

Research Article

Risk Assessment and Comparison for Historic Sites

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Abstract

Phra Nakhon Si Ayutthaya City Municipality is the location of the Historic City of Ayutthaya, registered as a World Heritage Site, due to an abundance of archaeological sites. However, rapid urbanization poses multi-dimensional risks to specific historic sites. This research aimed to assess and compare urban development risks to these sites based on three conceptual approaches: the Historic Urban Landscape (HUL), People–Nature–Culture (PNC) and Cultural Landscape and Contemporary Urban Development (CL & CUD), and to analyze key risk factors affecting historic sites in Phra Nakhon Si Ayutthaya City Municipality. The instruments consisted of a field survey and Multi-Criteria Evaluation (MCE). For assessment based on HUL approach, 27 sites were at low risk, including 18 temples, with key risk factors related to proximity to water and roads, surrounding buildings, and land use. Based on the PNC approach, temples showed the greatest risk, with 9 at moderate risk, mainly associated with water proximity, flooding, and building design. Based on the CL & CUD approach, temples again constituted the largest category, with 32 at moderate risk. Key risk factors included proximity to water and roads, surrounding buildings and land use. Preventive conservation should incorporate overlay measures, setback and special control zones, controls on the types and scales of surrounding land use, and the preservation of green spaces as buffer zones to enhance resilience. Integrated approaches should promote stakeholder participation and incentives, while conservation measures should be prioritized across short, medium, and long term actions to support sustainable historic site conservation.

Keywords: Risk assessment, Historic sites, Historic urban landscape, People nature culture, Cultural landscape and contemporary urban development, Urban planning measure

1. Introduction

Phra Nakhon Si Ayutthaya was the capital of Thailand between 1350–1767 A.D. Its previous role as a major city on the Chao Phraya River is obvious within the Phra Nakhon Si Ayutthaya City Municipality because it is the location of the former capital, with geographic features including an island surrounded by three rivers, i.e., the Chao Phraya River, Pa Sak River, and Lop Buri River (Ayutthaya Province, 2016), with this large network of rivers and canals acting as transportation routes, drainage, and deployment during wars, as well as facilitating farming and agriculture. These water networks provide not only an economic foundation but are also part of a riverine cultural landscape, reflecting the inhabitants' understanding of natural changes (Yodsurang, 2022). Phra Nakhon Si Ayutthaya City Municipality is thus the location of numerous historic sites, comprising old towns and local communities, e.g., Hua Ro Market Community, etc.; palaces, e.g., the Chakkrawat Phaichayon Throne Hall, etc.; museums, e.g., Thai Boat Museum, etc.; temples, e.g., Wat Singharam, etc.; archaeological and antiquities sites, e.g., Chong Kut Gate, etc.; and monuments and memorials, e.g., Phra Chedi Sri Suriyothai, etc.

The Fine Arts Department has explored, registered, and restored these major archaeological sites since 1935, with the establishment of the Ayutthaya Historical Park project in 1982, in order to provide systematic and continuous maintenance of the archaeological sites in Phra Nakhon Si Ayutthaya. Until 13 December 1991, Ayutthaya Historical Park was designated as a World Heritage Site under the name "Historic City of Ayutthaya" by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). At present, the historic City of Ayutthaya and archaeological sites in Phra Nakhon Si Ayutthaya City Municipality have been conserved continuously under the Fine Arts Department, the primary agency responsible for its maintenance (Office of Natural Resources and Environmental Policy and Planning, 2023).

However, because of the roles and significance of Phra Nakhon Si Ayutthaya City Municipality as the economic, administrative, and social development center of the province, it also contains a concentrated population and an increasing number of constructions. This can be traced back to 2025, when Phra Nakhon Si Ayutthaya City Municipality had a population of up to 47,059 (Phra Nakhon Si Ayutthaya Provincial Statistical Office, 2025). Subsequently, urbanization has resulted in negative impacts on the historic sites, e.g., the invasion and destruction of archaeological sites, and unpleasant visual pollution.

Over the last few decades, there have been a large number of research studies conducted on historic site conservation in Phra Nakhon Si Ayutthaya City Municipality. For example, the research of Rattanathavorn et al. (2013) revealed that historic site conservation should be focused on travel networks, promoting walks for increasing local trade and commerce, and maintaining the original urban structures so that historic cities can retain their cultural value and sustainable use among communities. Yodsurang (2023) studied the relationships among archaeological sites, water management, and ways of life. The findings indicated that the transformation of transportation systems from water to land resulted in deteriorated canal networks, lower adaptation to floods, and the isolation of archaeological sites from nature, and thus, folk wisdom regarding how to live with water should be re-applied. Thanvisitthpon (2016) examined the effects of tourism development policy and found that economic benefits for local inhabitants were not inclusive on account of government policies and there was a lack of community participation. In addition, one-day trips hindered the full growth efficiency of accommodation businesses and employment. For this reason, what should be promoted further are community participation, suitable infrastructural development, and more opportunities for local inhabitants to gain equal benefits from tourism. Daunghima and Kazunori (2013) explored the effects of floods on archaeological sites, and found that high-value archaeological sites located in high-risk areas should be protected first. Current administration and management still rely on government agencies, with a lack of local community participation. Thus, local participation should be strengthened by promoting knowledge, awareness, and cooperation in archaeological site protection and restoration. Kittipongvises et al. (2020) studied the assessment of flood risk in communities around Phra Nakhon Si Ayutthaya City Municipality, the World Heritage Site, and found that over half of the communities and the World Heritage zone were high-risk sites, particularly around the Pratu Chai District. The factors with the highest risk were water runoff volumes and road density, reflecting the effects of urban expansion. Thus, there should be risk mapping and unambiguous evacuation plans, in addition to more efficient communication with the local people.

Despite the significant amount of previous research on historic site conservation in Phra Nakhon Si Ayutthaya City Municipality, few of them have reflected the obvious local risks of urban development on historic sites. Thus, this research aims to fill this gap through the integration of the Historic Urban Landscape (HUL), People–Nature–

Culture (PNC), and Cultural Landscape and Contemporary Urban Development (CL & CUD) approaches, as well as GIS. Undoubtedly, the results obtained could fulfil the objectives and answer the research questions “Which factors affected the vulnerability of historic sites most?” and “To what extent did all three concepts have similar and different effects on risk analysis toward historic site conservation?” This referred to the methodological development and providing of useful city plan suggestions for the World Heritage Site in planning the conservation and protection of these sites in accordance with local plans and laws, which will finally lead to the achievement of the sustainable development goal, i.e., SDG 11.3: Strengthen efforts to protect and safeguard the world’s cultural and natural heritage.

2. Literature Review

2.1 Historic Urban Landscape (HUL)

In the past, cultural heritage conservation emphasized archaeological sites (monument focused) only, but in 2011, UNESCO announced adoption of the Recommendation on the Historic Urban Landscape. Thus, cultural heritage refers to historic cities with dynamic systems (UNESCO, 2013), and Historic Urban Landscape itself is also connected to communities (Ripp et al., 2025).

Jingsen and Muyun (2021) explored historic site restoration based on Historic Urban Landscape (HUL) in Italy. The findings indicated that historic site restoration is a process with multidimensional connections with an assessment system that covers physical and intangible values while balancing between administration by the government sector and community participation for long term, sustainable conservation and urban development. Rey-Pérez and Roders (2020) suggested that HUL transformed conservation perspectives from focusing on archaeological sites and main buildings to the total perspectives of urban systems. The operational process contains six steps, i.e., data survey, community participation, vulnerability analysis, data integration, prioritization, and intersectional collaborations. Nonetheless, community participation, data integration, and collaborations are still relatively limited. Thus, promoting community roles for decision making and developing suitable tools for the context of each area are necessary to put HUL into practice.

The Historic City of Ayutthaya contains prominent physical features with a canal system and archaeological sites spread out amidst contemporary urban communities (Rong, 2025). Thus, the landscape features that belong to a historic city should connect to geomorphology

and hydrology, with a blue network or canal system as the essence of the landscape (Huybrechts, 2018). This means that an appropriate historic city must maintain the relationship between its urban structure and water sources (Ripp et al., 2025), i.e., preserving the landscape with combined archaeological sites and contemporary architecture (UNESCO, 2013), new building design with original contexts and promoting and retaining space as well as green space networks (Huybrechts, 2018). Thus, the current landscape in the Historic City of Ayutthaya should not be simply regarded as the fence around archaeological sites but a living urban ecosystem (UNESCO, 2013).

2.2 Cultural Landscape

The concept of Cultural Landscape alters the perspective toward the world heritage from being just “monuments or places” to the holistic dimension arising from interactions between humans and the natural environment (Taylor, 2018). Studies on cultural landscape have also been integrated with “scenario theory.” “Scenarios” refer to areas, physical structures, people/individuals, activities, and values. They are a key mediators in the transfer of cultural meanings (Mao et al., 2023). Thus, this concept describes that heritage is not a stationary object but the outcome of dynamic interactions between humans and the environment. True understanding of the changes and complications of cultural landscape must therefore go beyond architectural forms and shapes to an understanding of the values and ways of life that generate a landscape (Gong et al., 2022; Taylor, 2018).

2.3 People-Nature-Culture Approaches

People, nature, and culture are related to one another. Thus, historic site management requires an integration process between nature and culture for a balance between ecosystems and historical value (Rössler & Lin, 2018). For example, communities in the past could adapt to the challenges of nature, particularly water resources, e.g., water delivery through Roman aqueducts for supporting sanitation and agricultural systems (Nováková, 2024); pilgrimage to sacred lakes; or the use of water resources in religious rituals (Wood et al., 2024). People–Nature–Culture approaches point out that cultural heritage conservation is not only the protection of bricks or cement but the maintenance of the relationship between humans and the environment. Communities in the past proved their intelligent adaption by living with water resources under balance. In a world with climate variability, understanding the cultural landscape as a

living system and the perceived unity between cultural heritage and nature are the keys to future sustainable development and resilient society.

2.4 Risk Factors

Historic sites are facing both external and internal threats, causing destruction of their identities. External factors that pose threats to historic sites are divided into three characteristics. The first one is physical change, e.g., moisture and flood related damage (Nguyen, D.-M.T. et al., 2024). The next one is urbanization, e.g., building and construction encroachment, visual obstruction from high rise buildings (Nguyen, D.-M.T. et al., 2024; Sukhwai & Srinurak, 2024). The last characteristic is related to biological change, e.g., overgrown and unmanaged vegetation (Blavier et al., 2023; Coombes & Viles, 2021). Internal factors are usually related to the structural characteristics of buildings and construction (D'Ayala et al., 2020; Ravan et al., 2023; Salazar et al., 2024; Yang et al., 2023).

In this regard, climate change can cause damage to the cultural landscape. The potential factors include (1) the changing of original occupations and migration; (2) deteriorated historical buildings due to pollution and natural disasters; (3) drought, floods, and sandstorms; (4) loss of local plants and ecological wisdom; and (5) lack of integrated policies as well as community participation (Aktürk & Dastgerdi, 2021; Moussavi & Lak, 2024). There are a great number of research studies that have been conducted on the analysis of risks to historic sites. For example, Nicu (2016) relied on the analytic hierarchy process (AHP) and geographic information systems (GIS) to collect data on natural factors, e.g., water networks etc., and human related factors, e.g., road networks etc., along with analyzing and mapping cultural World Heritage Sites of which the vulnerable parts were divided into low, moderate, high or very high. Wei et al. (2024) used remote sensing (RS) technology and GIS to collect variables in the harm dimension, e.g., earthquake, landslides, etc., and the vulnerability dimension, e.g., land use, proximity, road density, etc. For analyzing and mapping the risks of natural disasters affecting cultural heritage. Ravan et al. (2023) applied the Cultural Heritage Vulnerability Index (CHVI) and prioritization to collect variables in the vulnerability dimension, e.g., structures, materials, etc.; handling abilities and adaptability, e.g., risk mitigation plans, financial resources, etc.; and analyzing and mapping vulnerabilities classified by disaster types. Allam et al. (2025) used GIS and AHP to collect variables in terms of flood related factors, e.g., rainfalls, altitudes, etc.; and landslide-related factors, e.g., slope levels, geological

features, etc.; in order to analyze and map vulnerabilities to floods and landslides.

2.5 Classification of Historical Sites

Historic sites are classified according to UNESCO as follows (Cosovic et al., 2019). (1) Classification by physical appearances, i.e., tangible cultural heritage, physical inventions (Renewal, Innovation and Change: Heritage and European Society [RICHES], 2014) with historical value (Munjeri, 2004); both movable, e.g., paintings and sculptures, and non-movable such as monuments, archaeological sites, and historical buildings, whereas intangible cultural heritage signifies knowledge, skills, objects, and community cultural areas (UNESCO, 2024). (2) Classification by sources under the Convention Concerning the Protection of the World Cultural and Natural Heritage, in which the key component refers to sites of world cultural heritage, classified into three categories, i.e., memorials, building groups, and archaeological sites (Office of Natural Resources and Environmental Policy and Planning, 2018). (3) Classification based on distinctive characteristics for assessment, classified into cultural landscapes, historic cities, canal heritage, and route heritage (Office of Natural Resources and Environmental Policy and Planning, 2018).

Classification by agencies in charge of administering historic sites in Thailand are as follows. (1) The Fine Arts Department: It is directly in charge of cultural heritage protection (The Fine Arts Department, 1985). All archaeological sites with historical structures (Saldin et al., 2025) are registered on the list of national archaeological sites, including maintenance approaches for local cultural heritage (Musigakama, 2019). (2) The Office of Natural Resources and Environmental Policy and Planning: This agency acts as a central coordinator of the Convention Concerning the Protection of the World Cultural and Natural Heritage as well as environmental and art work management (Saldin et al., 2025). This refers to man-made features with historical, archaeological, and technological value (Office of Natural Resources and Environmental Policy and Planning, n.d.). They are classified into seven categories focusing on spatial management planning (Office of Natural Resources and Environmental Policy and Planning, 2019), i.e., (1) monuments, memorials, and city pillar shrines; (2) temples, abandoned temples, and religious places; (3) museums, architecture, and palaces; (4) archaeological and antiquities sites, and ancient kilns; (5) ancient communities, ancient cities/towns, and historical parks; (6) old towns and historic cities/towns; (7) and old communities.

2.6 Conservation of Historical Sites

Historic cities such as Phra Nakhon Si Ayutthaya City Municipality are confronting the pressures of urbanization and climate change (Rong, 2025). Thus, efficient spatial conservation of historic sites should demonstrate the following characteristics: (1) Preventive conservation: The purpose is to reduce loss in the future (Lucchi, 2017), e.g., control and strict law enforcement of surrounding land use, etc., (2) Immunity-oriented conservation (D'Ayala et al., 2020): To seriously deal with upcoming threats, e.g., buffer zone arrangement, etc., (3) Integrative conservation: It emphasizes coordination and efficient operations, budget allocation, promoting cooperation between agencies and local communities (Coombes & Viles, 2021), and integrating conservation plans into land use planning and the National Economic and Social Development Plan (Nguyen, K.N. et al., 2024) and (4) proactive conservation: For aligning conservation with the contemporary ways of life and urbanization, e.g., modifying old buildings into creative spaces or accommodations (Ripp et al., 2025), and promoting qualitative tourism rather than quantitative mass tourism (Rong, 2025). Furthermore, using a geographic information system (GIS) to set the databases of historic sites (Nguyen, D.-M.T. et al., 2024), spatial risk analysis (risk mapping) by data conversion and threat-related weight analysis (Vojinovic et al., 2016), and buffer zone analysis will bring the best benefits for historic site conservation.

World Heritage Sites currently face pressure from globalization and climate change, balance among economic development, cultural value conservation, and promotion of resilience related to climate change. These are the key factors for sustainable urban development. Fumagalli (2019) and Jhong et al. (2020) studied the risks of flooding in the Kyoto World Heritage Sites, and found that lower flood risk in those sites required physical as well as social consideration along with spatial planning. Also, multiple and suitable adaptation measures must be chosen for each specific area. Surprisingly, Nguyen, D.-M.T, et al. (2024) investigated how to deal with floods in Hoi An Ancient Town World Heritage Site, and found that communities there viewed floods as part of their way of life rather than a disaster. Thus, they handled floods by showing adversity acceptance and resilience to live with nature rather than approaches of control or avoidance. They designed suitable housing for floods, avoided large preventive structures, and prepared for, handled, and focused on post-flood restoration.

Due to the historic sites in Phra Nakhon Si Ayutthaya City Municipality being announced as World Heritage sites, Phra Nakhon Si Ayutthaya City Municipality is under a number of laws, e.g., Ministerial Regulations regarding Phra Nakhon Si Ayutthaya Comprehensive Town Plan Enforcement B.E. 2560 (2017), Regulations of the Fine Arts Department on the Rules and Procedures for Requesting Permission to Construct Buildings in archaeological sites, Phra Nakhon Si Ayutthaya, B.E. 2566 (2023), etc. (The Government Gazette, 1979; The Government Gazette, 1992; The Government Gazette, 2017; The Fine Arts Department, 1985; The Fine Arts Department, 2023). These laws affect the spatial management of the internal and external historic sites, to be clarified as follows. (1) Repair, modification, alteration, demolition, add-on, destruction, removal, or excavation of an archaeological site must be permitted by the Fine Arts Department. (2) Color spray or marking on a wall, a building, a tree, or certain parts of a roadside or public building is prohibited, except when it is done by a government agency. (3) The owners of a building located within 20 meters of a roadside with a surface not less than 8 meters wide must keep the building clean and well-managed. (4) A hotel, a condominium, or a dormitory on the banks of the Chao Phraya River, Pa Sak River, or Lop Buri River must keep a distance alongside the bank not less than 25 meters (5) The banks of the Chao Phraya River, Pa Sak River, Lop Buri River, and Noi River must keep space alongside not less than 12 meters and within the distance between 12 to 50 meters from the riverbank for residences not over 2 stories. (6) A building requested for construction must be not less than 10 meters from another building or the remains of an archaeological site. (7) A gable roof or hip roof is required for a building, with a wall color consistent with the archaeological site. In addition, the conservation of historic sites should also give precedence to legislation on heights and skylines in areas nearby that also contain historical value. There should be no buildings higher than the primary ones within the territory of this world heritage city because they will distort the skyline landscapes, as summarized in [Table 1](#), while [Figure 1](#) illustrates the conceptual frameworks.

Table 1. Comparison of the key concepts of the Approaches

Issue	Historic Urban Landscape	Cultural Landscape	People–Nature–Culture
Beginning and objectives	Urban conservation and restoration connecting to multidimensional values, with physical and intangible value assessment, balance between administration by the government sector and community participation, giving precedence to geographical environments, particularly rivers canals	Consideration of historic sites or the World Heritage Sites as non-stationary but a resource or part of ecosystems under ongoing changes.	Historic site management based on mutual development between humans and nature in the contexts of ecosystems and community ways of life.
Analysis level	The entire urban system.	Areas, physical structures, individuals, activities, values, and ways of life.	Local communities-old towns-and historic cities, and temples that reflect the relationship between humans and nature.
Outcomes	Systematic historical city, with liveliness, ongoing changes, and HUL connected to communities.	Understanding the mechanisms of changes and complications of CL.	Adaptability to natural conditions.

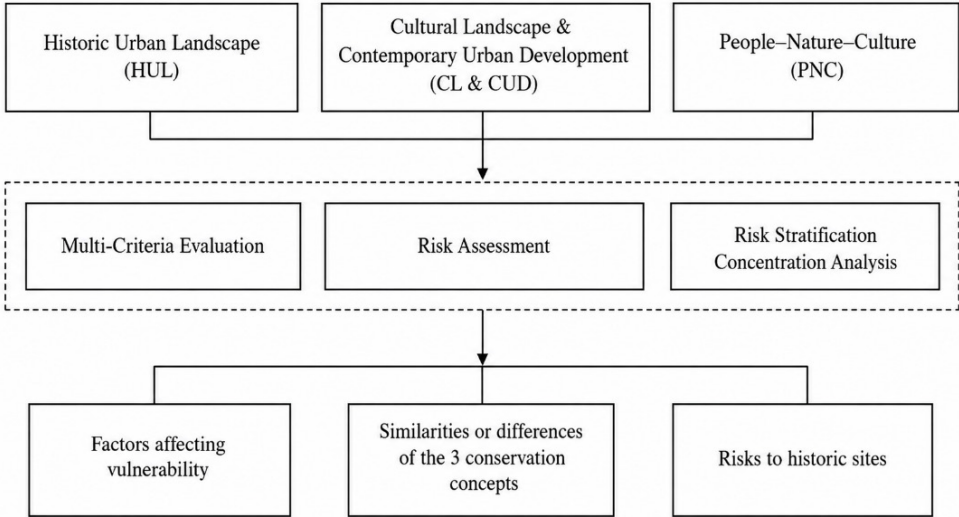


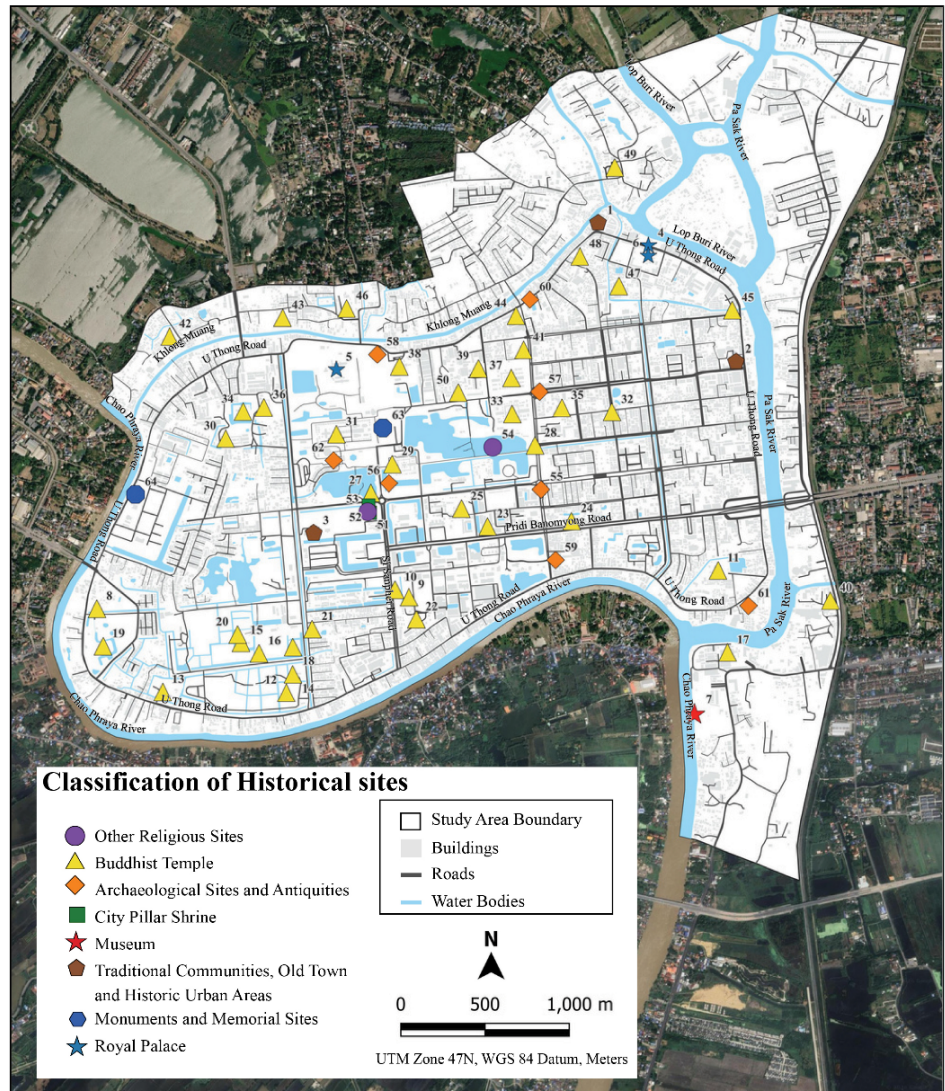
Figure 1. Conceptual Frameworks.

3. Methodology

3.1 Participants and Data Collection

The historic sites in this article included major archaeological sites (The Fine Arts Department, 2022) in the province and the list of art and cultural heritage based on the GIS of the Fine Arts Department (The Fine Arts Department, 2025). They were classified by registration with the Fine Arts Department; the Act on Ancient Monuments, Antiquities, Objects of Art, and National Museums B.E.

2504 (1961); the government gazettes; the criteria of the Fine Arts Department; and the Office of Natural Resources and Environmental Policy and Planning. There were eight categories, covering a total of 64 sites, i.e., (1) three local communities, old towns, and historic cities; (2) three palaces; (3) one museum; (4); 43 temples (5); two city pillar shrines; (6) two religious places; (7) eight archaeological and antiquities sites; and (8) two monument and memorial sites. The classification of historical sites is shown in Figure 2.



ID	Name	ID	Name	ID	Name
1	Hua Ro Market Community	23	Wat Pa Sak	45	Wat Rang (Kha Ngok Longnai Kai)
2	Chao Phrom Community	24	Wat Khun Mucang Chai	46	Wat Na Phra Meru
3	Ayutthaya Historical Park	25	Wat Saphan Nak	47	Wat Senasanaram Ratchaworawihan
4	Chantharakasem Palace	26	Wat Suan Luang Sob Sawan	48	Wat Khun Saen
5	Phra Ratchawang Boran	27	Wat Ket	49	Wat Sam Wihan
6	Dara Rasmi Mansion	28	Wat Pet	50	Wat Chum Saeng
7	Baan Hollanda	29	Wat Phra Ram	51	Phra Nakon Si Ayutthaya Old City Pillar Shrine
8	Wat Chang	30	Wat Lokayasutharam	52	Phra Nakon Si Ayutthaya City Pillar Shrine
9	Wat Singharam	31	Wat Phra Si Sanphet	53	San Phra Kan
10	Wat Borom Phuttharam	32	Wat Khok Muang	54	Thewasathan (Rang)
11	Wat Suwan Dara Ram Ratchaworawihan	33	Wat Mahathat	55	Chikun Bridge
12	Wat Chao Prab	34	Wat Worachetharam	56	Bueng Phra Ram
13	Wat Wang Chai	35	Wat Chaiyaphum	57	Pa Than Bridge
14	Wat Ubosot	36	Wat Worapho	58	Ancient Water Level Gauge
15	Wat Sangka Tha	37	Wat Ratchaburana	59	Pratu Chin Bridge
16	Wat Chediya	38	Wat Thammikarat	60	Pom Pratu Khao Plucak
17	Wat Phanan Choeng Worawihan	39	Wat Su Wan Ja Dec	61	Chong Kut Gate
18	Wat Chao Phram	40	Wat Prasat	62	Ancient Water Tank
19	Wat Maha Saman	41	Wat Phalaphla Chai	63	Statue of King Ramathibodec I
20	Wat Sangka Thac	42	Wat Sala Pun Worawihan	64	Phra Chedi Sri Suriyothai
21	Wat Som	43	Wat Choeng Tha		
22	Wat Suan Luang Khangkhao	44	Wat Suwannawat		

Figure 2. The classification of Historical sites.

Source: Google earth image modified by the authors (2026).

3.2 Data Analysis

Factor Setting and Assessment Prioritization

This article considered only the external risk factors or potential factors related to the existence and value of the historic sites. These factors were obtained from theoretical synthesis, the literature review, and field surveys under the three different concepts as follows.

1) Concept 1 - Historic Urban Landscape (HUL): This concept prioritizes the connections among communities, landforms, city views and contemporary urban community structures. The risk criteria were divided into three groups and 17 sub-variables.

2) Concept 2 - People–Nature–Culture (PNC): This concept underlines the integration between nature and culture, along with the balance between ecosystems and historical value. The risk criteria were divided into four groups and 15 sub-variables.

3) Concept 3 - Cultural Landscape and Contemporary Urban Development (CL & CUD): This concept concentrates on human and urban creation as well as the development process. The risk criteria were divided into five groups and 25 sub-variables. According to these three concepts, each conceptual framework was prioritized, with rank-order weighting for the variables. This technique directly clarified the significance of the variables in each framework using principle synthesis, academic concepts through theoretical interpretation, and specific context surveys by the researcher and the city planning team. Prioritization and weighing were considered based on the roles of the variables under each conceptual framework. Although the same variables might have different roles on a risk despite some common factors, different risks as well as significance caused differences in factor weights. Table 2 presents the prioritized factors of each concept. “Proximity to water sources” was ranked first and second in the concepts of HUL and PNC, which still emphasized the relationship

between historic sites and connection to communities. CL and CUD prioritized the risk of floods in urban development at present.

Table 2. Comparison of each prioritized concept

No.	Type	Criteria/Factor	HUL Priority	PNC Priority	CL & CUD Priority
1	Water sources	Proximity (meters)	1	2	8
2		Examples	2	3	9
3		Use (Adaptation to nature)	—	1	7
4	Floods	Undergoing floods	3	4	1
5		Water levels/marks (meters)	5	6	3
6		Frequency (months)	4	5	2
7	Surrounding buildings/land use, design, and roles	Closest proximity (meters)	18	10	18
8		Type of buildings nearby	17	9	19
9		Height of the nearest building (meters)	19	11	20
10		Number of floors of the nearest building (floors)	20	12	21
11		Characteristics of other buildings	11	—	17
12		Building design	9	7	10
13		Surrounding buildings/land use within 0–10 meters	12	—	12
14		Surrounding buildings/land use within 11–20 meters	13	—	13
15		Surrounding buildings/land use within 21–50 meters	14	—	14
16		Surrounding buildings/land use within 51–100 meters	15	—	15
17		Surrounding buildings/land use ≥ 101 meters	16	—	16
18		Surrounding buildings/land use that promote the economy	—	—	23
19		Reputation and the variety of activities	—	—	22
20		Key roles in communities	10	8	11
21	Roads (Closest proximity)	Proximity to main roads (meters)	6	13	4
22		Proximity to secondary roads (meters)	7	14	5
23		Proximity to tertiary roads (meters)	8	15	6
24	Surrounding environments	Cleanliness	—	—	24
25		Spray, scratches, marks, writing, or drawing on a wall.	—	—	25

Data Analysis Methods

1) **Database setting:** GIS was used for setting the database of historic sites, with the attribute data in each factor taken from the designed database and from the survey, based on the three separate concepts (Vojinovic et al., 2016) in order to analyze the risks to all 64 archaeological sites. Multi-Criteria Evaluation (MCE) was used. The procedures were completed as follows. (1) Criteria selection: The factors obtained by the survey and reviewed literature were determined. (2) Ranking: All of the three concepts were prioritized, based on the roles of factors under each particular framework, and their ranks were converted into weight. (3) Normalized weight: Weights were calculated by Malczewski (1999):

$$W_i = \frac{n - r_j + 1}{\sum (n - r_k + 1)}$$

(4) Threshold based standardization: All factors were converted into the same scale, divided into three risk levels, i.e., Low, moderate, and high (1–3, respectively). Due to different characteristics and measurement units of the variables, they could not be compared directly. The research team set this calculation based on the frameworks and each concept to reflect different risks. (5) Weighted scores were calculated. (6) Classification or Ranking: All scores from each concept were applied for dividing the risks into three levels, for interpretation, and for risk analysis. Table 3 presents comparison of the three prioritized concepts, value setting, thresholds, and risk level of each framework. Ten respective variables with significant comprehensiveness were exemplified. According to the compared main points, it was found that the groups of water sources, use, designs, and roles of surrounding land and buildings, and roads caused chronic exposure because they were related to settlement,

adaptation from the past, land use, building modification, urban structure and development around historic sites. Simultaneously, the variables in the groups of floods and environments caused acute risks. According to the weights calculated by the researcher and the research team, comparative assessment was convenient in accordance with the contexts and with the relationships of the risk analysis factors under the three different concepts. For example, the variable “Surrounding buildings and land use that promoted the economy” was applied for risk analysis as per CL & CUD only because it is a variable that reflected contemporary urban development, which conformed to the key issue of the concept. “Proximity to water sources” was applied for analyzing the risks of all concepts, but with different weights. This means that if it was HUL and PNC, despite their high priority, their proximities to water were different. To clarify, HUL generated low risk historic sites because water sources are indispensable for community ways of life and for access to historic sites. However, in CL & CUD, low proximity to water sources led to high risk historic sites because water sources can possibly result in overflow or flooding.

2) **Spatial analysis based on the three proposed concepts:** Risk levels were divided respectively (Nguyen D.-M.T. et al., 2024). Concentration of high-risk sites was also analyzed (Sukwai & Srinurak, 2024), along with analysis of historic sites that demonstrated high risk based on the weight scores of the factors and crosstab among the correlated factors. The results illustrate the risks of urban development on historic sites under the concepts of HUL, PNC, and CL & CUD. The key points from the studied issues can be used to set the measures and mechanisms to mitigate risks under the laws that protect archaeological sites and cultural heritage.

Table 3 Comparison of Rankings and Defined Thresholds for 10 Selected Significant Criteria

Variable	Conceptual Framework / Risk Levels (Low = 1, Moderate = 2, High = 3)			
	Historic Urban Landscape (HUL)	People–Nature–Culture (PNC)	Cultural Landscape and Contemporary Urban Development (CL & CUD)	Differences of Prioritization and Variables of Each Framework
1. Proximity to Water (meters)	Priority = 1	Priority = 2	Priority = 8	HUL and PNC prioritized this variable most. When viewed in close proximity, floods were at low risk, reflecting relationship between historical contexts and water landscapes. CL & CUD viewed areas close to water as at high risk and with a risk of disasters.
	1 = 0–300 m	1 = 701–1,500 m	1 = 701–1,500 m	
	2 = 301–700 m	2 = 301–700 m	2 = 301–700 m	
	3 = 701–1,500 m	3 = 0–300 m	3 = 0–300 m	
2. Examples of Water Sources	Priority = 2	Priority = 3	Priority = 9	HUL highly prioritized this variable through the connection of settlements in major cities surrounded by the river basins. As for PNC, ways of life close to water sources were adaptable. CL & CUD considered the risks and severity that can cause disasters.
	1 = Rivers	1 = Ponds	1 = Ponds	
	2 = Canals	2 = Canals	2 = Canals	
	3 = Ponds	3 = Rivers	3 = Rivers	
3. Use of Water Sources (Adaptation to nature)	No criteria	Priority = 1	Priority = 7	PNC prioritized this variable most, reflecting adaptability to nature and the use of available water sources.
		1 = ≥4 aspects	1 = ≥4 aspects	
		2 = 2–3 aspects	2 = 2–3 aspects	
		3 = ≤1 aspects	3 = ≤1 aspects	
4. Floods	Priority = 3	Priority = 4	Priority = 1	Thresholds were the same in all concepts, but CL & CUD prioritized this variable most because it is risky to activities and current development.
	1 = Unflooded	1 = Unflooded	1 = Unflooded	
	2 = Peripheral	2 = Peripheral	2 = Peripheral	
	3 = Flooded	3 = Flooded	3 = Flooded	
5. Flood Frequency (months)	Priority = 4	Priority = 5	Priority = 2	Thresholds were the same in all concept, but CL&CUD showed apparently higher prioritization due to likelihood of disasters to structures and urban development activities.
	1 = 6 months	1 = 6 months	1 = 6 months	
	2 = 8–9 months	2 = 8–9 months	2 = 8–9 months	
	3 = 10–11 months	3 = 10–11 months	3 = 10–11 months	
6. Proximity to Main Roads (meters)	Priority = 6	Priority = 13	Priority = 4	Thresholds were the same in all concept, but CL&CUD prioritized access/road networks connected to urban development.
	1 = >6 m	1 = >6 m	1 = >6 m	
	2 = 4–6 m	2 = 4–6 m	2 = 4–6 m	
	3 = 1–3 m	3 = 1–3 m	3 = 1–3 m	
7. Proximity to secondary roads (meters)	Priority = 7	Priority = 14	Priority = 5	Thresholds were consistent across all concepts, but PNC assigned lower priority, emphasizing water use and adaptation to nature, but CL&CUD focused on urban structures and activities
	1 = >6 m	1 = >6 m	1 = >6 m	
	2 = 4–6 m	2 = 4–6 m	2 = 4–6 m	
	3 = 1–3 m	3 = 1–3 m	3 = 1–3 m	
8. Proximity to tertiary roads (meters)	Priority = 8	Priority = 15	Priority = 6	Different priorities reflected different prioritization to tertiary roads and access to urban activities.
	1 = >6 m	1 = >6 m	1 = >6 m	
	2 = 4–6 m	2 = 4–6 m	2 = 4–6 m	
	3 = 1–3 m	3 = 1–3 m	3 = 1–3 m	

Table 3 Comparison of Rankings and Defined Thresholds for 10 Selected Significant Criteria (continued)

Variable	Conceptual Framework / Risk Levels (Low = 1, Moderate = 2, High = 3)			Differences of Prioritization and Variables of Each Framework
	Historic Urban Landscape (HUL)	People–Nature–Culture (PNC)	Cultural Landscape and Contemporary Urban Development (CL & CUD)	
9. Types of buildings nearby	Priority = 17	Priority = 9	Priority = 19	The same thresholds represented the meaning of building contexts that mirrored different activities and density, respectively; resulting in the different priorities of each concept.
	1 = Detached houses/religious places/archaeological sites etc.	1 = Detached houses/religious places/archaeological sites etc.	1 = Detached houses/religious places/archaeological sites, etc.	
	2=Public/commercial buildings, etc.	2=Public/commercial buildings, etc.	2 = Public/commercial buildings, etc.	
	3 = Common buildings/plants/large buildings, etc.	3 = Common buildings/plants/large buildings, etc.	3 = Common buildings/plants/large buildings, etc.	
10. Surrounding buildings / economy-supporting land uses	No criteria	No criteria	Priority = 23	The priority of CL&CUD reflected local identities and cultural heritage as the social and economic capital.
			1: Commercial uses / shops / markets 2: Government / institutional / educational uses / parking 3: Green spaces/temples/religious places/vacant lands	

Table 4. Risk levels of historic sites based on the separate concepts

Concept	Risk Level			
	Number of Sources	Low	Moderate	High
Historic Urban Landscape (HUL)	64	27 (42.2%)	26 (40.6%)	11 (17.2%)
People–Nature–Culture (PNC)	21	3 (14.3%)	9 (42.9%)	9 (42.9%)
Cultural Landscape and Contemporary Urban Development (CL & CUD)	64	22 (34.4%)	32 (50.0%)	10 (15.6%)

4. Results

Historic sites were classified into eight categories covering a total of 64 sites, with different characteristics based on their roles, historical significance, and interactions between urban structures and communities from the past up until today. All eight categories were assessed using the three concepts (Table 4).

1. Historic Urban Landscape (HUL):

This concept refers to risk assessment reflecting the relationship between natural and culture values, parallel to the significance of geographic features, particularly rivers and canals as the primary historical resources of Phra Nakhon Si Ayutthaya. These resources have affected the city structure and way of life from the past until now. Thus, assessment in this group was done on all eight categories with a total of 64 sites. The key factors were prioritized, i.e., water sources (unique identity; the closer, the better), proximity to roads, surrounding buildings/land use, and building designs (representing identity

coherence). For the significant roles of sites on communities, the total score ranged between 0.91–1.58. According to the assessment results, it was found that most historic sites were low- to moderate-risk. There were 11 high-risk historic sites, i.e., seven temples (63.6% of high-risk sites). There were also one city pillar shrine and three archaeological antiquities sites. The examples of high-risk sites were Wat Singharam, Wat Borom Phuttharam, Pa Than Bridge, Wat Pa Sak, and Wat Suan Luang Khangkhao. According to Figure 3, the high risk historic sites were different in terms of settlement and environment related locations and were mostly found in the central area. Some temples were located in areas with road networks, with a high density of buildings and construction,

and environments near water sources but not totally comprehensive. Thus, the risks falling into this concept arose from a mutual relationship among water sources as the indispensable elements of historic landscapes, accessibility to roads, change in land use and buildings/constructions.

2. People–Nature–Culture (PNC):

The criteria reflected adaptation of communities to live with water sources, a current primary resource. The risk criteria in this group focuses on development between humans and nature in the contexts of ecosystems and ways of life (Rössler & Lin, 2018). Thus, assessment was separated for the specific context of historic sites in which there was interaction with humans and the environment/nature. Thus, only two categories of sources were

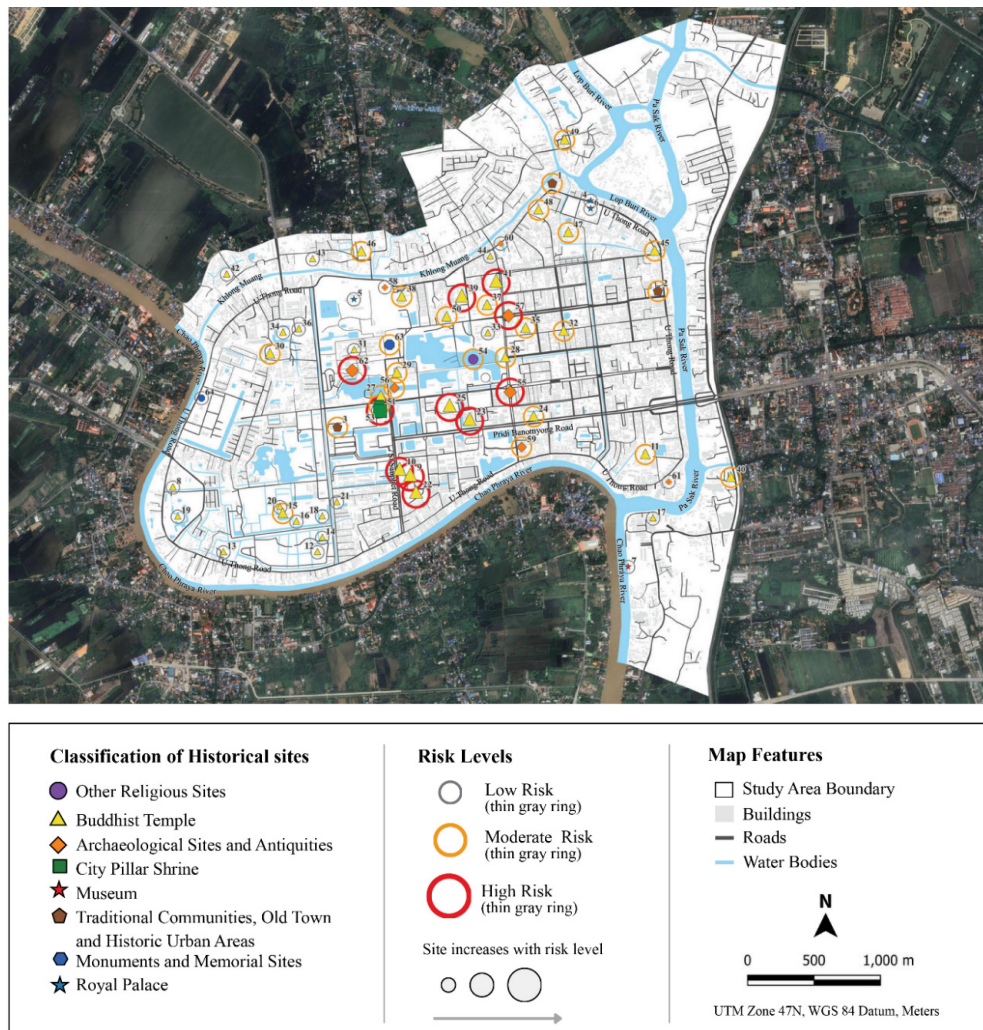


Figure 3. Risk levels in historic sites based on the concept of HUL
Source: Google earth image modified by the authors (2026).

assessed, i.e., “Local communities-old towns-and historic cities” and “Temples” (surrounded by communities) as the center of the beliefs and culture of communities (Wang et al., 2023) with a total of 21 sites. The factors were prioritized, i.e., water sources (Use and adaptation to nature), floods (Frequency and water levels), surrounding buildings/land use, and building designs (Indicating local identity and adaptation), significant roles on communities, and proximity to roads. The total scores ranged between 1.42–2.41. According to the assessment, there were nine high risk historic sites and nine moderate risk historic sites (totally 85.8%). There were three low risk historic sites. The high risk historic sites were different from HUL; namely, there was co-existence of

historical communities and temples, i.e., Hua Ro Market Community Chao Phrom Community Wat Khun Mueang Chai, Wat Prasat, and Wat Som. Thus, it was possible that communities with the use of riverbank resources could retain their ongoing livelihood and socioeconomic activities, with accessible transportation and riverbank relationships under natural risks. As seen in Figure 4, high risk historic sites are spread all throughout communities and water sources (rivers and canals) rather than around historic sites or archaeological sites. Thus, these high risk sites under this concept were more closely related to water resources than accessibility to roads, with prominence in community adaptation and living with water sources, water sources, and floods.

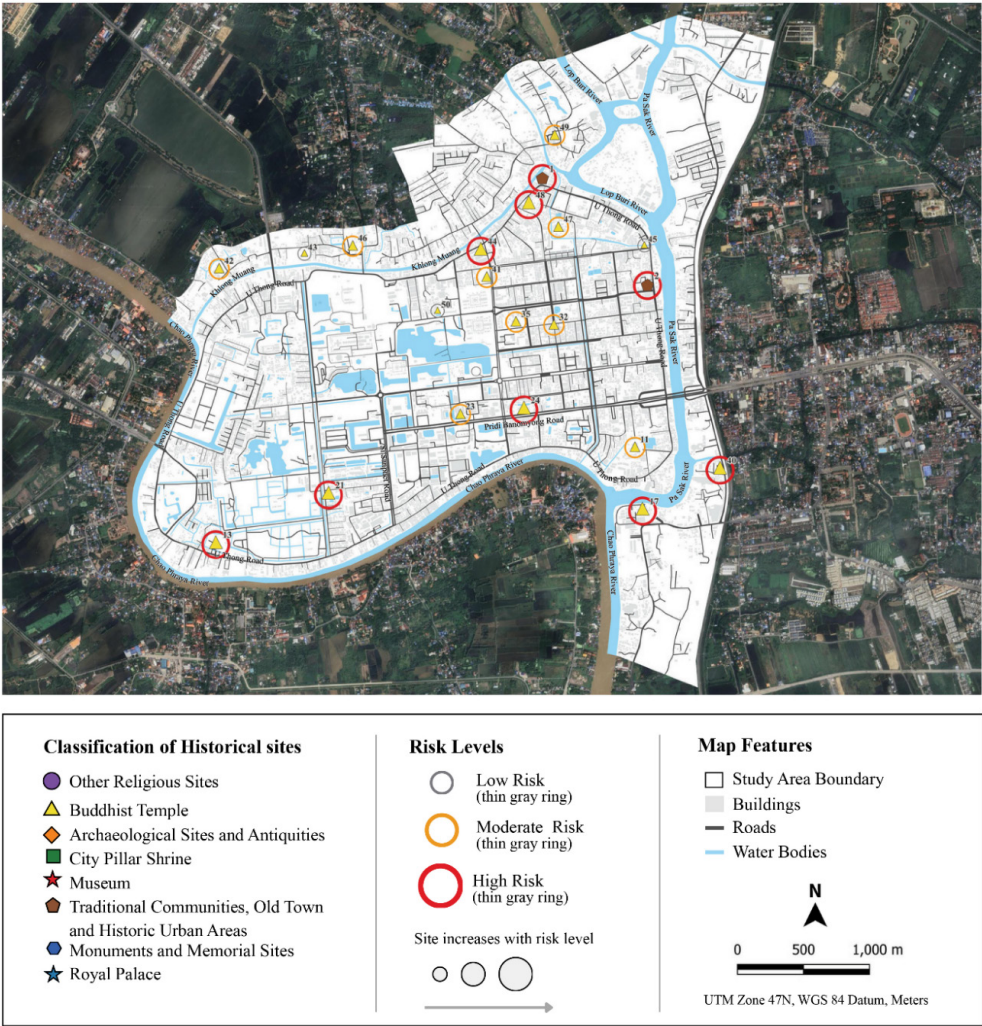


Figure 4. Risk levels in historic sites based on the concept of PNC
Source: Google earth image modified by the authors (2026).

3. Cultural Landscape and Contemporary Urban Development (CL & CUD): These criteria view historic sites as a resource in ecosystems under changes over time. For this reason, today's urban development must protect historic sites as a fundamental structure of the city parallel to urban development planning. Thus, evaluation in this group included all eight categories, with a total of 64 sites, with prioritization, i.e., floods (Frequency and water levels), proximity to roads, water sources (way of life and water use), building designs (local identity and adaptation), significant roles in communities (registration of archaeological sites, in particular), and surrounding buildings/

land use. The total scores ranged between 1.47–2.30. According to the assessment, there were 10 high-risk historic sites, i.e., two local communities-old towns-and historic cities, one palace, five temples, and two archaeological and antiquities sites. Moderate-risk historic sites were found most (50.0%). There were various types of high risk historic sites, i.e., communities, temples, palaces, and archaeological-antiquities sites. However, according to the spatial consideration in Table 3, moderate risk historic sites were found mostly spread throughout the central and northern areas along road networks and near buildings and construction. As shown in Figure 5, high

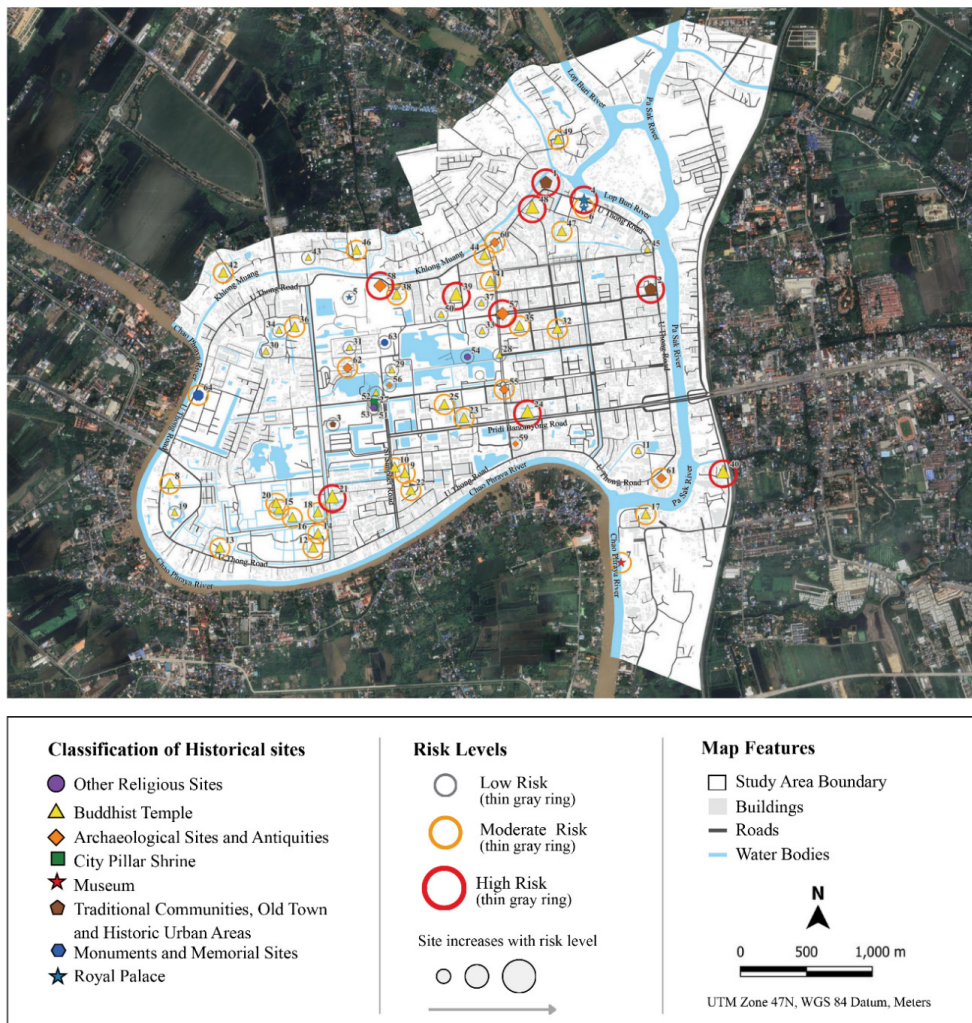


Figure 5. Risk levels in historic sites based on the concepts of CL & CUD
Source: Google earth image modified by the authors (2026).

risk historic sites, e.g., Hua Ro Market Community, Chao Phrom Community, Wat Khun Saen, and Chantharakasem Palace, were found in areas with road networks and sites with activities resulting from land use; parallel to building density and proximity to water sources, reflecting the co-existence under the urban development activities and environmental risks.

According to the comparative analysis of risk levels among historic sites in all three concepts, the following conclusions can be drawn.

1.Types of sources and risk levels: The high-risk sites included temples and communities. Temples spread throughout the central part according to HUL were related to access of road networks, construction density, and water sources as historic landscapes. The high-risk sites according to PNC and CL & CUD included Hua Ro Market Community and Chao Phrom Community because of their residential locations with economic, social, and transportation activities, which resulted in development risks.

2. Location and concentration of sites at risk: Based on HUL, most locations of sites at risk were related to historic landscapes in the central part of areas with access of road networks, water sources, and archaeological sites. In PNC, they were spread across temples, riverbank communities, and the central areas. This revealed the relationship based on the concept between water systems and community adaptation. In CL & CUD, they were spread over the central and northern parts, with multidimensional factors, i.e., flood risk, road accessibility, and land use with building density due to the urban development process.

It can thus be seen that the risk of valuable areas contained multiple factors and were based on each concept. Apparently, Hua Ro Market Community and Chao Phrom Community were at high risk, based on both PNC and CL & CUD. Wat Phanan Choeng Worawihan close to the Pa Sak River and high-risk communities all around were based on PNC because they must use water sources and adapt to flood risks and vulnerability from development, but with low risk according to HUL due to the factors related to the proximity of rivers with historic landscape value.

5. Discussion

According to the risk assessments based on the concepts, it was reflected that the risks of valuable sites arose from the relationship of historic sites' prominent physical features with water-based settlements. The roles of water sources were crucial for community ways of life

and accessibility, adaptation to nature, and contemporary urban development. The different frameworks resulted in a variety of risk levels among the valuable sites in the same areas due to different weights and significance. These reflected issues can be summarized as follows.

1. Risk levels and the spatial vulnerability of historic sites that should be protected: It was found that temples and communities should be protected as the first priority due to their moderate–highest risk levels. According to the spatial contexts, it was found that the center of the municipality at present has changed and developed further, so that it is currently surrounded by dense urban structures with access to road networks, building density, local activities, and land use changes. These all bring about risks of the surrounding elements on the temples. Also, their locations are close to riverbanks, canals, and surrounding communities and thus, the same risks have remained until now on account of the physical features and risk levels. Pertaining to the major communities, they were Hua Ro Market Community and Chao Phrom Community as the high-risk sites under PNC and CL & CUD. Water sources were a risk in terms of moisture and flow velocity, while proximity to roads, residing in communities, surrounding buildings/land use, e.g., markets generate intensive urban activities and increase the concentration of surrounding land uses. Building height reflects greater population and development density, while high-rise buildings may adversely affect the visual integrity of historic sites, obstruct important views, and reduce airflow and spatial openness. These development pressures increase heritage vulnerability, particularly in the northern and central parts of the municipality.

2. The relationship of the conceptual frameworks and urban development planning: According to the results, historic sites in the same areas had various risk levels under the assessment of different frameworks. Proximity to water sources was an obvious indicator. For example, Wat Phanan Choeng Worawihan close to Pa Sak River had low risk under HUL, but had high risk and moderate risk under PNC and CL & CUD, respectively. In terms of planning, historic sites assessed as high risk under more than one of the concepts were compared to overlapped risks echoing the vulnerability of those sites, e.g., Hua Ro Market Community and Chao Phrom Community. Thus, risk assessment based on several concepts could reflect vulnerability levels more efficiently, facilitating risk management prioritization based on consideration of the chance of risk under each concept, which was connected to urban development plans. Conservation planning should be based on heritage

resilience, enabling historic sites to adapt to change while retaining their significant heritage values. At the same time, surrounding areas should accommodate ongoing urban development, with the scale and pattern of change appropriately managed according to the levels of risk and vulnerability of historic sites.

3. Mechanisms for Implementing Urban Planning Measures to protect historic sites: According to the assessment results, urban planning measures can be adopted as mechanisms to protect historic sites and surrounding areas, including land use management, building use, roads and accessibility, water resources, and activity density control. The approaches can be summarized as follows. 1) Assessed sites and surrounding contexts were at high risk due to overlapped frameworks; thus, a “Heritage Overlay Zone” should be established to control the density of activities. 2) Valuable historic communities with traditional ways of life can rely on integrated conservation and adaptive reuse to adjust or modify functions without destroying their original cultures. 3) Affected historic sites, e.g., Palaces, temples, and other sites, should be protected through the building of a buffer zone. 4) Preventive conservation and resilience measures for the protection of temples and other archaeological sites, particularly areas at risk from water sources and floods, should be trialed. Technological use should also be promoted for risk database management, parallel to flood monitoring systems, as per the details of measure application in the suggestions section

However, the application of urban planning measures in relation to risk levels should be supported by participatory mechanisms and incentive measures involving all relevant sectors. For effective implementation, these measures should be incorporated into land use regulations under the comprehensive plan and local ordinances, under the supervision of the Provincial Office of Public Works and Town & Country Planning, and Phra Nakhon Si Ayutthaya City Municipality. Meanwhile, valuable site conservation and protection should be under the supervision of the Fine Arts Department. The implementation sequence is divided into three phases. In the short term phase, the databases of areas at risk must be quickly created based on assessment of the combined three conceptual frameworks, leading to the preparation of risk priority maps. In the medium term phase, there should be policy planning to set the measures of suitable application following the risk levels and risk factors of historic sites. Finally, in the long term phase, a participatory system involving all relevant sectors should be established to support the sustainable conservation of historic sites.

6. Conclusions and Suggestions

6.1 Conclusions

According to the risk assessment divided into three concepts, the specific characteristics could be considered based on the following different criteria.

1. Assessment based on Historic Urban Landscape (HUL). Phra Nakhon Si Ayutthaya is a city with the prominent physical features of a canal system and archaeological sites widely distributed amidst contemporary urban structures. Risk assessment with various factors emphasizes the significance of the original natural environment and urban structure related to water sources that reflect the previous ways of life among communities around historic sites.

1.1 Categories and risk levels: eight categories of historic sites were assessed, covering 64 sites. The table of the compared categories and risk factors revealed that the category of “temples” had the highest number of risks but at a moderate level. Risk levels were divided as follows. (1) 11 high risk historic sites included seven temples, one city pillar shrine, and three archaeological antiquities sites. (2) Twenty six moderate risk historic sites included three local communities old towns historic cities, 18 temples, one city pillar shrine, one religious place, two archaeological antiquities sites, and one monument/memorial. (3) Twenty seven low risk historic sites included three palaces, one museum, 18 temples, one religious place, three archaeological antiquities sites, and one monument.

1.2 For the significant risk factors impacting historic sites involving water sources, being located far from these sources affected the use of these water resources. In terms of use, it was related with building designs, roles of surrounding buildings and lands influenced by contemporary urban structures. Moreover, in terms of roads, it was related to proximity to roads.

2. Assessment based on People–Nature–Culture approaches (PNC).

The relationships between humans and the environment were basically considered based on the use of water sources, mirroring human adaptation to original nature.

2.1 Categories and risk levels: Historic sites to be assessed included only communities and temples, with a total of 21 sites. According to the table of the compared historic site categories and risk factors, it was found that the category of “local communities’ old towns and historic cities” had the highest number of risks but at moderate-low levels. Despite “temples” being the highest risk category, they were still a few in number. Nevertheless,

risk levels could be divided as follows. (1) There were nine high risk historic sites, i.e., Seven temples and two local communities' old towns and historic cities. (2) There were nine moderate risk historic sites, i.e., Nine temples. Further, (3) there were three low risk historic sites, i.e., three temples.

2.2 The risk factors of historic sites were related to water sources, i.e., proximity to rivers, floods (water levels and frequency), the use of water sources that were no longer mainly for agriculture and transportation, and building designs that did not represent their original identities.

3. Assessment based on the concept of Cultural Landscape and Contemporary Urban Development (CL & CUD): Community culture must be related to the ways of life. Thus, urban development planning must be concerned about the relationships of historical value in communities; ways of life; current changes in the physical, economic, and social dimensions; adaptation, connections between history and peripheral economic zones; and community participation.

3.1 Categories and risk levels: eight categories of historic sites were assessed, including 64 sites. As seen in the table of the compared historic site categories and risk levels, it was found that the category of "temples" had the highest number of risks but at a moderate level. According to the results, the risk levels were divided as follows: (1) 10 high risk historic sites, i.e., two local communities old towns and historic cities, one palace, five temples, and two archaeological and antiquities sites; (2) 32 moderate risk historic sites, i.e., one palace, one museum, 25 temples, four archaeological and antiquities sites, and one monument/memorial; and (3) 22 low risk historic sites, i.e., one local community old town and historic city, one palace, 13 temples, two city pillar shrines, two religious places, two archaeological and antiquities sites, and one museum.

3.2 The key risk factors impacting historic sites included proximity to water sources and roads, surrounding buildings and land use, communities, and building heights.

6.2 Suggestions

Regarding the benefits for planning management, conservation, and protection of historic sites, four considerable guidelines are presented, i.e., preventive conservation, immunity oriented conservation, integrated conservation, and proactive conservation (Lucchi, 2017; D'Ayala et al., 2020; Ripp et al., 2025). These should be applied to the involved urban planning measures under conformity to the local plans as well as laws, as described below.

1. Historic Urban Landscape (HUL): The category of "temples" had the highest number of risks. The risk factors included water sources, building designs, roles of surrounding buildings/lands, and proximity to roads. The feasible conservation measures are suggested as follows. (1) Preventive conservation measures: To prevent alteration of water source roles and use, with prioritized original ways of life. Thus, what should be done are suggested as follows. 1) Set special controlled zones and limit the proximity of activities that can undermine water sources and increase risks, apart from the Regulations of the Fine Arts Department on Rules and Procedures on Requesting Permission to Build Buildings in Archaeological Sites, Phra Nakhon Si Ayutthaya, B.E. 2566 (2023), particularly vulnerable areas near the Pa Sak River. 2) Set an additional overlay zoning measure for specific areas under the enforced comprehensive plan and control in compliance with the Act on Ancient Monuments, Antiquities, Objects of Art, and National Museum B.E. 2504 (1961) in high to moderate risk sites, e.g., Pridi Banomyong Road and U-Thong Road. To control the density of various activities, there should be regulations to control proximity, heights, (Floor Area Ratio (FAR), and build-to-line because historic sites in the center of the municipality usually contain a large number of tourists and heavy land use, particularly the old city pillar shrine and provincial city pillar shrine that have not been protected by law yet because they have not been registered as archaeological sites by the Fine Arts Department. (2) A proactive conservation measure: Set an overlay zoning measure to regulate creative modification of building designs in line with ways of life and urban development, particularly in tourist sites and at the edge of the municipality, in order to minimize value destruction while promoting the local tourism economy.

2. People–Nature–Culture (PNC): The categories of "local communities' old towns and historic cities" and "temples" had the highest number of risks. The following measures should thus be taken into consideration. (1) Preventive conservation measures at riverbank high risk sites: To reduce flood risks, set an overlapping measure to control the proximity of activities (other than buildings and constructions), prevent subsidence and blocked waterways, set fixed heights, and set activities based on proximity. (2) Immunity oriented and integrated measures: These should be implemented with an incentive measure to create buffer zones and green spaces, particularly for temples surrounded by communities, e.g., Wat Sala Pun Wat Sam Wihan, which has a crucial role in the community. The measure should also emphasize community participation. For example, the municipality may allocate

a budget and integrate the local conservation plans. (3) A proactive conservation measure: To reduce flood risks. Inhabitants and local people and communities around temples at risk can modify building designs to generate immunity against floods by floor elevation, but this should be done harmoniously and not disregard their original environmental contexts.

3. Cultural Landscape and Contemporary Urban Development (CL & CUD): The category of “temples” had the highest number of risks, followed by “local communities’ old towns and historic cities.” The key risk factors included proximity to water sources, proximity to roads, and surrounding buildings and land use that increases the density of activities and people. The practical measures are as follows. (1) Preventive conservation measures: Set rules and regulations to control the types and scales of surrounding land use. Establish setbacks and water sources, particularly the sites with high vulnerability and risk levels based on assessment using the three concepts, i.e., Hua Ro Market Community, Chao Phrom Community, Wat Khun Saen, and F National Museum. Other sites near main and secondary roads, e.g., U-Thong Road and Pridi Banomyong Road, must be provided with space, green spaces, or horizontal buffer zones between rivers and sites of not less than 12 meters. There should also be regulations on how to use the surrounding lands, which are mostly still available, with commerce and markets. In those areas, excessive activities and people should not be allowed, and activities must be in accordance with the current land use. (2) Preventive conservation measures: Because sites at risk are spread throughout communities and located along riverbanks and canals on U-Thong Road, there should be cooperation with local communities to determine creative building designs that meet the culture and original context for attraction of tourists in order to protect the community and to prevent inappropriate use of buildings while promoting the economy and tourism around the municipality. For the long term plan for archaeological site protection, technology should be utilized for setting future databases of historic sites at risk, leading to benefits for sustainable historic site conservation.

However, this study has several methodological limitations, i.e., weight valuation based on the discretion of the researcher or a small number of experts; setting external risk assessment factors, rather than the internal ones, e.g., construction materials, building structures, etc.; cross-sectional analysis or contemporary situations; lack of model validation using comparison with actual damage or consideration of stakeholders; and the possibility that the three overlapping concepts might produce similar

results. For these reasons, the results can only be applied to meet the objectives within the conceptual frameworks.

Suggestions for Future Research, future studies incorporate additional internal and external risk factors, assess temporal changes, apply alternative weighting methods, and extend the methodology to other World Heritage Sites.

Conflict of Interest

Authors declare that there is no conflict of interest.

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CRediT Authorship Contribution Statement

Waralak Khongouan: Conceptualization; methodology/study design; validation; formal analysis; investigation; data curation; writing – original draft; writing review and editing; visualization; supervision; project administration; funding acquisition; **Putpunnin Khamwachirapithak:** Conceptualization; methodology/study design; validation; formal analysis; investigation; data curation; writing – original draft; writing review and editing; visualization; supervision; project administration; funding acquisition.



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