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Damage mapping as a diagnostic tool for pathological manifestations in Historical Buildings: A literature review

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Mapa de danos como ferramenta de diagnóstico de manifestações patológicas em Edificações Históricas: Uma revisão da literatura

RESUMO

Objetivo – Analisar a aplicação da técnica de mapas de danos para identificação de manifestações patológicas em edificações históricas, considerando sua relevância para a preservação do patrimônio cultural.

Metodologia – Foi realizada uma Revisão Sistemática da Literatura com base no protocolo PRISMA, utilizando critérios específicos de seleção, avaliação e síntese de artigos. Para a análise dos estudos selecionados, foram adotados aspectos quantitativos (ano de publicação, origem dos pesquisadores e frequência de palavras-chave) e qualitativos (tipos de análises, estruturas estudadas e metodologias empregadas para investigar as manifestações patológicas), sendo eles escolhidos devido a sua relevância para o contexto em que a pesquisa está inserida.

Originalidade/relevância – O estudo se destaca por reunir e sistematizar as principais abordagens sobre a utilização dos mapas de danos em construções históricas, contribuindo para o entendimento do estado da arte e para a consolidação dessa técnica como ferramenta de referência na conservação de bens culturais.

Resultados – Os resultados evidenciaram uma evolução contínua nas pesquisas que empregam mapas de danos, revelando avanços nas metodologias complementares utilizadas. Identificou-se ainda que essa técnica tem sido cada vez mais integrada a outras ferramentas de análise, ampliando sua precisão e confiabilidade.

Contribuições teóricas/metodológicas – O estudo oferece uma síntese estruturada sobre a aplicação dos mapas de danos, apresentando parâmetros relevantes para pesquisas futuras e destacando lacunas a serem exploradas. Além disso, aponta meios metodológicos para aprimorar a prática, integrando a técnica a métodos analíticos mais robustos.

Contribuições sociais e ambientais – Ao fortalecer a preservação do patrimônio histórico, os avanços discutidos neste trabalho contribuem para a valorização da memória coletiva e da identidade cultural. Do ponto de vista ambiental, o aprimoramento das práticas de conservação reduz a necessidade de intervenções invasivas e desperdício de materiais, favorecendo estratégias de restauro mais sustentáveis.

PALAVRAS-CHAVE: Mapeamento de danos. Manifestação patológica. Patrimônio histórico.

Damage Mapping as a Diagnostic Tool for Pathological Manifestations in Historical Buildings: A Literature Review

ABSTRACT

Objective – To analyze the application of damage mapping techniques for the identification of pathological manifestations in historical buildings, considering their relevance for the preservation of cultural heritage.

Methodology – A Systematic Literature Review was conducted based on the PRISMA protocol, using specific criteria for the selection, evaluation, and synthesis of articles. The selected studies were analyzed through quantitative aspects (year of publication, researchers' origin, and frequency of keywords) and qualitative aspects (types of analyses, structures studied, and methodologies employed to investigate pathological manifestations), chosen due to their relevance to the research context.

Originality/Relevance – The study stands out for gathering and systematizing the main approaches to the use of damage maps in historical constructions, contributing to the understanding of the state of the art and consolidating this technique as a reference tool in cultural heritage conservation.

Results – The findings revealed a continuous evolution in research employing damage maps, showing advances in complementary methodologies. It was also identified that this technique has increasingly been integrated with other analytical tools, enhancing its accuracy and reliability.

Theoretical/Methodological Contributions – The study provides a structured synthesis of the application of damage maps, presenting relevant parameters for future research and highlighting gaps to be explored. Furthermore, it suggests methodological ways to improve practice by integrating the technique with more robust analytical methods.

Social and Environmental Contributions – By strengthening the preservation of historical heritage, the advances discussed in this work contribute to the appreciation of collective memory and cultural identity. From an environmental perspective, the improvement of conservation practices reduces the need for invasive interventions and material waste, favoring more sustainable restoration strategies.

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KEYWORDS: Damage mapping. Pathological manifestation. Historical heritage.

Mapa de daños como herramienta de diagnóstico de manifestaciones patológicas en Edificaciones Históricas: Una revisión de la literatura

RESUMEN

Objetivo – Analizar la aplicación de la técnica de mapas de daños para la identificación de manifestaciones patológicas en edificaciones históricas, considerando su relevancia para la preservación del patrimonio cultural.

Metodología – Se realizó una Revisión Sistemática de la Literatura con base en el protocolo PRISMA, utilizando criterios específicos de selección, evaluación y síntesis de artículos. Para el análisis de los estudios seleccionados se adoptaron aspectos cuantitativos (año de publicación, procedencia de los investigadores y frecuencia de palabras clave) y cualitativos (tipos de análisis, estructuras estudiadas y metodologías empleadas para investigar las manifestaciones patológicas), elegidos por su pertinencia en el contexto de la investigación.

Originalidad/Relevancia – El estudio se destaca por reunir y sistematizar los principales enfoques sobre la utilización de los mapas de daños en construcciones históricas, contribuyendo a la comprensión del estado del arte y a la consolidación de esta técnica como herramienta de referencia en la conservación de bienes culturales.

Resultados – Los resultados evidenciaron una evolución continua en las investigaciones que emplean mapas de daños, revelando avances en las metodologías complementarias utilizadas. Asimismo, se identificó que esta técnica ha sido cada vez más integrada con otras herramientas de análisis, ampliando su precisión y fiabilidad.

Contribuciones Teóricas/Metodológicas – El estudio ofrece una síntesis estructurada sobre la aplicación de los mapas de daños, presentando parámetros relevantes para futuras investigaciones y señalando vacíos que deben ser explorados. Además, propone medios metodológicos para perfeccionar la práctica, integrando la técnica con métodos analíticos más robustos.

Contribuciones Sociales y Ambientales – Al fortalecer la preservación del patrimonio histórico, los avances discutidos en este trabajo contribuyen a la valorización de la memoria colectiva y de la identidad cultural. Desde el punto de vista ambiental, el perfeccionamiento de las prácticas de conservación reduce la necesidad de intervenciones invasivas y el desperdicio de materiales, favoreciendo estrategias de restauración más sostenibles.

PALABRAS CLAVE: Mapeo de daños. Manifestaciones patológicas. Patrimonio histórico.

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1 INTRODUCTION

A region's historical heritage encompasses cultural and material assets that preserve collective memory while transmitting the identity and traditions of its people (Amorim *et al.*, 2023). Within this context, historical buildings stand out as significant cultural markers, offering architectural and symbolic insights into past generations (Rodrigues *et al.*, 2021).

Over time, however, these constructions are inevitably impacted by various pathological manifestations. The literature frequently links the study of such phenomena to the broader effort to conserve urban heritage (Costa; Silveira; Torres, 2021). This relationship is crucial for raising public awareness about the need for preservation, as understanding the current condition of buildings – through the analysis of their structural pathologies – helps inform the selection of appropriate restoration strategies (Prieto *et al.*, 2017).

Pinheiro and Salomão (2021) emphasize that conservation efforts should follow the principle of "minimum intervention," prioritizing the preservation of original characteristics while avoiding invasive techniques that may compromise authenticity. Although the idea of safeguarding heritage predates this, formal concepts of conservation were only consolidated in the 1930s in response to the threats posed by modern urban planning. Since then, international and regional charters, conferences, and guidelines have shaped the discourse around revitalizing and rehabilitating historical areas.

Discussions on restoration must also consider the environmental impact of such actions. Rodwell (2007) argues that sustainability in this context involves extending a building's lifespan to reduce energy use, material waste, and costs. This perspective reinforces the intrinsic link between heritage revitalization and the planet's finite resources, aligning conservation efforts with the three pillars of sustainability – environmental, social, and economic – that highlights the importance of considering this issue before carrying out any type of restoration work (Silva *et al.*, 2024).

In Brazil, the National Institute of Historical and Artistic Heritage (IPHAN) oversees heritage preservation at the federal level. Decree-Law No. 25, enacted on November 30, 1937, provided the first legal definition of heritage, later expanded in Article 216 of the 1988 Federal Constitution. This article defines cultural heritage as encompassing both tangible and intangible assets that reflect the identity, memory, and practices of diverse social groups in Brazil (BRASIL, 1988). Since then, the Brazilian government has continued to update and standardize regulations to modernize preservation practices across all states (Vasconcelos *et al.*, 2024).

However, despite all these advancements in conservation guidelines, numerous historical buildings have continued to suffer from a lack of proper care in recent years, as reported by various media outlets across the country (Gortázar; Oliveira, 2021; Gullino; Éboli, 2021). This ongoing issue has prompted growing concern among researchers regarding the safeguarding of these structures, given their vital role in preserving the cultural memory of Brazilian cities (Domingues; Souto, 2025).

Currently, one of the most commonly used techniques for identifying pathological manifestations in historical buildings is the damage mapping technique. According to Tinoco (2009), the damage map has been widely used because it can illustrate graphically and photographically the state of conservation of a building. The use of this tool is extremely

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important for investigating existing damage in historical buildings, as it provides stakeholders with a qualitative understanding of the condition of the main pathological anomalies, in addition to showing the level of urgency for intervention required in the building (Bersch *et al.*, 2020).

Nevertheless, Carvalho, Oliveira and Zanoni (2020) observe that this tool remains underutilized, partly due to the absence of standard development protocols, which ends up hindering its universal understanding. Researchers often apply their own legends and criteria, leading to inconsistencies and difficulties in interpretation. Macedo (2016) underscores the growing consensus around the need to standardize damage mapping practices, given their critical role in guiding conservation, restoration, and intervention projects.

In light of this, the present study aims to identify major research efforts that have used damage mapping to detect pathological manifestations in historical structures. It also seeks to offer a critical analysis of the method's application, highlighting both strengths and limitations, with the ultimate goal of improving its use in restoration and conservation Works.

2 METHODOLOGY

For the planning and execution of this Systematic Literature Review (SLR), the Rayyan tool was chosen, a free online platform developed by the Qatar Computing Research Institute (QCRI). The review followed a structured process based on the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines established by Liberati *et al.* (2009), which are widely recognized for ensuring transparency and rigor in systematic reviews.

The research protocol, detailed in Table 1, outlines the specific procedures for article identification, selection, and inclusion in this review.

Table 1 – Research protocol of the Systematic Literature Review (SLR)

Research Guidelines	
Research questions	a. What are the advantages and disadvantages of using damage maps to survey pathological manifestations in historical buildings? b. In what ways can the damage mapping technique enhance current practices in restoration work?
Keywords	"*Pathological Manifestations*", "*Building Defects*", "*Damage Detection*", "*Damage Evaluation*", "*Damage Maps*", "*Mapping Damages*", "*Historical Heritage*", "*Conservation*" e "*Preservation*"
Search Period	Between 2008 and 2023
Databases	Scopus, Science Direct, Engineering Village, Web of Science and Google Scholar
Inclusion Criteria	(I) Focus specifically on surveying pathological manifestations in historical buildings. (I) Apply damage maps as a method for identifying, assessing, and presenting pathological issues in these structures within academic studies. (I) Clearly report the outcomes achieved and any challenges encountered during the application of the technique under review.
Exclusion Criteria	(E) Studies that are not directly related to the research objectives. (E) Duplicate studies, multiple publications of the same study, or articles that do not allow full access to the text. (E) Studies lacking relevant data, insufficient information for evaluation, or that do not present the damage maps used for mapping pathological manifestations.

Source: Created by the authors.

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The articles selected for this study were identified through searches in the Scopus, Science Direct, Engineering Village, Web of Science, and Google Scholar databases. These platforms were chosen for their extensive collection of peer-reviewed publications in multiple languages and their strong academic credibility.

To maximize search results, keywords were used in English, including: “Pathological Manifestations,” “Building Defects,” “Damage Detection,” “Damage Evaluation,” “Damage Maps,” “Mapping Damages,” “Historical Heritage,” “Conservation,” and “Preservation.” Boolean operators “AND” and “OR” were applied to combine these terms within database search fields, targeting studies that included them in titles or abstracts.

During the searches in the databases, some filters were applied to restrict the articles found, such as: considering only articles written in English and Portuguese, considering only articles published between 2008 and 2023, and considering only publications from journals and scientific magazines.

During the full-text review, studies were excluded if they did not employ the damage mapping technique to identify pathological manifestations in historical buildings, or if they failed to present the actual damage maps used in the analysis. In contrast, included studies clearly outlined their methodologies, procedures, findings, and any challenges faced while applying the technique to identify pathological manifestations in historical structures.

Finally, after selecting the articles through full reading, the following information was extracted for analysis: year and country of publication, type of historical building examined, specific areas where damage mapping was applied, types of analyses performed, major pathological issues identified, and the methodologies used to investigate them.

3 RESULTS

The database searches initially yielded 604 articles. After applying filters for language (English and Portuguese), publication date (2008–2023), and field of study (Architecture, Engineering, and Construction), this number was reduced to 281. A preliminary screening based on titles narrowed the selection to 127, followed by abstract screening, which resulted in 57 articles for full-text review.

Finally, after a thorough analysis of the content of each study, 28 articles were selected to compose the systematic review. The articles excluded in this final stage were removed because they did not address studies on historical buildings and because they did not present, in their findings, the damage maps developed for identifying the pathological manifestations present in the objects of study.

Figure 1 illustrates the systematic article selection process in the form of a PRISMA flowchart.

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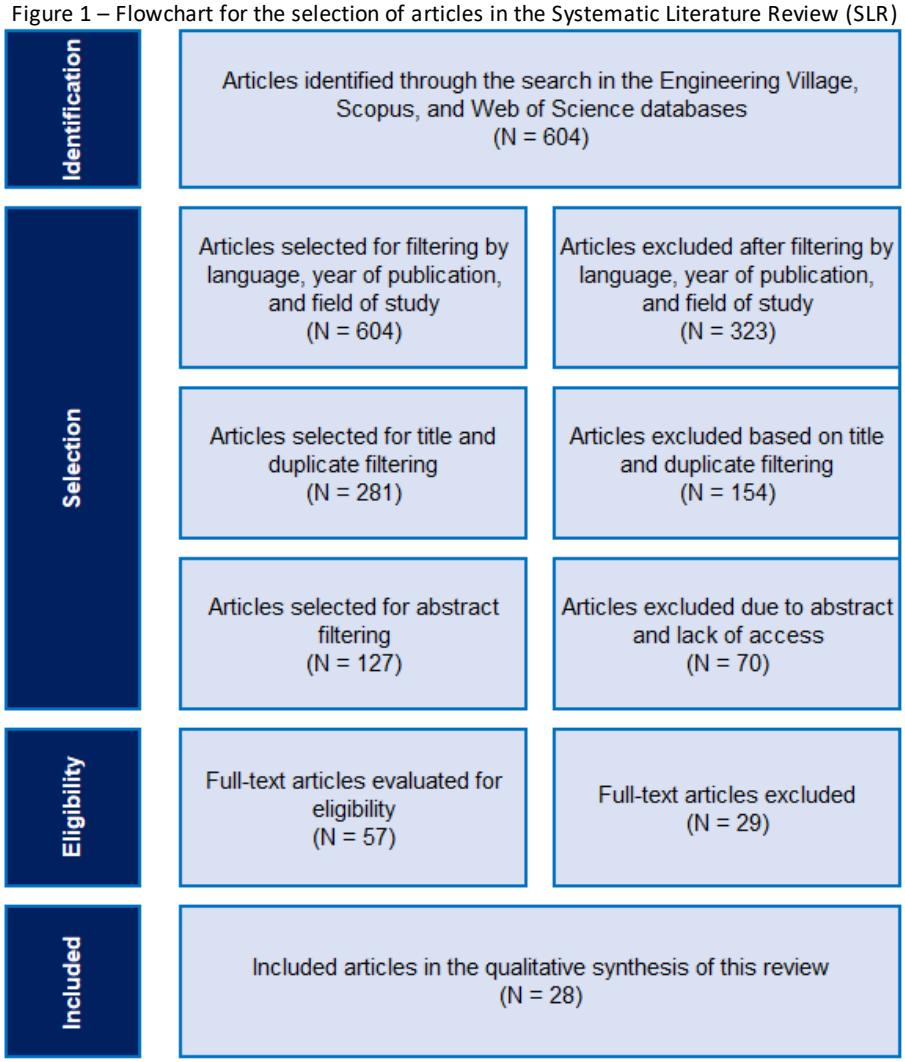
Figure 1 – Flowchart for the selection of articles in the Systematic Literature Review (SLR)



Source: Created by the authors.

3.1 Quantitative Analysis

After selecting the articles, three parameters were quantitatively analyzed: the year of publication, the countries of the researchers' affiliated institutions, and the frequency of keywords used in the studies. These parameters were chosen to demonstrate numerically the global development of research on this topic and to assess the number of publications in the area over the past 15 years.

Accordingly, Figure 2 presents the number of studies published during the selected period for analysis.

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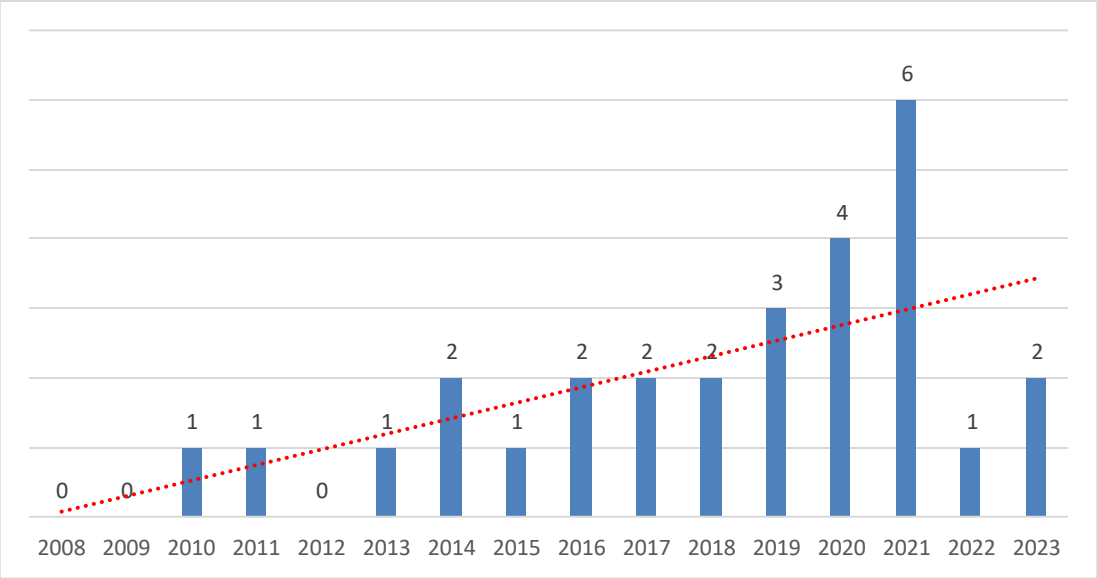
Figure 2 – Number of publications per year, from 2008 to 2023

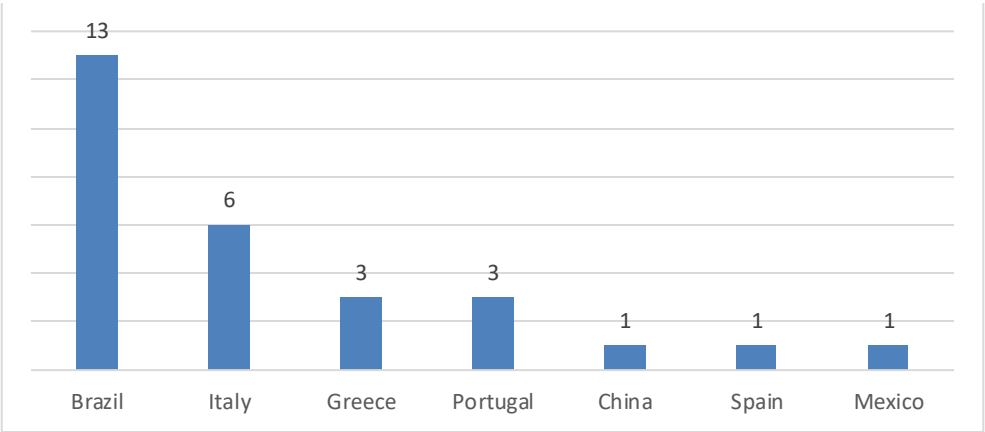


Source: Created by the authors.

Between 2008 and 2014, there were only five published studies, averaging at least one per year. In the years 2008, 2009, and 2012, however, no publications specifically addressed the subject, highlighting the limited attention given to this topic during that period. Starting in 2016, a noticeable increase in the number of studies can be observed, reaching a peak in 2021 with six publications. According to the graph's trend line, this upward trajectory suggests even greater growth in the coming years. This reflects how the subject has been gaining relevance in academic discussions and indicates a growing concern among researchers regarding the preservation of historical heritage in cities around the world.

The analysis of publication numbers based on the countries where the authors' institutions are located is presented in Figure 3. This analysis is valuable, as it highlights the countries contributing most actively to the body of literature on the topic throughout the analyzed period.

Figure 3 – Number of publications by country of the authors' affiliated institutions



Source: Created by the authors.

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The graph shows that authors affiliated with Brazilian institutions, totaling 13 publications, wrote nearly 50% of the published articles. This reflects the growing research interest in this area within the country. One reason for this is Brazil's abundance of historical buildings, where damage mapping is often a prerequisite for restoration projects. As a result, it becomes evident that analyses employing this technique are increasingly being explored and disseminated within academic circles – an essential process for fostering a culture of cultural heritage preservation among current and future generations. This is particularly relevant given that built heritage is subject to significant deterioration over time and, therefore, demands continuous conservation efforts.

Following Brazil, European countries collectively account for 13 publications, with Italy leading the region with six. Italy's prominence in this field can be attributed to its extensive collection of historical heritage sites and the long-standing need to preserve these culturally and historically significant buildings for the benefit of humanity. However, it is worth noting that some studies by European researchers were excluded from the final article count, as they did not meet the criteria established for this review.

Lastly, a word cloud was generated to illustrate the most frequently used keywords in the selected studies, as shown in Figure 4.

Figure 4 – Word cloud of the most frequently used terms in the selected articles

Source: Created by the authors.

From the word cloud, it is evident that the keywords "Pathological Manifestations," "Building Defects," "Damage Maps," "Mapping Damages," and "Historical Heritage" are the most prominent, indicating that these terms are the most frequently cited by the article authors. The word cloud aligns well with the central theme of this study, as it features terms closely related to the identification of pathological manifestations in historical buildings using damage mapping techniques. Furthermore, the inclusion of the word cloud in this research may assist future researchers in selecting appropriate keywords for conducting new studies on this topic.

3.2 Qualitative Analysis

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For the qualitative analysis, some information was extracted from the selected articles, with the synthesis of these data presented in Table 2.

Table 2 – Characterization of the selected studies for Qualitative Analysis (continued)

Authors	Object of Study	Type of Analysis	Methodology
Betti; Bartoli; Orlando (2010)	Italian Renaissance Palace	Quantitative and Qualitative	Finite Element Method and Damage Mapping
Lerma; Cabrelles; Portalés (2011)	Facades of a Historic Belgian Castle	Qualitative	Damage Mapping and Thermography
Labropoulos; Moropoulou (2013)	Bell Tower Facades from a Historic Church in Jerusalem	Quantitative and Qualitative	Damage Mapping and Ground-Penetrating Radar
Borges; Carasek; Cascudo (2014)	Clock Tower Facades in Goiânia, Goiás, Brazil	Qualitative	Damage Mapping and Adhesion Tests
Milani; Valente (2014)	Seven Historic Church Facades in Italy	Quantitative and Qualitative	Finite Element Method and Damage Mapping
Loureiro *et al.* (2015)	Historic Church in Belém, Pará, Brazil	Quantitative and Qualitative	Damage Mapping and Laboratory Analyses
Merello; Beltrán; García-Diego (2016)	Historic Building Walls, Pompeii – Italy	Quantitative	Damage Mapping and Analysis of Variance
Tsilimantou *et al.* (2016)	Historic Mansion, Athens, Greece	Qualitative	Damage Mapping and 3D Analysis
Branco; Sousa; Tsakanika (2017)	Roof Trusses from a Historic Building in Portugal	Quantitative and Qualitative	Damage Mapping and Strength Tests
Karanikoloudis; Lourenço (2017)	Historic Church, Cusco, Peru	Quantitative and Qualitative	Damage Mapping and Laboratory Analyses
Pacheco *et al.* (2018)	Historic Farm Facades, Cachoeira do Sul, Rio Grande do Sul, Brazil	Qualitative	Damage Mapping
Rocha *et al.* (2018)	Historic Church Facades, Olinda, Pernambuco, Brazil	Qualitative	Damage Mapping
Cavalagli *et al.* (2019)	Historic Palace Facades, Italy	Quantitative and Qualitative	Damage Mapping and Numerical Modeling
Micelli; Cascardi (2019)	Historic Church Tower Facades, Italy	Quantitative and Qualitative	Finite Element Method and Damage Mapping
Puy-Alquiza *et al.* (2019)	Historic Museum Facades, Guadalajara, Mexico	Quantitative and Qualitative	Damage Mapping and Laboratory Analyses
Bersch *et al.* (2020)	Facades from Two Historic Buildings, Porto Alegre, Brazil	Quantitative and Qualitative	Damage Mapping and Laboratory Analyses
Bianchini; Mendes; Lourenço (2020)	Historic Temple Facades, Myanmar	Quantitative and Qualitative	Finite Element Method and Damage Mapping
Izzo *et al.* (2020)	Facades of an Ancient Italian Historical Residence	Quantitative and Qualitative	Damage Mapping and Progressive Damage Index Calculation
Tsilimantou *et al.* (2020)	Facades of a Historical Building in Greece	Quantitative and Qualitative	Damage Mapping, Geographic Information Systems (GIS), and Building Information Modeling (BIM) Technology

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Barbosa; Rosse; Laurindo (2021)	Facades of a Historical Building in Minas Gerais, Brazil	Quantitative and Qualitative	Damage Mapping and Thermography
Costa; Sliveira; Torres (2021)	Facades of Historical Buildings in Pelotas, Rio Grande do Sul, Brazil	Quantitative and Qualitative	Damage Mapping and Degradation Measurement Method
Costa; Torres (2021)	Facades of Historical Buildings in Pelotas, Rio Grande do Sul, Brazil	Quantitative and Qualitative	Damage Mapping and Degradation Measurement Method
Iasio *et al.* (2021)	Facades of a Historical Chinese Temple	Quantitative and Qualitative	Damage Mapping and Statistical Analyses
Rodrigues *et al.* (2021)	Facades of a Historical Building in Recife, Pernambuco, Brazil	Qualitative	Damage Mapping
Verdum *et al.* (2021)	Facades of Three Historical Buildings in Rio Grande do Sul, Brazil	Quantitative and Qualitative	Damage Mapping and Degradation Measurement Method
Mendes *et al.* (2022)	Facades of a Historical Museum in Goiânia, Goiás, Brazil	Quantitative and Qualitative	Damage Mapping, Thermography, and Degradation Measurement Method
Amorim *et al.* (2023)	Facades of a Historical Building in Olinda, Pernambuco, Brazil	Qualitative	Damage Mapping
Rodrigues *et al.* (2023)	Facades of a Historical Building in Olinda, Pernambuco, Brazil	Qualitative	Damage Mapping

Source: Created by the authors.

An analysis of the research objects revealed that the vast majority of studies concentrated on identifying pathological manifestations on the facades of historical buildings, while only a few focused on the internal environments or other specific areas of the structures.

It was also noted that some studies directed their attention toward identifying pathological issues in historical churches. This focus is largely due to the widespread presence of such buildings around the world and their significant role in representing the historical and cultural heritage of various societies (Micelli; Cascardi, 2019).

Regarding the type of analysis conducted in each study, it was observed that most works (68%) employed more than one methodological approach, incorporating both quantitative and qualitative analyses of the pathological manifestations.

Only one study focused exclusively on the quantitative analysis of the observed manifestations, while eight studies conducted solely qualitative analyses of the anomalies, as illustrated in Figure 5.

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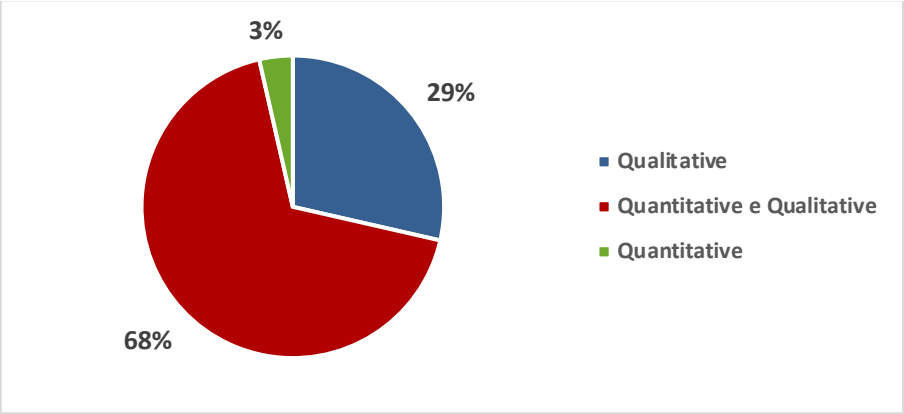
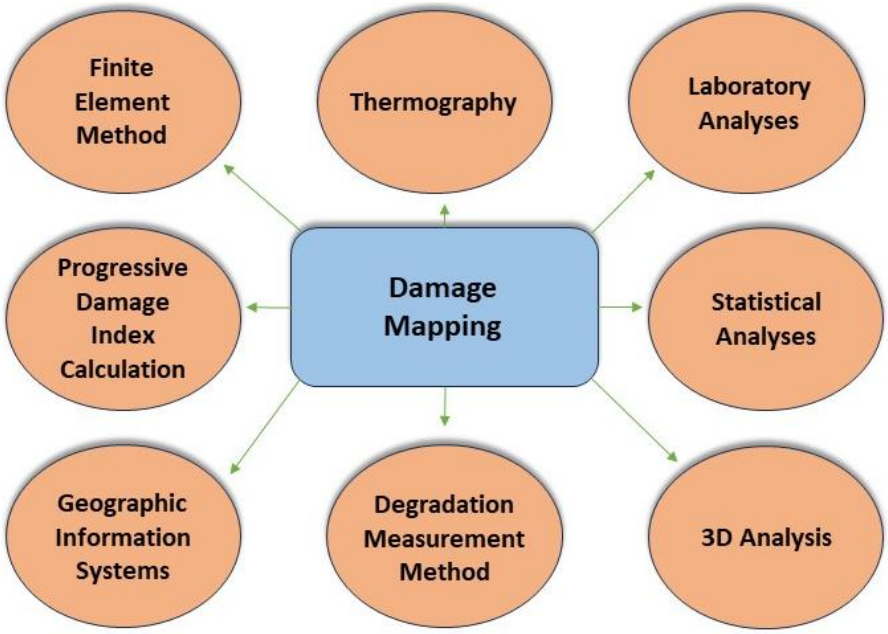
Figure 5 – Types of analyses conducted in the selected articles



Source: Created by the authors.

Finally, the last topic addressed concerns the methodologies employed to identify and analyze the pathological manifestations observed in the studied buildings. The range of methodologies adopted in the reviewed research is presented in Figure 6.

Figure 6 – Research methodologies used in the reviewed articles



Source: Created by the authors.

It was observed that in the majority of the studies, the "damage map" technique was employed in conjunction with other methods. In studies which two types of analyses were conducted, the "damage map" was used during the qualitative analysis of the building, while the other method (Finite Element Method, Degradation Measurement Method, among others) was used for the quantitative analysis of the manifestations.

Additionally, other studies adopted different complementary methods to enhance the qualitative analysis provided by the damage maps. In these cases, tools for 3D modeling of the buildings were used, making the pathological manifestations more visible, as seen in the work

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of Tsilimantou *et al.* (2020), for example, which used Geographic Information Systems (GIS) for 3D modeling of the façades of the studied historical building.

4 DISCUSSIONS

From the analysis of the 28 articles selected for this systematic literature review, it was observed that the use of the "damage map" technique, aimed at identifying pathological manifestations in historical buildings, has been increasing over time. This was evident in the quantitative analysis of the studies, which showed that the number of articles published per year has been growing since 2016.

Another point worth noting is the number of publications by country, based on the institutions to which the authors are affiliated. During the analyzed period, it was observed that authors from Brazilian universities led in published articles, with 13 publications in the last 15 years, averaging almost one article per year. This demonstrates the interest of Brazilian researchers in preserving the numerous historical heritage sites in the country, as well as an increase in the pursuit of modernizing current conservation techniques.

Following the Brazilians, Italian researchers appeared with 6 publications. In addition to focusing their studies on the degradation of historical heritage due to the effects of time and climate change (Cavalagli *et al.*, 2019; Izzo *et al.*, 2020), the Italians also focused their research on damage caused to historical buildings by seismic events, which occur with some frequency in certain regions of the country (Milani; Valente, 2015; Micelli; Cascardi, 2020).

From the qualitative analysis, it was possible to observe that the majority of the studies focused on the analysis of the facades of historical buildings. This is due to the fact that these elements are directly exposed to weather conditions, leading to the emergence of anomalies over time. Amorim *et al.* (2023) and Rodrigues *et al.* (2023) pointed out that the lack of appropriate conservation strategies in these buildings led to a higher level of structural degradation over the years. To ensure that conservation techniques are applied correctly, it is necessary to develop a periodic maintenance plan to identify pathological manifestations in their early stages. Thus, the creation of damage maps is essential to assist in the development of these plans, as they identify areas requiring more urgent repairs in the buildings.

It was also found that 68% of the studies conducted both quantitative and qualitative analyses in their research, using a complementary method to the damage map. This is because many authors aim to quantify the levels of structural degradation and, to do so, they used mathematical models to obtain these results, as damage maps alone cannot achieve this goal. One of the most commonly used methods was the Finite Element Method, which determines the minimum resistance values of elements through differential equations (Betti; Bartoli; Orlando, 2010; Milani; Valente, 2014; Micelli; Cascardi, 2019; Bianchini; Mendes; Lourenço, 2020).

Another point worth mentioning is the use of more current technologies alongside the development of damage maps, as observed in the research by Tsilimantou *et al.* (2020). In their study, the author used an Unmanned Aerial Vehicle (UAV) to conduct a more detailed and precise photographic inspection of the studied building. Based on the data obtained by the UAV, it was possible to create 2D and 3D damage maps of the façades using BIM modeling techniques

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and Geographic Information Systems (GIS), which contributed to a better recognition of the existing problems in the study object.

Finally, it was also noted that the authors used damage maps in various areas of the buildings, demonstrating how versatile and useful this technique is for mapping pathological damage in historical constructions. Additionally, the importance of this tool for developing intervention plans for historical buildings was highlighted, as it assists in designing more precise and efficient restoration works (Rocha *et al.*, 2018).

5 FINAL CONSIDERATIONS

Through the meticulous analysis of the selected articles, it was concluded that the use of damage maps could bring numerous advantages in identifying pathological manifestations in historical buildings. Due to its simplicity, this technique can be applied to various parts of a building, ranging from the façade to the internal structural components. It was also concluded that the technique helps in the visual identification of existing pathological problems in a construction, as it uses colors to specify each anomaly found.

Furthermore, from reading the articles, it was also possible to perceive that damage maps yield better results when associated with other methods, whether quantitative or qualitative. Moreover, the vast majority of the studies employed the damage map in conjunction with a complementary method, with the aim of presenting characteristics that the damage map alone would not be able to provide.

Nevertheless, there has been an increase in the number of studies using this technique in recent years, and the trend is for even greater growth in the future, aiming at modernizing the restoration activities currently performed on historical buildings.

Therefore, it is suggested that future research focus on the use of damage maps integrated with new technologies, such as BIM methodologies, with the aim of continuously innovating the way damage maps are developed. Furthermore, it is recommended to promote the dissemination of knowledge about this technique in engineering and architecture schools, with the goal of increasing the use of this tool as a means of identifying pathological manifestations.

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DECLARATIONS

CONTRIBUTION OF EACH AUTHOR

- **Conception and Design of the Study**: Felipe Duan Moura Vasconcelos, Emilia Rahnemay Kohlman Rabbani e Eliana Cristina Barreto Monteiro.
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- **Funding Acquisition**: Programa de Pós-graduação em Engenharia Civil da Escola Politécnica da Universidade de Pernambuco.
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DECLARATION OF CONFLICTS OF INTEREST

We, **Felipe Duan Moura Vasconcelos, Camila Marques do Rêgo Gonzaga, Emilia Rahnemay Kohlman Rabbani, Eliana Cristina Barreto Monteiro** and **Juliana Santa Cruz Souza** declare that the manuscript entitled "**Damage Mapping as a Diagnostic Tool for Pathological Manifestations in Historical Buildings: A Literature Review**":

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