



Enhancing the Safety and Resilience of Maldivian Cultural Heritage

Strategies for Disaster Prevention and Climate Change adaptation



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Overview

The Maldives is a low-lying island nation in the Indian Ocean, consisting of approximately 1,190 islands grouped into 26 natural atolls. Its unique geography, characterized by small islands, narrow land areas, coral reefs, and coastal settlements, makes the country highly exposed to natural hazards. Most islands are only a few metres above sea level, while many cultural heritage sites are located close to the coast. These conditions make the safety and protection of cultural heritage an important national concern.

The cultural heritage of the Maldives includes historic coral-stone mosques, archaeological sites, cemeteries, monuments, traditional buildings, and places associated with the country's religious, social, political, and maritime history. Many of these sites are valuable not only for their architectural and historical significance but also for their connection to local communities and traditional practices. The preservation of these sites is therefore closely linked to the protection of cultural identity and historical memory.

Maldivian heritage sites are exposed to a range of hazards, including coastal erosion, storm surges, flooding, heavy rainfall, strong winds, fires, saltwater intrusion, structural deterioration, and other human-induced risks. Climate change is expected to increase the frequency or severity of some of these hazards, creating additional challenges for heritage protection. The low elevation and limited land area of many islands further increase the potential consequences of disasters. According to Disaster Statistics of Maldives 2024 (MDMA) Rainwater flooding and fire incidents are most high impacting hazard towards the heritage. In 2024, 93 incidents of rainwater flooding and 83 fire incidents were reported. In MDMA's report 57 strong winds incidents were also reported.

Safety and disaster prevention require a proactive approach rather than relying only on emergency response after an incident occurs. Heritage sites need to be systematically assessed to identify structural, environmental, fire, coastal, and other risks. Regular inspection and condition monitoring can help identify vulnerabilities at an early stage, allowing preventive conservation and maintenance to be carried out before significant damage occurs.

Disaster preparedness is also essential. Heritage institutions, local authorities, site managers, communities, and emergency services should have clearly defined roles and procedures for responding to fires, flooding, storms, structural failures, and other emergencies. Emergency response plans, evacuation procedures, fire protection, early-warning systems, emergency equipment, documentation, and trained personnel can significantly reduce the potential loss of heritage during disasters.

For the Maldives, disaster prevention should also consider the specific characteristics of traditional heritage structures. Many historic buildings are constructed using coral stone and other traditional materials that can be particularly vulnerable to moisture, salt, physical impacts, and prolonged environmental exposure. Conservation and safety measures should therefore be carefully designed to protect the heritage values of these structures while improving their resilience to hazards.

A comprehensive heritage disaster-risk management approach should integrate **risk identification, prevention, preparedness, response, recovery, and long-term adaptation**. Documentation and digital recording of heritage sites are also important safeguards, particularly for sites that may face irreversible damage or loss. Accurate records can support conservation planning, emergency decision-making, and future restoration.

Strengthening the safety and disaster resilience of Maldivian cultural heritage requires cooperation among government institutions, heritage professionals, local councils, communities, emergency services,

researchers, and international partners. By combining scientific risk assessment with traditional knowledge and local experience, the Maldives can develop practical and sustainable strategies to prevent disasters and reduce their impact on cultural heritage.

Protecting heritage from disasters is not only a matter of preserving buildings and archaeological remains. It is also about safeguarding the historical knowledge, cultural identity, traditions, and collective memory of Maldivian communities for future generations.

Strategies to Enhance safety and resilience of Maldivian Cultural Heritage

The first step in ensuring the safety, resilience, and long-term preservation of a cultural heritage site is to **identify the threats and risks that may affect the site**. Heritage conservation should not begin only after visible damage or structural failure has occurred. Instead, potential hazards should be identified, assessed, monitored, and addressed through a preventive and risk-based management approach.

This research examines the safety and disaster-prevention approaches used by the **National Research Institute of Cultural Heritage (NRICH), particularly its Safety and Disaster Prevention Division (SDPD), Republic of Korea**, and explores how selected approaches can be adapted to the Maldivian context. The objective is not to replicate the Korean system exactly, but to assess which methods and technologies can be effectively applied to Maldivian heritage sites considering the country's geography, climate, traditional construction materials, available technical capacity, and dispersed island settlements.

For the purpose of this research, **Malé Friday Mosque (Maale Hukuru Miskiy)** has been selected as the pilot site. The mosque is an important example of Maldivian coral-stone architecture and provides an appropriate case study for examining methods of threat identification, condition assessment, structural monitoring, and disaster prevention.

Identifying Potential Threats

Before selecting monitoring equipment or conducting detailed structural investigations, the threats affecting a heritage site must first be identified. The risk profile of a heritage property is influenced by the type and probability of hazards, the site's exposure, the vulnerability of its materials and structure, its cultural significance, and the capacity available to respond to an emergency. The SDPD assessment proposes a risk framework based on:

Hazard probability × exposure × physical vulnerability × heritage significance × response capacity.

In the Maldivian context, threat identification should consider both natural and human-induced hazards. Priority threats may include:

- Coastal flooding and storm surge
- Sea-level rise and recurrent inundation
- Coastal erosion and shoreline movement
- Saltwater intrusion and salt crystallization

- Extreme rainfall and drainage failure
- High humidity and moisture-related deterioration
- Biological growth and insect activity
- Strong winds and severe weather
- Fire, particularly in dense settlements and historic timber structures
- Structural movement, settlement, and deformation
- Vibration caused by nearby construction or traffic
- Accidental and human-induced damage
- Development pressure surrounding heritage properties

These hazards should not be treated as isolated events. Environmental exposure, climate change, material deterioration, structural vulnerability, and human activity can interact and gradually weaken a heritage property. The SDPD framework similarly emphasizes that preventive management should consider the interaction between environmental exposure, disasters, and material deterioration rather than focusing only on individual disaster events.

For the Maldives, particular attention should be given to **coastal flooding, salinity, erosion, groundwater, high humidity, and sea-level rise**, as these represent important differences from the hazard priorities of the Korean system.

Establishing a Baseline Condition

Once the potential threats have been identified, the next step is to establish the current condition of the heritage site. A baseline record is essential because future changes can only be accurately identified when there is reliable information about the site's original or existing condition.

NRICH conducts regular safety inspections of architectural cultural heritage using various measuring devices to assess the risk of damage and implement preventive measures. Its Safety and Disaster Prevention Division also undertakes research into structural stability, safety inspection, disaster prevention, and emergency assessment.

For a Maldivian heritage site, the baseline survey should include:

1. Visual inspection of the entire structure.
2. Detailed photographic documentation.
3. Identification and mapping of cracks and defects.
4. Recording of moisture and water-related deterioration.
5. Documentation of salt deposits and surface deterioration.
6. Assessment of structural elements.
7. Documentation of previous repairs and interventions.
8. Recording of the surrounding environment and drainage.
9. Measurement of the site's relationship to the shoreline.
10. Digital documentation through drawings, photogrammetry, or 3D recording where appropriate.

High-resolution cameras and drones can assist in documenting roofs, façades, inaccessible areas, and the surrounding environment. The information should be systematically stored in a digital database so that future inspections can be compared against the baseline condition.

The SDPD assessment recommends establishing a national digital heritage risk register containing baseline photographs, drawings, 3D records, construction information, past repair and disaster history, hazard exposure, condition assessments, inspection schedules, emergency contacts, and monitoring data.

Initial Visual Inspection and Photographic Survey

The first stage of the physical survey should be a systematic visual inspection. This provides an overall understanding of the condition of the building before more advanced equipment is introduced.

During the inspection of Malé Friday Mosque, attention should be given to:

- Cracks in walls, columns, floors, and other structural elements
- Displacement or leaning of structural components
- Deterioration of coral stone
- Loss or deterioration of lime-based finishes
- Salt deposits and salt-related damage
- Dampness and water infiltration
- Roof leakage
- Biological growth and mold
- Timber deterioration
- Drainage problems
- Evidence of previous structural repairs
- Changes in the surrounding ground or pavement
- Potential fire hazards
- Vibration or disturbance from nearby activities

Fixed photographic viewpoints should be established so that the same locations can be photographed during future inspections. This allows changes to be identified more reliably over time.

The SDPD approach emphasizes regular surveys and monitoring to establish scientific baseline information for the conservation and management of heritage properties. NRICH's monitoring programs include structural safety, conservation condition, and biological damage.

Detailed Measurement and Structural Assessment

If the initial inspection identifies areas of concern, the survey should progress to more detailed technical investigation. The purpose of this stage is to determine whether observed defects represent stable conditions or continuing structural or environmental changes.

Depending on the identified threat, appropriate technologies may include:

- Total Station measurements
- Crack-width measurements
- Displacement measurements
- Tilt measurements
- Vibration measurements (Ground-level measurements)
- Structural movement monitoring
- Temperature and relative-humidity monitoring
- Moisture measurements
- Water-level monitoring
- Groundwater monitoring
- Salinity measurements
- Shoreline and erosion measurements

The SDPD uses structural engineering tests and measurements to understand the behaviour of traditional architectural heritage, including analysis of structural characteristics, natural frequency, and damping behaviour.

For Maldivian heritage, additional research should focus on the behaviour of **coral-stone masonry, lime mortar, timber, and traditional roof systems** under marine environmental conditions. Particular attention should be given to salt crystallization, repeated wetting and drying, high humidity, moisture penetration, and the compatibility of modern repair materials with traditional materials.

Displacement and Movement Monitoring

One of the important approaches demonstrated through the SDPD research is the measurement of structural movement over time.

In the case of **Gapsa Temple's Daewoong Jeon Hall**, displacement surveys were conducted by establishing specific measurement points on structural elements. By measuring the position of these points repeatedly using surveying equipment such as a Total Station, changes in the position and alignment of structural elements can be identified.

A similar methodology could be investigated for Malé Friday Mosque. Appropriate measurement points could be established on selected structural elements following consultation with conservation and structural specialists. Repeated measurements would allow researchers to determine whether observed movement is stable, seasonal, or progressive.

This is important because a crack or slight displacement observed during one inspection does not necessarily indicate immediate structural danger. However, repeated measurements can establish whether the condition is changing and whether further intervention is required. The frequency of repeated measurements should be determined according to the condition and risk level of the heritage site.

Continuous Monitoring

For heritage sites identified as being at higher risk, periodic inspections may not be sufficient. Continuous monitoring can provide information about changes that occur between inspection periods.

The SDPD uses various monitoring technologies, including displacement gauges, tiltmeters, laser-distance sensors, temperature and humidity sensors, rainfall and water-level measurements. Some monitoring systems collect data at intervals of approximately 10–30 minutes.

The Maldives should not attempt to install sophisticated monitoring systems at every heritage site. However, the risks can be determined by studying the National Disaster Management’s Report. Since the report already identify the condition general area, a **risk-based and proportionate monitoring system** would be more appropriate:

Risk Level	Suggested Monitoring
Lower risk	Annual inspection and standard photographic documentation
Moderate risk	Seasonal inspection, moisture and crack measurements
High risk	Water level, humidity, salinity, crack and tilt monitoring
Critical risk	Automated sensors, remote alerts and frequent professional review

For Maldivian heritage sites, particularly relevant measurements would include relative humidity, temperature, wall moisture, salinity, flood depth and duration, groundwater level, crack width, structural movement, tilt, settlement, wind exposure, and shoreline erosion.

Continuous Monitoring at Magoksa Temple’s Dae Woong Bo Jeon Hall

The monitoring approach demonstrated at **Magoksa Temple’s Dae Woong Bo Jeon Hall** provides an example of how continuous structural monitoring can be used to identify gradual changes in a heritage structure. Sensors installed on the building monitor movement and tilt, with measurements transmitted to a central system at regular intervals.

The value of this approach is that it allows changes to be detected even when they are too gradual or small to be identified through ordinary visual inspection. Continuous data can also help establish relationships between structural movement and environmental conditions.

For the Maldives, a similar approach could be tested on selected high-risk heritage structures. However, monitoring equipment should be selected according to the specific risk identified at each site. The SDPD assessment emphasizes that technology should follow risk identification and that monitoring data are useful only when clear thresholds, responsible officers, and response procedures are established.

Structural Engineering Testing and Future Research Capacity

At the National Research Institute of Cultural Heritage facility in Chung-ju city, the Structural Engineering Testing demonstrates Korea’s advanced approach to assessing the safety and performance of heritage

buildings. The facility conducts research on **material testing, structural stability, timber and wood testing, building load testing, and overall performance evaluation**. These researches are particularly valuable for understanding how historic structures respond to different loads, stresses, material deterioration, and structural conditions.

Although structural stability research is highly important for the long-term protection of heritage buildings, the Maldives currently needs to give greater priority to **basic documentation, condition surveys, material characterization, environmental monitoring, disaster-risk assessment, and climate-related vulnerability studies** due to the country's specific heritage and environmental challenges. However, as Maldives develops its heritage conservation capacity and technical research infrastructure, structural stability testing and performance evaluation could become an important area of future research, particularly for vulnerable coral-stone structures and other historic buildings requiring detailed structural assessment.

Condition and Damage Grading

The information obtained through visual inspection, measurement, and monitoring should be used to classify the condition of the heritage site and prioritize conservation action.

The grading system identified in the research material provides a useful framework:

- **Grade A – Good:** The heritage property is in good condition.
- **Grade B – Minor Repairs:** Minor repairs or routine maintenance are required.
- **Grade C-1 – Caution/Observation:** The condition requires continued observation.
- **Grade C-2 – Partial Repairs:** Partial or localized repairs are required.
- **Grade D – Detailed Diagnosis:** Detailed technical investigation is required.
- **Grade E – Repair:** Significant repair and conservation intervention are required.
- **Grade F – Immediate Action:** Immediate action is required because of serious risk or damage.

A grading system allows limited conservation resources to be directed towards sites where intervention is most urgent. It also creates a common language for communicating the condition of heritage properties between heritage authorities, engineers, local councils, emergency services, and site custodians.

NRICH's monitoring programmes similarly use focused management of heritage properties requiring more intensive monitoring and detailed measurement. For example, Korea has operated focused monitoring programmes for designated architectural heritage, including structural safety, conservation science, and biological damage.

From Reactive Repair to Preventive Conservation

The most important lesson that can be adapted from the SDPD approach is the transition from **reactive repair to preventive, risk-based heritage management**.

A preventive management cycle can be established as:

Inventory → Threat Identification → Risk Assessment → Condition Survey → Detailed Diagnosis → Targeted Monitoring → Early Intervention → Emergency Response → Damage Investigation → Updated Risk Assessment

This cycle allows heritage managers to identify problems before they develop into major damage.

The SDPD approach combines periodic condition surveys, risk assessment, structural diagnosis, continuous monitoring for priority sites, intervention before serious failure, post-disaster investigation, and the subsequent improvement of standards and policies.

Application to Malé Friday Mosque

Malé Friday Mosque will serve as the pilot site for evaluating the applicability of selected Korean safety and disaster-prevention methods to Maldivian heritage.

The pilot study could begin with a comprehensive visual and photographic survey, followed by the identification and mapping of existing threats. Areas requiring further investigation can then be selected for detailed measurement.

The research may investigate:

1. The current physical condition of the coral-stone structure.
2. Visible cracks and their characteristics.
3. Moisture and salt-related deterioration.
4. Structural displacement or movement.
5. Environmental conditions affecting the building.
6. Drainage and water exposure.
7. Potential fire and human-induced risks.
8. Changes in the surrounding environment.
9. The feasibility of digital documentation and monitoring.
10. The suitability of a condition-grading system for Maldivian heritage.

The purpose is not to introduce technology for its own sake. Instead, each technology should answer a specific question about the safety or deterioration of the heritage site.

For example, if visual inspection identifies a potentially active crack, crack monitoring may be appropriate. If structural displacement is suspected, Total Station measurements may be considered. If moisture and salt deterioration are identified as major threats, environmental and material monitoring may be more valuable than structural sensors.

Developing a Maldivian Heritage Safety System

The findings from the pilot study could contribute to the development of a broader national safety and disaster-prevention framework for Maldivian heritage.

A national system could include:

- A national heritage risk register
- Standard condition-assessment forms
- Regular inspection schedules
- Risk-based heritage classification
- Digital photographic and 3D documentation
- Selected continuous monitoring systems
- Emergency heritage assessment procedures
- Fire and flood preparedness
- Post-disaster inspection procedures
- Training for island-level heritage focal points
- Coordination with local councils and emergency services
- Integration of heritage sites into national disaster-management plans

Because Maldivian heritage is geographically dispersed across many islands, local participation is particularly important. Island-level custodians could be trained to report new cracks, leaning, roof leakage, salt deposits, dampness, mold, timber deterioration, drainage problems, shoreline erosion, fire hazards, and damage following storms or flooding.

This local observation system could complement professional surveys and advanced monitoring rather than replacing them.

Future Application of Advanced Technology

In the future, the Maldives could explore the use of advanced technologies such as **satellite imaging, remote sensing, drones, and Artificial Intelligence (AI)** for large-scale monitoring of cultural heritage sites. These technologies could help identify coastal erosion, flooding, environmental changes, and deterioration of heritage structures over time. However, such systems currently require significant financial investment, technical expertise, data infrastructure, and specialized equipment, making them **difficult to implement under the present circumstances in the Maldives**. Therefore, the immediate priority should be on practical and affordable methods of documentation, regular site inspections, condition surveys, and risk monitoring. As national technical capacity and resources develop, satellite imagery and AI-based monitoring could gradually be introduced as **supplementary tools to support, rather than replace, conventional heritage monitoring methods**.

Natural Frequency Measuring and Damping Ratio Analysis

During my visit to **Gangneung Ojukheon**, I observed the measurement of the building's natural frequency and damping ratio using high-sensitivity vibration sensors. On-site measurements were conducted inside and outside the traditional heritage building, with synchronized multi-channel data acquisition to ensure reliable and accurate recording. The collected vibration data were processed and analyzed to understand the building's dynamic characteristics and structural performance. Natural frequency helps determine how a historic building naturally oscillates when subjected to small vibrations, while the damping ratio shows how quickly the building dissipates vibration energy over time. This experience demonstrated how advanced vibration monitoring can support the assessment and long-term safety of traditional heritage structures.

This method could be beneficial to the Maldives because it would provide a more scientific way to monitor the structural condition of historic buildings, especially coral-stone heritage sites such as the Malé Friday Mosque. By measuring natural frequency and damping ratio, conservation teams could establish a baseline of the mosque and identify changes in its structural behaviour over time. This could help detect possible structural problems at an early stage, particularly where heritage buildings are exposed to **vibrations, coastal conditions, high humidity, strong winds, and other environmental stresses**. In the future, regular vibration monitoring could complement visual inspections and photographic documentation, allowing the National Centre for Cultural Heritage to make better-informed decisions about conservation, maintenance, and structural safety. For the Maldives, this technology could be introduced gradually, starting with **basic and affordable monitoring methods before moving toward more advanced structural testing systems**.

Ground Condition Research

Ground conditions are also an important factor in understanding the **stability and long-term preservation of heritage buildings**. Investigating soil conditions, settlement, ground movement, groundwater, and changes caused by coastal and environmental factors could help identify risks to heritage structures, particularly those located close to the shoreline. Combining ground-condition research with structural and environmental monitoring could provide a more complete understanding of the factors affecting Maldivian heritage sites and support better conservation and disaster-prevention planning in the future.

Conclusion

The identification of threats should be considered the foundation of heritage safety and disaster prevention. The experience of NRIC and its Safety and Disaster Prevention Division demonstrates the value of combining regular inspection, scientific assessment, structural monitoring, risk analysis, emergency investigation, and preventive management.

For the Maldives, the Korean approach should be adapted to the country's particular environmental and geographical conditions. Coastal flooding, storm surge, sea-level rise, erosion, salinity, groundwater, high humidity, and marine exposure require greater emphasis, while coral-stone construction and the dispersed nature of Maldivian heritage require appropriate material-specific and locally manageable approaches.

The proposed pilot study at Malé Friday Mosque can therefore serve as a practical demonstration of how **threat identification → scientific assessment → monitoring → risk grading → preventive intervention** can be applied to Maldivian heritage.

The ultimate objective is to move from a system that responds to damage after it occurs toward one that **identifies threats early, monitors changes continuously where necessary, prioritizes intervention according to risk, and strengthens the resilience of cultural heritage before disasters occur**.