmatic, cost-effective, practical, and sustainable approach for the preservation of heritage sites and buildings [6-9].

It is critical to differentiate between the acts of maintenance and repair. The concept of maintenance revolved around the medical idea of “prevention is better than the cure”. Therefore, prevention aims to create a set of regular or continuous practices that deter any failure that would require repair. In heritage buildings, maintenance is a set of routine check-ups, building analysis, and tests, which identify any harm before it becomes severe and allows taking small steps to remedy it. All those steps are taken while ensuring the integrity of the site. On the other hand, repair is extensive work to remedy existing or apparent damages. Repairs usually include the blocking of the site for example and are more costly than maintenance [8,10]. Due to the importance and benefits of maintenance, it is essential that maintenance be surveyed and mapped.

Based on analysis of previous review articles, it was observed that the literature lacks a research study which can look and synthesize the different current maintenance trends, technologies, and techniques in the field of heritage site maintenance as well as their advantages and disadvantages. In view of the above, this research study aims at the following objectives:

1. Survey the current state of the art in the field of heritage sites maintenance.
2. Provide an overview of the existing trends in the research field.
3. Provide an overview of the technologies and techniques that are used in the field and their advantages and limitations.

## 2 Methodology

In this section, research methodology on maintenance approaches of heritage sites indicated in order to provide future suggestion for researchers to study and evaluate the trends topics interims around the globe of maintenance of heritage sites. In

addition, researchers can be conducted more efficient and intensive research, a “mixed review method” is implemented in this research. In Figure 2, expressions a holistic framework of the research methodology. Hence, mixed review methodology comprises both quantitative (scientometric approach) and qualitative review (systematic approach) and therefore delivers the platform for the combination of the advantages of the two approaches. Moreover, in the next step mixed-review method has been acknowledged by many authors due to its ability to eliminate biased conclusion and subjective interpretation while providing an in-depth understanding of domain knowledge and research trends. In the systematic review research, using mixed-methods can be defined as combining the findings of qualitative and quantitative studies within a single systematic review to indicate the same overlapping or complementary review questions [11]. Furthermore, the mixed methods approach to conducting systematic reviews is a process whereby (a) comprehensive syntheses of two or more types of data (e.g. quantitative and qualitative) are conducted and then aggregated into a final, combined synthesis, or (b) qualitative and quantitative data are combined and synthesized in a single primary synthesis [12]. It is also worth mentioning that mixed review method is a widely adopted approach that has been previously implemented in several and diverse applications such as energy efficient related purpose [10], modular construction [13] and etc.

Figure 2 dissects the procedure that was followed to achieve the article’s objectives. The first step is to select a scientific database. In the case of this article, the database is “Web of Science”. After database selection, a series of searches is conducted around the keyword “Maintenance of heritage sites”. Repeating the search using variations of the same keyword is essential to ensure that all related articles are found. All the articles that are collected throughout the search are compiled into a new database that will be MAHs database. The MAHs database serves as the basis for all the work in this article. The MAHs database is then analyzed to determine the trends that are ongoing in the field and shed some light on them, then 15 articles are selected to be further analyzed. The in-depth analysis of the 15 randomly selected articles helps shed the light on some current technologies and their advantages and disadvantages. Also, it helps identify the progression of the research demographics on the level of topics. Additionally, the analysis helps in identifying the direction of the future work in the field based on the needs of the industry and the limitations of certain approaches.

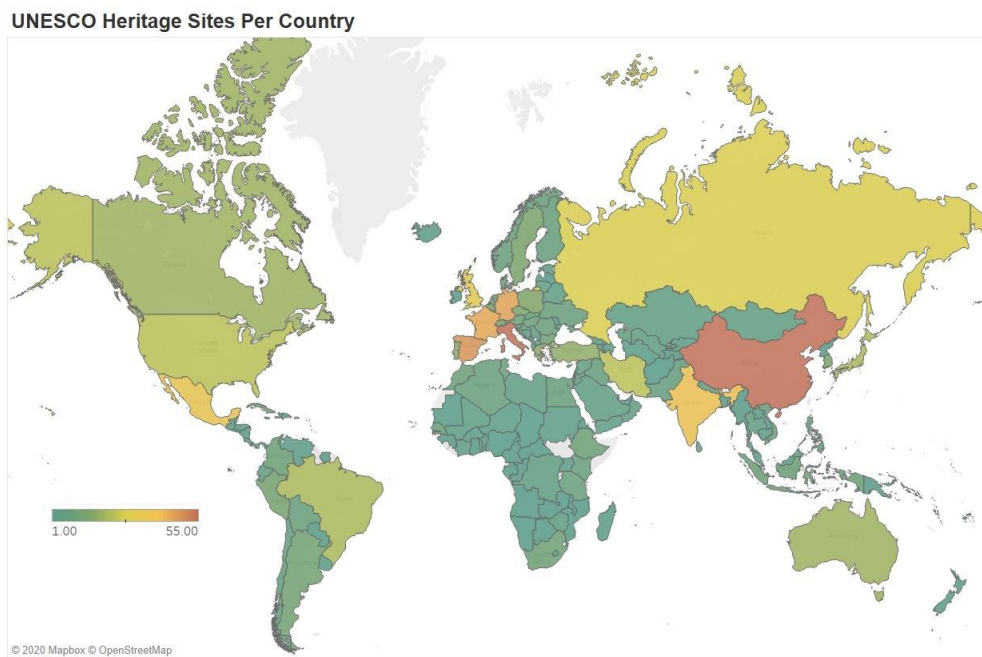


Fig.1: UNESCO heritage sites per country.

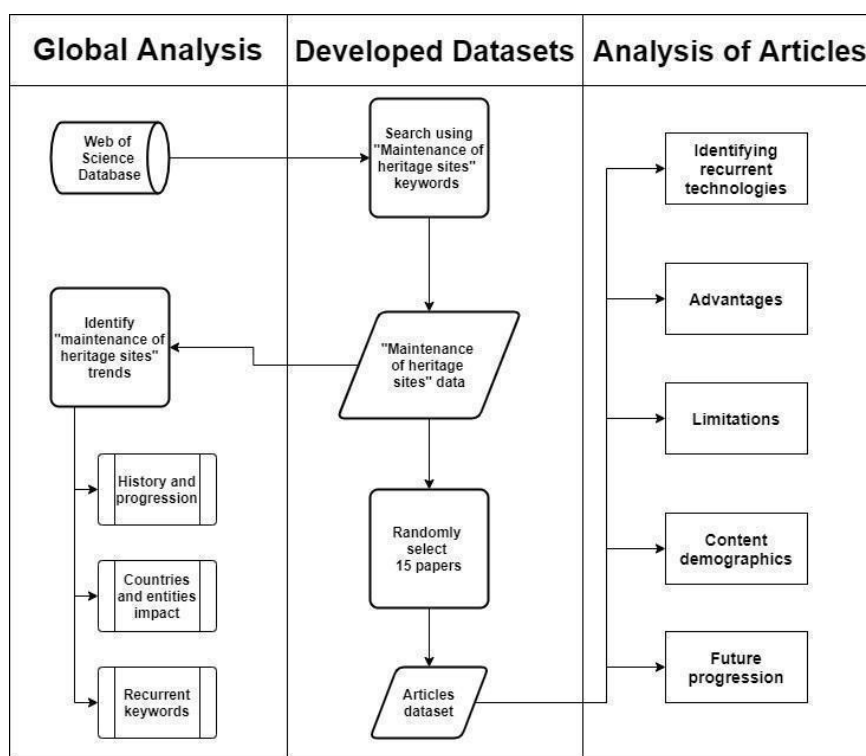


Fig.2: Overall framework of research methodology.

### 3 Defining Maintenance of Heritage Sites

As highlighted in the background, maintenance is the act of preserving the fabric of heritage sites so that they may remain beacons of human history

transferred from generation to generation. Poullos [14] classified the acts of maintenance into 5 main activities as follows:

- 1- Partial replacement of existing material with same material
- 2- Partial renewal of existing material with different material
- 3- Total physical renewal

- 4- Immersion of physical material
- 5- Replacement of entire structure

The list starts with the least intense activity and ends with the most demanding and intense activity. Each of those activities has its own sets of advantages, disadvantages, and implications on the repair site [14]. The first technique is the partial replacement of the existing material with the same material. In this technique, materials from the same nature, chemical structures, or even the exact same structure are utilized to repair damages in heritage sites. Such damages may include spalling, deterioration, and cracks. Although uncommon, this practice is utilized in areas where organic materials were used for the construction of heritage sites that are located in areas with hostile environments [14, 15].

Partial repair using different material relies on doing repairs by utilizing materials that are assessed to be stronger and better than the original material and do not violate the sacredness or integrity of the heritage site and structure. This practice is common as usually the new material is more effective and much stronger than the old material [16]. Total physical renewal is a common practice mostly due to religious practices where certain parts of sacred sites are renewed in a ritualistic fashion. This also can occur in certain cases where it is safer to provide a total physical renewal to certain areas of the site for safety reasons. This is

done while keeping in mind the fabric and rich culture of the site [17]. The immersion of physical material and the replacement of the entire structure in the maintenance of heritage sites usually occur for ritualistic reasons as well. In certain practices, if an element of a heritage site is damaged it needs to be replaced completely [14].

To decide on which maintenance and repair approach to utilize, decision-makers rely on a variety of assessment tools that provide them with insight on the current condition of the site as well as the locations of any defect. A list of the most common techniques has been compiled and recorded in Tables 1, 2 and 3. They enlist the name of the technique along with its mode of application, advantages, disadvantages, and references to real-life applications.

Table 1: A summary of common heritage site assessment techniques.

<b><i>3D analysis and digital photogrammetry</i></b>	The development and analysis of computer-based 3D replicas of heritages sites and monuments. This can be done using advanced tools and sensors.	<ul style="list-style-type: none"> <li>▪ Accurate</li> <li>▪ Portable</li> <li>▪ Cost efficient</li> <li>▪ Time efficient</li> <li>▪ Flexible</li> </ul>	<ul style="list-style-type: none"> <li>▪ Requires further development</li> <li>▪ Not widely available or used</li> </ul>	[17-21] (Al-Kheder et al. 2009; Remondino and Rizzi 2010; Dore and Murphy 2012; Jahanshahi et al. 2013; Galantucci and Fatiguso 2019)
<b><i>Atomic absorption spectrometry</i></b>	A device sends beams of light onto a sample (the specific form and origin of the light depends on the manufacturer, usually hollow cathode lamps). Behind the sample will be a reader that determines how much of the light was absorbed by the sample.	<ul style="list-style-type: none"> <li>▪ Effective in determining chemical profiles of samples</li> <li>▪ Can be combined with other techniques to be more effective</li> </ul>	<ul style="list-style-type: none"> <li>▪ Subject to interference</li> <li>▪ Interacts with a limited number of elements in heritage sites</li> <li>▪ Requires taking a sample from the site which may not be viable</li> </ul>	[22, 23] (Filho et al. 2011; Pinheiro et al. 2019)
<b><i>Colorimetric evaluation</i></b>	A sample is collected and analyzed with a reactive coloring chemical to determine the chemical composition of the sample.	<ul style="list-style-type: none"> <li>▪ Effective when dealing with limestone and plasterwork.</li> <li>▪ Cost effective</li> <li>▪ Portable</li> </ul>	<ul style="list-style-type: none"> <li>▪ Requires the collection of a sample which may not always be viable</li> <li>▪ Does not work effectively with</li> </ul>	[24, 25] (Comite et al. 2017; Collado-Montero et al. 2019)

				other construction materials	
<b>3D analysis and digital photogrammetry</b>	The development and analysis of computer-based 3D replicas of heritages sites and monuments. This can be done using advanced tools and sensors.	<ul style="list-style-type: none"> <li>▪ Accurate</li> <li>▪ Portable</li> <li>▪ Cost efficient</li> <li>▪ Time efficient</li> <li>▪ Flexible</li> </ul>	<ul style="list-style-type: none"> <li>▪ Requires further development</li> <li>▪ Not widely available or used</li> </ul>		[17-21] (Al-Kheder et al. 2009; Remondino and Rizzi 2010; Dore and Murphy 2012; Jahanshahi et al. 2013; Galantucci and Fatiguso 2019)

Table 2: A summary of common heritage site assessment techniques (Cont'd).

<b>Eddy current thermography</b>	Eddy currents thermography relies on creating eddy current pulse via induction that would heat the area that is being tested. After the tested region is heated thermography is applied to detect any defects.	<ul style="list-style-type: none"> <li>▪ Non-destructive</li> <li>▪ Can detect surface and subsurface defects</li> </ul>	<ul style="list-style-type: none"> <li>▪ Only works on materials that allow induction</li> </ul>		[26, 27] (Arndt 2010; De Capua et al. 2018)
<b>Fourier transform infrared test</b>	A device emits infrared radiation through a given sample from the material to be tested. Depending on the components a portion of the radiation will be absorbed. The absorbed radiation will be converted to energy. This energy will create a vibrational signal that can be analyzed to determine the material footprint.	<p>Accurate</p> <ul style="list-style-type: none"> <li>▪ Non-destructive</li> <li>▪ Highly sensitive</li> <li>▪ Specific</li> <li>▪ Helps identify material composition (organic, inorganic, polymer)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Infrared has room for interference when used in the field</li> <li>▪ Requires the collection of a sample if the test is done in lab</li> </ul>	Identifying the components of a sample may not be informative enough to assess its condition	[28-30] (Castillo et al. 2012; Fierascu et al. 2019; Rosi et al. 2019)
<b>Nuclear magnetic resonance</b>	A collected sample would be placed in a magnetic field. Then, the sample is subjected to nuclear magnetic resonance by means of radio waves until the nuclei within the sample reach a resonance state. This produces a field spectrum that can be analyzed to determine the composition of the sample.	<ul style="list-style-type: none"> <li>▪ Non-destructive</li> <li>▪ Highly sensitive</li> <li>▪ Specific</li> <li>▪ Helps identify material composition (organic, inorganic, polymer)</li> </ul>	<ul style="list-style-type: none"> <li>▪ Require the collection of a sample which may not always be viable</li> </ul>	Identifying the components of a sample may not be informative enough to assess its condition	[31, 32] (Capitani et al. 2012; Proietti et al. 2014)

Table 3: A summary of common heritage site assessment techniques (Cont'd-2).

<b>Scanning electron microscopy and dispersive X-ray spectroscopy</b>	An electron beam is generated by the device and is directed towards the surface of the sample that is being analyzed. The collision creates secondary electrons from the sample while some of the applied electrons scatter around the device. Those interactions are measured by a detector to develop an X-ray electromagnetic spectrum. The spectrum can be analyzed	<ul style="list-style-type: none"> <li>▪ Non-destructive</li> <li>▪ Highly sensitive</li> <li>▪ Specific</li> <li>▪ Helps identify material composition (organic,</li> </ul>	<ul style="list-style-type: none"> <li>▪ Works only on a surface level thus no deep insights can be provided</li> <li>May require sampling in certain scenarios</li> </ul>		[33-35] (Camm et al. 2003; Melcher and Schreiner 2005; Vasiliev et al. 2016)
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	to determine the surface elemental concentrations.	inorganic, polymer)		
<b>Ultrasonic testing</b>	An emitter and a receiver are placed on opposite ends of the investigated element. The emitter sends ultrasonic waves throughout the body that are collected by the receiver. The travel time is recorded. With data such as gap distance, the internal structure of the element is constructed.	<ul style="list-style-type: none"> <li>▪ Non-destructive</li> <li>▪ Does not require sampling</li> </ul> Provides deep analysis	Might be difficult to assess in structures of unknown material composition or composite structure	[36-38] (Ruedrich et al. 2013; Akoglu et al. 2020; Rucka et al. 2020)

## 4 Results and Discussion of Scientometric Review of MAHs

### 4.1 Network Analysis of Journals Contributing to MAHs

Analysis of the journals which publish articles related to MAHs is a necessary step in the scientometric review to identify the high impact journals, map its network, and hence guide the researchers to the key journals in this field. The identification of academic journals containing papers on MAHs in construction was undertaken using the Web of Science. Journal of Destination Marketing & Management, Ace-Architecture City and Environment, Anais Brasileiros De Estudos Turisticos-Abet, Boletin De La Asociacion De Geografos Espanoles, Cuadernos De Turismo, Historic Environment-Policy & Practice, International Journal of Architectural Heritage, Journal of Cultural Heritage Management And Sustainable Development, Pasos-Revista De Turismo Y Patrimonio Cultural, Annals of Tourism Research were recognized as the top ten (10) journals among the retrieved results. Table 4 reports the ranking of the retrieved journals. All these journals have their respective virtual libraries including Elsevier, ASCE, Wiley Online, Canadian Science Publishing and Emerald Insight which are among the leading virtual libraries in construction engineering research. Table 4 also indicates the top 10 Journals on MAHs research identified from the search for the period under study. For instance, Sustainability journal contains four researches related to MAHs with 13 citations, and Tourism Management journal contains three researches related to MAHs with 147 citations.

Table 4: Search History – Overview of Results.

Selected Journals	No. of papers from search
Destination Marketing & Management	4

Ace-Architecture City and Environment	3
Anais Brasileiros De Estudos Turisticos-Abet	3
Boletin De La Asociacion De Geografos Espanoles	3
Cuadernos De Turismo	3
Historic Environment-Policy & Practice	3
Int. J. of Architectural Heritage	3
J. of Cultural Heritage management and Sustainable Development	3
Pasos-Revista De Tuismo Y Patrimonio Cultural	3
Annals of Tourism Research	2
<b>Total</b>	<b>30</b>

### 4.2 Assessment of Contributions

Researches and academic institutions contribute to the industrial practises through different ways, the most significant being the publication of their research papers. Furthermore, the number of research contributions in a country signifies its progress on the subject in that country [39]. Therefore, identifying active contributors to a field is a solid approach to understanding the general research trend of that particular field [40]. As a result, researchers can make use of this approach to track the contributions of previous researchers and utilize the results for further improvement on previous works by other researchers. Accordingly, this approach was used to provide insights on the current state of industrial developments in different countries related to MAHs as well as research contributions of researchers from their respective countries and institutions are presented and discussed in the subsequent session of this paper.

The study aims at highlighting the contributions of countries, institutions and researchers to MAHs research. Also, assessing the contributions of

researchers, institutions and countries have been of interest to several researchers [41-44]. Hence, this study explored the contributions of countries, institutions and researchers to MAHs research during the studied period. The score matrix provided in Table 5 was applied in the calculation of the contributions of countries, institutions and researchers. In order to obtain the total contribution score for a particular country and institution, the individual scores of all authors from the same country and institution are summed up. For example, if author 'Y', from a particular country, has the first and second authorship, respectively, in two different papers, in which there are just two authors, according to the score matrix, author 'Y' is scored one point (0.6 & 0.8) each for his or her country and institution. The approach is utilized for the sake of computing the contributions of countries and institutions of the selected papers. For example, Sustainability journal contains four researches related to MAHs with 13

citations, and Tourism Management journal contains three researches related to MAHs with 147 citations, so the total link strength for the second journal is higher from the first one as shown on Table 5. Similarly, historic environment-policy & practice journal has 3 papers with 8 citations. As a result, journal of destination marketing & management has the highest ranking across the different journals in the area of MAHs based on its number of published articles and their citations. In addition, the publisher Elsevier has the highest number of published articles with 58. Although, results also determined that the collaboration between Ecuador and Spain accomplished the highest ranking, such that the strength link was valued to be equal to 3. Besides, the highest repetitive keywords were indicators with 20 times and cultural heritage cities with 19 times as shown in Table 5.

Table 5: Search History – Overview of Results.

Source	Papers	Citations	Link Strength
Sustainability	9	13	31
Destination Marketing & Management	4	23	99
Ace-Architecture City and Environment	3	1	12
Anais Brasilerios De Estudos Turisticos-Abet	3	2	10
Boletin De La Asociacion De Geografos Espanoles	3	4	32
Cuadernos De Turismo	3	0	22
Historic Environment-Policy & Practice	3	8	9
Int. J. of Architectural Heritage	3	3	1
J. of Cultural Heritage management and Sustainable Development	3	5	13
Pasos-Revista De Tuismo Y Patrimonio Cultural	3	7	30
Tourism Management	3	147	72
Annals of Tourism Research	2	256	6
Int. J. of Contemporary Hospitality Management	2	45	78
Sustainable Cities and Society	2	5	3
Tourism Geographies	2	12	12

### 4.3 Annual Maintenance Approaches

Figure 3 below, depicts information pertinent to the number of MAHs research publications per year over the last three decades. It has been observed that research on MAHs in the construction field has received considerable attention from the research community. For the first two decades, between 1990 and 2010, there were only papers published on MAHs. As for the third decade (2011-2020), research on MAHs has fluctuated between the period from 2011 to 2020. Moreover, an all-time peak of 22

publications was obtained in 2019. Such an increase in the number of publications is not unexpected as the need for increasing the preservation of heritage sites due to the frequent neglect and damage to which they are exposed.

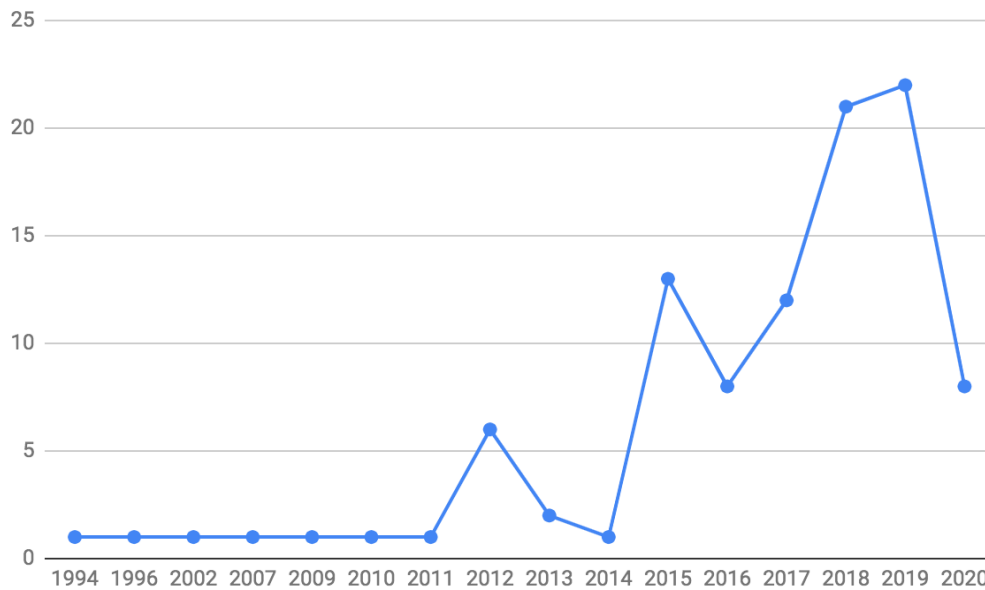


Fig.3: Annual maintenance approaches of heritage sites (MAHs) research publication from 1990 to 2020.

#### 4.4 Assessment of Contributions

Figure 4 shows that the main journals in the field of MAHs are (1) Sustainability MDPI, (2) ACE: Architecture, City, and Environment journal, (3) Journal of destination marketing and management, and (4) the international journal of contemporary hospitality management. A view of the scopes of those journals provides a larger view of the topics at hand. Sustainability aims to be a form for sustainability-based research and sustainable development including the cultural heritage. Accordingly, the journal publishes articles on the sustainable development of cultural heritage. ACE focuses on the architectural and environmental aspects of heritage development. Accordingly, their research on maintenance follows those topics as well. Journal of destination marketing and management focuses on maintenance research that would help tourist destinations (heritage sites included) be more attractive and appealing to visitors. Similarly, the international journal of contemporary hospitality management targets the maintenance and management of heritage sites from a touristic point of view. Based on what proceeded, there appears to be a need for more dedicated venues that focus on the maintenance of heritage sites from a pure scientific and historical perspective.

Figure 5 provides information about the main keywords related to the subject. For example, rehabilitation, built heritage, conservation, sustainability, participation, word heritage, heritage cities, historic urban landscape, tourism, design.

Also, Figure 5 provides information about the main keywords related to the subject. For example, rehabilitation, built heritage, conservation, sustainability, participation, word heritage, heritage cities, historic urban landscape, tourism, design. From the results reported in Table 6, the subject of MAHs has been undertaken in many countries, making it a topic of global concern. However, the major part of the research was conducted in Spain, Ecuador, and Mexico which had the most significant number of institutions publishing papers on MAHs research.

Table 6: Top 10 Publishers in MAHs research.

To 9 Publishers	
Elsevier	58
MDPI	14
Taylor & Francis Ltd.	10
Taylor & Francis Inc.	7
MDPI AG	5
Hindawi Ltd.	4
Emerlad	2
Penerbit UTM Press	2
Assoc Chemical Eng.	1
IGI	3





Fig.4: Network of high impact journals on MAHs.

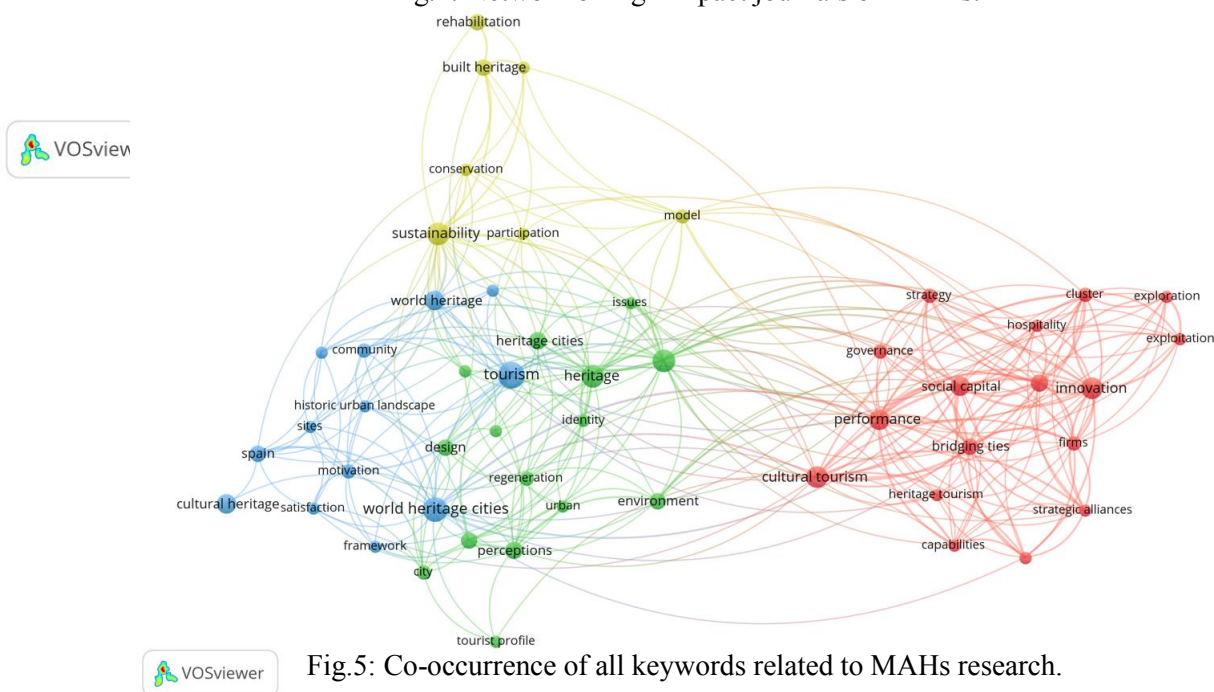


Fig.5: Co-occurrence of all keywords related to MAHs research.

In order to determine the relationship among the various countries, VOSviewer software was utilized to determine the most influential countries and the collaborations between them, which is challenging to derive using the score matrix. The type of analysis selected was “co-authorship”; the unit of analysis was “countries”, and the counting method employed was “fractional counting”. Moreover, the minimum number of documents of a country and the minimum number of citations from a country were both set at five. Eleven countries met these thresholds and were

included in the resultant network which is visualized in Figure 6. The most influential countries were identified in the network by using weighted degree values. Nodes were recoloured and resized based upon their weighted degree values, with larger nodes and lighter shades indicating higher weighted degrees values. Figure 7 presents the distribution of citations per country.

Table 7: Score matrix for multi-authored papers.

No. of authors	Order of specific author								
	1	2	3	4	5	6	7	8	
1	1.00								
2	0.67	1.00							
3	0.44	0.67	1.00						
4	0.30	0.44	0.67	1.00					
5	0.20	0.30	0.44	0.67	1.00				
6	0.13	0.20	0.30	0.44	0.67	1.00			
7	0.09	0.13	0.20	0.30	0.44	0.67	1.00		
8	0.06	0.09	0.13	0.20	0.30	0.44	0.67	1.00	

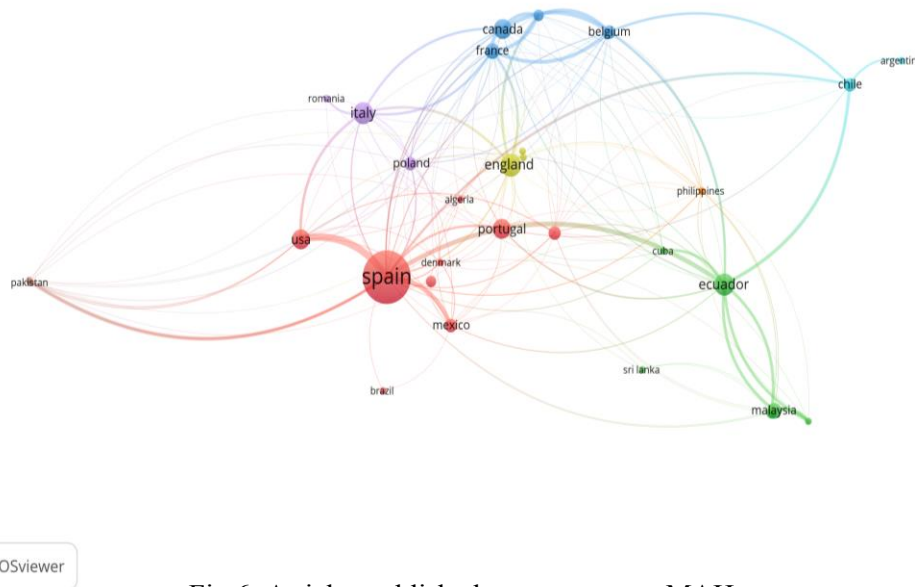


Fig.6: Articles published per country on MAHs.

The fundamental purpose of this analysis was to ascertain the various collaborations among countries with regards to MAHs research. Table 7 presents the link strength in terms of collaborations among the top countries publishing MAHs research. Ecuador and Spain had the highest collaboration strength link of 3. These results show that research collaboration on MAHs exists between these countries, indicating an exchange of information. Despite that the United States had the most significant contribution in MAHs research, its collaboration with other contributed countries such as Spain, China and Italy is not satisfactory. This may be a lack of cross-country comparative studies in the existing MAHs research, and hence collaborations among these countries should be encouraged to produce more diverse research in MAHs.

Table 8: Top Researchers in MAHs Research.

Researcher	Papers	Score %
Martinez-Perez, A	10	3.56
Garcia-Villaverde, PM	9	3.32
Elche, D	8	3.05
Lopez-Guzman, T	3	1.18
Bajgier-Kowalska, M	2	0.80
Caldeira, AT	2	0.80
Candeias, A	2	0.81
Carrillo-Hidalgo, I	2	0.82
Del Rio, M	2	0.82
Galvez, JCP	2	0.83

## 5 Analysis of Selected Papers

The production of knowledge per country over the analyzed time span shows that the top three countries based on the number of articles published in the Web

of Science database are Spain, the United Kingdom, and Italy. The list of countries is further mapped out in Figure 8. The top 3 countries share one interesting trait, i.e. all three countries possess a wealth of heritage sites and historical landmarks. Spain possesses 4% of all world heritage sites inscribed by UNESCO, the UK has 2.67%, and Italy has 4.59% [45]. It is plausible to argue that the abundance of research materials in these countries allows the proliferation of research that is related to the field. In Table 8, 9 and 10, it is equally important to highlight that the work and research conducted to preserve heritage sites is the duty and responsibility of all nations as it is work performed to preserve the history of humanity.

Table 9: Strength Links among the 12 Top Countries Publishing MAHs Papers.

Countries	Link Strength
Ecuador and Spain	3
Chile and Ecuador	2
Mexico and Spain	2
Belgium and Canada	1
Belgium and Chile	1
Belgium and Ecuador	1
Belgium and France	1
Belgium and Germany	1
Canada and France	1
Canada and Germany	1
Canada and Italy	1
Chile and Spain	1

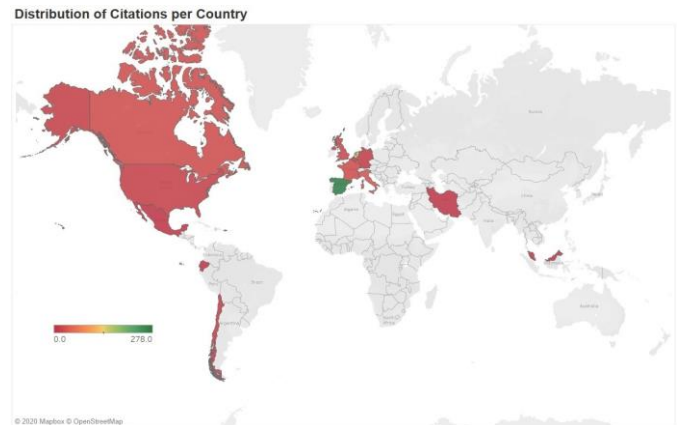


Fig.7: Distribution of citations per country.

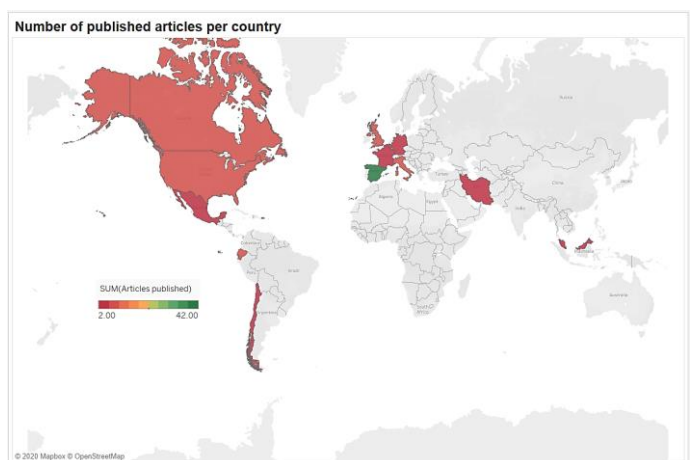


Fig 8: Distribution of citations per country.

Table 10: Keyword and strength link to MAHs research.

Keyword	Link Strength
Indicators	20
Cultural Heritage Cities	19
Satisfaction	19
World Heritage	19
Stakeholders	16
Sustainable Development	16
Built Heritage	13
Historic Tourism	13
Historic City	10
Cluster	9
Historic Urban Landscape	9
Tourism	9

## 6 Technologies and Approaches Overview

Several researches have been showed to develop effective maintenance management systems for large public organizations. These comprise the following studies:

Howard [46] and Al-Sakkaf et al. [47] stated on the practices and actions for preventative maintenance for school buildings. These studies stated further that “without these practices, a preventive maintenance program may not fulfill its goals”. In addition, the best practices comprise “inventory building components and assess their conditions, build the capacity for ranking maintenance projects and evaluating their costs, plan purposefully for preventive maintenance in the long-and-short-term, structure a framework for operating a preventive maintenance program, use tools to optimize the preventive maintenance program, advance the competence of maintenance workers and managers, and involve appropriate maintenance personnel in decision-making and in communicating buildings’ needs”. This research has not implied how the effectiveness of these best practices can be adjudicated to preserve the proposed use of heritage buildings.

According to the World Heritage Sites (2011) recommended average life expectancy for equipment and building components which include building enclosures, roofing systems, windows and exterior doors, interior construction, plumbing systems, elevators, heating, ventilation and air conditioning , electrical systems, site work and utilities. For example, they suggested the average life expectation for all types of elevators is 15-20 years. This initiative can be useful as an input in the process of developing a maintenance management standard of heritage buildings.

Legat and Jurča [48] determined how a general quality management system according to ISO 9000: 2000 is implemented in maintenance processes. Moreover, the authors presented many factors for asset requirements on maintenance and achievement of defined maintenance quality characteristics. These factors include basic requirements for maintenance of assets, organizational structure, procedures and processes, maintenance financing, internal and external maintenance (outsourcing) and Information system and maintenance documentation. Nevertheless, Legat and Jurča have been failed short of developing a standard for maintenance

management that can be applied in heritage maintenance domain.

Levitt [49] indicated that maintenance management as a quality assurance process by projecting the ISO 9001: 2000 standard on the maintenance management activities. Levitt stated that “most modern maintenance management activities are not linked to quality management systems”. Conversely, Levitt has not presented any quality criteria which can be clearly used for developing maintenance management standards. Lam [50] listed several quality criteria such as high reliability of services, quick response to maintenance problems, on-going improvement and compliance with statutory requirements. Although these quality criteria can be expended in developing maintenance management standards of heritage sites.

Iwarere and Lawal [51] presented some factors that can be considering the adverse consequences of an effective maintenance in public facilities, these factors include “excessive machine breakdown, disproportionate investment in spare parts and maintenance materials, poor utilization of staff, low quality of service, abnormal overtime cost, irregular operating time, shortened life span of facilities, loss in production output, frequent machine breakdown”. Ali and Mohamad [52] evaluated the existing facilities maintenance management in public hospitals in Malaysia. Their assessed based on five elements namely: (1) Leadership; (2) Policies, plan and procedures; (3) Training and orientation; (4) Monitoring and supervision; and (5) Service performance. Every one of these elements has many subsystems or factors, for example when they evaluate that service performance that provided by contractors, they have developed 12 factors which include: (1) Asset registers management; (2) Infrastructures support ; (3) Spares management; (4) PPM task lists; (5) PPM scheduling; (6) Safety management; (7) Statutory compliance; (8) Plant room management; (9) Maintenance performance; (10) Equipment history; (11) Quality assurance and (12) Competency training.

Cholasuke et al. [53] clarified the status of maintenance management in UK manufacturing organizations. They conducted a survey which divided into two parts: General information and Maintenance measurement. They have developed ten elements for maintenance performance measures which encompass: (1) Maintenance effectiveness; (2) Maintenance policy and organization, (3) Maintenance approach, (4) Task planning and scheduling, (5) Information management and CMMs; (6) Spare part management; (7) Human resource management, (8) Contracting out

maintenance, (9) Financial aspect, and (10) Continuous improvement.

Shamsuddin et al. [54] listed several quality criteria to implement total quality management (TQM). These criteria comprise maintaining basic equipment condition, prevention of human error, detection of error at the source, caring for cleanliness and tidy working environment, worker skill development for self-maintenance, maintaining operating standards, improving design weakness, established repair methods, prediction of deterioration, looking to shop floor as the source of ideas, empowerment of workers, and Formation of small group activities. Alsyof [55] aimed that analyzing the maintenance practices which are implemented in Swedish industry. Al-Sakkaf et al. [56] indicated several quality criteria that should be considered to analyze maintenance practices. López [57] stated that the most important of these criteria include Implementation of computerized maintenance management systems (CMMS), recording and analyzing failure data to improve causes of equipment failure, monitoring the rate of poor quality, monitoring spare parts and keeping it at the level low, delivering inventory between machines, comparing maintenance tasks based on statistical modeling and condition monitoring of heritage buildings.

## 7 Discussion

In this section, Journal of Destination Marketing & Management has the highest ranking across the different journals in the area of MAHs based on its number of published articles and their citations. In addition, the publisher Elsevier has the highest number of published articles with 58. Results also demonstrated that the collaboration between Ecuador and Spain accomplished the highest ranking, such that the strength link was estimated to be equal to 3. Moreover, the highest repetitive keywords were indicators with 20 times and cultural heritage cities with 19 times. This study will help researchers to understand the current trends, progress, methodologies and challenges related to maintenance of heritage sites. Also, it provides a critical and synthesized evaluation of the current research studies in domain of maintenance approaches of heritage sites.

## 8 Conclusion

53 journal articles were surveyed in this study to provide an overview of the maintenance of heritage

sites. Results showed that the highest collaboration research was between Spain and Ecuador has 3 link of strength while Mexico and Spain has 2 link of strength in number of publication related to MAHs. This was proven by comparing the most publishing countries (Spain, Italy, and the UK) with their percentage of research contributions in the examined articles pool. The analysis of countries shows that nations around the world should have stronger collaborations for the research conducted in heritage as heritage belongs to all humanity. An assessment of the quality of the assessed publications was conducted and showed that Spain has a high quality of publications due to the high average number of citations per publication. Also, the highest researcher in terms of number of publication was Martinez-Perez with 10 papers and scoring of 3.56%. To sum up, maintenance approaches were surveyed and identified along with their preferred setup and how are they applied. Popular condition assessment technologies were also identified and defined. Their advantages and disadvantages were listed to provide a quick overview of the state of the art in the field. Furthermore, real-life referred research examples were provided for each technique to establish direction for researchers who intend to investigate a specific technique further.

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## **Contribution of individual authors to the creation of a scientific article (ghostwriting policy)**

Abobakr Al-Sakkaf analyzed the findings and the results of the models and aided in writing the article. Samer El-Zahab developed the methodology and concept and aided in writing the article. Eslam Mohammed Abdelkader aided in developing the methodology and concept and writing the article. Ghasan Alfalah aided in analyzing the models and writing the article.

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