Research Paper

Sorrow for Heritage

Inwa Assessment of Cultural Trauma, post-earthquake

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Abstract

In March 2025, a strong earthquake struck Inwa Ancient City in Myanmar, which dramatically destroyed thousands of brick and stone pagodas. The goal is to overcome the major challenges on issues such as a shortage of resources right after the disaster event and delays in assessment.
This research develops a rapid and quantifiable earthquake trauma assessment framework of cultural heritage to support scientific decision-making on priorities in restoration. This paper first estimated the value of cultural heritage from the four dimensions of age, form, spatial pattern, and pre-earthquake preservation status of 426 pagodas based on a pre-earthquake systematic survey that had set up a high-precision geographic information system. Then, through the deep learning semantic segmentation model, pre-and post-earthquake high-resolution remote sensing images were compared and analyzed to automatically identify and classify the damage levels of pagodas caused by the earthquake. Finally, through spatial overlay in GIS, the results of value assessment and damage assessment were synthesized to get the "cultural trauma degree" of each pagoda.
The value-integrated rapid assessment presented in this study not only provides a direct basis for precise post-disaster policy decisions in Inwa Ancient City but also a technical approach that can be replicated in disaster resilience assessments and emergency management of cultural heritage in the Global South.

Keywords

Inwa, Multi-data, Earthquake, Cultural Trauma

1. Introduction

Accelerated global climate change and the frequency of extreme disasters in recent years have brought the issue of "resilience" in cultural heritage to the attention of international organizations such as UNESCO. In 2007, a UNESCO assessment report showed that climate change has already had a significant impact on World Heritage sites and creates severe risks. The United Nations 2030 Agenda for Sustainable Development, adopted in 2015, further integrated protection of cultural heritage into the global agenda; Goal 11.4 explicitly called for enhanced responses to climate-related threats. In 2022, the ICOMOS even announced "Heritage and Climate" as the theme for the International Day for Monuments and Sites, further highlighting the urgency for heritage adaptation to climate change.

From the perspective of the Global South, cultural heritage is an important carrier of identity and provides a key resource for enhancing tourism and poverty reduction. However, its vulnerability in the event of disaster is quite prominent. Taking Southeast Asia as an example, world-class heritage sites such

as Angkor, Bagan, and Inwa possess extremely high value but are in a state of inadequate protection due to a dual lack of funding and technology. The low structural redundancy and rapid material aging these ancient structures have mostly been built under low-technology and low-intensity construction conditions. Under the combined impact of earthquakes, floods, typhoons, and other disasters, they show significant systemic vulnerability. Once damaged, the "Outstanding Universal Value" carried by them would face irreversible loss. Therefore, how to quickly, accurately, and replicably assess the degree of heritage damage after a disaster and formulate a scientific restoration sequence based on this has become a key scientific issue that urgently needs to be resolved in the field of heritage protection.

On March 28, 2025, a magnitude 7.9 earthquake hit Myanmar, and the focal depth of 30 kilometers was the largest magnitude earthquake this year. Inwa is close to the epicenter and has served as the capital of Myanmar four times. There are 426 brick and stone pagodas from the 15th to 18th centuries in Inwa, possessing important historical, artistic, and religious compound values. This disaster caused more than 70% of the pagodas in this area to be badly damaged. However, after this disaster happened, most of the government resources were focused on humanitarian relief; thus, it was difficult to organize systematic assessments and surveys for heritage buildings in a short period of time. Therefore, many brick and stone heritage structures were in danger of further damage. In such a situation, urgent work like a rapid general disaster damage assessment was needed to form an overall survey of heritage damage that would be helpful for subsequent in-depth surveys and orderly restoration.

The research team of this study conducted systematic field surveying and architectural mapping in Inwa, Myanmar in 2018. It acquired highprecision pre-earthquake baseline data such as architectural form, structural characteristics, and preservation status. （Figure 1） Baseline information was obtained for use in possible disaster response and heritage reconstruction. This study conducted a cultural heritage value evaluation for each pagoda within the ancient city based on this batch of pre-earthquake field data. Then it showed the automation of identification and grading of building damage by fusing deep learning algorithm with multitemporal high-resolution remote sensing images before and after the earthquake. Integrating the two datasets together, this study established the quantified assessment system of the cultural trauma degree of various pagodas in Inwa. The system was intended to provide scientific decision-making support for deciding post-disaster restoration priorities and resource allocations.

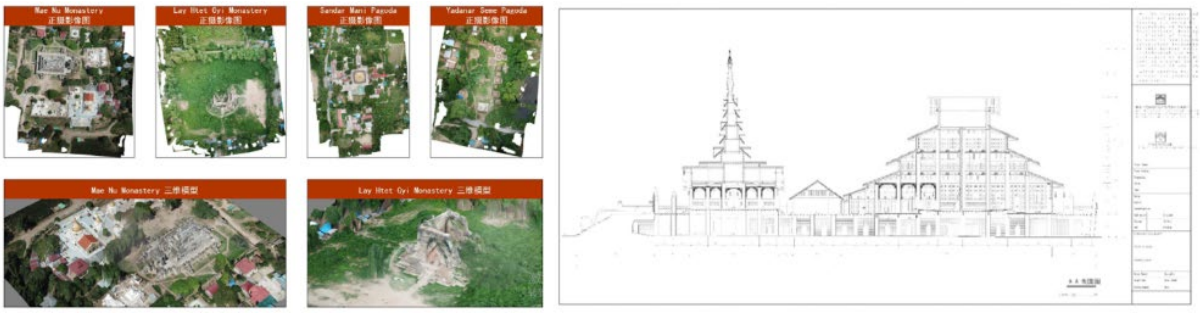


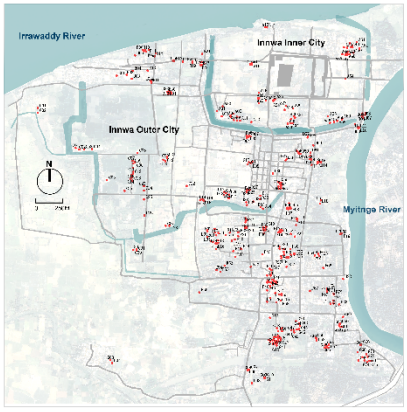
Figure 1. Inwa Ancient City Cultural Heritage Database. Source: Drawn by the research team.

2. Methodology

2.1 Study Area

It is located in Mandalay Region, Myanmar. Inwa Ancient City has been the capital of Myanmar for almost 360 years and was considered the powerhouse of Upper Myanmar. It has become the most important representative of ancient cities in the Mandalay City group due to the integrity of its large-scale heritage preservation and unique historical background.

Within Inwa Ancient City, there are scattered pagodas and temples. They were continuously added to, renovated, and reconstructed across four dynasties: "First Inwa (Ava Dynasty, 1364–1555), Second Inwa (Taungoo Dynasty, 1597–1752), and Third and Fourth Inwa (Konbaung Dynasty, 1763–1837)." The Ava Dynasty laid the foundation for the early Pagan–Ava style of brick pagodas. The Taungoo Dynasty added golden spires, bellshaped domes, and ambulatories during post-war reconstruction, forming a "pagoda-temple integration" pattern. The Konbaung Dynasty concentrated on construction when relocating the capital to Ava, using pagodas as spatial declarations of royal legitimacy, and reached a peak in quantity and artistry before the 1839 earthquake. After nearly five centuries of cumulative construction, there are still remains today. According to incomplete statistics, more than 60–70 temples and pagoda groups remain today. Some temples contain dozens of pagodas, and countless pagodas are hidden in the wild, covered by trees and on the verge of collapse. There are 426 pagodas remaining through team field surveys that together write a visible "Inwa dynastic history," recording political-religious changes in Myanmar from the center of the Burmese people to multi-ethnic governance and from exclusive veneration of Buddhism to cultural integration. (Figure 2)



Code	Name	Established dynasty	Materials	Pre-earthquake state	Level	Pre-earthquake preservation condition
A01	unknown	1	brick	Using	Secondary tower	Completely retained
A02	Shwezigon pagoda	1	brick	Using	Main tower	Completely retained
A03	unknown	2	brick	Using	Secondary tower	Completely retained
A04	unknown	1	brick	Using	Secondary tower	Completely retained
A05	unknown	1	brick	Using	Secondary tower	Completely retained
A06	unknown	2	brick	Using	Secondary tower	Completely retained
A07	unknown	2	brick	Using	Secondary tower	Completely retained
A08	unknown	2	brick	Using	Secondary tower	Completely retained
A09	unknown	2	brick	Using	Secondary tower	Completely retained
A10	unknown	2	brick	Using	Secondary tower	Completely retained
A11	unknown	2	brick	Using	Secondary tower	The basic form is retained
A12	Myo Thet Mingalar Pagoda	4	brick	Using	Secondary tower	The basic form is retained
A13	Yin Ye Mote Htor Pagoda	1	brick	Using	Main tower	Completely retained
A14	unknown	1	brick	Using	Secondary tower	Completely retained
A15	in ye pagoda complex/ Naga Yone	4	brick	Using	Secondary tower	The basic form is retained
A16	in ye pagoda complex/ Naga Yone	4	brick	Using	Main tower	The basic form is retained
A17	in ye pagoda complex/ Naga Yone	4	brick	Using	Secondary tower	The basic form is retained
A18	unknown	4	brick	Using	Secondary tower	Completely retained
A19	unknown	4	brick	Using	Secondary tower	Completely retained
A20	unknown	4	brick	Using	Secondary tower	Completely retained
A21	Phwar Nu Pagoda complex	4	brick	Using	Main tower	Completely retained
A22	Man Aung Yathana Pagoda	2	brick	Using	Main tower	Completely retained
A23	Thitsar Taik Pagoda	2	brick	Using	Main tower	Completely retained
A24	unknown	2	brick	Using	Secondary tower	Completely retained

Figure 2. The Inwa Pagodas Record. Source: Drawn by the author.

2.2 Research Framework and Methods

The logical and clear technical route of this study is divided into three major steps with the aim of systematic quantification of seismic cultural trauma degree for pagodas in Inwa Ancient City.

First, the evaluation of the cultural heritage value is conducted. The present study constructs a value evaluation system from four dimensions. These are: (1) Age: According to the four historical periods when Inwa Ancient City served as the capital (Ava Dynasty, Taungoo Dynasty, early Konbaung Dynasty, late Konbaung Dynasty), scores are assigned from 4 to 1, giving higher scores to earlier periods. (2) Pagoda specifications and forms: For main pagodas, 4 points were given; for subsidiary pagodas, 1 point was given.

(3) Contribution to spatial pattern: The authors hereby present that Inwa Ancient City has a dual-driven spatial structure of "royal power and religious power." The northern inner city represents the area of the royal palace, and an east-west axis through the city from this zone connects the fortress, important pagodas, royal palace, defensive towers, and important city gates. In the southern part lies the religious area, whose north-south axis connects the river with the royal palace, important temples, residential areas, and the outside world. In general, the development of Inwa Ancient City is inextricably linked with the power of royalty and religion; besides being inseparable, they are mutually restrictive and together drive the development of the capital. So, in the assessment, whether the pagoda was within the royal palace, on the main axis, or at the core node was assessed, in which every single one was given 1 point for each criterion and cumulative scoring was done. (4) Pre-earthquake preservation completeness: Based on the data of the field survey in 2018, the pre-earthquake state of the pagodas was divided into three levels: "intact", "basically intact", "severely damaged", and their scores were added as 4, 3, and 0, respectively. The total cultural value score for every single pagoda is obtained by summing the scores of the four dimensions.

Then, seismic deformation and damage degree assessment are conducted. In this study, the semantic segmentation technology of deep learning is adopted to handle high-resolution remote sensing images before and after earthquakes. Specifically, it uses the classic U-Net network architecture, taking ResNet34 as the backbone network to build a two-stage model: it trains the model using pre-earthquake images in stage one to capture the contour and location of each pagoda, and then in the second stage of the processing, using a two-branch network structure that takes input from both pre- and post-earthquake images simultaneously, shares weights trained in the first stage to efficiently identify the changes after earthquakes and categorizes their damage degrees into four levels, respectively, namely "unaffected," "moderately severe," "very severe," and "extremely severe."

At last, the cultural trauma degree is synthesized. The assessment results of the scores of cultural value and earthquake damage level are overlaid in space on the GIS platform. The key logic behind the method of calculating the degree of cultural trauma is that the pagodas with higher pre-earthquake value and more serious post-earthquake damage have suffered greater cultural trauma. By executing a quantitative overlay, a total score of the cultural trauma degree for each pagoda is given and visually presented in space.

2.3 Data Collection and Preprocessing

This research relies on high-quality multisource data, the collection and processing of which are done in three steps.

First, a basic spatial database is established. Based on the large-scale field investigation results of the research team in Inwa Ancient City in 2018, a high-precision heritage geographic information system was established on the ArcGIS Pro platform, locating all 426 pagodas in space with point vectors, recording the attribute information of each pagoda, such as dynasty, name, pre-earthquake preservation status, main/subsidiary pagoda level, etc., and forming core baseline data in later value evaluation.

The second step is the acquisition of multi-temporal remote sensing images. Through Changguang Satellite Company, an order for High-definition images from the "Jilin-1" Wide Field 01 satellite was made for two periods, pre-earthquake and post-earthquake, of the study area: March 1st, 2025, and April 3rd, 2025. The resolution is 0.75m, with less than 5% cloud cover and a less than 8° difference in the side view angle, which can effectively ensure that the images before and after the earthquake are comparable, while satisfying the severe requirements of disaster detection.

Third, the deep learning sample data is generated. With the pagoda vector points as the center in the GIS platform, two-period images are batch-cropped with a fixed window of 128×128 pixels, corresponding to approximately 96 meters×96 meters on the ground, generating 128 pairs of "pre-earthquake-post-earthquake" corresponding image slices. This not only reduces the data volume but ensures that each sample fully covers the pagoda body and its peripheral environment. The samples are then manually annotated using Labelme software: pre-earthquake images are annotated with pagoda contours, and post-earthquake images are annotated according to the aforementioned four damage levels based on visual interpretation. As there is a problem in the quantity of samples, the CutMix data augmentation technique is used in concert with rotation and flipping methods to increase the dataset and lay the foundation for model training. (Figure 3)

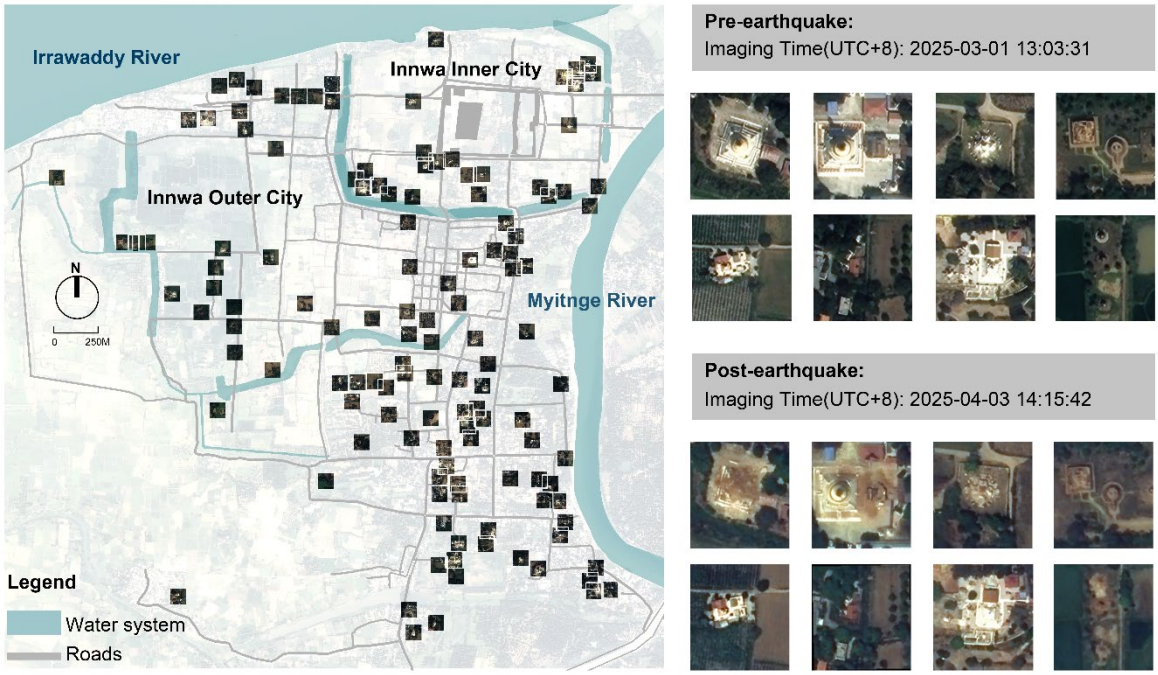


Figure 3. Earthquake Damage Assessment Data Collection. Source: Drawn by the author.

2.4 Results and Analysis

(1) Spatial Pattern of Cultural Value

According to the value assessment system put forward in this paper, the score for each of the 426 pagodas was given and visualized with ArcGIS (Figure 4). It can be found from the figure that the high-value pagodas are not at all scattered around but highly agglomerated along the two core axes-royal axis and religious axis-and the key nodes in the historical development process of Inwa Ancient City, especially in the northern and southern core areas of the palace district and religious district respectively. This spatial pattern of distribution definitely confirms the dual role in shaping the historic urban pattern by the royal power and religion and further justifies the rationality of this assessment system.

(2) Spatial Heterogeneity of Seismic Damage

After prediction by the two-stage deep learning model, pixel-level damage level results for all pagodas were obtained. A post-earthquake damage spatial distribution map was created through spatial mosaicking and attribute linking (Figure 5). The analysis result shows that the seriousness of the damage to the pagodas reflects obvious spatial heterogeneity. Seriously damaged pagodas are relatively concentrated in areas either with poor geological conditions or aging building materials. Therefore, the model identified a continuous damage state of structurally intact to complete collapse quite effectively, thereby realizing the quick and objective assessment of the disaster situation.

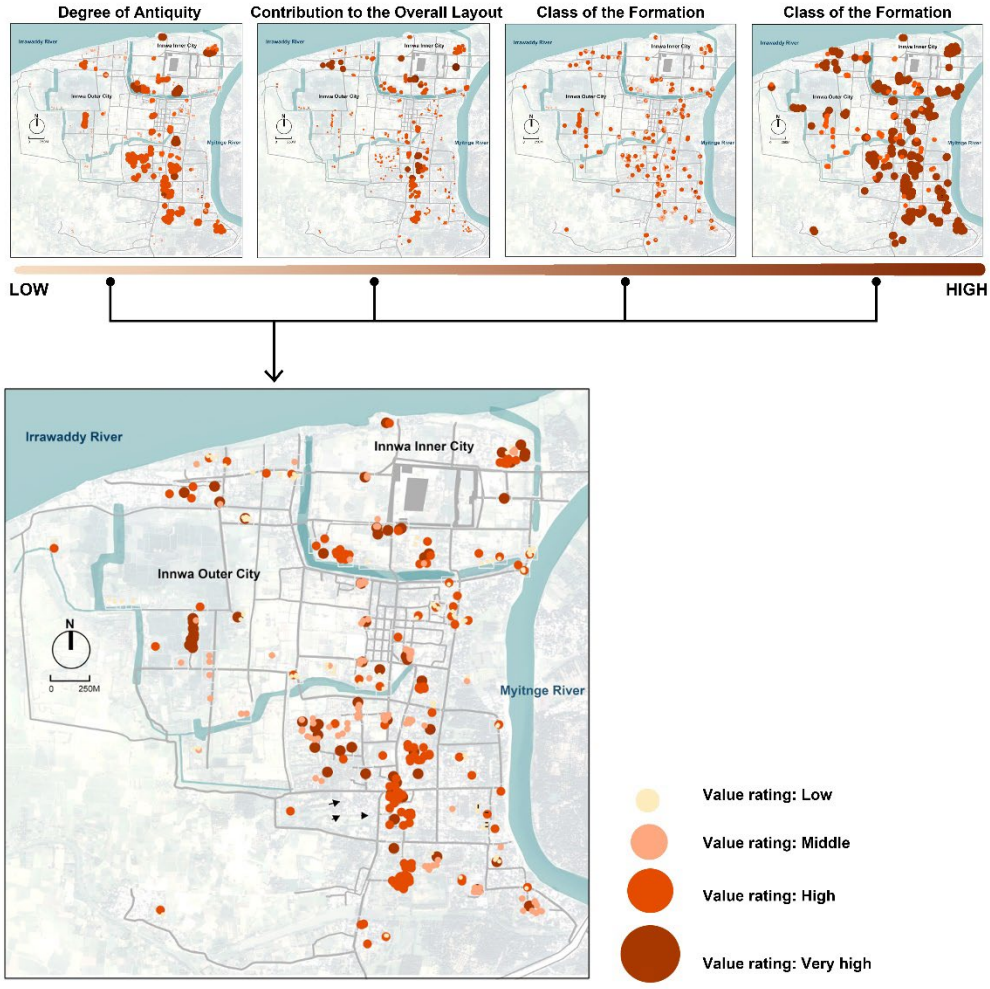
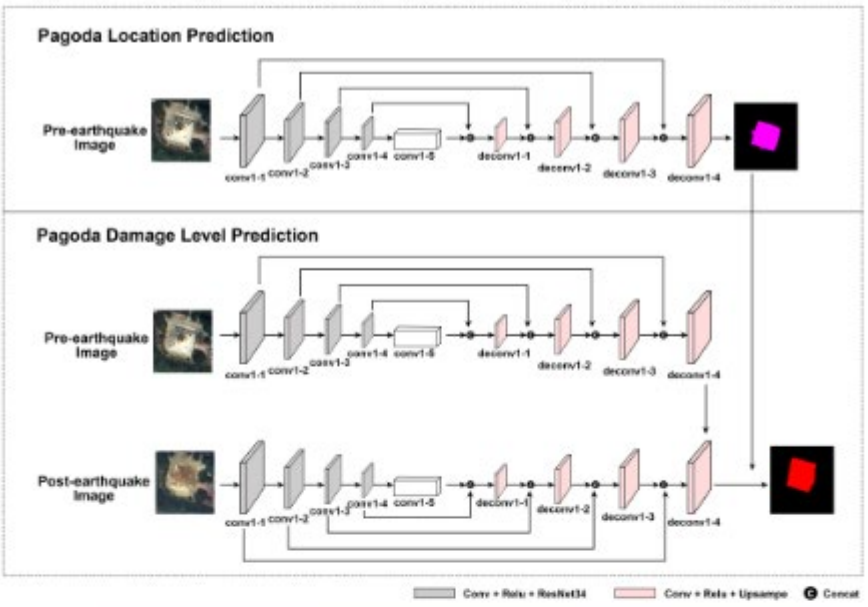


Figure 4. Cultural Value Assessment Results. Source: Drawn by the author.

(3) Degree in Cultural Trauma Assessment

By overlaying the map of the cultural value scores with that of earthquake damage distribution, a comprehensive evaluation map of the cultural trauma degree of the pagodas in Inwa Ancient City was finally obtained (Figure 6). This intuitively reflects the areas suffering from the most serious losses in cultural heritage. The pagodas with both a high historical value, such as being situated in the core of the

early capital and possessing large-scale forms, and having gone through "very severe" or "extremely severe" physical damage are marked as "hotspots" of cultural trauma and should be listed as the top priorities for post-earthquake restoration and resource allocation. The result provides a scientific basis for decision-making by linking the abstract heritage value loss with specific physical damage.



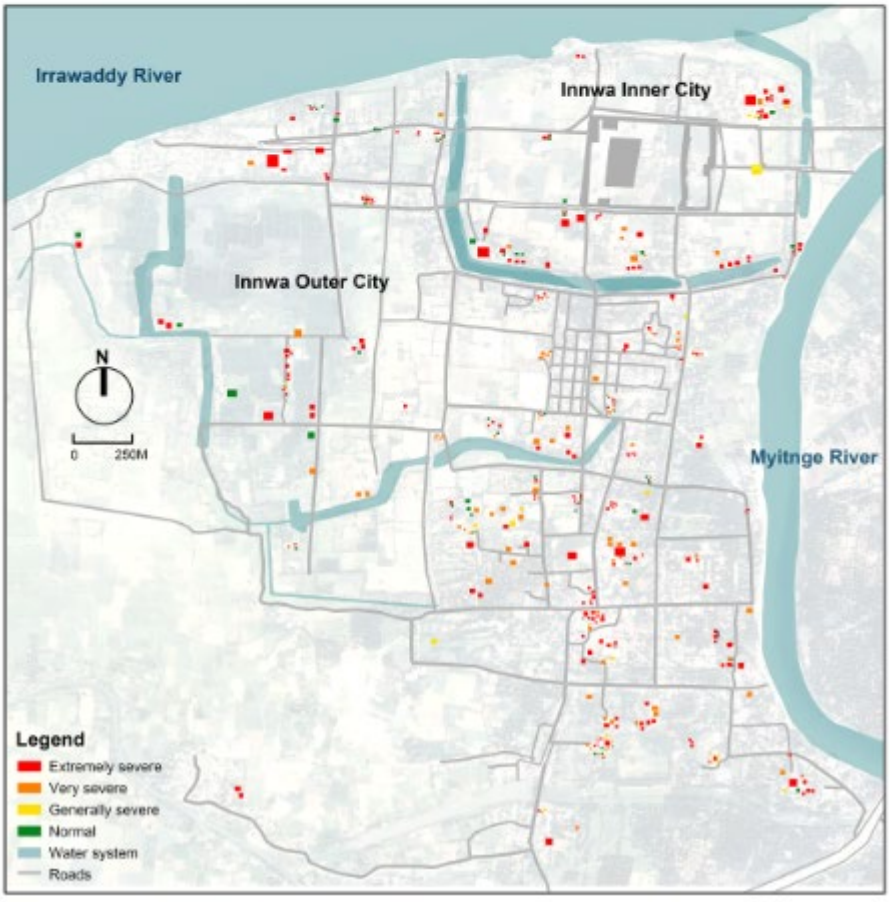


Figure 5. Earthquake Damage Assessment Results. Source: Drawn by the author.

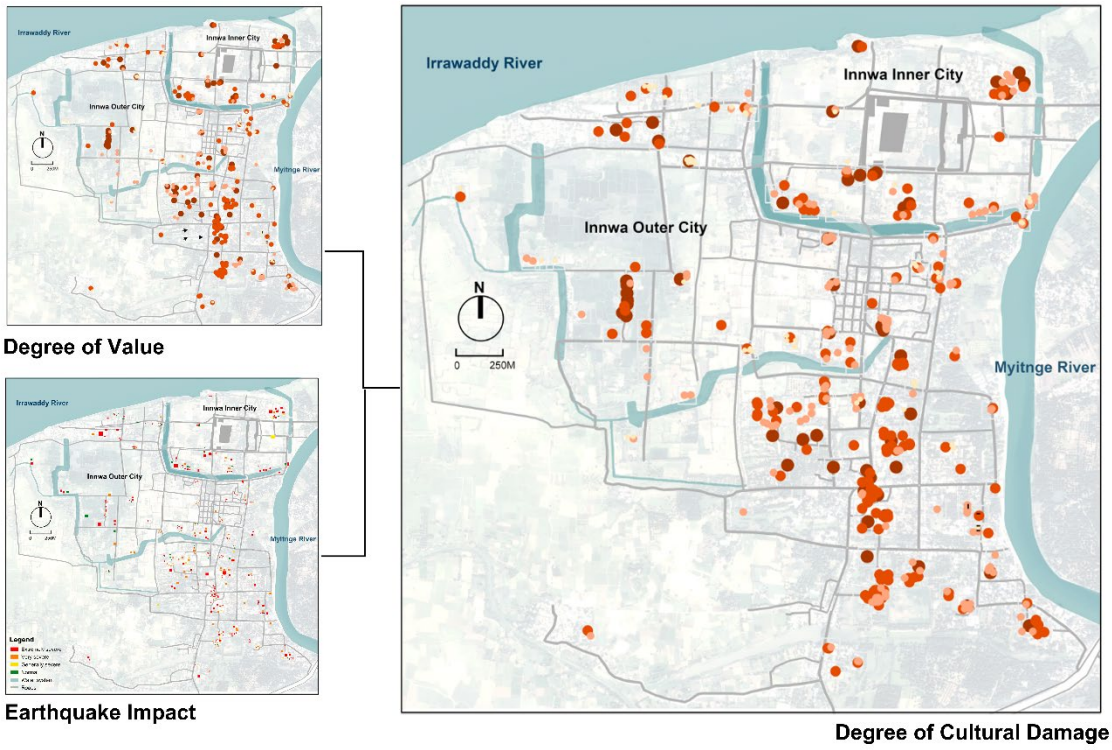
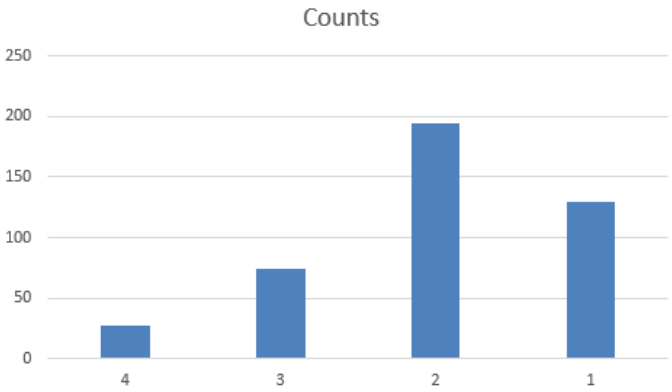


Figure 6. Cultural Trauma Assessment Results. Source: Drawn by the author.

3. Results

3.1. Proportion of Final Cultural Trauma Degrees

In general, the cultural trauma degrees have significant differences: 27 pagodas have extremely high trauma levels, 74 have high trauma levels, 195 have moderate trauma levels, and 130 have low trauma levels. Pagodas with extremely high trauma levels are visibly concentrated in the royal city in the northern part of the ancient city and the core religious area in the south. This is highly consistent with the historical spatial structure of the Inwa ancient city driven by the dual centers of "royal power-religious power" in its



history. That means the heritage in the core functional areas suffered the most serious loss in cultural values during the earthquake. (Figure 7)

Figure 7. Proportion of Final Cultural Trauma Degrees. Source: Drawn by the author.

3.2. Data Composition Analysis

In order to further disclose the inner composition mechanism of the degree of cultural trauma, cross-analyses were conducted for its two core components, which are cultural value and earthquake damage.

(1) Correlation Analysis between Cultural Trauma Levels and Cultural Value Levels

Of the highly traumatised pagodas, 11 had high value points making up 42%; 16 had extremely high value points, making up 58%. Of those highly traumatised, 3 had low value points, accounting for 4%; 28 had middle value points, accounting for 38%; 24 had high value points, accounting for 32%, while 19 had extremely high value points, accounting for 26%. Of the pagodas in a moderate trauma state, 4 had low value points, accounting for 2%; 43 had middle value points, accounting for 22%; 113 had high value points, accounting for 58%; while 39 had extremely high value points, accounting for 20%. Of the pagodas showing low trauma, there are 39 with low value points, accounting for 30%; while 91 have middle value points, accounting for 70%.

(2) Correlation Analysis between Cultural Trauma Levels and Earthquake Damage Levels:

All pagodas having very high trauma possess very high damage levels. From the highly traumatized state of the pagodas, the contribution of medium-level damages includes 22 or 30% and high-level damages include 22 or 30%, while very high damage amounts to 30 or 40%. Among the moderately traumatized pagodas, low damage levels were found in 117 or 60% and medium in 78 or 40%, while in the pagodas in low trauma, 120 or 92% had low damage levels and 10 or 8% had medium damage levels.

It can be seen from the data composition that the points with the extremely high earthquake damage level basically caused extremely high trauma and high trauma. The points at the low damage levels but extremely high in value are also categorized under high trauma. (Figure 8)

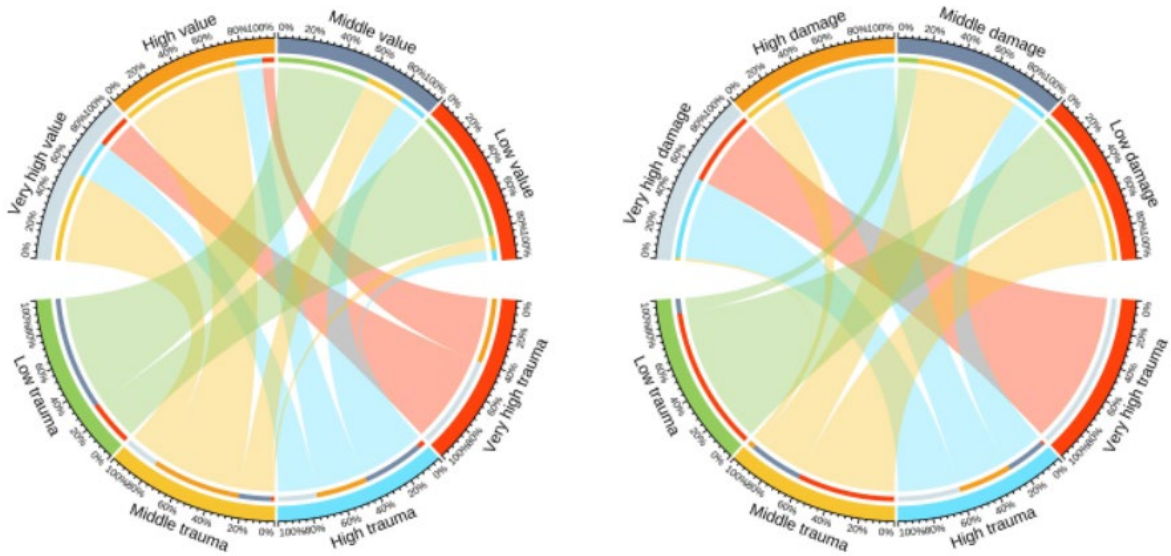


Figure 8. Correlation Analysis Results. Source: Drawn by the author.

4. Disscussion

4.1 Discussion on Categorized Policy Measures

One of the most important application values of this batch of assessment results is that they can provide a direct basis for differentiated protection and restoration strategies. According to the degree of trauma, a clear course of action can be identified: For those heritage sites with "extremely high trauma," it is necessary to immediately start the highest-level emergency protection and systematic restoration because their value is very great and the damage is serious; any delay may result in losses that cannot be recovered. In heritage sites with "high trauma," different situations need to be distinguished-if they have been selected because of their high value, they should be given priority for preventive reinforcement and planned restoration; if they have been selected because of high damage, the focus should be on structural emergency rescue. Objects with moderate and low trauma levels can be integrated into routine monitoring and batch maintenance plans. Such a classified policy based on the assessment result can precisely allocate limited protection resources to the most urgent and most critical sites, giving full play to the effectiveness.

4.2 Discussion on the Weighting of the Assessment Framework and Directions for Optimization

The current assessment framework places more weight on the "degree of damage." Indeed, it may lead to a phenomenon: Some pagodas without top-level intrinsic value and cultural significance may also gain a high trauma level in the assessment due to extremely severe physical damage and thus are ranked high in the restoration priority order. The result reflects the choice that the framework has made between "urgency of protection" and "importance of value," with its original intention to focus resources on rescuing endangered assets. However, it also suggests the direction for optimization of the framework in the future: In subsequent iterations, more diversified decision-making dimensions such as "restoration feasibility," "technical difficulty," and "cost-effectiveness" can be introduced, or the "heritage value" can be further decomposed into more refined secondary indicators (such as historical, artistic, scientific, and socioeconomic values) to form a more comprehensive priority assessment system. In this way, resource allocation is not only based on "the degree of danger" but also reflects "the comprehensive value" of heritage more effectively.

5. Conclusion

Faced with the urgent needs of suddenly occurring disasters, this study has succeeded in constructing and implementing a rapid assessment framework for "cultural trauma degree" that integrates cultural heritage value and earthquake physical damage; it is able to achieve precise investigation and quantitative ranking of 426 post-disaster conditions of pagodas in Inwa Ancient City. A future, more generalized heritage protection decision-making model will still need more diversified dimensions, including restoration feasibility, technical difficulty, cost-effectiveness, and community sentiment. This study has taken an essential step in accelerating disaster risks under climate change, establishing a scientific, efficient, and sustainable heritage resilience protection paradigm in resource-constrained environments. It provides a key methodological basis and supporting evidence in decision-making, and its core ideas have great reference significance for cultural heritage sites under similar challenges in the world.

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