Indonesian Journal of Science & Technology

Journal homepage: http://ejournal.upi.edu/index.php/ijost/

Heritage Preservation in Flood-Prone Urban Areas: Bibliometric, Risk Index, and Spatial Analysis of Historic Buildings in Semarang

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ABSTRACT

Historic buildings in coastal and low-lying cities are increasingly threatened by tidal flooding, land subsidence, and climate-driven sea-level rise. Preserving these assets requires a framework that integrates cultural heritage values with disaster risk assessment. This study applies three approaches: bibliometric analysis to examine research trends on historic buildings and disasters; weighting analysis of cultural values based on Burra Charter parameters, including historical, aesthetic, social, and authenticity aspects; and spatial analysis using GIS and Digital Elevation Model data to map flood-prone zones. The results show that landmark buildings with strong historical and architectural significance are consistently prioritized for preservation. In contrast, structures with limited cultural importance or advanced deterioration rank lower in feasibility for conservation. Spatial mapping highlights that heritage sites in flat and low-lying areas face the greatest exposure to flooding and sea-level rise. This interdisciplinary framework provides a scientific basis for prioritizing heritage preservation in flood-vulnerable urban environments. It also supports adaptive conservation strategies that align cultural continuity with resilience to environmental hazards.

ARTICLE INFO

Article History:

Submitted/Received 15 May 2025
First Revised 20 Jun 2025
Accepted 25 Aug 2025
First Available Online 26 Aug 2025
Publication Date 01 Apr 2026

Keyword:

Burra charter,
Conservation,
Flood prone area,
Historic buildings,
Tidal flood.

1. INTRODUCTION

The preservation of historic buildings in coastal urban areas requires an interdisciplinary strategy that integrates cultural heritage conservation principles with flood risk assessments and adaptive spatial planning. Tidal flooding, exacerbated by sea-level rise and land subsidence, is increasingly undermining both the physical integrity and cultural significance of heritage preservation assets. A key challenge is that current conservation practices, while influenced by guidelines such as those outlined in the Burra Charter, rarely incorporate a systematic analysis of hydrological risks and spatial vulnerabilities [1]. Post-disaster reconstruction requires the development of a framework that not only addresses architectural and structural damage to buildings but also incorporates climate adaptation measures that consider socio-economic, spatial, and environmental factors [1,2].

Recent advances in flood risk assessment methodologies have emphasized the use of geospatial modeling and decision support systems to evaluate vulnerability factors specific to historic preservation structures [3,4]. Ferreira and Santos demonstrate an integrated approach where flood hazard mapping and risk matrix analysis provide insights into spatial planning interventions, such as retrofitting or relocating at-risk buildings [5]. Similarly, other literature proposed a regional-scale flood risk assessment framework that combines hydrodynamic data with building preservation vulnerability indicators [6]. These models can effectively guide prioritized interventions to enhance the resilience of historic preservation areas [7]. Furthermore, the integration of urban flood management with conservation practices has been explored by many researchers [8-10]. A paradigm that balances the conservation of historic buildings with disaster risk reduction is a crucial component of this study [11,12]. Their analysis demonstrates that participatory planning, where local communities, technical experts, and policymakers collaborate, is crucial for developing culturally sensitive interventions that incorporate robust technical approaches. This approach is critical in coastal environments where environmental risks are exacerbated by fragmented institutional responsibilities and a lack of adequate preventive technical guidelines [13-15]. The preservation of historic buildings is crucial for maintaining a nation's cultural identity. The Burra Charter, an internationally recognized conservation guideline, provides a comprehensive framework for preserving places of cultural significance. This article aims to identify and explain key variables in the preservation of historic buildings, based on the principles outlined in the Burra Charter, supported by current academic references.

Semarang is the capital of Central Java Province, Indonesia. Semarang is a city located on the northern side of Java Island. During the rainy season, Semarang is often flooded, and puddles can be found along the roads on the north side of the city, which directly borders the coastal area. The preservation of historic buildings requires several specific considerations, not only regarding the conservation of these buildings, but also why they should be preserved. What parameters can be used to preserve historical buildings? Several researchers utilize specific parameters outlined in the Burra Charter to evaluate the feasibility of historical buildings [16,17]. In fact, for aesthetic and tourist attraction reasons, the preservation of historical buildings can be a desirable feature in urban areas. This city not only offers the grandeur of development, but also offers historical value and architectural beauty that are worthy of pride [18,19]. On the other hand, disaster preparedness efforts are one strategy so that every individual and even city residents have guidelines in facing disasters [20-24, 14]. This study aims to identify historic buildings in Semarang to determine which ones are worthy of preservation. In addition to the numerous historic buildings remaining from the Dutch colonial era in Semarang, the locations of these buildings are unique: they are located in areas

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

frequently affected by flooding during the rainy season. Several researchers have even made specific projections regarding flood risk in Semarang [9,12], indicating the need for preventive measures to protect historic buildings located in flood-prone areas [25]. The purpose of this research is to identify historic buildings in areas at risk of tidal flooding using the historic building preservation parameters outlined in the Burra Charter. To support this goal, several stages of research implementation are underway to address the problem, including; (i) Bibliometric Analysis: used to review and identify research trends related to historic buildings based on previous research data; (ii) Weighting of Historic Buildings; using several preservation and conservation parameters that refer to the Burra Charter; and (ii) Spatial analysis using ArcGIS, to delineate flood-prone areas based on historical events and create zones of affected areas based on elevation data and satellite data analysis.

Using the technical approaches mentioned above, the results of this study will likely include identifying historic buildings that have the potential to be preserved due to their historical role and significance. Aesthetic factors such as unique building elements and architectural styles also make them worthy of assessment, with a weighting to determine whether they are worthy of preservation or other technical approaches. The location of a building in a flood-prone area is a crucial consideration for maintaining the building or implementing structural measures as a preventive measure against flood risk, which directly impacts historic building preservation efforts in Semarang [26,27]. The novelty of this research is (i) an in-depth study of the preservation of historic buildings in areas affected by tidal flooding. Similar studies have been lacking, particularly those linking historic building preservation efforts to the risk of tidal flooding. Several studies have linked the disasters in question to war events, rather than natural disasters such as flooding, and (ii) the assessment of buildings using the parameters outlined in the Burra Charter, adding weight to each parameter deemed important, such as the building's historical significance and uniqueness.

2. LITERATURE REVIEW

Semarang is the capital of Central Java Province. Astronomically, Semarang is located between 6°50' – 7°10' South Latitude and 109°35' – 110°50' East Longitude. The altitude of Semarang ranges from 0.75 meters to 348 meters above sea level. Semarang has an area of approximately 373.70 km² or 37,366,836 hectares, consisting of 16 districts and 117 villages. Areas with altitudes ranging from 0.75 to 90.5 meters are included in the Semarang Center area (North Semarang Lowlands), which is characterized by high points such as the Tanjung Mas Port area, Simpang Lima, and Candibaru. Meanwhile, areas with altitudes ranging from 90.5 to 348 meters are located on the outskirts of Semarang, spread across various cardinal directions, and are represented by high points such as Jatingaleh and Gombel in South Semarang, as well as the Tugu, Mijen, and Gunungpati areas.

Historic buildings serve as witnesses to a community's history and culture. Their preservation requires a systematic approach based on the cultural values embodied in the buildings. The Burra Charter, developed by the Australian International Council on Monuments and Sites (ICOMOS), has become the international standard for preserving places of cultural significance [28]. This article provides a conceptual overview of the variables involved in preserving historic buildings, based on the Burra Charter. In response to this challenge, emerging research is advocating an adaptive framework that integrates technical flood risk reduction strategies with an assessment of the preservation value of buildings. Rubio-Bellido et al. illustrate that climate adaptation strategies for historic dwellings can be effectively conceptualized by aligning conservation and preservation principles with modern engineering solutions, such as improved drainage infrastructure and structural reinforcement

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

[2]. Furthermore, integrative conservation policies that combine cultural and environmental considerations offer a pathway to resilience [29]. Their work emphasizes the importance of reformulating conservation strategies to address not only the aesthetic and historical value of a site but also its dynamic exposure to hazards triggered by climate change.

Developing an integrated preservation strategy for historic buildings in Semarang, located in areas prone to tidal flooding, requires a comprehensive methodology. This comprehensive methodology involves: (a) mapping and spatial analysis to identify overlapping zones between preservation efforts and environmental risks [5,6], (b) using a decision support system to assess their vulnerability through multi-criteria evaluation [1,7], and (c) formulating adaptive conservation policies that integrate technical, cultural, and community-based considerations [2,29].

Such an interdisciplinary approach not only addresses the immediate threat posed by tidal flooding but also lays the foundation for sustainable urban transformation and cultural heritage resilience. The novelty of this research is the preservation of historic buildings in flood-risk areas. Therefore, preventive efforts undertaken to preserve historic buildings are not only about building conservation but also about how buildings can adapt to flood-prone environments. The variables for historic building conservation according to the Burra Charter are as follows:

- (i) Cultural Significance: Cultural significance is the core value underlying all conservation activities. It encompasses historical, aesthetic, scientific, social, and spiritual values.
- (ii) Place: The concept of "place" in the Burra Charter encompasses not only the physical aspects of a building, but also non-material values such as social and spiritual connections [30] (Hanna, 2015).
- (iii) Conservation, Conservation encompasses a range of actions, including maintenance, preservation, restoration, and reconstruction, undertaken to preserve the cultural significance of a place.
- (iv) Use: New uses are permitted as long as they do not compromise the cultural value of the place. Adaptation is also considered part of a conservation strategy.
- (v) Environment: The environment surrounding a historic building influences its cultural meaning and value. Therefore, conservation must also consider its spatial context.
- (vi) Change; Changes can be made carefully, based on careful documentation and assessment, to ensure that cultural values are maintained.

To assess the historical buildings in Semarang using the parameters of the Burra Charter, we will compile an evaluation table using the criteria established by the Burra Charter. The Burra Charter is a cultural heritage conservation document widely used as a guideline for conservation, particularly in the Asia-Pacific region. Meanwhile, the assessment parameters based on the Burra Charter emphasize cultural heritage values, which can be grouped as follows:

- (i) Historical Value: Significance to history and past events.
- (ii) Aesthetic Value: Architectural or landscape aesthetics.
- (iii) Scientific and Archaeological Value: Potential to provide scientific information about the past.
- (iv) Social and Cultural Value: Social significance for the community.
- (v) Spiritual and Religious Value: Spiritual or religious significance.
- (vi) Integrity: The original condition of the building.
- (vii) Authenticity: The degree of originality of materials, design, and techniques.
- (viii) Functionality: Whether the building still serves a relevant function today.

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

Each value will be given a weight (scale 1–5), where 5 = Very High, 4 = High, 3 = Medium, 2 = Low, and 1 = Very Low. The scale used is the Likert scale, an attitude measurement method developed by Rensis Likert in 1932. The Likert scale is often used to measure the extent to which someone agrees or disagrees with a statement.

The Likert scale is widely used in social research because it enables the transformation of qualitative opinions or attitudes into quantitative data that can be analyzed statistically [21, 31]. **Figure 1** is an example of an assessment of a historic building using several important parameters as assessment variables or weights, such as historical significance, building location, monumentality, architectural style, architectural elements, building construction strength, and building ownership. The historic building in the image above was formerly a grocery store, and during the war of independence, the building was abandoned by its owner. Then, quite extreme renovations were carried out, making the building very beautiful, both during the day and at night.

Building	A	B	C	D	E	F	G	H	Score
Spiegel	3	4	3	4	3	2	5	3	27

Figure 1. Weighting of historic buildings with Burra Charter parameters (sample).

Tidal flooding or coastal inundation caused by high tides has become a recurring and increasing hazard in Semarang, Indonesia. This phenomenon is primarily driven by a combination of sea-level rise, land subsidence, and inadequate coastal infrastructure [32]. In Semarang, tidal flooding locally known as rob increasingly inundates low-lying districts such as North Semarang, Tugu, and Genuk, causing significant disruptions to transportation, settlements, and economic activity. The frequency and extent of tidal flooding in Semarang are worsening due to both natural processes and anthropogenic pressures, including excessive groundwater extraction and uncontrolled urban expansion [33]. Several studies have investigated various aspects of tidal flooding in the city. The slow spatial dynamics of flooded areas and the interaction between geomorphological factors and rapid urban development exacerbate this problem [32,34]. The socio-economic impacts of recurring tidal

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

flooding reveal how vulnerable communities are continually exposed to chronic hazards that undermine their adaptive capacity and long-term resilience [35,36]. Adaptive strategies in Semarang have varied from physical interventions, such as the construction of sea walls, polder systems, and retention ponds, to community-based approaches involving early warning systems, evacuation planning, and participatory risk communication [33]. However, the effectiveness of mitigation measures remains limited due to fragmented institutional coordination, inadequate local governance, and financial constraints in financing long-term adaptation [37,38].

However, significant research gaps remain. While much of the existing literature focuses on the physical and infrastructural aspects of tidal flooding, relatively few studies have developed integrative socio-spatial vulnerability assessments that incorporate climate projections and local demographic dynamics. The absence of a multidimensional vulnerability framework encompassing indicators such as social capital, access to services, and spatial planning has hampered the formulation of inclusive adaptation strategies [39]. Furthermore, the interactions between tidal flooding, land-use change, and long-term urban development patterns in Semarang remain underexplored, despite their potential role in preventing exposure and risk accumulation [12]. This research bridges the existing gaps to build a holistic, sustainable, and equitable adaptation approach for Semarang's coastal communities, particularly in efforts to preserve historic buildings in Semarang from the threat of flooding [40-42].

Several studies mention a combination of parameters related to tidal flooding. It is stated that tidal flooding is a phenomenon of seawater inundation in coastal areas that occurs due to a combination of astronomical tides, sea level rise, land subsidence, and extreme weather factors such as storm surge or heavy rain over a long period. Mathematically, the total sea level can be written as the sum of the average sea level (mean sea level), tidal components, and storm surge [43]. Significant land subsidence, such as that occurring in coastal cities, also exacerbates the risk of tidal flooding by lowering the relative elevation of the land relative to sea level [43]. Another approach uses the superposition of maximum tide factors, long-term sea level rise, subsidence rate, and storm components, minus land elevation, to calculate tidal inundation height [44]. Recent research in Demak, Central Java, shows that the height of the tidal flood reached 56.7 cm with an inundation area of more than 1,200 hectares due to a combination of rising sea levels or high tides and land subsidence [44].

Tidal flood prediction is typically performed using the harmonic method, where sea level is influenced by the amplitude, frequency, and phase of specific tidal components. Furthermore, the contribution of waves to water level rise is calculated using the run-up concept, which depends on the significant wave height and coastal characteristics. The combination of tides, run-up, and sea level rise results in the total water level (TWL), which is a key indicator of potential tidal inundation [45]. On the other hand, land runoff that enters the coastal drainage system can also exacerbate flooding, so that calculating discharge using the rational method remains relevant in analyzing tidal flooding [44]. Furthermore, numerical modeling based on shallow water equations has also been widely used in software such as Delft3D or HEC-RAS 2D to simulate tidal flood dynamics, allowing for more accurate spatial analysis and temporal inundation events in areas at risk of tidal flooding [46]. The following are several equations that can be used to predict tidal flooding events in coastal areas, especially at the research location:

(i) Tide Prediction

To determine the sea level that can cause tidal flooding, you can use the harmonic method, such as the following equation (1).

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

$$h(t) = H_0 + \sum_{i=1}^{n} H_i \cos(\omega_i t + \phi_i) \quad (1)$$

where H_0 is the average sea level; H_i is the amplitude of the tidal component, ω_i is the angular frequency of the component; and ϕ_i is the component phase.

(ii) Wave and Run-up Combination

To estimate the rise of the sea level due to waves, we can use the concept of run-up (R) as explained in equations (2) and (3).

$$R = \beta Hs \quad (2)$$

$$R = \xi Hs \quad (3)$$

where R is the run-up; Hs is the significant sea wave height, β is the coefficient that depends on the slope of the coast, and ξ is the coefficient that depends on the wave characteristics.

(iii) Storm Tide or Total Water Level

A combination of tides, run-up, and sea level rise can be determined in equation (4).

$$H_{total} = h_{tide} + R + SLR \quad (4)$$

where H_{total} is the total sea level, h_{tide} is the high tide, R is the run-up, and SLR is the sea level rise.

(iv) Discharge and Runoff Calculation

For land flooding that exacerbates tidal flooding, if you want to analyze the contribution of land runoff, you can use the following equation (5).

$$Q = C \cdot I \cdot A \quad (5)$$

where Q is the flow rate (m^3/s); C is the runoff coefficient; I is the rain intensity (mm/h); A is the catchment area (m^2)

(v) Model of Numerical Simulation

Typically, this model is calculated by Simulation Software such as MIKE, HEC-RAS 2D, Delft3D, CADMAS Surf, and others. This model typically solves the Shallow Water Equations. The basic form of the equation, without additional forces, is in equations (6), (7), and (8).

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \quad (6)$$

$$\frac{\partial (hu)}{\partial x} + \frac{\partial (hu^2 + \frac{1}{2}gh^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = -gh\frac{\partial \eta}{\partial x} \quad (7)$$

$$\frac{\partial (hv)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2 + \frac{1}{2}gh^2)}{\partial y} = -gh\frac{\partial \eta}{\partial y} \quad (8)$$

where h is the water depth (m); u and v are the flow velocity (x and y components, respectively); η is the water level elevation (m); g is the gravity (m/s).

It is often written by separating the free surface η into $\eta = zb + h$, assuming zb as the base elevation. The equation then becomes equations (9), (10), and (11).

$$\frac{\partial h}{\partial t} + \frac{\partial (hu)}{\partial x} + \frac{\partial (hv)}{\partial y} = 0 \quad (9)$$

$$\frac{\partial (hu)}{\partial x} + \frac{\partial (hu^2 + \frac{1}{2}gh^2)}{\partial x} + \frac{\partial (huv)}{\partial y} = -gh\frac{\partial z_b}{\partial x} - \frac{\tau_{bx}}{\rho} + \frac{\tau_{\omega x}}{\rho} - fhv \quad (10)$$

$$\frac{\partial (hv)}{\partial t} + \frac{\partial (huv)}{\partial x} + \frac{\partial (hv^2 + \frac{1}{2}gh^2)}{\partial y} = -gh\frac{\partial z_b}{\partial y} - \frac{\tau_{by}}{\rho} + \frac{\tau_{\omega y}}{\rho} - fhu \quad (11)$$

Where h is the water depth (m); u and v are the velocity components of x and y direction (m/s), respectively; g is the gravity (m/s); η is the elevation of free surface relative to datum (m); z_b is the base elevation (m) as explained $\eta = z_b + h$; ρ is the water density (kg/m^3); τ_{bx} and τ_{by} are the basic frictional stress (N/m^2) (for example, Manning/Chezy); $\tau_{\omega x}$ and $\tau_{\omega y}$ are the surface wind stress (N/m^2); and f is the Coriolis parameter (s^{-1}). Here are some equations commonly used to create a Risk Index (IR) or, in research addressing tidal flood risk indices, as in this study, by incorporating components such as *hazard–exposure–vulnerability–resilience* (HEVR). By including definitions for each variable and normalization options, the equations can be applied.

(vi) General Structure of the Index

The most common approach for the general structure of the index is explained in equation (12).

IR = f (H, E, V, R) (12)

where *H* is the *hazard*, characteristics of tidal flooding (depth, frequency, duration, inundation speed, subsidence trends, etc.); *E* is the *exposure*, population, assets, livestock, property, accessibility, and other infrastructure in the affected area; *V* is the *vulnerability*, susceptibility to damage to buildings, vulnerable groups, poverty, and other vulnerability factors; *R* is the *resilience*, coastal protection, drainage, embankments or polders, warning systems, response capabilities, and others.

Two forms of composites are frequently used:

The first form (if all constants (i.e., *a*, *b*, *c*, *d*) are higher than 0) is a multiplicative form (recommended for multiplicative interactions), see equation (13):

$$IR = \frac{H^a E^b V^c}{R^d} \quad (13)$$

where the exponents *a*, *b*, *c*, and *d* are weights (priorities). If there is no preference, we can take *a* = *b* = *c* = *d* = 1.

The second form is the weighted sum form (MCDA/AHP) (if the sum of constants is 1 ($\omega_H + \omega_E + \omega_V + \omega_R = 1, atau\ \omega_i > 0$), see equation (14).

$$IR = \omega_H H + \omega_E E + \omega_V V - \omega_H H \quad (14)$$

For Hazard (*H*), for example, indicators include: peak depth *d*, occurrence frequency *f* (times/year), flood duration *T* (hours), and effective sea level or subsidence trend *s* (mm/year). The general form of the equation is as follows (equations (15) and (16)).

$$H = \alpha_1 \hat{d} + \alpha_2 \hat{f} + \alpha_3 \hat{T} + \alpha_4 \hat{s} \quad (15)$$

$$\alpha_i \geq 0, \sum \alpha_i = 1 \quad (16)$$

Then, normalization (min-max) is in equations (17) and (18)

$$\hat{x} = \frac{x - x_{min}}{x_{max} - x_{min}} \in [0, 1] \quad (17)$$

$$\hat{d} = \min\left(\frac{d}{d_{ref}}, 1\right), \hat{T} = \min\left(\frac{T}{T_{ref}}, 1\right), \hat{f} = \min\left(\frac{f}{f_{ref}}, 1\right) \quad (18)$$

For Exposure (*E*), indicators of exposure (see equation (19)): affected population as *Pop*, asset value as *Asset*, length or area, and infrastructure as *Infra*.

$$E = \beta_1 \widehat{Pop} + \beta_2 \widehat{Asset} + \beta_3 \widehat{Infra}, \sum \beta_i = 1 \quad (19)$$

For Vulnerability (*V*), indicators of vulnerability: building vulnerability as *Bfrag*, social vulnerability as *Soc*, and Health as *Health* (e.g., proportion of vulnerable groups) (see equation (20)).

$$V = \gamma_1 \widehat{B_{frag}} + \gamma_2 \widehat{Soc} + \gamma_3 \widehat{Health}, \sum \gamma_i = 1 \quad (20)$$

For Resilience (*R*), indicators of resilience: drainage capacity as *Drain*, coastal protection as *Prot* (embankment/polder), and preparedness or early warning as *Resp* (see equation (21)).

$$R = \delta_1 \widehat{Drain} + \delta_2 \widehat{Prot} + \delta_3 \widehat{Resp}, \sum \delta_i = 1 \quad (21)$$

Using the multiplication form with a weight of 1, we can get equation (22):

$$IR = \frac{H \cdot E \cdot V}{R} \quad (22)$$

And, the values for each parameter are taken in equation (23):

$$H = 0.7, E = 0.6, V = 0.5, R = 0.4 \Rightarrow IR = \frac{0.7 \times 0.6 \times 0.5}{0.4} = 0.525 \quad (23)$$

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

For practical notes, we can get: Select indicators that are truly available (e.g., inundation depth, total water level, land elevation, frequency of occurrence from tidal time series, population, asset value from land use tax, design drainage capacity); Consistently use normalization (using min-max or technical reference) and weighting (using AHP; entropic weights or expert judgment); and For mapping, classify IR, for example, by quantile or natural breaks, into low, medium, high, and very high levels.

The coastal area of Semarang is about 5,039.17 hectares, covering 17 villages in several districts such as Tugu, North Semarang, West Semarang, and Genuk, with a total coastline length of approximately 25 kilometers. Inundation due to rain in coastal areas occurs when outflow to the sea is covered by high tide, so that all excess rainfall accumulates to a depth of inundation d. The following equations can be used to predict the area of inundation, the duration of inundation, and the depth of inundation due to tidal flooding.

(vii) Equation Framework (Storage Continuity)

During high tide, we can get equation (24).

$$\frac{dS}{dt} = i_{ex}A \rightarrow S\ (t) = A\int_0^t i_{ex}\ (\tau)\ d\tau \quad (24)$$

where $S = A\ d$. If the rainfall intensity is constant, I (mm/h), and the runoff coefficient is C (unitless), then the excess rainfall rate as depth per time is in equation (25):

$$i_{ex}\ = C\ I\ (0.001)\left[\frac{m}{jam}\right] \quad (25)$$

using the concept 1 mm = 0.001 m. Then the increase in the depth of the puddle is linear with time, with the following equation (26).

$$d\ (t) = i_{ex}t\ = C\ I\ 0.001\ t \qquad [m] \quad (26)$$

(viii) Flooded Time and Duration

This is the time required to reach a pool of water with a certain depth d. For the depth target in d (m), we can get equation (27).

$$t_{flooded} = \frac{d}{C\ I\ 0.001} \qquad [hour] \quad (27)$$

The area A (as long as there is no outflow) does not affect the time to depth d because they cancel each other water run out (volume and filling rate are both equal, but A determines the volume of the inundated flood area (see equation (28)).

$$V\ = d\ A\ \ (m^3) \quad (28)$$

(ix) Volume of Flooding

If the volume of inundation in an area is 100 ha and d = 25 cm, Area A = 100 ha = 100×10,000 = 1,000,000 m^2. Water depth d = 0.25 m. Detailed calculation is in equation (29).

$$V\ = d\ A = 0.25\ x\ 1{,}000{,}000 = 250{,}000\ m^3 \quad (29)$$

(x) Time Calculation (with Specified I and C values)

For example, rainfall intensity I = 50 mm/hour and runoff coefficient of dense built-up area C = 0.9 (see equation (30)).

$$t_{flooded} = \frac{0.25}{0.9\ x\ 50\ x\ 0.001} = \frac{0.25}{0.045} \approx 5.56\ hours \quad (30)$$

This means that if the flow to the sea is completely blocked, rainfall of 50 mm/hour for 5.6 hours will cause 25 cm of inundation across the entire area, assuming C = 0.9. However, if we refer to the risk of heavy rain with an intensity like that in Semarang, about 400 mm/hour, the time required for 25 cm of inundation is in equation (31).

$$t_{flooded} = \frac{0.25}{0.9\ x\ 400\ x\ 0.001} = \frac{0.25}{0.36} \approx 0.69\ hours \quad (31)$$

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

This means that if the flow to the sea is blocked due to high tides with heavy rainfall, with I = 400 mm/hour, assuming C = 0.9, it will cause a 25 cm inundation in 0.69 hours or about 41.67 minutes.

(xi) Alternative Equation

Equation (32) is often used to estimate the depth of excess rainfall that must be accumulated to reach d:

$$P_{excess,\ req} = d\ (m) \Rightarrow \text{in mm: } P_{excess,\ req} = 1000\ d\ (mm) \quad (32)$$

Since $P_{excess} = C\,P = C$ (with P = total of rain), then the total of rain required is in equation (33).

$$P_{req} = \frac{d}{C}\ x\ 1000\ \ (mm) \quad (33)$$

For example, when d = 0.25 m, C = 0.8, the equation (34) is used.

$$P_{req} = \frac{0.25}{0.8}\ x\ 1000\ = 312.5\ mm \quad (34)$$

Minimum intensity to achieve d in duration T (hours) is in equation (35).

$$I_{min} = \frac{d}{C\ 0.001\ T}\ \ [mm/hour] \quad (35)$$

For example, when d = 0.25 m, C = 0.9, T = 3 h, we can get equation (36).

$$I_{min} = \frac{0.25}{0.9\ x\ 0.001\ x\ 3} = \frac{0.25}{0.0027} = 92.6\ mm/hour \quad (36)$$

The assumption in the example above is that there is no outflow to the sea during the high tide period (qout = 0), infiltration or retention is represented simply by the coefficient C (which can be refined with SCS-CN, internal drainage capacity, or micro-storage or depression). In the calculation example, the specific values of I, C, and the tidal duration T are available or can be estimated, so that any scenario to be designed can be calculated, including sensitivity and other tidal flood risk events can also be calculated. As shown in **Figure 2**, a tidal flood event can occur under several conditions of (i) heavy rain, (ii) high intensity and long duration of rain, (iii) high sea water is high tide, and (iv) the urban drainage system is unable to accommodate the volume of rainwater falling onto the land. This condition results in excess rainwater runoff that cannot be immediately discharged into the sea because at the same time, the sea water is high tide.

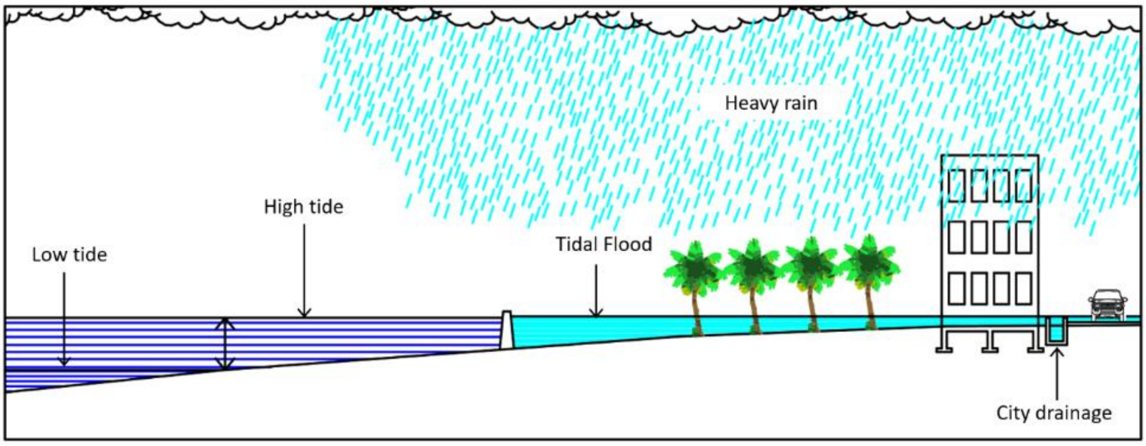

Figure 2. Illustration of tidal flooding in coastal areas.

3. METHODS

There are several important stages in conducting research. The initial stage involves conducting a bibliometric study to map research trends related to historic buildings and their relationship to disasters. In the initial research activities using bibliometrics, several facts

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

were found that historic buildings are more closely associated with keywords such as war, historical facts, the use of applications to study landmark buildings, and very diverse perspectives or points of view in viewing historic buildings. The next stage of research involves identifying areas affected by flooding in Semarang, particularly those caused by tidal flooding, through spatial analysis using ArcGIS software and other relevant software. The next step is to develop a weighting guide for historic buildings by referring to the Burra Charter. In the Burra Charter itself, conservation activities can be classified into several approaches based on the condition of the building to be preserved [30]. **Figure 3** is a research flowchart that begins with spatial analysis, the weighting of historic buildings, the prediction of flood-affected areas using geospatial artificial intelligence, and recommendations for building and environmental preservation scenarios.

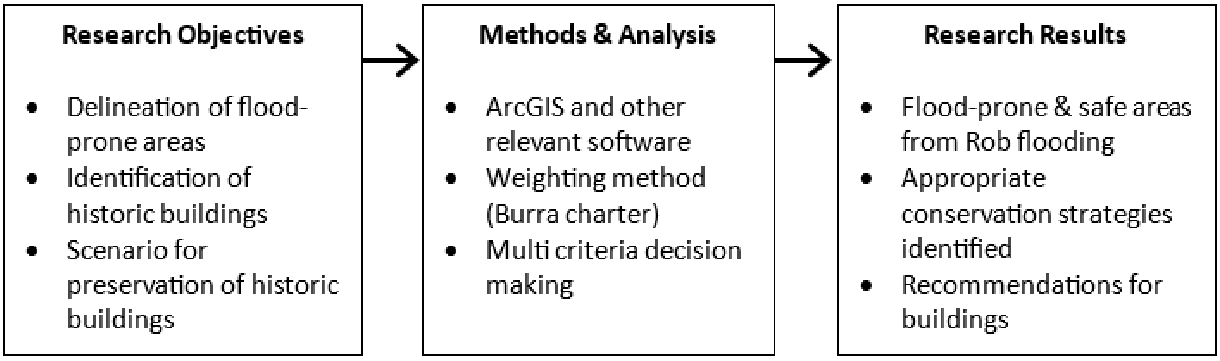

Figure 3. Flowchart of historic building conservation research.

In the conservation of historic buildings, various approaches or levels of intervention describe the extent of changes made to a building's original elements. The Burra Charter is one of the international guidelines that comprehensively outlines the principles of cultural heritage conservation, particularly in the Australian context, but has become a global reference:

(i) Demolition. This is the most drastic and lowest level of intervention in the conservation hierarchy. Demolition generally contradicts the principle of cultural preservation because it removes physical elements and historical significance from a building.
(ii) Reconstruction. This involves rebuilding lost parts of a structure based on historical or archaeological evidence. This is done only when necessary to understand the cultural significance of the site.
(iii) Adaptation. This process involves modifying a building to suit new needs or functions without compromising its significant historical value. Adaptation can extend the useful life of a building and improve sustainability.
(iv) Revitalization. Revitalizing a historic area or building through new economic, social, or cultural activities. This process often involves adapting and restoring old functions while making adjustments to fit a modern context.
(v) Restoration. Returning a building to the condition it was at a specific point in its history, based on accurate evidence. This approach may involve removing elements added later.
(vi) Preservation. Focusing on maintaining the current condition of a building without making significant changes. This action prevents further deterioration and maintains the integrity of the original materials.
(vii) Conservation. Conservation is an umbrella term for all of the above approaches aimed at preserving cultural values holistically. This includes documentation, maintenance,

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

care, and protection from degradation. This is the highest level of conservation intervention, as it maintains both physical continuity and cultural significance.

Some of the conservation assessment parameters for buildings include: (1) historical value, (2) building aesthetic, (3) archaeological value, (4) social and cultural value, (5) Spiritual and religious value, (6) building integrity, (7) building authenticity, and (8) building functionality. Different from conventional assessment methods, this study also includes the level of importance of each parameter, with values of 25 (low), 50 (medium), and 100 (high). **Table 1** is an example of using a table to assess historical buildings at the research site.

Table 1. Assessment of buildings by the weighting method.

Building Code	1	2	3	4	5	6	7	8	Score
1F	100	25	25	50	25	25	50	25	650
	2	2	2	2	2	2	2	2	
2A	100	25	25	50	25	25	50	25	1,350
	5	5	2	3	3	3	5	5	
3D	100	25	25	50	25	25	50	25	1,025
	3	3	2	3	3	3	2	2	

The assessment result is as follows;

(i) 500 – 1100 : Demolition, reconstruction, and adaptation
(ii) 1100 – 1225 : Revitalization and restoration
(iii) 1225 – 1550 : Preservation and conservation

Tidal flooding is flooding that occurs in coastal areas due to sea levels rising above the shoreline or coastal land. Tidal flooding is defined as flooding caused by rising sea levels. When sea levels rise, coastal areas are inundated. Tidal flooding often occurs in areas where the land surface is lower than sea level. Because it is caused by seawater runoff reaching land, the water inundating areas due to tidal flooding tends to be clearer than water from regular floods [12,25,32]. The Semarang flood map (see **Figure 4**) illustrates areas prone to or historically affected by flooding, with the dotted box indicating the study area. Blue shapes superimposed on the base map indicate flood-affected zones, with varying densities indicating the severity and frequency of flooding. The northern region of Semarang, particularly along the coastline bordering the Java Sea, is characterized by a high density of blue, highlighting its vulnerability to tidal flooding. This flooding phenomenon is common in Semarang due to the low coastal topography and land subsidence. Moving south toward the city center, the blue markers remain prominent, indicating frequent urban flooding. This is likely due to poor drainage systems and high rainfall intensity.

Flooding in this urban area is often exacerbated by rapid development and inadequate infrastructure. In contrast, the southern part of Semarang, which is higher and hillier, shows fewer flood zones, although there are scattered blue areas. These zones likely correlate with river valleys or low-lying areas prone to runoff flooding [35,33]. Overall, this map is a crucial tool for city planners, emergency responders, and policymakers to identify high-risk zones and design effective flood mitigation and climate change resilience strategies in Semarang. The delineation of flood zones on the map is based on the annual flood history and topographic conditions of Semarang.

The potential for tidal flooding in Semarang is categorized as a high-risk disaster. North Semarang District is one of the areas highly vulnerable to tidal flooding, which occurs almost daily [32]. At least 1,346 hectares of Semarang coastal area are subject to tidal flooding throughout the year. Nearly 95% of this area consists of densely populated residential areas,

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p- ISSN 2528-1410 e- ISSN 2527-8045

resulting in losses for residents, including 5–100% damage to house components, waterlogging that impacts environmental health, and damage to various residential infrastructure [9,25].

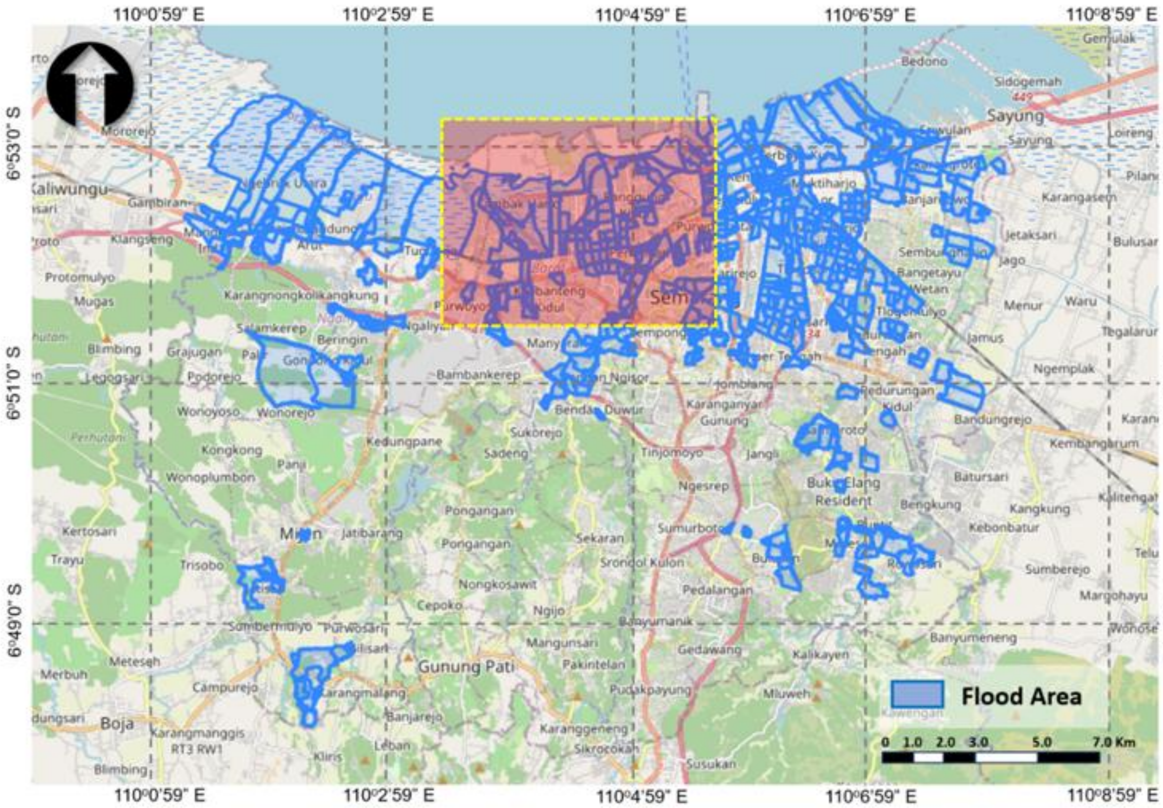

Figure 4. Flood-prone areas in Semarang.

4. RESULTS AND DISCUSSION

4.1. Bibliometric Analysis

In recent years, systematic reviews and bibliometric analyses have gained popularity in research, serving as an approach to synthesize large amounts of literature and identify trends in research themes within scientific studies. Detailed information regarding the use of bibliometric is explained elsewhere [47-49]. Much research regarding bibliometric analysis has been well-documented (**Table 2**).

Table 2. Previous studies in bibliometric analysis.

No	Title	Reference
1	Dental suction aerosol: Bibliometric analysis	[50]
2	Bibliometric analysis of nano metal-organic frameworks synthesis research in medical science using VOSviewer	[51]
3	Research trends from the Scopus database using keyword water hyacinth and ecosystem: A bibliometric literature review	[52]
4	Use of blockchain technology for the exchange and secure transmission of medical images in the cloud: Systematic review with bibliometric analysis	[53]
5	Chatbot artificial intelligence as educational tools in science and engineering education: A literature review and bibliometric mapping analysis with its advantages and disadvantages	[54]
6	How technology can change educational research? Definition, factors for improving quality of education and computational bibliometric analysis	[55]

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Table 2 (continue). Previous studies in bibliometric analysis.

No	Title	Reference
7	Effects of sustained deficit irrigation on vegetative growth and yield of plum trees under the semi-arid conditions: Experiments and review with bibliometric analysis	[56]
8	Hydroxyapatite as delivery and carrier material: Systematic literature review with bibliometric analysis	[57]
9	Development of intelligent tutoring system model in the learning system of the Indonesian national armed forces completed with bibliometric analysis	[58]
10	How bibliometric analysis using VOSviewer based on artificial intelligence data (using ResearchRabbit Data): Explore research trends in hydrology content	[59]
11	Artificial intelligence (AI)-based learning media: Definition, bibliometric, classification, and issues for enhancing creative thinking in education	[60]
12	Comprehensive review on wastewater treatment using nanoparticles: Synthesis of iron oxide magnetic nanoparticles, publication trends via bibliometric analysis, applications, enhanced support strategies, and future perspectives	[61]
13	Role of coastal vegetation belts in mitigating tsunami waves: Bibliometric analysis, numerical, and spatial analysis	[24]
14	Synthesis and characterization of acetylene alcohols via alkynylation of heteroatomic aldehydes with phenylacetylene under various reaction parameters completed with spatial chemical structure, literature review, and bibliometric analysis	[62]
15	How to teach fraction for empowering student mathematics literacy: Definition, bibliometric, and application using digital module	[63]
16	Smart electric resistance welding based on artificial intelligence (AI) based on real-time adaptive statistical features completed with bibliometric analysis	[64]
17	Contributing factors to greenhouse gas emissions in agriculture for supporting sustainable development goals (SDGs): Insights from a systematic literature review completed by computational bibliometric analysis	[65]
18	Current strategies for mitigating airborne pathogen transmission: An integrative review based on aerosol science and particle technology to support the Sustainable Development Goals (SDGs), complemented by a bibliometric analysis	[66]
19	What evidence supports the advancement of language learning through digital innovation? Toward achieving Sustainable Development Goals (SDGs) in the 21st century completed with bibliometric analysis	[67]
20	Bibliometric analysis of briquette research trends during the COVID-19 pandemic	[68]
21	Bibliometric data analysis of research on resin-based brake-pads from 2012 to 2021 using VOSviewer mapping analysis computations	[69]
22	Past, current and future trends of salicylic acid and its derivatives: A bibliometric review of papers from the Scopus database published from 2000 to 2021	[70]
23	Correlation of metabolomics and functional foods research in 2020 to 2023: Bibliometric analysis	[71]
24	The use of zeolite material as a filtration media in waste treatment: Bibliometric analysis	[72]
25	Techno-economic feasibility and bibliometric literature review of integrated waste processing installations for sustainable plastic waste management	[73]
26	Production of wet organic waste ecoenzymes as an alternative solution for environmental conservation supporting sustainable development goals (SDGs): A techno-economic and bibliometric analysis	[74]

DOI: https://doi.org/10.17509/ijost.v11i1.89659
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Table 2 (continue). Previous studies in bibliometric analysis.

No	Title	Reference
27	Hazard identification, risk assessment, and determining control (HIRADC) for workplace safety in manufacturing industry: A risk-control framework complete with bibliometric literature review analysis to support sustainable development goals (SDGs)	[75]
28	The research trend of statistical significance test: Bibliometric analysis	[76]
29	A bibliometric analysis of global trends in engineering education research	[77]
30	Bibliometric analysis using VOSviewer with Publish or Perish of Chinese speaking skills research	[78]
31	Bibliometric analysis using VOSViewer with Publish or Perish of metacognition in teaching English writing to high school learners	[79]
32	Evaluation of assessment projects in English language education: A bibliometric review	[80]
33	Bibliometric analysis using VOSviewers with Publish or Perish of "academic reading"	[81]
34	Bibliometric analysis using VOSviewer with Publish or Perish of CEFR-based comparison of English language teaching models for communication	[82]
35	Exploring global research trends on the integration of information technology in pragmatic studies: A bibliometric analysis	[83]

Systematic reviews aim to comprehensively evaluate previous research, while bibliometric analyses provide quantitative insights into publication trends, influential publications, and new research areas that have been unexplored by other researchers [24,84,85]. The use of bibliometric databases as a literature assessment strategy is beneficial in various areas, such as disaster vulnerability modeling and studies related to historic buildings, where interdisciplinary approaches using geospatial technologies are rapidly evolving [86,87]. **Figure 4** presents a bibliometric analysis conducted using the Google Scholar database, with the keywords "historical buildings" and "disaster" queried in March 2025. The data collected and analyzed from Google Scholar comprises 1,000 manuscript titles from books, journals, and conference proceedings, spanning the data range from 2015 to 2025. Some essential keywords closely related to the word "historical buildings" include historical data, perspectives, applications, energy consumption, challenges, war, cultural history, and human history. Meanwhile, research that links the words "historical buildings" with "disaster" does not show a positive trend because only a few manuscript titles are found that discuss "historical buildings" and "disaster" simultaneously.

A bibliometric analysis conducted using Google Scholar with the keywords "historic buildings" and "disaster" revealed several interesting findings related to research trends in the existing literature. Based on data collected and analyzed from 1,000 manuscript titles spanning books, journals, and conference proceedings from 2015 to 2025, this analysis provides insights into the primary focus and recent developments in the study of historic buildings and their relationship to disasters. The analysis revealed that research discussing historic buildings is generally more dominant than that discussing their ties to disaster. In this regard, there has been a significant increase in topics focused on historic building conservation, for example, technology-based approaches, cultural preservation, and sustainable architecture. However, research that combines the terms "historic buildings" and "disaster" remains very limited. Some of the most frequently appearing keywords related to historic buildings are historical data, perspective, application, energy consumption, challenges, war, cultural history, and human history. The analysis indicates that most research focuses on the historical and cultural aspects of the buildings, with little attention paid to the

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p- ISSN 2528-1410 e- ISSN 2527-8045

influence of disasters, even though disasters pose a significant threat to the preservation of historic buildings in many areas, particularly those located in disaster-prone regions such as floodplains or earthquake zones.

Research linking historic buildings to disasters (especially natural disasters such as floods, earthquakes, or fires) is minimal. Few studies highlight disaster mitigation strategies or sustainability approaches in the context of preserving historic buildings in disaster-prone areas, as shown in **Figure 5**. This limited exposure indicates a research gap that needs to be addressed, particularly in developing effective historic building conservation strategies that can mitigate the challenges posed by natural disasters. Although current research trends have limited exposure to disasters in the context of historic buildings, there is a significant opportunity to develop new research that combines these two areas, given the increasing intensity of disaster phenomena (e.g., tidal flooding, earthquakes, and global warming).

Integrating geospatial technology to map the vulnerability of historic buildings to disasters can pave the way for new interdisciplinary research that other researchers have rarely explored. **Table 3** shows the distribution of publications related to landmark buildings and disasters from 2015 to 2024, based on data from Google Scholar, Scopus, and Web of Science (WoS). The table shows an increasing trend in the number of publications related to historic buildings and disasters over the past decade. Google Scholar displays a higher number of publications compared to Scopus and Web of Science, which may be attributed to its broader coverage of sources, including theses, conference proceedings, and non-peer-reviewed articles. Publication trends from reliable sources are crucial for understanding the direction of research developments with similar themes and approaches [24,86,88].

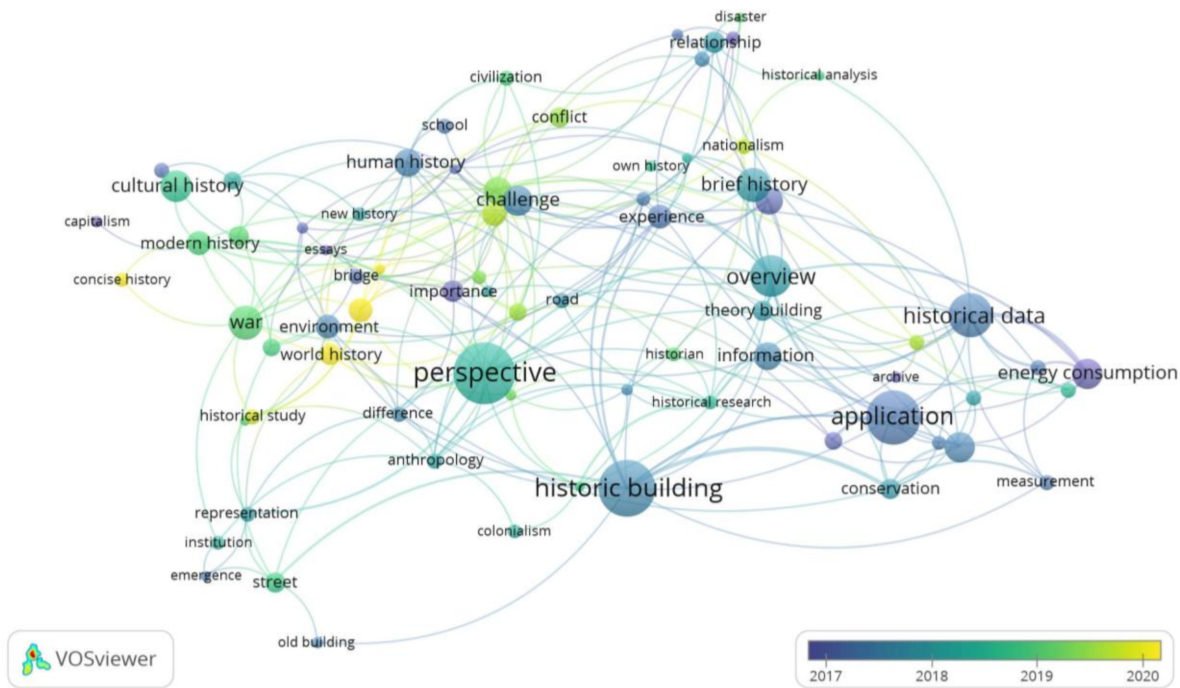

Figure 5. Bibliometric diagram of the keyword "historical building" by VOSviewer.

The increasing number of publications on the theme of historic building preservation and disaster management reflects the growing academic and research attention to the conservation of historic buildings in the context of disaster risk. The increasing number of publications not only reflects the growing intellectual attention but also demonstrates the importance of an interdisciplinary approach that combines geospatial technology, artificial

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intelligence, and cultural conservation to develop effective and sustainable disaster mitigation strategies.

Table 3. Distribution of publications on historic buildings and disasters 2015-2025.

Year	Google Scholar	Scopus	Web of Science
2015	15	12	10
2016	22	18	15
2017	35	25	20
2018	44	30	25
2019	53	40	35
2020	60	50	45
2021	72	60	55
2022	88	70	65
2023	97	80	75
2024	115	90	85

However, it should be noted that despite this increase in publications, a gap remains in research specifically examining the interaction between historic buildings and disasters. Therefore, more studies are needed that focus on developing conservation frameworks that consider disaster risk, especially in vulnerable areas such as Semarang. Integrating data from various bibliometric sources can thus provide a more comprehensive picture of research developments in this field and help identify areas requiring further attention.

4.2. Weighting Analysis

To weight historical buildings in Semarang, **Table 4** is the result of the weighting carried out based on eight parameters contained in the burra charter, namely (1) historical value, (2) aesthetic value, (3) scientific/archaeological value, (4) social and cultural value, (5) spiritual/religious value, (6) integrity, (7) authenticity, and (8) functionality. The results of the weighting of historical buildings, as presented in **Table 2**, utilize conventional methods without incorporating constant values for each parameter. In the rightmost column, there is information about the preservation level of each building based on the initial weighting results. The information about the preservation feasibility level of the building is: * low priority, ** moderate priority, and *** high priority. Sometimes, visually, the building shows an aesthetic condition and is still used as a place of activity. However, other preservation values, such as historical role, archaeological value, spiritual value, and authenticity in the building, are low, so a historic building can be included in the Iowa priority category with * in the final assessment.

Table 4 shows the results of the weighting of historical buildings in Semarang, which presents the results of the assessment of 65 historical buildings out of 142 historical buildings in the town of Semarang based on several criteria, which are marked in columns 1 to 8, with the total score in the last column. Assessment of historical buildings is conducted to determine their level of significance, physical condition, potential for reuse, and vulnerability to disasters, particularly tidal flooding, which is a significant issue in the Old City area of Semarang. There are three colour classifications in the table: green for high scores (≥ 30), indicating high-value buildings that are very worthy of preservation or revitalization. Yellow for medium scores (26–29) can indicate moderate conditions; buildings need special attention in certain aspects. While a red score (≤ 25) indicates high vulnerability or deteriorating physical conditions, possibly requiring intensive restoration or re-evaluation for preservation. Some buildings with High scores (≥ 30), such as Station of Tawang (No. 4), Church of Blenduk

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

(No. 66), Jiwasraya (67), Hot Noorden (No. 63), Catholic Church of St. Yusuf (No. 46), and Post office of Semarang (No. 54).

These buildings are historical icons of the city and have high significance in the context of cultural heritage, and with high potential as tourist attractions. Meanwhile, buildings with very low scores (≤ 25), such as Semarangsche Automobiel Mij (No. 39), Lindeteves-Stokvis (No. 49), Javasche Boschexploitatie Mij (No. 48), and Butterworth & Co. (No. 24). These buildings have low historical value, are in poor physical condition, or are located in less strategic locations for preservation.

The weighting table for historic buildings is a crucial tool for informed decision-making regarding the preservation and revitalization of historic areas in Semarang, particularly in the face of challenges such as tidal flooding and land-use changes. The total score provides an overview of intervention priorities, whether preservation, adaptation, or even demolition if no longer viable. However, **Table 2** is a relatively conventional weighting method, so researchers deemed it necessary to assign a specific constant value to each assessment variable.

This value is considered fair because, regardless of the reason, historical value should have the highest priority in determining the suitability of a building for preservation when it is compared with other values or parameters. In contrast to **Table 4**, the building data in **Table 5** represent the evaluation results of historical buildings spread across Semarang after adding weights based on the level of importance of the historical building preservation criteria. Each parameter is given a score based on several assessment criteria based on the Burra Charter, such as; historical value (100), aesthetics (25), archaeology (25), social and cultural value (50), spirituality (25), integrity (25), authenticity (50), and functionality (25).

Table 4. Weighted assessment of historic buildings in flood-prone urban areas.

No	Building	1	2	3	4	5	6	7	8	Score	Level
1	Minaret of William III	5	4	3	3	2	3	3	3	26	**
2	Marabunta	4	4	3	4	1	3	4	4	27	**
3	Hall of Yasa Hoofdkantoor N.V. Maatschappij	4	3	3	3	1	3	3	3	23	*
4	Station of Tawang d.h. Station NIS	5	5	4	5	2	4	5	5	35	***
5	House of Widayat Basuki Dharmowiyono	3	3	2	3	2	3	3	3	22	*
6	Worship Building See Hoo Kiong	4	4	3	4	5	3	4	3	30	***
7	Mosque of the Minaret	4	3	3	4	5	3	4	3	29	***
8	Nederlandsch Indische Gas Maatschappij	5	5	4	3	1	3	5	4	30	***
9	Bridge of Berok d.h. de Willemsbrug	5	5	3	4	1	3	5	5	31	***
10	Koninklijke Paketvaart Maatschappij (KPM)	5	5	4	4	1	4	5	5	33	***
11	Nederlandsche Handel Maatschappij (NHM)	5	4	3	4	1	3	4	4	28	**
12	Stoomvaart Maatschappij Nederland	4	3	3	3	1	3	3	3	23	*
13	De Semarangsche Handelsvereeniging	5	4	3	4	2	4	4	4	30	***
14	NV Cultuur Maatschappij der Vorstenlanden	5	5	4	3	1	5	5	5	33	***
15	De Koloniale Bank	5	5	4	3	1	4	5	5	32	***
16	N.V. Escompto Bank – NIEM	5	5	3	3	1	3	4	4	28	**
17	De Spaarbank	5	5	3	3	1	5	3	5	30	***
18	N.V. Indische Lloyd	5	4	4	4	1	3	4	3	28	**
19	Monod Diephuis d.h. Agriculture Office	5	4	4	4	1	3	4	3	28	**
20	N.V. Dagblad De Locomotief (center)	5	4	4	4	1	3	4	3	28	**
21	Homeland Publisher	4	3	3	3	1	3	3	3	23	*
22	Hygeia Drinking Water Factory	5	4	3	3	1	3	4	3	26	**
23	Dagblad De Locomotief	4	3	3	3	1	3	3	3	23	*
24	Butterworth & Co.	4	3	3	3	1	3	3	3	23	*
25	Soesmans Kantoor – Borsumij Wehry	5	4	4	4	1	3	4	3	28	**

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

Table 4 (continue). Weighted assessment of historic buildings in flood-prone urban areas.

No	Building	1	2	3	4	5	6	7	8	Score	Level
26	Bank Vereeniging Oei Tiong Ham Concern	5	4	4	4	1	3	4	3	28	**
27	RNI Building	5	4	4	4	1	3	4	3	28	**
28	Insurance Building	4	3	3	3	1	3	3	3	23	*
29	Nederlandsch-Indische Handelsbank	5	5	4	4	1	4	4	5	32	***
30	Building of Marba	5	5	4	4	1	4	5	3	31	***
31	Law Office Kepodang St No.36	4	3	3	3	1	3	3	3	23	*
32	Office Lindeteves Stokvis	5	4	4	4	1	3	4	3	28	**
33	House Pseudo-Nieuwe Bouwen	4	3	3	3	1	3	3	3	23	*
34	House Indies Awal Cottage	4	4	3	3	1	3	3	3	25	*
35	Building of Cigate Factory	3	3	2	3	1	3	3	3	21	*
36	Spiegel d.h. N.V. Winkel Maatschappij	5	4	3	3	1	3	4	5	28	**
37	Hall of Inheritance	4	3	3	3	1	3	3	3	23	*
38	Semarangsche Automobiel Mij	3	3	2	3	1	3	3	3	21	*
39	Printing of Saka Aksara & Indomart	3	3	2	3	1	3	3	3	21	*
40	Editorial Bureau Handelsblad & Car Importer	4	3	3	3	1	3	3	3	23	*
41	House Indies d.h. Maurice Wolf Juwelier	4	4	3	3	1	3	4	3	25	*
42	Hotel Pelangi Indah	3	3	2	3	1	3	3	3	21	*
43	Military District Supplies – Technische School	5	3	4	3	1	4	3	3	26	**
44	Kindergarten & El. School St. Fransiskus R.K.	4	3	3	4	4	3	4	3	28	**
45	Catholic Church of St. Joseph	5	4	3	4	5	3	4	3	31	***
46	Cigarette Factory of Praoe Lajar	5	3	4	3	1	3	4	3	26	**
47	Javasche Boschexploitatie Mij	4	3	3	3	1	3	3	3	23	*
48	Building 'Mega Eltra' – Lindeteves-Stokvis	4	4	3	3	1	4	3	3	25	*
49	Central Kanisius Foundation	4	3	3	4	4	4	3	3	28	**
50	Zikel & Co. – Coffee Shop	5	4	2	3	1	5	4	5	29	**
51	Hotel Centrum	4	4	3	3	1	3	4	4	26	**
52	Former Building "Bank Indonesia" – Javasche Bank	5	5	4	4	1	3	4	5	31	***
53	Post Office of Semarang	5	5	4	5	1	3	5	5	33	***
54	Tax Service Office of Central Semarang 2	4	3	3	3	1	3	3	3	23	*
55	House of Peace	5	4	3	4	1	3	4	3	27	**
56	Sputnik Pharmacy	3	3	2	3	1	3	3	3	21	*
57	Military Office of Kodam IV/Diponegoro	4	3	3	3	1	3	3	3	23	*
58	Building of 'Gedhong Dhuwur'	5	3	3	3	2	3	3	2	24	*
59	Jatingaleh Market	3	3	2	3	1	3	3	3	21	*
60	Building of Old BPJS	3	3	2	3	1	3	3	3	21	*
61	Health Centre of Candi Lama	3	3	2	3	1	3	3	3	21	*
62	Office of 'Suara Merdeka' – Het Noorden	5	4	3	4	1	4	4	5	30	***
63	Borneo Sumatra Maatschappij (Borsumij)	5	4	4	4	1	5	4	5	32	***
64	Church of Blenduk	5	5	3	4	5	4	5	4	35	***
65	Building of Jiwasraya	5	5	4	4	3	2	5	5	34	***

Note: (1) History, (2) Aesthetic, (3) Archeology, (4) Social and Culture, (5) Spirituality, (6) Integrity, (7) Authenticity, and (8) Functionality. Level: * low priority, ** moderate priority, *** high priority.

In **Table 5**, the weighted score ranges from 900 to 1500, reflecting varying levels of significance based on the preservation parameters in the Burra Charter and the weighting of importance assigned to each variable. The building with the highest score is the Tawang Station (NIS Station) with a score of 1500, confirming its vital role as an icon of colonial transportation history and architecture. Followed by the Semarang Post Office and the Catholic Church of St. Yusuf & Pastorate, both scored 1375, indicating the dominant colonial spiritual and architectural values to this day. Meanwhile, there are several buildings with the

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

lowest scores, such as Soesman's Office, Hotel Pelangi Indah, and Building of CV Gudang Ragam, which each only scored 900, indicating that despite their historical value, their overall contribution to the context of building preservation, culture, and architecture is not as significant as other buildings. An interesting aspect of the assessment results, including weights for each parameter, is that several buildings initially rated low (red) in the first weighting. However, after including importance weights for each variable in the second weighting, their scores increased and entered the medium category. This was found in the assessment of Buildings 1 (Minaret of William III), 12 (PT Djakarta Lyod), 37 (Spiegel), 51 (Zikel & Co), and other buildings.

Some historical buildings inherited from the Dutch colonial era experienced a change in status to high priority after they were given a weighting of importance. 13 buildings were previously assessed as medium priority to high priority, such as building number 7 (Mosque of minaret), 11 (NHM), 16 (NIEM), 18 (Indische Lloyd), 19 (Monod Diephuis), 20 (Dagblad De Locomotief), 25 (Borsumij Wehry), 26 (Bank Vereeniging), 27 (RNI Building), 32 (Lindeteves Stokvis), 36 (Spiegel), 50 (Zikel & Co) and 55 (House of peace). Four buildings were previously included in the low-priority assessment, after being assessed with importance weights such as History (with a weighting of 100), Culture (with a weighting of 50), and so on; they were changed to a medium-priority assessment. These buildings include numbers 34 (House Indies Awal Cottage), 41 (Maurice Wolf Juwelier), 48 (Lindeteves Stokvis), and 58 (Gedhong Dhuwur). Overall, the scores given show a commitment to assessing historic buildings not only from the aesthetic aspect or the old age of the building because it was built during the Dutch colonial era, but from the social function, historical role, spirituality, and authenticity of the building's form as an essential foundation in developing a strategy for preserving historic buildings in Semarang.

Table 5. Changes in the assessment of historic buildings with weighting of importance levels.

No	Name of Building	1	2	3	4	5	6	7	8	Total	Score	Level
7	Mosque of the Minaret	4	3	4	5	3	4	3	3	29	1225	**
11	Nederlandse Handel Maatschappij (NHM)	5	4	4	1	3	4	4	3	28	1275	**
16	N.V. Escompto Bank – NIEM	5	4	4	1	3	4	4	3	28	1250	***
18	N.V. Indische Lloyd	5	4	4	1	3	4	4	3	28	1275	**
19	Monod Diephuis d.h. Agriculture Office	5	4	4	4	1	3	4	3	28	1275	**
20	N.V. Dagblad De Locomotief (center)	5	4	4	1	3	4	4	3	28	1275	***
25	Soesmans Kantoor - Borsumij Wehry	5	4	4	1	3	4	4	3	28	1275	***
26	Bank Vereeniging Oei Tiong Ham Concern	5	4	4	1	3	4	4	3	28	1275	***
27	RNI Building	5	4	4	1	3	4	4	3	28	1275	***
32	Office Lindeteves Stokvis	5	4	4	1	3	4	4	3	28	1275	***
34	House Indies Awal Cottage	4	3	3	3	1	3	4	4	25	1100	*
36	Spiegel Bar & Resto d.h. N.V. Winkel Maatschappij	5	4	4	1	3	4	4	3	28	1250	***
41	House Indies d.h. Maurice Wolf Juwelier	4	3	3	3	1	3	4	4	25	1100	*
48	Building 'Mega Eltra' – Lindeteves-Stokvis	4	4	3	3	1	3	3	4	25	1100	*
50	Zikel & Co. – Coffee Shop	5	4	2	3	1	5	4	5	29	1275	***
55	House of peace	5	4	4	1	3	4	4	2	27	1250	**
58	Building of 'Gedhong Dhuwur'	5	3	3	2	1	3	3	4	24	1125	*

Note: (1) History, (2) Aesthetic, (3) Archeology, (4) Social and Culture, (5) Spirituality, (6) Integrity, (7) Authenticity, and (8) Functionality. Level: * low priority, ** moderate priority, *** high priority. The assessment result in a star mark (*) is as follows: (i) 500 - 1100(*): Demolition, reconstruction, and adaptation; (ii) 1100 - 1225(**): Revitalization and restoration; (iii) 1225 – 1550 (***): Preservation and conservation.

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

4.3. Spatial Analysis

To conduct a spatial study of flood-prone areas in Semarang, the image below is a map of the contour lines and slope gradients of Semarang based on DEM (Digital Elevation Model) data. Referring to the image, the coastal area is indeed very gentle, with a slope of only 0-2% and has a flat area in the northern part of Semarang. The slope maps of Semarang, as shown in **Figure 6**, the area is susceptible to tidal flooding during the rainy season, particularly during the full moon, due to rising sea levels.

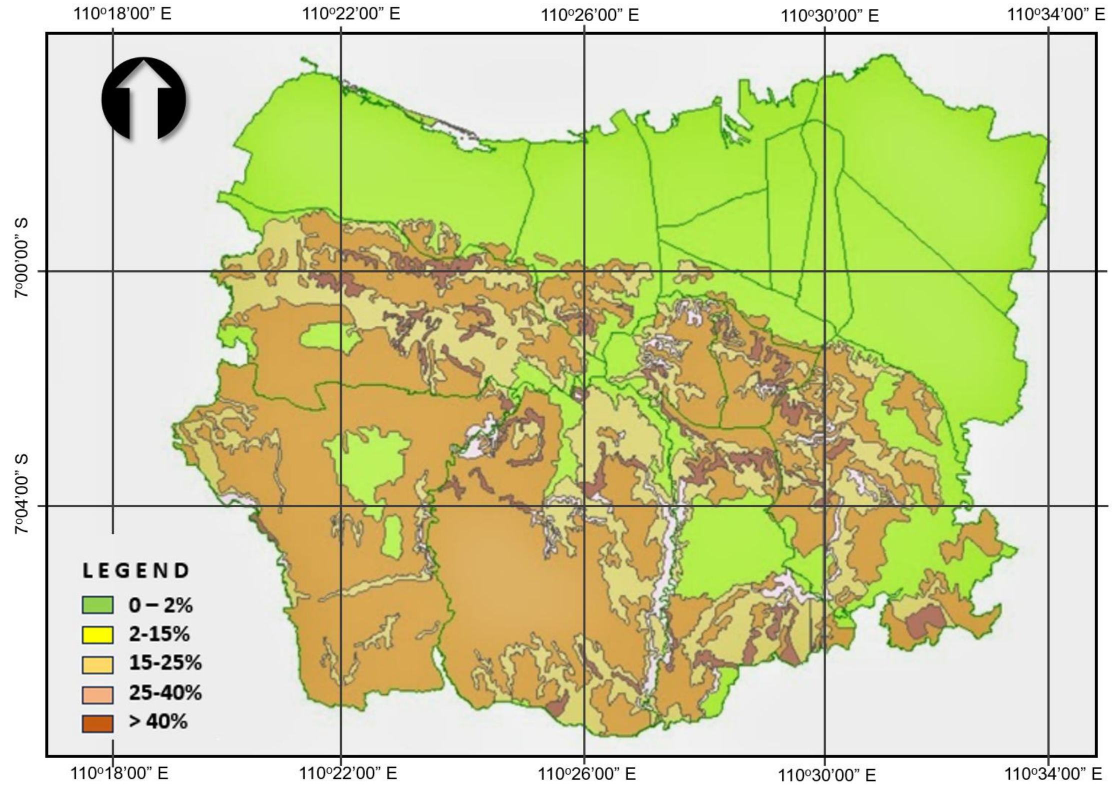

Figure 6. Contour lines and slopes of Semarang.

Spatial analysis is an essential method for understanding the phenomenon of tidal flooding, particularly in coastal urban areas. This type of flooding is caused by sea level rise, tidal fluctuations, and land subsidence, which is often exacerbated by climate change and human activities. Through spatial analysis, researchers can identify flood-prone zones, assess inundation levels, and model future scenarios. Geographic Information System (GIS)-based software enables the integration of various spatial data, including topography, land use, hydrology, and socioeconomic data, to evaluate risks, vulnerabilities, and threats. Digital Elevation Models (DEMs), satellite imagery, and flood simulation models are commonly used to map areas potentially affected by tidal flooding. This analysis supports better decision-making in urban planning, disaster mitigation, and infrastructure development. This enables local governments to design more resilient strategies, such as spatial regulations, early warning systems, or coastal protection infrastructure. **Figure 7** is a contour line that depicts the topographic conditions of the area on the north side of Semarang, which is dominated by an altitude of 0 – 10 meters. Referring to **Figures 6** and **7**, which show the northern area of Semarang as flat with a slope of less than 2%, it is clear that the elevation in the northern area of Semarang ranges from 0 to 10 m above sea level. During the rainy season and periods of high sea levels, the potential for tidal flooding is very high, and the northern area of Semarang is likely to experience prolonged inundation.

Figure 8 is a photo mapping the distribution of several historic buildings in North Semarang, located in the city's flooded area, that have the potential to be preserved at the highest level of preservation. The photo mapping below represents only a small portion of the historic buildings in Semarang; the actual number could reach tens or even hundreds.

Figure 9 is a map of Semarang which is at risk of being affected by tidal flooding, the red line shows the areas at risk of being affected by tidal flooding with the highest level of risk, the yellow line for areas with moderate risk, and the green line is the area with the lowest risk of being exposed to tidal flooding. As shown in **Figures 6, 7, 8, and 9**, the northern region of Semarang is dominated by land with relatively flat slopes. This flat area has the potential for urban development. **Figure 9** also shows that areas with gentle slopes and relatively flat elevations of less than 4 m are at high risk of tidal flooding, while elevations between 4 and 10 m are categorized as areas at moderate risk of flooding. Urban areas with elevations greater than 10 m above sea level are relatively safe from tidal flooding.

If we refer to the coastal area in Semarang is 5,039.17 Ha, with a total coastline length of about 25 kilometres, then the volume of rainwater that must be accommodated by the urban drainage system is about 12.59 million m3 with an assumed inundation height of 25 cm. The volume of rainwater of 12.59 million cubic meters becomes a burden on the Semarang drainage system, which, if distributed to all the drainage channels of Semarang along 991.2 km, there is still 20% of rainwater runoff that will spill onto roads and urban land.

This research groups the historical buildings within a scientifically accountable preservation framework. According to the official website of cultural heritage buildings in the Semarang (https://cagarbudaya.semarangkota.go.id/), there are 142 cultural heritage buildings, comprising residences, places of worship, offices, schools, and other structures. In this study, only 65 buildings were assessed and weighted because the other 77 buildings were primarily residences in inferior condition and lacked historical significance or socio-cultural value.

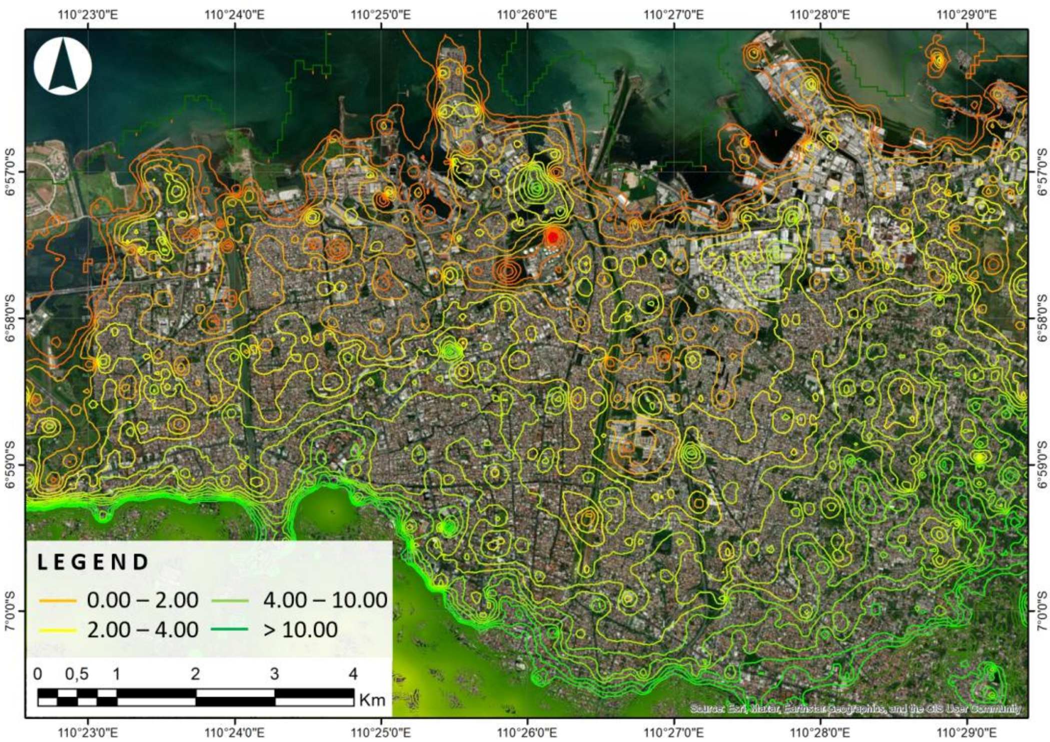

Figure 7. Contour line of Semarang (North area).

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

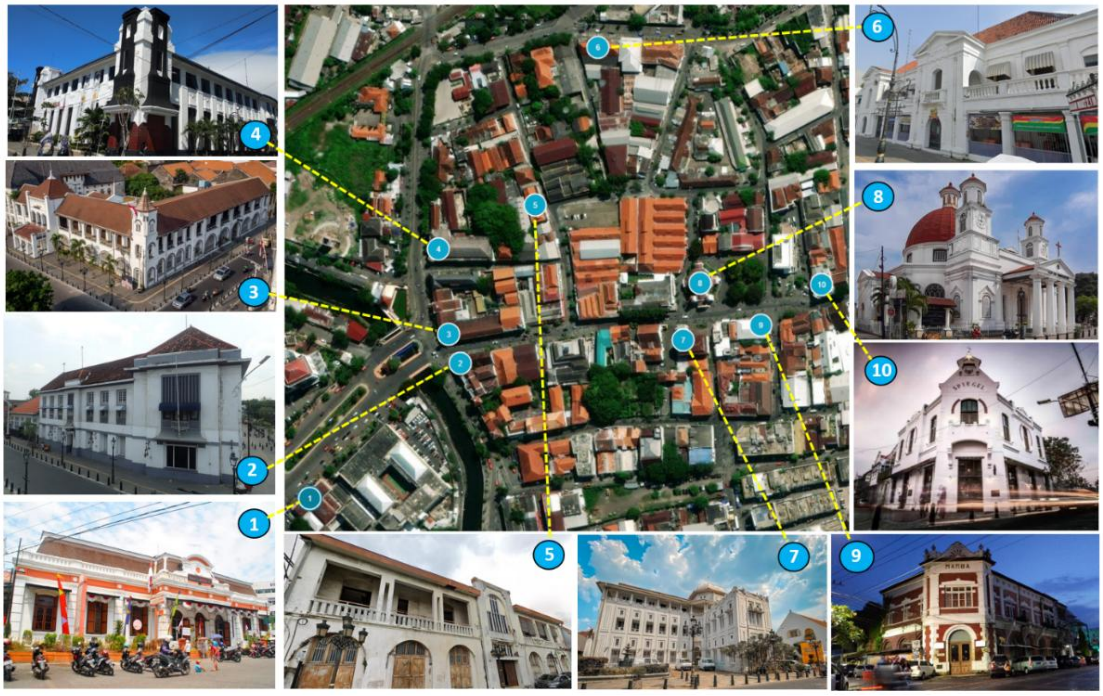

Figure 8. Photo map of a historical building in North Semarang.

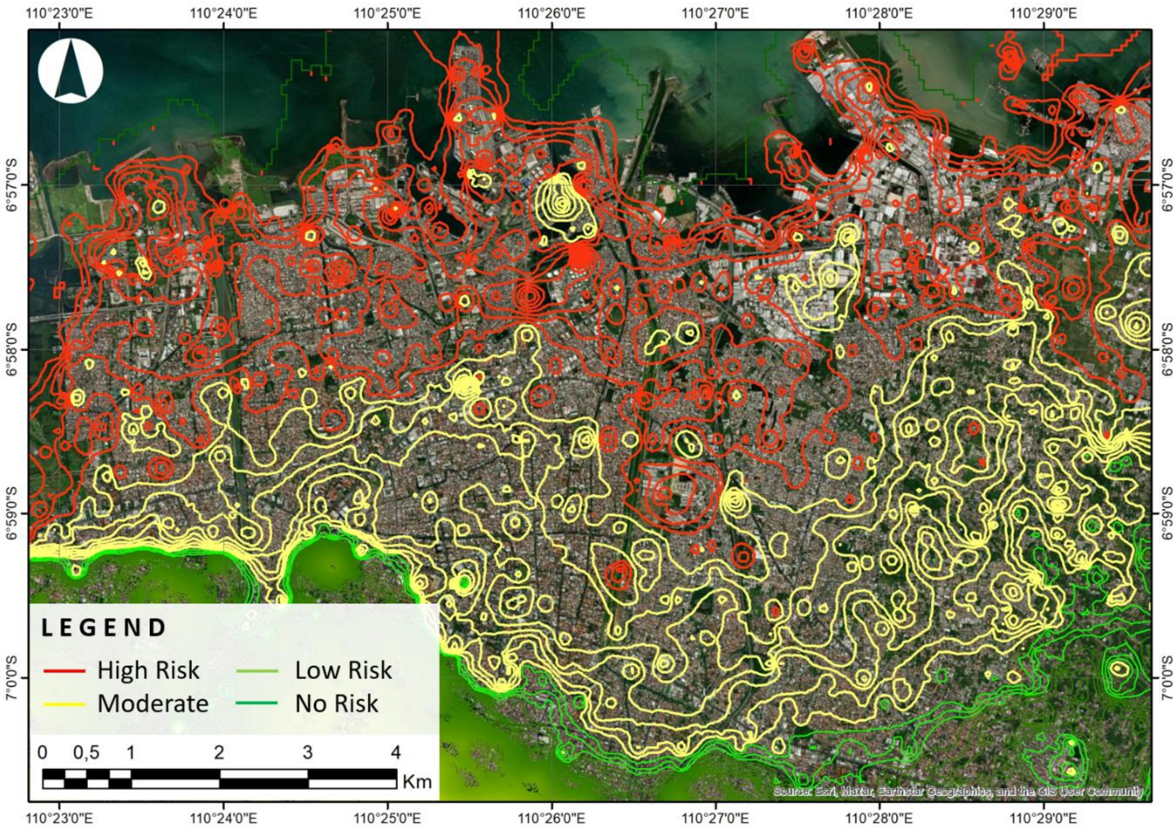

Figure 9. Map of the risk area in North Semarang.

4.4. Discussion

Bibliometric analysis reveals that, despite the broad scope of historic buildings, the relationship between historic buildings and disasters remains underexplored in the existing literature. Therefore, research that combines cultural preservation with disaster mitigation strategies presents an up-and-coming area for further development. This could pave the way for the development of geospatial-based predictive models that integrate historical, topographic, and natural hazard data, thereby improving the preparedness and resilience of historic buildings to future disaster impacts.

The results of this study confirm that the preservation of historic buildings in Semarang, particularly in areas prone to tidal flooding, requires an interdisciplinary approach that integrates disaster risk analysis and conservation based on the Burra Charter principles. Spatial mapping revealed a concentration of historic buildings in coastal zones with slopes of 0–2%, which are hydrologically highly vulnerable to inundation due to sea level rise and high rainfall [25,32,33] (Berkat & Fitriana, 2021; Marfai & King, 2008; Yuwono et al., 2024). These findings align with studies by [5,6], which emphasize the importance of combining flood hazard modeling with historic building vulnerability indicators to formulate intervention priorities. However, this study expands on this approach by incorporating the weighting of Burra Charter conservation parameters (historical, aesthetic, socio-cultural, authenticity, and functionality), which has not been widely explicitly applied in coastal areas of Southeast Asia.

This weighting approach revealed that buildings such as Tawang Station and Blenduk Church had the highest preservation scores, while several low-value colonial commercial buildings required limited adaptation or revitalization strategies. This strategy aligns with the concept of climate adaptation for historic buildings proposed by [2], which combines technical interventions such as structural reinforcement with the preservation of historic values. From a policy perspective, the integration of conservation and flood risk management found in this study also supports the arguments of other studies [10,29] that successful cultural heritage protection in disaster-prone areas requires collaborative and adaptive governance. However, the results of this study indicate that socio-economic factors and the adaptive capacity of local communities surrounding historic buildings are still not widely integrated into evaluation frameworks despite their crucial role in ensuring the sustainability of conservation interventions.

Although this study successfully mapped historic buildings and assessed their preservation feasibility, taking into account the risk of tidal flooding, there are significant research gaps that need to be addressed in future studies. One major shortcoming is the limited integration of socio-economic indicators and the adaptive capacity of communities surrounding historic buildings. Furthermore, few studies have specifically explored institutional responses and public policies to conservation in disaster-prone areas. Social dynamics, land ownership, and local community involvement in the conservation process remain elements that have not been fully addressed in this study. Future research is recommended to develop a spatial information system-based conservation model that integrates climate change projections, as well as participatory analysis involving local stakeholders, to support more comprehensive historic building preservation efforts. Longitudinal studies of the impact of implementing adaptive conservation strategies are also crucial for evaluating the long-term effectiveness of these interventions. With this multidimensional approach, historic building preservation efforts will not only be technical and architectural but also social, ecological, and systemic in nature.

Previous literature tends to focus on two poles of study: (1) Cultural heritage conservation studies that emphasize historical, aesthetic, and architectural values [16,89], but rarely integrate in-depth hydrological risk analysis. (2) Urban flood mitigation studies that utilize GIS and spatial modeling [12,25], but generally ignore cultural and historical value parameters in intervention prioritization.

DOI: https://doi.org/10.17509/ijost.v11i1.89659
p- ISSN 2528-1410 e- ISSN 2527-8045

Few studies systematically combine these two approaches, especially considering socio-cultural indicators and the adaptive function of buildings [7]. Therefore, this study fills this gap by developing a Burra Charter-based weighting method combined with spatial analysis of tidal flood risk, focusing on the Semarang coastal area with its unique topography and colonial history, which has not received much attention in the international literature, and offering an adaptive conservation evaluation framework that can be integrated into climate-resilient spatial planning. This approach is expected to serve as a model for replication for other coastal cities in Southeast Asia facing similar challenges, such as Malacca in Malaysia or Hoi An in Vietnam.

Furthermore, spatial analysis using ArcGIS successfully identified the northern area of Semarang as the zone with the highest risk of tidal flooding, particularly during the rainy season months of January to March. The mapping results show a strong correlation between the locations of significant historical buildings and the most vulnerable areas to flooding. Therefore, this study not only highlights the importance of preservation from a cultural and historical perspective but also encourages the integration of disaster risk mitigation strategies into building conservation policies. These findings provide a scientific basis for spatial planning decisions that are resilient to climate change and coastal urbanization.

5. CONCLUSION

The assessment of historic buildings in Semarang is closely tied to urban flooding, an annual event in Semarang, particularly in the Old Town area. Historical value is a primary reason for preserving historic buildings in Semarang. The assessment of Dutch colonial heritage buildings at the research site yielded diverse results, particularly in determining the most suitable actions, such as preservation, reconstruction, restoration, adaptation, demolition, or revitalization. Geospatial analysis using ArcGIS indicates that the risk of tidal flooding is estimated to occur every February due to the high rainfall intensity in that month. Meanwhile, January, March, and December, which also experience high rainfall intensity, contribute to increasing the risk of tidal flooding. Meanwhile, flooding conditions in April, May, June, July, August, September, and October show a decreasing trend due to the onset of the dry season. The research findings show that of the 65 historic buildings assessed in Semarang, there is significant variation in the level of preservation suitability based on the Burra Charter parameters. Several buildings, such as the Tawang Station, the Semarang Post Office, and the Catholic Church of St. Yusuf, received the highest scores and are considered worthy of complete preservation due to their high historical, aesthetic, and spiritual value, as well as their structural integrity. Conversely, several other buildings scored lower due to their deteriorating physical condition or their non-strategic locations, necessitating different conservation approaches, such as limited revitalization or functional adaptation.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

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