Sufficiency of Technology Adaptation in Risk Monitoring Criteria for Heritage Sites Management in Malaysia: Site-Based Classification

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Abstract

Cultural heritage sites worldwide are increasingly vulnerable to disasters and climate-related risks, threatening their physical integrity and cultural value. In Malaysia, iconic sites such as Masjid Kampung Laut and Bangunan Sultan Abdul Samad have experienced the impacts of such hazards. However, heritage conservation efforts in the country still largely rely on conventional methods, lacking the integration of advanced technologies like Geographical Information Systems (GIS) and Building Information Modeling (BIM). These tools offer significant potential for comprehensive disaster risk assessments and proactive site management, yet their application remains limited. The absence of GIS and BIM in Conservation Management Plans (CMPs) has resulted in reactive conservation practices that leave heritage sites susceptible to irreversible damage caused by environmental threats and urban encroachment. This study investigates the sufficiency of technology adaptation in the monitoring criteria of Malaysia’s heritage management plans, particularly for sites located in disaster-prone areas. Employing a qualitative research design, the study conducts a detailed content review of selected CMPs and on-site observations of the two heritage sites. The findings reveal a significant gap in the incorporation of technology-driven risk assessment, indicating an urgent need for reform in the monitoring and conservation practices. The study highlights the importance of GIS in spatial risk classification and BIM in structural analysis and mitigation planning. Aligning with UNESCO’s “Managing Disaster Risk for World Heritage” manual, the study advocates for a technology-enriched conservation framework that promotes data-driven, predictive, and resilient strategies for safeguarding cultural heritage in Malaysia.

1. Introduction

1.1 Research Background

Cultural heritage sites around the world are dealing with threats from disasters and climate-related risks, which affect their physical integrity and jeopardize their cultural significance. Despite the many instances of heritage site degradation resulting from disaster impacts, including the Masjid Kampung Laut and Bangunan Sultan Abdul Samad in Malaysia, the field persists in utilizing a conventional conservation approach, which limits the advantages of incorporating technology into conservation practices. This involves the application of Geographical Information Systems (GIS) spatial analysis and Building Information Modeling (BIM) intelligence to conduct comprehensive disaster risk assessments for impacted heritage sites, a practice that is still rare in heritage conservation efforts.

The absence of GIS and BIM integration in heritage management results in a reactive approach, which exposes sites to the risk of irreversible damage caused by climate change, natural disasters, and urban encroachment (Mohammadi & Saffari,2020; Rashid & Kamal,2022). Therefore, this paper will look into the appropriateness of technology adaptation in risk monitoring criteria for heritage site management, specifically in Malaysia’s disaster-prone areas. This paper will be guided by one (1) research question;

RQ: How sufficient has the technology adaptation been incorporated in Malaysia’s heritage management plan monitoring criteria for heritage sites in disaster-prone areas?

2. Risk Monitoring Criteria In Conservation Management Plan

2.1 Lack of Risk Monitoring Criteria in Global Heritage Conservation Management Guidelines

Global heritage conservation management frameworks have been instrumental in shaping conservation practices across countries. However, a growing body of literature suggests that these frameworks, including the widely respected Burra Charter, often fall short in incorporating detailed risk monitoring criteria, particularly in the face of escalating disaster and climate-related threats (Moropoulou et al.,2020; Ng,2019). This limitation reflects a broader research gap that affects not only national but also international conservation practices, undermining efforts to protect heritage assets against emerging environmental and anthropogenic risks.

The Burra Charter (Australia ICOMOS,2013), one of the most referenced documents in heritage management, emphasizes the importance of understanding cultural significance, maintaining authenticity, and using conservation processes such as maintenance, preservation, and restoration. While it mentions the need for careful planning and cyclical maintenance, the Charter does not provide explicit guidelines or frameworks for risk identification, monitoring, or technological integration in managing disaster-prone heritage sites. The Burra Charter, while emphasizing the need for knowledge-based and cautious interventions, lack prescriptive detail on disaster preparedness or the use of tools like GIS and BIM for heritage risk evaluation (Australia ICOMOS,2013; Rahman et al.,2022). It focuses on philosophical approaches to conservation, but remains largely silent on methodologies that address environmental stressors such as floods, earthquakes, and sea-level rise (Forster & Kayan,2009). Its absence of actionable tools for risk assessment makes it less effective in addressing the increasing complexity of environmental hazards, especially for heritage located in vulnerable geographic zones (Zamani & Akbari,2021).

Similarly, the Operational Guidelines for the Implementation of the World Heritage Convention by UNESCO advocate for risk preparedness but remain largely descriptive. Although the "Managing Disaster Risks for World Heritage" manual (UNESCO,2010) acknowledges the importance of integrating disaster risk reduction into heritage management, it does not mandate the use of advanced tools like GIS and BIM, nor does it offer a standardized protocol for applying these technologies across different contexts (Mohammadi & Safari, 2020; UNESCO,2021). This lack of operational clarity creates inconsistencies in national heritage management, where countries like Malaysia struggle to translate international recommendations into actionable and context-specific Conservation Management Plans (CMPs) (Ng,2019; Hasan & Ibrahim,2020).

2.2 Varying Interpretation and Applications of Risk Management for Heritage Sites

The lack of prescriptive global frameworks leads to varying interpretations and applications of risk management in conservation practice. In Malaysia, for example, Conservation Management Plans (CMPs) rarely incorporate disaster risk analysis as a core component, resulting in reactive conservation practices that address issues only after they arise (Rashid & Kamal,2022). This stands in contrast to the dynamic and data-intensive approaches required to address 21st-century challenges such as climate change, urbanization, and infrastructural stress.

Even D'Ayala and Fodde (2008) also suggested that risk monitoring and mitigation in cultural heritage require a multi-disciplinary approach that integrates structural engineering, spatial analytics, and environmental science, where these elements are often excluded from CMP development due to a lack of technological adaptation and policy mandates. However, most conservation management plans (CMPs) lack operational mechanisms to facilitate such interdisciplinary engagement (Gonzalez-Ruibal et al.,2018; Labadi & Logan,2021). This lack of institutional integration results in reactive rather than preventive conservation responses, further amplifying the vulnerability of heritage sites to climate-induced and anthropogenic threats (Larsen & Loga, 2019; Rockman et al.,2016).

2.3 Technology Adaptation in Heritage Sites Risk Assessments

The application of GIS and BIM plays a pivotal role in advancing risk assessment for heritage site conservation. GIS enables the spatial analysis of hazard-prone zones by integrating environmental, climatic, and topographic data to identify and map the vulnerability of heritage assets (Lin et al.,2020; Grussenmeyer et al.,2014). This includes flood risk mapping, seismic exposure evaluation, and urban encroachment monitoring, which are essential for long-term conservation planning. Remote sensing data, integrated into GIS platforms, enhances real-time monitoring and facilitates the detection of environmental changes impacting heritage sites (Brovelli et al.,2019). These capabilities allow authorities strategies with disaster risk reduction frameworks (UNESCO,2010; Yung & Chan,2012).

Meanwhile, BIM contributes to heritage resilience by digitally documenting structural and material characteristics in a 3D environment. This enables detailed simulations of structural responses to disasters such as earthquakes or heavy rainfall (Moropoulou et al.,2020). In heritage contexts, BIM can also incorporate sensor data for deterioration monitoring and virtual testing of retrofitting techniques (Fregonese et al.,2017). When GIS and BIM are integrated, they offer a comprehensive system that combines site-wide spatial risk data with building-specific structural information (Lo Brutto et al.,2020).

3. Methods

3.1 Investigation Strategies

This study employed a qualitative research design to examine the adequacy of risk monitoring criteria in heritage conservation practices in Malaysia. A dual-monitoring approach was adopted, incorporating: 1) Field-based site observations and 2) a content review of Conservation Management Plans (CMPs). The methodology aimed to triangulate visuals, structural, and documentary data to critically assess the alignment of heritage site management with recognized risk assessment frameworks.

The site observation enabled the identification of visible deterioration patterns, environmental vulnerabilities, contextual risks such as urban encroachment, flooding potential, and lack of adaptive infrastructure. During the site observation process, systematic visual assessments were documented through a photographic survey. This included capturing structural elements such as walls, foundations, roofing materials, and points of deterioration or environmental exposure (eg., cracks, moisture stains, water damage). To triangulate findings, the field data were analyzed in relation to the existing CMP documents, particularly to evaluate how comprehensively disaster-related risk assessments were integrated into their management frameworks.

3.2 Rationale of the Case Study Selection

Two case study sites were selected: Bangunan Sultan Abdul Samad, located in Kuala Lumpur, and Masjid Kampung Laut, located in Kelantan. The selection was guided by two criteria: (a) both sites are gazetted under the National Heritage Act, and (b) both are situated in disaster-prone areas, with historical records of exposure to floods, riverbank erosion, or urban stressors.

3.2.1 Masjid Kampung Laut in Kelantan

Masjid Kampung Laut, located in Kampung Laut, Kelantan, is one of the oldest surviving traditional wooden mosques in Malaysia, believed to have been built in the late 18th or early 19th century. Its architectural design exemplifies a unique fusion of local Malay craftsmanship and early Islamic influence, particularly evident in its tiered roof structure, timber joinery techniques, and pillar-based construction without nails, a method typical of the Nusantara Malay world (Ismail,2013; Mohd Yusof et al.,2017).

Historically, Masjid Kampung Laut holds significant value as a symbol of early Islamic propagation in the northern region of the Malay Peninsula and reflects the architectural ingenuity of pre-colonial Musli communities.

Figure 1. Masjid Kampung Laut in Kelantan.

Disaster Risk Exposure

Masjid Kampung Laut has experienced a significant history of flood-related disasters due to its original location along the banks of the Kelantan River in Tumpat, a region highly vulnerable to seasonal monsoon floods. The most devastating flood event occurred in 1966, when the Kelantan River overflowed and submerged large areas of the riverbank, severely endangering the structural integrity of the mosque. As a result, the mosque was dismantled and relocated to Nilam Puri for preservation (Ismail & Ahmad,2012; Harun et al.,2015). Despite the relocation, the mosque remains exposed to hydrological risks, including riverbank erosion and heavy rain-induced flooding during the monsoon season (Mohd Yusof et al.,2017).

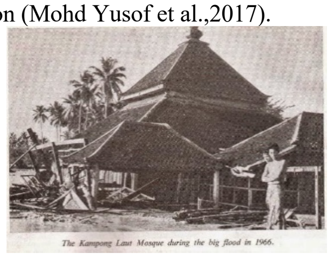

Figure 2. Masjid Kampung Laut was damaged due to a big flood in 1966.

3.2.2 Bangunan Sultan Abdul Samad in Kuala Lumpur

The Bangunan Sultan Abdul Samad, completed in 1897, is one of Malaysia’s most iconic colonial-era buildings, located prominently in front of Dataran Merdeka (Independaence Square) in Kuala Lumpur. Designed by A.C Norman, with contributions from R.A.J Bidwell and A.B. Hubback, the building served as the administrative center for the British colonial government in Malaya and later housed the superiors courts of Malaysia (Gullick,2000; Ahmad,1997).

Historically, the building represents both colonial dominance and post-independence national identity. It was originally the Secretariat Building for the British administration, but later became a symbol of Malaysian nationalism when it hosted the declaration of independence on 31st August 1957.

Figure 3. Bangunan Sultan Abdul Samad in Kuala Lumpur.

Disaster Risk Exposure

Bangunan Sultan Abdul Samad, located adjacent to the Klang River and the historic Padang Merdeka, has also faced increasing risks from urban flooding due to rapid development, riverbank modification, and inadequate stormwater management systems. Kuala Lumpur experiences flash floods during heavy rainfall, and the location of the building places it within the flood-prone catchment area of the Klang basin (Abdullah et al.,2020; Loo et al.,2015). Historical records highlight multiple incidents of water pooling and seepage within the building’s basement and lower floors, often exacerbated by outdated drainage infrastructure (Zamani & Akbari,2021).

Figure 4. Flooding history at Bangunan Sultan Abdul Samad (Left photo: Flood event in 2021; Right photo: Flood event in 1971) (Source: Berita Harian)

3.3 Content Review

This study employs a qualitative research methodology, utilising Content Review as the main data collection tool to substantiate the findings from the previous site observation conducted. Content review plays a vital role in assessing the criteria outlined in the Conservation Management Plan (CMP), as it facilitates a systematic evaluation of the comprehensiveness, quality, and inclusion of disaster risk reduction (DRR) elements. The method offers a systematic approach that aids in identifying patterns, gaps, and inconsistencies among the various CMPs, thereby enhancing the understanding of how DRR is addressed (Bowen,2009).

The author is able to perform an analysis regarding the incorporation of disaster risk reduction measures, including risk assessments, mitigation plans, and climate adaptations, via the content review process. This analysis will enable the author to identify opportunities for enhancing the protection of heritage sites against the risks posed by disaster impacts. For this particular study, only Bangunan Sultan Abdul Samad was equipped with CMP, while the content review for Masjid Kampung Laut was conducted on the conservation documentation book titled “Masjid Lama Kampung Laut, Ibarat Sireh Pulang ke Gangang”, where the book documented the procedure of conservation works conducted at the site, including during relocation of the building structure back to the original site.

4. Result And Discussion

4.1 Site Observation Findings on Masjid Kampung Laut

4.1.1 The Geographical Condition

Masjid Kampung Laut where partially destroyed by the massive flood disaster in the year 1966-1967, which led to relocation to Nilam Puri to save the remaining structure of the building. After over 5 decades, Masjid Kampung Laut has finally been relocated back to the original location of Kampung Laut, 300 meters away from the actual site coordination, which is already submerged by the river.

The original location of Masjid Kampung Laut has been lost as a result of erosion and soil deposition along the Kelantan River over time. The site of the mosque has eroded by approximately 64 meters and subsided by about 10 meters. Consequently, the authorities decided to select a new site nearby within Kampung Laut.

The decision to relocate the Masjid Kampung Laut back to its original place required the involvement of various experts such as architects, engineers, and local authorities. Detailed engineering calculation was made, including strengthening the riverbank of the proposed new location of Masjid Kampung Laut. Acknowledging that Tumpat was severely affected by the flood event in 2014, the Department of Irrigation and Drainage (JPS) decided to build a flood barrier standing 2.4 metres high along the banks of the Kelantan River as a precautionary barrier against riverbank erosion.

Figure 5. Flood barrier along the Kelantan River protecting the Masjid Kampung Laut. (Source: Author)

4.1.2 The Structural Integrity

Masjid Kampung Laut is one of the finest surviving examples of early Malay-Islamic architecture in Malaysia, noted for its resilient structural system that has endured for more than two centuries. Despite its relocation from Tumpat to Nilam Puri in 1966, many of its original structural components, notably the timber framework, roof form, columns, and floor system, have remained intact and continue to reflect the craftsmanship of its builders (Ismail &Ahmad,2012; Harun et al.,2015).

The mosque was constructed using chengal hardwood, a native tropical timber renowned for its exceptional durability and natural resistance to termites and rot (Kamarul Syahril & Ahmad,2015). The structure follows a post-and-beam system with mortise-and-tenon joints, eliminating the use of nails, which was a traditional Malay carpentry technique. This system, combined with elevated flooring supported by stilts, helped protect the mosque from ground moisture and flooding.

Figure 6. The original 20 structure pillars were supported with modern concrete footing. (Source: Author)

The floor level of the mosque was elevated 3 feet from the ground level; the same floor raise level as per it was first built in year 14th century.

Figure 7. The timber pillar foundation was supported with a metal support. (Source: Author)

Due to the aging wooden structure, new modern joinery support, such as bolt-and-nut, has been adopted to strengthen the overall building structure. The bottom part of the timber pillar was badly damaged compared to the other length of the pillar due to its frequent submergence under water during flood disaster.

Figure 8. The original main pillar that was believed to remain from the first built Masjid Kampung Laut structure in the 14th Century.

The pillar was presumed to be the original main pillar due to its distinct appearance, size, and damage markings compared to the other pillars. The Malaysian Timber Industry Board (MTIB) has conducted an examination and confirmed that the pillar is composed of cengal hardwood, while the other pillars were constructed from red balau, thereby reinforcing the theory of the *Soko Guru* pillar.

Figure 9. The first Soko Guru to be erected during the reconstruction work in 2021. (Source: ECERDC,2022)

Many of the original 20 timber pillars (tiang seri) are still standing and provide vital vertical support to the mosque’s superstructure. The preservation of these columns, along with the original beam network and wooden panelling, reflects the high-quality workmanship and architectural foresight embedded in traditional Malay construction practices (Ismail,2013).

Figure 10. The mortise-and-tenon join for roof trusses is now supported with a metal structure to strengthen the roof. (Source: Author)

By looking at this reconstruction detailing, by practice, it was recorded as a success and historical reconstruction works of Masjid Kampung Laut. However, as a gazetted cultural heritage, this work shall be accompanied by a Conservation Management Plan (CMP) to record all initial assessments of the site before conducting the reconstruction, and to suggest a proper reconstruction strategy before commencing the work, rather than documenting the overall process in a coffee-table documentation book. It brings an alarm on the importance of having a CMP before proceeding with the conservation works to any cultural heritage assets. Specifically, the coffee-table book documentation is not sufficient to be referred to for future preservation works of this site. Therefore, it is crucial to have a proper CMP to protect this site from now on.

4.2 Site Observation Findings on Bangunan Sultan Abdul Samad

4.2.1 The Geographical Condition

Historically, Malaysia has been vulnerable to flood disasters, with Kuala Lumpur identified as one of the cities most at risk of flooding within the country. Kuala Lumpur, unlike other Malaysian states affected by monsoon or flash flood risks, is particularly vulnerable to both monsoon and urban flooding. Tis vulnerability is attributed to its geographical location within a floodplain and the rapid urban development, which exacerbates the potential impact of flood-related disasters.

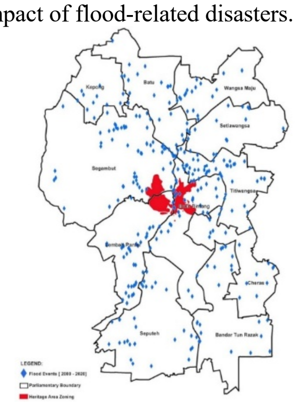

Figure 11. Integrated map of Heritage Area and Flood Hotspot in Kuala Lumpur (Source: Author)

This site, despite its disadvantageous location in the floodplain, holds historical significance as the original place of tin trading in Kuala Lumpur. Vanderlinden et al. (2020) observed that human settlements have traditionally clustered around water sources, leading to the proximity of numerous cultural heritage sites to rivers.

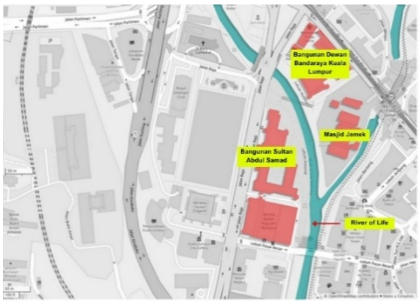

Figure 12. Location of the Bangunan Sultan Abdul Samad near interconnection of 2 main river line.

The city's location within the river basin of two major rivers has rendered floods inevitable (Bhuiyan et al.,2018), resulting in frequent occurrences of flash floods during the monsoon season or following extended periods of heavy rainfall. Kuala Lumpur has experienced several significant flood events, including the "Great Flood" in 1926 and another in 1971, which impacted 180,000 individuals and resulted in 32 fatalities. These incidents prompted the government to implement serious measures to address flood-related challenges (Samsuri et al.,2018).

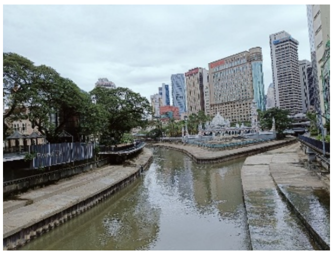

Figure 13. The intersection of the Gombak River and Klang River, just behind the Bangunan Sultan Abdul Samad.

4.2.2 The Structural Integrity

Although this heritage building has withstood the test of time, its structural integrity has increasingly been compromised by environmental stressors, notably urban flooding, vibration from traffic, and climate-related deterioration.

Flash floods in Kuala Lumpur have become more frequent due to urbanization, poor drainage infrastructure, and riverbank modifications, which reduce natural water absorption and retention (Loo et al.,2015).

Figure 14. Poor perimeter drainage system of Bangunan Sultan Abdul Samad (Source: Author)

The drainage system surrounding the Bangunan Sultan Abdul Samad was found to be very narrow, and some of the drainage was blocked by road access modification.

Figure 15. Additional components (Spotlight and piping) were obstructing the existing drainage

The impact of new and non-strategic development and modification conducted at the heritage sites leads to this inappropriate position of all these "add-on" items, including blocking and drainage lines, which are already too narrow to accommodate the overflow of heavy rainwater into the stream.

Figure 16. Water damage in the Wall and Foundation

Water infiltration into the basement and lower-level walls due to the frequent flood occurrence has caused rising damp, efflorescence, and mortar degradation, weakened the brick joints and increased the building's vulnerability to structural fatigue. Moisture-related damage is most evident in plaster spalling and cracks at arch junctions and column bases.

Figure 17. The wall cracked, and plaster spalled.

These issues are exacerbated during intense wet seasons, which are projected to worsen due to climate change impacts on rainfall variability. Beyond flooding, the building also suffers from vibrational stress induced by the high vehicular activity along Jalan Raja and the nearby construction of underground transit systems. These vibrations contribute to micro-cracking in the plaster and render layers, which it left untreated. In a prolonged duration, it can compromise the load distribution and lead to progressive material fatigue (Harun et al.,2015; Moropoulou et al.,2020).

Figure 18. Additional electrical DB and conduit exposed to public access. (Source: Author)

The additional concern that warrants attention at this location pertains to public safety. The alterations made to the site were executed in a manner that was not suitable, resulting in the clear exposure of additional electrical distribution boards along the public walkway. Any acts of misconduct or vandalism directed at the exposed electrical distribution board could potentially result in a disastrous fire incident.

4.2.3 Conservation Management Plan Monitoring Criteria

To further validate the research, a content review was conducted on the Bangunan Sultan Abdul Sasmad CMP (BSAS CMP) document. The CMP was benchmarked against two authoritative references: the Conservation Management Plan Guidelines published by Malaysia's National Heritage Department, and the Burra Charter (Australia ICOMOS,2013). These documents provide internationally and nationally accepted standards for heritage conservation, including the necessity of incorporating risk identification, disaster preparedness, and stakeholder-informed strategies.

The extensive review of the content was carried out in alignment with the comparative analysis of the monitoring criteria outlines in the CMP documents. The author analysed the extend to which disaster risk reduction in incorporated within the risk assessment elements of the CMP. The findings were subsequently encapsulated in a tabular format to illustrated the integration of the DRR components within the overarching monitoring criteria of the BSAS CMP.

No.	Description
1	Executive Summary
2	Introduction of Sites / Heritage Buildings
3	History Background of the Sites/Heritage Building
4	Physical Assessment
5	Cultural Significance Assessment
6	Issue, Analysis, and Recommendations
7	Policy
8	Impact on the Environment
9	Information Management
10	Maintenance Schedule

Table 1. List of Content in CMP Guidelines by Malaysia's National Heritage Department

Both the Burra Charter and Malaysia's CMP Guidelines show the consistency of monitoring criteria to be included in the CMP documents. However, in order to investigate the possibility of incorporating sufficient risk assessment into the CMP standard, the author has re-examined the general monitoring criteria that formed the foundation of the CMP documents.

No.	Description	Monitoring Aspect	Level of DRR	Remarks
1	Executive Summary	Summary of the heritage sites significance and the purpose of the CMP document	Poor	-
2	Introduction of Sites / Heritage Buildings	Explanation of the heritage sites' gazetted status, the location, and the current condition of the heritage sites.	Poor	Only CMP for Bangunan Sultan Abdul Samad had featured the flood history that hit the heritage sites.
3	History Background of the Sites/Heritage Building	Explanation of the history of the existence of the heritage sites, their functions, and historical events involving the heritage sites.	Poor	Only CMP for Bangunan Sultan Abdul Samad had featured the flood history that hit the heritage sites.
4	Physical Assessment	Assessment of the current condition of the heritage sites/buildings with supporting photograph evidence and detail elaborations.	Poor	Insufficient explanation of the underlying causes of damages, particularly those resulting from disaster risks such as flooding or fire.
5	Cultural Significance Assessment	Identification of the cultural significance of the heritage sites, the efforts to be taken to protect the significance value.	Poor	The cultural significance assessment could be differ with consideration on disaster risk impact.
6	Issue, Analysis, and Recommendations	Highlighting any issues occurred that might impacted the heritage sites/buildings conditions, and proposing relevant actions to be taken.	Minimal	Identification of issues in regard to safety and disaster but most of the CMP had focus on the fire safety management plan.
7	Policy	Identification of the involved policy that to be referred during the preparation of the CMP for specified heritage sites/building.	Poor	Only involved the policy in regard to town planning and heritage management.
8	Impact on the Environment	Identified the impact on the environment during the undertaken of the conservation works done.	Poor	Mostly explained the initiatives to be taken to protect the environment when the conservation work is done.
9	Information	Highlighting the issues	Poor	Generally discussed

	Management	in regards to lack of resource management, and references.		on how to manage the resource and information in regards to the heritage conservation works.
10	Maintenance Schedule	Proposed maintenance schedule to support the conservation works to be done for the heritage sites as recommended in the CMP document.	Poor	Only focusing on the repair efforts.
11	Action Plan (Only included in BSAS CMP)	Proposed recommendation (short-term & long-term).	Minimal	Briefly highlight the recommendation on the needs for conducting the risk assessment on flood and fire risk.

Note: The level of DRR consideration in CMP is measured according to; **Poor** (Absence of DRR), Minimal (Minimum feature of DRR), **Average** (Briefly incorporated DRR), **Good** (Incorporated DRR with future recommendation in plans)

Table 2. Consideration of DRR in CMP Monitoring Criteria.

Table 2 outlines the ten fundamental elements required for the preparation of CMP documents as executed in Malaysia. Nonetheless, the incorporation of disaster risk reduction elements is still insufficient for the preservation of heritage sites, particularly in regions vulnerable to disasters, where these sites are especially at risk from the consequences of such threats. The advancement of CMP is dependent on particular conditions. Upon a thorough examination of the Bangunan Sultan Abdul Samad (BSAS) CMP, which is situated within the floodplain at the confluence of the Klang and Gombak rivers, the evaluations and recommendations articulated in the documents reveal a lack of adequate consideration for the implications of the frequent flood risk on the heritage sites. The immediate corrective measures for structural fabric imperfections are generally included in the physical evaluation of the BSAS CMP.

5. Critical Gap of BIM and GIS Applications In Conservation and CMPs of Bangunan Sultan Abdul Saman and Masjid Kampung Laut

Despite the existence of a CMP for Bangunan Sultan Abdul Samad, it remains rooted in traditional documentation methods, lacking modern tools like BIM and GIS that are vital for precise structural assessment and environmental risk analysis. The absence of BIM limits tracking of material deterioration and structural changes, while the lack GIS impedes flood risk evaluation near the Klang River. In the case of Masjid Kampung Laut, the absence of a formal CMP and reliance on descriptive records highlight an even greater gap, with no use of digital modelling or spatial analysis to assess flood vulnerability from the Kelantan River or simulated long-term impacts on its timber structure (Zamani & Akbari, 2021; Abdullah et al.,2020; Yusof et al.,2017; Ismail & Ahmad,2012)

Overall, the lack of BIM and GIS in both heritage sites reflects a broader technological gap in Malaysia's conservation practice, which remains heavily reliant on conventional methodologies. This disconnect poses significant risks as climate change, urban encroachment, and natural disasters become more frequent and intense. Incorporating these technologies would not only enhance the scientific rigor of conservation work but also align Malaysia's efforts with international best practices outlined by UNESCO and ICOMOS (UNESCO,2010).

6. Conclusion and Recommendations

To enhance the effectiveness of heritage conservation in Malaysia, it is recommended that the Conservation Management Plan (CMP) formally incorporate BIM and GIS into its monitoring criteria. BIM can be used to create detailed 3D digital models of heritage buildings, allowing conservation professionals to simulate and monitor structural performance over time. This includes identifying stress points, material degradation, and predicting structural failures, particularly vital for aging timber or masonry structures such as Masjid Kampung Laut and Bangunan Sultan Abdul Samad. Through BIM, interventions can be virtually tested before on-site application, minimizing physical impact on the heritage fabric. Additionally, a digital database embedded in the BIM model can store all documentation, repair histories, and conservation decisions, improving long-term asset management.

In parallel, GIS can support spatial risk assessment and environmental monitoring by mapping flood zones, seismic areas, climate trends, and urban encroachment near rivers. GIS-based flood modelling is essential to determine flood vulnerability and recommend buffer zones. Similarly, for Bangunan Sultan Abdul Samad, GIS can track changes in surrounding urban land use and drainage infrastructure. Integrating GIS into CMPs ensures that decision-making is data-driven, location-specific, and forward-looking. To implement these tools effectively, Malaysia's heritage authorities, such as the National Heritage Department, must revise existing CMP guidelines to include digital documentation requirements and provide training for conservation practitioners to build BIM and GIS proficiency (Rashid & Kamal,2022; Abdullah et al.,2020).

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