

# Risk Assessment and Disaster Preparedness of Museums in Ombilin Coal Mining Heritage of Sawahlunto, Indonesia

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Tourism has become a key option for many former mining cities in the post-mining period. The tangible and intangible value of mining heritage has often been treated as museums. Before the transformation, former mining infrastructures were frequently in obsolete and decay conditions. A disaster management plan becomes an important task for the destination manager to guarantee the visitor's safety. This study aims to assess potential risk and disaster preparedness of six museums at the Ombilin Coal Mining Heritage of Sawahlunto (OCMHS), a new UNESCO World Heritage site in Indonesia. The study revealed that an earthquake is a significant risk in all study objects. Fire, flood, and intrusion of groundwater also become a potential risk for some museums, ranging from moderate to significant level.

**Keywords:** *post-mining city, mining heritage, risk assessment, disaster preparedness*

## 1. Introduction

Mining heritage tourism is continually acknowledged as an economic engine for many former mining sites, particularly in small-sized post-mining cities. Unlike major post-mining cities, these cities have faced budget limitations, low organizational capacity, and limited political attention<sup>1</sup>. The successful redevelopment of small post-mining towns depends primarily on the ability to earn funding from the national government<sup>2</sup>. Therefore, the use of both tangible and intangible forms of mining heritage properties is regarded as a potential new income generation. Mining heritage resources, such as old heritage buildings, defunct mining infrastructures, abandoned mining landscapes, mining traditions, and customs, are tourism resources that could make a post-mining city superior to competitors. Many post-mining sites are even listed in UNESCO World Heritage, the most effective international legal instrument for the protection of cultural and natural heritage<sup>3</sup>

Mining heritage resources are inherited from the mining industry. These resources are often abandoned when mines are closed and frequently utilized as museums in the post-mining period, for example, the Yubari coal mine museum in Hokkaido, Iwami Ginzan silver mine museum in Shimane and Tagawa coal mine museum in Fukuoka, Japan. These endowed resources are considered as core resources in the tourism industry, the primary motivation for destination appeal<sup>4</sup>. Traditionally, mining museums preserve, exhibit, and encourage the appreciation of the past. However, museums are evolving as educational facilities and offering a wide range of tangible or intangible services and experiences<sup>5</sup>. Interactions between visitors and museums are now part of the exhibition. In mining museums, experiencing miners' activity in cramped tunnels, riding steam locomotives, or preparing food in public kitchens are valuable experiences for the visitors.

Mining museums were not initially designed for visitation. The buildings or former mining sites needed revitalization, conservation, or restoration before being opened to the public. Visitors' safety must be a priority for destination managers. Additionally, reliable disaster preparedness and proper disaster response could mitigate the loss of cultural value caused by the disaster. The devastating earthquake in Kathmandu, Nepal, on 25<sup>th</sup> April 2015, or massive fire in Notre Dame cathedral in Paris, France, on 15<sup>th</sup> April 2019 have proven that disaster is a significant threat to cultural heritage properties. This study aims to assess potential risk and disaster preparedness of several museums in the delineation of the Ombilin Coal Mining Heritage Sawahlunto (OCMHS), a newly inscribed post-mining site on the UNESCO World Heritage list. In the case of disaster, mining-related museums are more vulnerable because of the old buildings' obsolete condition. Furthermore, as a new UNESCO WHS site, museums in OCMHS have not had a disaster management plan. Therefore, this study could be an initial stage for the sites in dealing with imminent disaster. In the forepart, a brief description of the sites is described to show how mining supporting facilities were converted as museums. The potential risk was measured in considering the geographical and hydrological conditions of the site. Meanwhile, disaster preparedness was examined from the availability of disaster prevention equipment and the management staff's capability to address disaster events.

## **2. Disaster risk management for museums**

Disaster risk management (DRM) has been on the international agenda since the United Nations (UN) held a world conference on Disaster Risk Reduction (DRR) in 1994. A growing number of catastrophic disasters have raised global awareness and the importance of providing disaster risk mitigation plans. In the following world conference in 2005, held in Kobe, the UN established the Hyogo Framework for Action (HFA) (2005-2015), where protection of world cultural heritage properties from disaster aroused global concern. In 2007, the UNESCO World Heritage Committee recommends the inclusion of risk preparedness in world heritage site management plans and training strategies. The integration of disaster risk reduction in heritage management was intended to safeguard outstanding universal values<sup>6)</sup>, prevent losses to heritage, and guarantee sustainable development and local economies<sup>7)</sup>. The UNESCO strategy to reduce the risk of disaster comprises five priorities, namely strengthening support within institutions, the use of knowledge and education, risk identification and assessment, reduction of underlying risk factors, and strengthened disaster preparedness of WH properties<sup>8)</sup>. The subsequent UN world conference in 2015 (The Sendai Framework for Disaster Risk Reduction, 2015-2030) highlights four priorities in reducing cultural heritage losses. Understanding the risk and enhancing disaster preparedness for effective response are acknowledged as top priorities<sup>9)</sup>.

Disasters are described as the combination of exposure to a hazard, conditions of vulnerability that are present, and insufficient capacity or measures to reduce or cope with potential negative consequences<sup>10)</sup>. Potential hazards that may lead to disaster may be natural, such as earthquakes, flash foods, or landslides, or human-induced hazards, such as fire or infrastructure failure. Some potential hazards are predictable so that vulnerable communities can prepare safety measures to minimize the adverse impact of the disasters, but others suddenly occur without an alert. In response to these potential hazards, there is a need to develop a systematic process to mitigate the adverse impacts of the hazards and the possibility of disaster, which globally recognize as disaster risk management (DRM)<sup>10)</sup>. The DRM includes circular actions taken before, during, and after the disaster, known as DRM cycle<sup>11)</sup>. Comprehensive disaster management is based upon four distinct components: mitigation, preparedness, response, and recovery<sup>12)</sup>. This study focuses on mitigation and preparedness stages which is conducted before a disaster happen. Mitigation effort is including assessment of potential hazards and the vulnerability of study area to disaster. Meanwhile, preparedness activity involves the compliance of disaster prevention equipment, the knowledge on what to do, and how to act effectively in disaster.

Museums play an essential role in the preservation of cultural value and education of society. International Council of Museum (ICOM) defines a museum as a non-profit, permanent institution in the service of society and its development, open to the public, which acquires, conserves, researches, communicates and exhibits the tangible and intangible heritage of humanity and its environment for the purposes of education, study and enjoyment<sup>13</sup>). Specifically, the function of a museum could be distinguished into asset-based and activity-related roles. The asset-based function is related to collecting, documenting, and preserving the collections. Meanwhile, activity function is associated with research, display, and interpretation of cultural objects<sup>14</sup>). In the context of mining-related museums, these functions could be translated into the preservation of mining heritage resources and education of the historical value of the mining industry.

Security and protection of cultural heritage property is still the most critical consideration in the administration of any museum<sup>15</sup>). Disaster in museums could result in significant loss, damage, or destruction of the collections if proper action is not taken immediately. Therefore, museum managers have to prepare an appropriate emergency plan and respond immediately to every dangerous situation. A comprehensive emergency plan begins with the assessment of potential hazards<sup>16</sup>). In museums, a wide range of disasters, including natural disasters, technological disasters, accidents, and human negligence, could generate emergency situations. The next stages are identifying assets, assessing vulnerabilities, measuring the preparedness and developing a response plan.

### 3. Methodology

This study analyses the risk assessment and disaster preparedness of six museums in Ombilin Coal Mining Heritage of Sawahlunto, namely *Goedang Ransoem*, *Mbah Soero*, the Railway Museum, Painting Museum, Music Museum, and Dance Museum. A brief description is presented to illustrate each museum's development, focusing on their initial conditions before the renovation project and current situation. Risk assessment is formulated as the probability or likelihood x its consequences<sup>12</sup>). There are two types of methods in conducting risk analysis; quantitative and qualitative methods. The quantitative approach uses mathematical or statistical data to achieve a numerical description of risk. Meanwhile, the qualitative approach uses defined terms or words to describe and categorize the hazard risk likelihood and consequence value outcomes. Due to the unavailability of specific data on disaster records, this study employed qualitative methodology. A 5x5 matrix was used to distinguish the risk level. The risk score was calculated by multiplying the likelihood of risk with the magnitude of consequences. The likelihood and consequences of potential risk criteria are presented as in Table 1 and 2 below.

Table 1. Likelihood/ probability of risk occurrence

Likelihood/ Probability	Rating of the occurrence
Rare (1)	Almost zero, may occur in exceptional circumstances
Unlikely (2)	Extremely rare, no recorded incidents
Possible (3)	Rare, might occur at some time
Likely (4)	Will probably occur in most circumstances, regular recorded incidents
Almost certain (5)	Very frequent, high level of recorded incidents

Table 2. Consequences of risk

Magnitude	Rating of the consequence on human life and property
Insignificant (1)	No injuries or fatalities, no damage on properties
Minor (2)	Small number of injuries, slight damage
Moderate (3)	Medical treatment needed, moderate damage
Major (4)	Significant hospitalization and fatalities, high damage
Catastrophic (5)	Large number of severe injuries and significant fatalities, severe damage in the collection

A risk assessment matrix was then designed with likelihood and consequences values projected onto the chart's x and y axes. The risk matrix and the categorization of risk are presented in Table 3.

Table 3. Risk assessment matrix

Likelihood	Consequences				
	Catastrophic (5)	Major (4)	Moderate (3)	Minor (2)	Insignificant (1)
Almost certain (5)	Very High (25)	High (20)	High (15)	Moderate (10)	Low (5)
Likely (4)	High (20)	High (16)	Moderate (12)	Moderate (8)	Low (4)
Possible (3)	High (15)	Moderate (12)	Moderate (9)	Low (6)	Low (3)
Unlikely (2)	Moderate (10)	Moderate (8)	Low (6)	Low (4)	Low (2)
Rare (1)	Low (5)	Low (4)	Low (3)	Low (2)	Very Low (1)

Risk category: Intolerable risks (25), Significant risks (15,16,20), Moderate risks (8,9,10,12), Tolerable risks (2,3,4,5,6), Insignificant risks (1)

The vulnerability of the museums to potential threats were measured by analyzing their disaster prevention equipment and disaster response practices. A set of observation checklists were used to collect data on disaster prevention and response tools. In addition, the questionnaires were distributed to measure management staff's basic understanding of disasters knowledge and their response practices in case of disaster. Ten questions were asked to all management staff in March 2020, and descriptive statistics were employed to interpret the research results.

#### 4. Results and Discussions

In OCMHS, mining heritage properties are preserved, which is acknowledged as part of UNESCO WHS. The outstanding universal value (OUV) of the site includes the interchange of human value within a cultural area and an outstanding example of a type of building, architectural, or technological ensemble or landscape that illustrates significant stages in human history<sup>17</sup>. All mining heritage properties are protected by *Peraturan Daerah* Kota Sawahlunto, the municipal regulation on the management of archaeological properties (Law 9, 2016) and on a national level through *Peraturan Pemerintah*, the national law on cultural heritage (Law 11, 2010). However, the disaster risk management plan is an ongoing task because state parties have not established any strategic plan for disaster mitigation. The distribution of museums in Sawahlunto is presented in Figure 1.

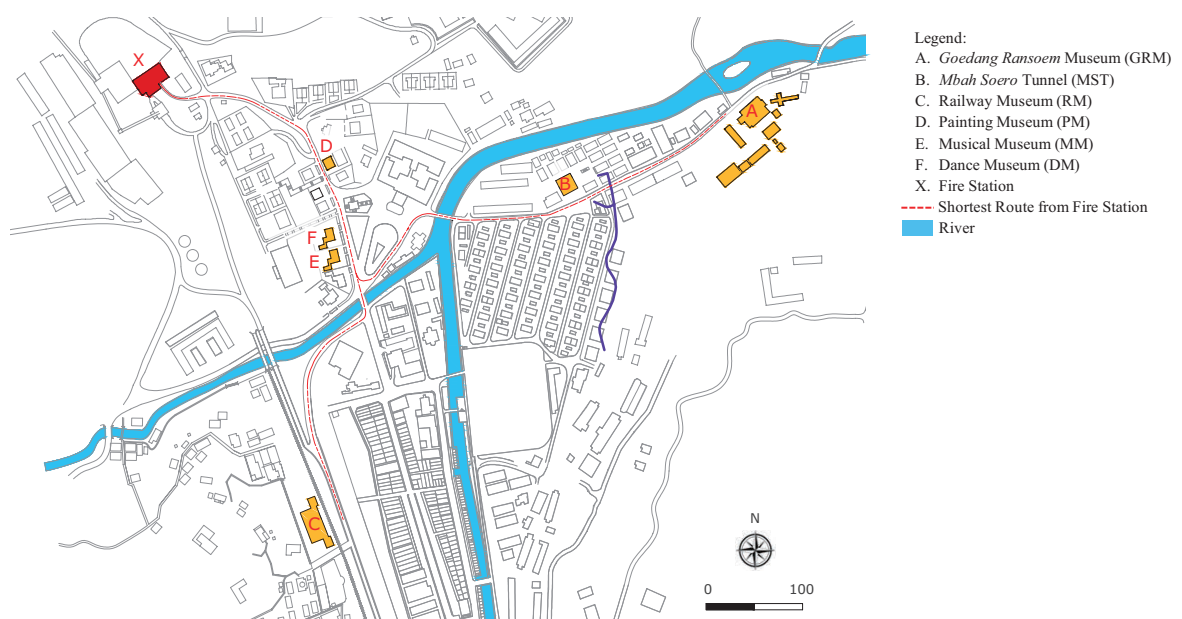


Figure 1. Map of museums in Ombilin Coal Mining Heritage of Sawahlunto (Authors, 2020).

Sawahlunto is adjacent to the Great Sumatran (Semangko) fault line. This 1900 km-long active strike-slip fault zone runs along the backbone of Sumatera island<sup>18)</sup>. The area is also prone to seismic movements of Indian-Australian plates. This combination may mean the risk of the potential earthquake to Sawahlunto, as shown in Figure 2.

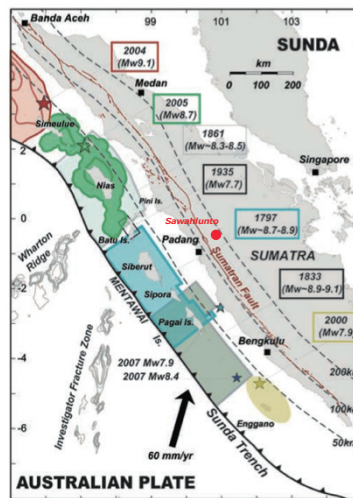


Figure 2. The Great Sumatran fault line and seismotectonic zone in Sumatera island  
Source: Chlieh et.al., 2008

**(1) Goedang Ransoem (public kitchen museum)**

*Goedang Ransoem* was originally a public kitchen in a coal mining era. It was established in 1918 to supply foods for miners and patients at the Ombilinjijnen hospital. This site experienced several functional shifts until 2005 when the Indonesian vice president inaugurated the former public kitchen sites as a museum. The *Goedang Ransoem* museum has an area of 8632 m<sup>2</sup>. Initially, the site consisted of nine integrated buildings, namely the main kitchen hall, two indoor steam generators, an outdoor steam generator reserve, ice factory, rice mill, warehouse, grocery building, health clinic, and slaughterhouse. Now, the buildings have been converted as public kitchen museums, science centers, and secretariat offices of OCMHS.

Museum buildings were built in the early 1990s. Although the conservation project was conducted with consideration local building code, its obsolete and decay condition makes it vulnerable to collapse in earthquake disaster. Also, the museum site is just 25 m away from the main river, thus increasing exposure to flood disasters. The risk assessment for *Goedang Ransoem* museum is presented in Table 4 below.

Table 4. Risk score and category for *Goedang Ransoem* museum

Potential hazards	Probability	Magnitude	Risk Score	Risk Category
Earthquake	4	4	16	Significant risk
Fire	3	4	12	Moderate risk
Flood/ Flash flood	2	4	8	Moderate risk
Landslide	2	3	6	Tolerable risk
Structural collapse	2	4	8	Moderate risk
Explosion	1	4	4	Tolerable risk
Electrical power failure	2	1	2	Tolerable risk
Broken water or sewer pipes	1	1	1	Insignificant risk

Based on the calculation of probability and magnitude of potential hazard in Table 4, the earthquake is considered as a significant risk in *Goedang Ransoem* museum site. At the same time, fire, flood, and structural collapse are listed as moderate risk. All these hazards potentially damage the properties and threaten the visitor and management staff.

A measurement on disaster preparedness revealed that *Goedang Ransoem* museum is equipped with limited disaster prevention equipment, including air conditioning systems, fire extinguisher, power generator set, and first-aid medical boxes. Primary disaster prevention tools, such as warning alarm system, fire alarm, smoke detector, sprinkler, fire hydrant, and water hoses, are not available. There are also no notification boards for prohibition action or advice for safety inside the buildings. Although an evacuation meeting point is provided in the center of the site, the museum management does not provide evacuation route signboard, disaster information card, and evacuation map for the visitor.

An examination of disaster response practice was conducted to all eight museum management staff. It revealed that none of them have enrolled in disaster mitigation training or lectures nor had participated in a disaster evacuation drill. 7 out of 8 staff claimed that they understood what to do in case of a disaster occur and could recognize the position of prevention equipment and safe route to the meeting point. However, only 2 of them regularly explain disaster risk and evacuation plan to the visitors on the admission.

An analysis of regular maintenance of the site discovered that management staff occasionally check the condition of disaster prevention equipment. Also, 4 out of 8 staff members asserted that potential threat, such as cracks, broken electrical equipment and leaked on the water pipe, falling of exhibition items were periodically inspected.

## (2) *Mbah Soero* mining tunnel

*Mbah Soero* was a distinguished mining supervisor in the first coal mining site in the city; his name was given to the site due to his work from the opening of the tunnel in 1898. The tunnel stretched thousands of meters underneath the city. A total of 205 m of tunnel is accessible for visitors. The tunnel is roughly 2.2 m wide and 2.75 m tall and can be divided into three segments. From the entrance, the tunnel is 30 m in length and 45° slope and turns right 200 m in flat terrain. The third segment is a 30 m exit tunnel at the opposite side of the entrance. The assessment of potential risk in this site is presented in table 5 below.

Table 5. Risk score and category for *Mbah Soero* mining tunnel

Potential hazards	Probability	Magnitude	Risk Score	Risk Category
Earthquake	4	4	16	Significant risk
Fire	4	4	16	Significant risk
Flood/ Flash flood	2	4	8	Moderate risk
Landslide	1	2	2	Tolerable risk
Structural collapse	3	5	15	Significant risk
Explosion	4	5	20	Significant risk
Electrical power failure	3	2	6	Tolerable risk
Air circulation failure	3	1	3	Tolerable risk
Intrusion of ground water	4	2	8	Moderate risk

The explosion is considered as a significant risk in this mining tunnel site. The probability of the occurrence is likely to happen as the tunnel was naturally composed of coal and contains a high degree of flammable gas, such as methane. In the past, the mining tunnel in Sawahlunto recorded some catastrophic that cause a large number of severe injuries and fatalities. Meanwhile, earthquakes, fire, and structural collapse are also categorized as significant risks. Other moderate risks are flood and the intrusion of groundwater into the tunnel. Destination management installed prevention equipment for these hazards, including air blower and concrete structural reinforcement. Air blower circulates fresh air into the tunnel and sucks out flammable gas (see Figure 3.a), while the concrete frame minimizes underground movement (see Figure 3.b).

Even though explosion and fire have been categorized as significant risks, the site is still unequipped with other necessary prevention tools, such as fire alarm, smoke detectors, sprinklers, fire hydrant, and CCTV. Also, the site is not equipped with an adequate number of water pumps and sandbags to minimize moderate flood risk and intrusion of the groundwater. As a result, the tunnel is repeatedly inundated by groundwater, as can be seen in Figure 3.c

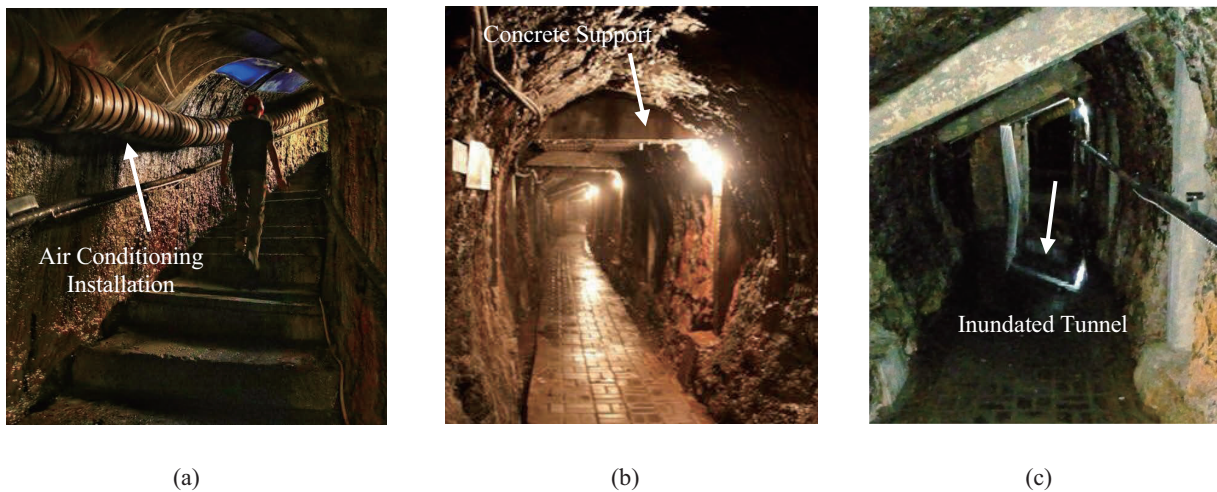


Figure 3. (a) Air conditioning installation. (b) Concrete support frame. (c) The tunnel was inundated due to intrusion of ground water. Image: *Mbah Soero* mining tunnel (2020)

### (3) Railway Museum

The railway was operated from 1912, not only for mining companies but also for public transportation. In 2003, railway transportation from Sawahlunto was officially closed, following the closure of coal mining in 2000. All railway infrastructures were then preserved and relaunched as railway museums in 2005. The main station hall was refurbished as a gallery exhibiting 149 railway display items. The risk assessment of the museum is depicted in Table 6.

Table 6. Risk score and category for railway museum

Potential hazards	Probability	Magnitude	Risk Score	Risk Category
Earthquake	4	4	16	Significant risk
Fire	2	4	8	Moderate risk
Flood/ Flash flood	2	2	4	Tolerable risk
Structural collapse	2	3	6	Tolerable risk
Electrical power failure	2	1	2	Tolerable risk

Earthquake is calculated as the only significant risk in this museum. The building is in obsolete condition, thus increase the vulnerability to collapse in an earthquake. The museum has a moderate level of fire risk and a tolerable level of the flood, structural collapse, and electrical failure risks. Nevertheless, these risks could lead to major disasters because the assessment of disaster prevention equipment discovered that portable fire extinguisher was the only preventive instrument in the museum, while others were not available. Analysis of the disaster response of museum staff also confirmed the lack of disaster knowledge. The museum is managed by only three staff, which none of them experienced disaster mitigation training nor had participated in a disaster evacuation drill. They claimed that maintenance and identification of potential threats were occasionally conducted, but at the same time, they admitted that they have limited knowledge of proper action in case of disaster.

### (4) Painting Museum, Musical Museum, and Dance Museum

Launched in 2017, these three museums are not directly associated with coal mining in Sawahlunto; they exhibit art instruments, such as paintings, musical instruments, and local customs. The museums used former housing for higher-class mining officers which have been adjusted through renovation to damaged sections without changing the original shape of the buildings. The risk assessment of these three museums is displayed in table 7. Earthquake is calculated as moderate risk, while others are tolerable risks.

Table 7. Risk score and category for painting museum, musical museum, and dance museum

Potential hazards	Probability	Magnitude	Risk Score	Risk Category
Earthquake	4	3	12	Moderate risk
Fire	2	3	6	Tolerable risk
Flood/ Flash flood	2	2	4	Tolerable risk
Structural collapse	2	3	6	Tolerable risk
Electrical power failure	2	1	2	Tolerable risk

## 5. Conclusion

This study analyses potential risks in six museums in Ombilin Coal Mining Heritage of Sawahlunto (OCMHS). The risk level was calculated by considering the probability and the magnitude of risk consequences. Five levels of risk were established, namely, insignificant risk, tolerable risk, moderate risk, significant risk, and intolerable risk. Study results indicated that the earthquake is a significant risk in major museums. It might be related to the position of Sawahlunto in prone earthquake disaster areas and the structural condition of museum buildings. In *Mbah Soero* mining tunnel, the explosion of flammable gas is calculated as significant risk. The site recorded several explosions in the past, and the absence of proper disaster prevention equipment increase the risk level. The intrusion of groundwater is categorized as a moderate risk in this tunnel, but an inadequate number of water pumps have frequently caused flooding, particularly in the rainy season. Other museums have relatively lower risk levels. Flood, structural collapse, and electrical failure were classified as moderate level risks, which cause a moderate destruction impact. Some examinations on disaster response of management staff in *Goedang Ransoem* museum and *Mbah Soero* mining tunnel discovered a limited disaster knowledge and improper disaster response.

## References

- 1) Harfst, J. : Constant crisis? Innovative approaches in old industrialised regions in Central Europe. In R. G. Mira & Dumitru Adina (Eds.), *Urban Sustainability Innovative Spaces, Vulnerabilities and Opportunities* (pp. 227–240). Coruna: International Association People-Environment Studies, 2014.
- 2) Su, Y. W., and Lin, H. L. : Analysis of international tourist arrivals worldwide: The role of world heritage sites. *Tourism Management*, 40, 46–58, 2014.
- 3) Frey BS, Pamini P, and Steiner L.: Explaining the world heritage list: an empirical study. *Int Rev Econ* 60(1):1–19, 2013.
- 4) Dwyer, L., and Kim, C. Destination Competitiveness : Determinants and Indicators. *Current Issues in Tourism*, 6, 369–414, 2003.
- 5) Chan, J. K. L.: The consumption of museum service experiences: Benefits and value of museum experiences. *Journal of Hospitality and Leisure Marketing*, 18(2–3), 173–196, 2009.
- 6) Ravankhah, M., Schmidt, M., and Will, T.: Multi-hazard disaster risk identification for World Cultural Heritage sites in seismic zones. *Journal of Cultural Heritage Management and Sustainable Development*, 7(3), 272–289, 2017.
- 7) Jigyasu R. : Heritage and resilience, issues and opportunities for reducing risks, 2013.
- 8) UNESCO : Strategy for reducing risks from disasters at world heritage properties (WHC-07/31.COM/7.2), 2007.
- 9) UNDRR : Sendai framework for disaster risk reduction 2015 – 2030, 2015.
- 10) UNISDR : Terminology on disaster risk reduction, 2009.
- 11) UNESCO/ ICCROM/ICOMOS/IUCN. : Managing disaster risks for world heritage, 2010.
- 12) Coppola, D. P.:Introduction to International Disaster Management, 2015.
- 13) ICOM. Museum Definition. <https://icom.museum/en/resources/standards-guidelines/museum-definition/>. Accessed 5 July 2020.
- 14) Lord, G. D., and Lord, B.: *The Manual of Museum Management*. Altamira Press, 2009.
- 15) Liston, D.: *Museum Security and Protection: A handbook for cultural heritage institutions*, 1993.
- 16) Lee, M. W., Dorge, V., and Jones, S. L.: Building an Emergency Plan: A Guide for Museums and Other Cultural Institutions. In *Journal of the American Institute for Conservation* (Vol. 40), 2001.
- 17) ICOMOS : Ombilin coal mining heritage of Sawahlunto (Indonesia), 2019.
- 18) Chlieh, M., et al.: Heterogeneous coupling of the Sumatran megathrust constrained by geodetic and paleogeodetic measurements. *Journal of Geophysical Research: Solid Earth*, 113(5), 1–31, 2008.