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Spatial Analysis for Fire Risk Reduction in Kampung Ampel Cultural Heritage Area, Surabaya

F. Hudanti[a], T. Okubo[b], P. N. Indradjati[c]*

[a] East Java Provincial Government Inspectorate, *Indonesia*
[b] Department of Civil Engineering, College of Science and Engineering, Ritsumeikan University, Japan
[c] School of Architecture, Planning, and Policy Development, Bandung Institute of Technology, Indonesia

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***Corresponding Author:**
Petrus N. Indradjati
School of Architecture, Planning, and Policy Development, Bandung Institute of Technology, Indonesia
Email: natalivan@sappk.itb.ac.id

Abstract: *The objective of the research is to improve fire risk reduction in Kampung Ampel Surabaya through [1] identifying the current firefighting system in Surabaya; [2] identifying the characteristics and conditions of Kampung Ampel; [3] identifying the structure of the problem; [4] proposing strategies for fire risk reduction in Kampung Ampel. The analysis will focus on determining the risks and resources of Kampung Ampel to fire hazards using Geographic Information System (GIS) analysis. Risk and resources are combined to find out the areas that have the highest risk of fire hazard. The results of the analyses consist of challenges and possible solutions. The challenges can be concluded as follow: [1] resources for firefighting cannot cover the entire area of Kampung Ampel; [2] resources for evacuation cannot accommodate all the population and visitors. The proposed solutions for those challenges are [1] reactivation of inactive fire wells; [2] utilization of source of water in Ampel Mosque; [3] proposing wider road to connect roads which are wider than 3.5 meters but are blocked by narrower roads; [4] the purchase of adapters to connect different types of fire hoses; [5] adding the number of fire hoses brought to the site; [6] remodeling the vulnerable buildings using inflammable materials with keeping the value of cultural landscape; [7] keeping portable fire pump in Ampel Mosque to facilitate the fire handling by residents; and [8] preparing evacuation route to the closest open space areas. The application of those solutions can reduce the high-risk area from 26.6% to 0.2%.*

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1. INTRODUCTION

Fire can be defined as a thermo-chemical reaction caused by three factors: oxygen, fuel, and heat, which will lead to fires that generate heat, flames, smoke, and gas. A fire incident is the existence of an unwanted fire. Fire events begin with burning, then the fire is out of control and threatens life and property (Mantra, 2005; Suprapto, 2008). A fire event has several processes until the fire is extinguished. The developmental process has several stage, i.e., (1) Ignition/ explosion phase: This stage is characterized by the emergence of fire caused by the heat energy of the material in space; (2) Fire growth phase: Fire has begun to develop by the quantity of fuel available. This phase is the best stage for evacuation. In this phase, fire sensors and extinguishers must have started working; (3) Flashover phase: A phase transition from the growth phase to the full combustion phase. This stage is high-speed, with the temperature usually ranges between 300º C and 600º C; (4) Full combustion phase: At this stage, the release's heat is the greatest because the fire has spread to the entire space, the temperature can reach 1200ºC; (5) Receding phase: at this point, all material was burned, and the temperature has begun to fall, and the firing rate also declined (Mantra, 2005).

A disaster occurs when a hazard strikes a vulnerable community. Thus it is a result of the interaction between hazards and vulnerability (Setiawan & Wiguna, 2012). However, vulnerability, a community, will also have capacities or strengths that help reduce the impact of the hazard. Therefore, in every disaster prevention effort, the three factors of hazard, vulnerability, and capacity are the assessment's main points. In terms of fire hazards, the factors that influence fire vulnerability are building density, population density, population activities, building material, number of stories, and building condition. Meanwhile, the factors that influence the capacity of an area include the availability of fire stations, firefighting infrastructure including water resources, road width, and availability of open space (Rijanto, 2010; Miadinar, 2009; Rusli, 2011; Sujatmiko, 2012; Adi et al., 2013; Latifah & Pamungkas, 2013; Rahman et al., 2015).

Mitigation measures aim to save the life of the human and reduce the loss of property and reduce the adverse consequences of economic and social activities. If mitigation sources are limited, mitigation actions can be targeted to the most effective elements that greatly impact their community activities. Vulnerability assessment is an important aspect of effective mitigation planning. Indirect vulnerabilities include vulnerability to physical damage, economic damage, and lack of resources for recovery from disasters (Sagala et al., 2013)

Protection against disaster threats can be achieved by eliminating the causes of the threat (reducing hazards) or by reducing the effects of threats if threats emerge. In other words, mitigation can be prepared by reducing vulnerability or increasing risky elements' capacity potential. Mitigation planning is a strategy developed to reduce disasters' impact on communities, facilities, regions, cities, or countries (Coburn et al., 1994; Moga, 2002).

In terms of fire mitigation, regarding the amount of water that should be available on-site, there are three firefighting phases (Okubo, 2003): [1] the first phase is that of a small fire, handled by citizens with small amounts of water. Water accessibility is most important in this phase; [2] the second phase is deemed a standard house scale fire, fought by professional firemen. The amount of water must be sufficient for professional use; [3] the third phase is block scale fire, grappled with by various support teams for fire fighting, usually from other cities. Continuous and ample amounts of water are needed, particularly in this last phase.

Previous research discusses fire risk reduction in densely populated areas such as cities (Price & Bradstock, 2014), industrial areas (Azad et al., 2018), residential and commercial areas (Sivakumar et al., 2018), low-income and informal settlements (Twigg et al., 2017). However, there are still a few studies that take case studies in cultural heritage areas. Furthermore, this study fills that gap by selecting study areas that have distinctive cultures.

The objective of the study is to improve fire risk reduction in *Kampung* Ampel Surabaya. The research will be conducted to determine the study area's spatial characteristics, including the current firefighting systems and cultural heritage buildings' characteristics. To address the objective, several steps will be conducted as follow: (1) To identify the current firefighting system in Surabaya; (2) To identify the characteristics and condition of the cultural heritage area in *Kampung* Ampel Surabaya; (3) To identify the structure of the problem based on the characteristics and conditions of *Kampung* Ampel area and the fire system of Surabaya city; (4) To propose strategies for fire risk reduction in *Kampung* Ampel. This study is important because it is conducted regarding the development plan of a valuable cultural heritage area prone to a fire disaster. In *Kampung* Ampel, besides the cultural heritage buildings that have been existed since the 15th century, there are also cultural nuance and activities of the Arab community that has been inherited by generations. Therefore, they need to be preserved due to the historical values that can give a city character or identity.

The study area covers the whole area of *Kampung* Ampel, Semampir sub-district, Surabaya, Indonesia, with approximately 40 ha, consisting of 17 RW. As the second-largest city in Indonesia after Jakarta, Surabaya, with a total area of 326,81 km^2, is considered a highly dense area. In 2013, the population of Surabaya accounted for 3,2 million, with the density reached 9,793 people/km^2. Due to the high density, Surabaya becomes vulnerable to fire. During 2005-2014, many fires that occurred in Surabaya accounted for 3,611 incidents with a loss of 280,475 million rupiahs or USD 21 million (BPS, 2015). *Kampung* Ampel, located in the Semampir sub-district in Surabaya, is a part of *Kota Lama* Surabaya (Old City of Surabaya), an important Cultural Heritage Area. *Kampung* Ampel is famous as a *kampung* inhabited by many Arab ethnicities for generations. During the era of Walisongo –The Nine Saints, known as the propagator of Islam in Java Island in the 15th century– *Kampung* Ampel was known as the center for the spread of Islam in Java (Silas et al., 2012). In *Kampung* Ampel, several cultural heritage buildings are assigned by the Surabaya City Government, such as the Great Mosque and Tomb of Sunan Ampel, Tomb of Habib Muhammad bin Idrus Alhabsyi, etc. (Bappeko 2012). Therefore, up to now, *Kampung* Ampel attracts thousands of visitors from within and outside Surabaya. However, according to Surabaya Spatial Plan 2014-2034, *Kampung* Ampel is an area prone to fire. During the last ten years, several fire incidents occurred. These incidents potentially harm cultural heritage buildings in *the Kampung* Ampel region.

2. DATA AND METHODS

This research will use descriptive analysis and GIS-based analysis to deal with data related to the physical condition of the study objects and the area. The GIS-based analysis will also provide some suggestions on how to develop the existing firefighting measures. The research will be started by conducting problem identification. After that, the literature review will be carried out to determine the aspects that need to be considered in developing the area regarding fire prevention. Data collection, including both spatial and non-spatial data, will be done afterward. Finally, spatial analysis using GIS will be conducted to provide development strategies for fire mitigation in the study area. The spatial analysis will be conducted according to Figure 1.

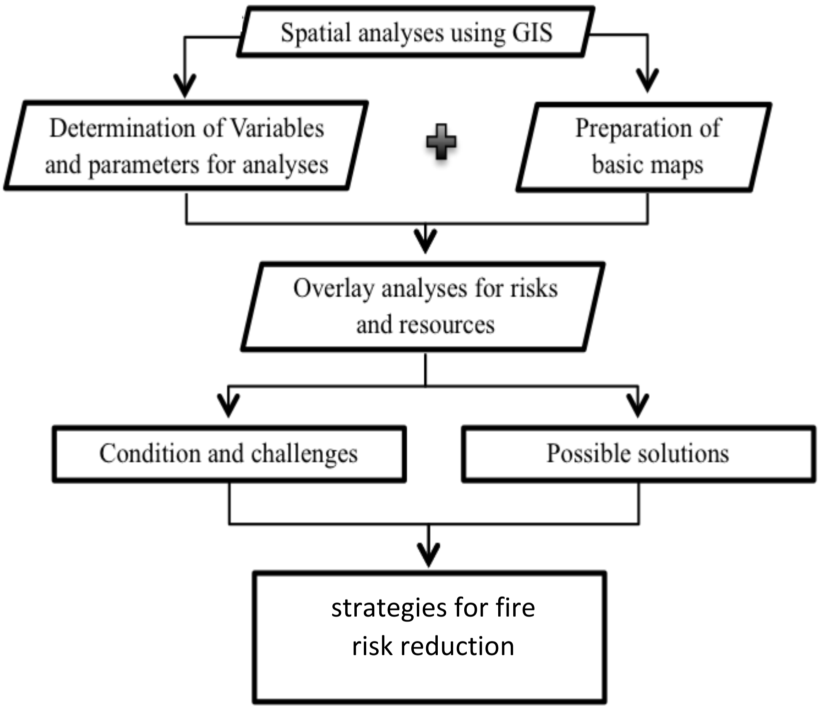

Figure 1. Spatial Analysis to be conducted

A disaster occurs when a hazard strikes a vulnerable community. However, vulnerability, a community, will also have capacities or strengths that help reduce the impact of the hazard. Therefore, in every disaster prevention effort, the three factors of hazard, vulnerability, and capacity are the assessment's main points. In this case, the hazard to be mitigated is urban fire. Furthermore, vulnerability and capacity factors to fire hazards need to be examined.

Risk management is all the efforts to understand and deal with possible negative impacts on the objectives. It includes identifying, analyzing, and prioritizing/evaluating risk (Pedersoli Jr & Michalski, 2016). Risk identification is to verify hazard factors from the cultural heritages and historical surrounding buildings to take responses and protective measures. To evaluate potential disaster risk in cultural heritage and historical buildings, there are six key principles, i.e., (1) Assess not only the main and visible factors but also potential hazard factors; (2) Consider the hazards resulting from the facility interior factors and the environment surrounding factors; (3) Establish the intent relationship between mitigation, preparedness, response, and recovery stage; (4) Establish an advanced risk management and assessment program to protect the value of cultural heritages; (5) Use traditional knowledge, engineering, and methods to achieve the purpose of mitigation; (6) Connect disaster risk management and preservation maintenance plan tightly in every stage (Jigyasu & Arora, 2014).

The objective of undertaking risk assessment of cultural heritage sites is to prioritize risk reduction strategies and decisions on mitigation. Risk identification and analysis may be undertaken at [1] heritage site level, [2] individual heritage building level, and [3] urban level. In this case, risk identification of *Kampung* Ampel will be carried out at the heritage site level.

Risk identification and analysis includes the following aspects, i.e., (1) Establishing the values and significance of the site (heritage value assessment); (2) Listing all the natural and human-induced hazards that could potentially have an adverse impact on cultural heritage; (3) When combined with potential hazards, identifying the issues could cause a disaster risk to the site. These may be issues of site management, physical conditions of the site and/ or buildings and movable objects, underlying social and economic issues, etc; (4) Analyzing the cause-effect relationships between various primary hazards and underlying risk factors increases the vulnerability and exposes it to disaster risk (Jigyasu & Arora, 2014).

The major planning framework for risk-preparedness for cultural heritage properties (Stovel, 1998) consists of three major phases, preparedness, response, and recovery. Preparedness phase includes reducing risk at source, reinforcing the ability of a property to resist or contain the consequences of the disaster, providing adequate warning of impending disaster, developing emergency response plans. Response phase includes ensuring the availability of the response plan and mobilizing the conservation team. Recovery phase consists of efforts to mitigate the negative consequences of the disaster, efforts to rebuild the physical components of the property and the social structure of using the property and its community, efforts to reinstate and enhance preparedness measures.

To determine the most important location and the most vulnerable to fire, fire vulnerability factors will be studied. The factors that mostly affect the vulnerability to the fire include: [1] building density; [2] population density; [3] population activities/ building activity; [4] number of stories; [5] building construction/ construction material type/ percentage of the non-permanent building; and [6] building condition/ building quality (Adi et al., 2013; Latifah & Pamungkas, 2013; Miadinar, 2009; Rijanto, 2010; Sujatmiko, 2012; Rahman et al., 2015).

In addition to the vulnerability factor, to conduct a disaster risk assessment, it is also necessary to understand the capacity factors. The capacity factor reflects the ability to overcome or prevent the occurrence of hazards. Simply put, capacity factors can be defined as the positive aspects of the situation. In fire hazards, capacity factors include [1] availability of fire station; [2] firefighting infrastructure including water resource/ water supply/ hydrant; [3] road width/ road network/ accessibility; [4] fire prevention facilities including vehicles, personnel, equipment; and [5] availability of open space (Adi et al., 2013; Rusli, 2011; Latifah & Pamungkas, 2013; Rijanto, 2010; Sujatmiko, 2012; Rahman et al., 2015).

From the abovementioned variables, most of the variables are suitable for the study area and used in the analysis process. Also, because *Kampung* Ampel is a cultural heritage area often visited by tourists, tourist arrivals and cultural heritage buildings should also be considered. Because both cultural heritage buildings and tourists are objects that need to be protected during a fire event, then both fall into the category of vulnerability factor. After obtaining variables to be used in the analyses, it is necessary to specify each variable's parameters. These parameters will then be used to score each map as a basis for further analysis. Consequently, the variables and parameters that will be used in the analysis are displayed in Table 1.

Table 1. Variables and parameters to be used in the analyses

Factor	Variable	Parameter			
		Basic	Medium	High	Very High
Vulnerability	Population density	<150 people/ha	151-200 people /ha	201-400 people /ha	> 400 people/ha
	Building density	11-22 building/ha	23-45 building/ha	> 45 building/ha	-
	Flammable material	<20%	20-30%	31-40%	-
	Cultural heritage value	Outside the buffer	-	Inside the buffer	-
	Building importance	Housing	-	Public facilities, commercial, restaurant, shop house	-
	Distribution of visitors	Outside the buffer	-	Inside the buffer	-
Capacity	Accessibility	Areas within the range of fire hoses	-	Areas that are not within the range of fire hoses	-
	Fire infrastructure	Areas covered by water resources	-	Areas that are not covered by water resources	-
	Availability of open space	-	-	-	-

3. RESULTS AND DISCUSSION

3.1. Kampung Ampel Cultural Heritage Area

In 2017, the total population in the area accounted for 21,766 persons (*Kelurahan* Ampel 2017). This *kampung* is dominated by Arab ethnicities (60%), and the density reached 577 people/ha. Due to the high density and high building density, *Kampung* Ampel is considered an area vulnerable to fire. Table 2 shows the incidents of fires in *Kampung* Ampel from 2008-2016. *Kampung* Ampel is a cultural heritage area that exists since the 15th century. Thus, in this region, several cultural heritage objects have many cultural and historical values that can give Surabaya character or identity, particularly for the *Kampung* Ampel itself.

The cultural heritage objects in *Kampung* Ampel are; (1) Great Mosque and Tomb of Sunan Ampel. Ampel Mosque is an ancient mosque built in 1421 by Sunan Ampel. The area accounts for 120x180 square meters. Ampel Mosque also has a 50-meter high minaret. The Tomb of Sunan Ampel is also located in the vicinity. It is a cemetery complex of Sunan Ampel, his wife, five of his relatives, his students, and 182 other Muslims who died during pilgrimage to Mecca (IS, 2014; Mappaturi, 2015). Towards the area of Great Mosque and Tomb of Sunan Ampel, there are five *gapura*/ gates which symbolize the five pillars of Islam such as (a) Gapura Paneksen This gate symbolizes the first pillar of Islam, shahada, or the declaration of faith. When deciding to be a Muslim, the first thing one is obliged to do is to recite the shahada as a declaration of faith. (b) Gapura Madhep symbolizes the second pillar of Islam, salat, or five daily prayers. After declaring the faith, a Muslim is obliged to perform five daily prayers. (c) Gapura Ngamal symbolizes the third pillar of Islam, zakat, which means compulsory charitable giving according to each person's amount of property and income. (d) Gapura Poso symbolizes the fourth pillar of Islam, fasting in the month of Ramadhan. During the Ramadhan month, Muslims are obliged to do fasting, increase worship, and good deeds. (e) Gapura Munggah symbolizes the fifth pillar of Islam, namely *the hajj*. *Hajj* is a pilgrimage to Mecca, the holy city for Muslims located in Saudi Arabia.

Furthermore, the other several symbols illustrate the heritage such as (1) Tomb of Habib Muhammad bin Idrus Alhabsyi. Tomb of Habib Muhammad bin Idrus Alhabsyi is a family cemetery complex built in the 18th century. Habib Muhammad bin Idrus Alhabsyi settled in Surabaya in the mid of 20th century. He was a great scholar and died in Surabaya in 1917 (Sulistiowati, 2000). (2) Al-Irsyad Hospital. Al-Irsyad Hospital used to be a residential house of 2,600 m^2 built by the Baswedan family. In 1973, most of the building was donated to Al-Irsyad Foundation for future development activities in north Surabaya. Since 2002, expansion is done by gradually increasing the building floor, but the main building parts are still maintained and preserved as a cultural heritage building (surabaya.go.id, 2015; Al-Irsyad, 2016). (3) House of Oesman Nabhan Family. The building, built-in 1915, was owned by the Dutch and was functioned as Elementary School for the Arab community. The size of this building is 40x30m. During the Japanese colonial period (1942-1945), it functioned as a military brigade headquarters of the Army/8 Brawijaya Regional Military Command. Bought by the family in 1974, the building currently belongs to Oesman Nabhan family (Akasah, 2011). (4) *Kemajuan Hotel*. *Kemajuan Hotel* was built in 1928. The two-story building is owned by Al-Irsyad Foundation Surabaya. One of the objectives of this hotel's development is to fund a school run by Al-Irsyad Foundation. From the construction until today, the building is relatively unchanged. This hotel's area accounts for around 740 m^2 (realita.co., 2014; surabaya.go.id, 2015).

Table 2. Fire incidents in *Kampung* Ampel in 2008-2016 (Surabaya Fire Department, 2017)

Date	Time	Location	Victims/ Lost	Description
14 July 2008	09:30	Jl. Ampel Sawahan Gg. II No. 17	Warehouse	Causes: short circuit Effort: 4 units of fire truck were deployed to the scene
13 Nov 2012	07:55	Jl. Nyamplungan No. 95	Household appliances	Causes: burning mattress Effort: 1 unit fire truck was deployed to the scene
6 Sept 2014	08:15	Pegirian RT 04 RW 13	6 houses	Causes: a gas stove explosion Effort: 17 units of fire trucks were deployed to the scene
7 Nov 2015	19:20	Jl. Pertukangan B (Baru) No. 22E	1 bedroom	Causes: short circuit Effort: 1 unit fire truck was deployed to the scene
4 Jan 2016	04:26	Jl.Nyamplungan Gg.VII	1 big tree (d=50cm; h=3m) owned by local government	Causes: open flame[1] Effort: 1 unit fire truck was deployed to the scene
19 Agt 2016	09.50	Jl. Nyamplungan IX/49	Rice stall (3x3=9m^2)	Causes: open flame Effort: 1 unit fire truck was deployed to the scene

[1] According to Surabaya Firefighting Department, open flame includes fire caused by a cigarette butt, people who burn garbage (usually in the field/ open space), and LPG explosion

3.2. Disaster Risk Assessment of Kampung Ampel

Before beginning the spatial analysis discussion, it is necessary to identify general disaster risk in the study site. Identifying all the risks that threaten the heritage building, monument, or site is necessary to propose effective risk reduction strategies and decisions. The spatial analysis will be conducted afterward to present evidence for the disaster risk assessment entries. To begin with, the following hazards, vulnerability, and capacity are factors that necessary to be considered. Vulnerability factors affect the vulnerability to fire hazards and determine whether the fire hazard will cause greater damage or not. On the other hand, capacity refers to all the strengths, qualities, and resources available within a community or society to manage and reduce disaster risks (Jigyasu & Arora, 2014). The disaster risk assessment will be identified using these three tools of hazard, vulnerability, and capacity (Table 3). After conducting spatial analyses on risks and resources in *Kampung* Ampel, there are several highlights as presented in Table 4.

Table 3. Disaster risk assessment of *Kampung* Ampel

Hazard	Vulnerability	Capacity
Fire	High population density	Availability of fire station near Kampung Ampel
	High building density	
	Narrow passages	
	The existence of cultural heritage objects	Availability of active fire wells
	A large number of buildings are utilized as souvenir shops which sell flammable goods: clothing, snacks, accessories, books	Located nearby Pegirian River
	Restaurants play a role in increasing the vulnerability of the area	
	The high number of visitors, up to 20,000 in the peak season	
	Lack of open space area allows for evacuation	
	Building material (the usage of timber/ flammable materials)	
	No firefighting infrastructures such as hydrant or fire alarm	

The aforementioned proposed solution can be illustrated as follow:

1) Reactivation of inactive fire wells.

Out of seven fire wells located in the vicinity of *Kampung* Ampel, four of them are inactive fire wells. There are several reasons why fire wells are inactive (see Table 4). If possible for reactivation, the coverage area of firefighting resources will be wider, thus increasing the safety in the area (see Figure 2).

2) Utilization of source of water from Ampel Mosque.

Ampel Mosque, located right in the middle of *Kampung* Ampel, has a water source that is believed to be the holy water that brings goodness to the drinker. The existence of that water source can be an alternative water resource to help secure the area (see Figure 3). The utilization of this water source can be an effective solution since the Ampel Mosque is one area that falls into the high-risk category (Rijanto, 2010; Miadinar, 2009; Rusli, 2011; Sujatmiko, 2012; Adi et al., 2013; Latifah & Pamungkas, 2013; Rahman et al., 2015). However, since Surabaya City Fire Department does not own the water source, the water resources volume in this mosque is unknown. Also, it should be investigated whether it is possible to be utilized in the case of an emergency (see Figure 4).

Table 4. Condition, challenges and possible solutions for fire risk reduction in *Kampung* Ampel

No.	Condition and challenges	Possible solutions
1	Resources for firefighting cannot cover the entire area of *Kampung* Ampel	Reactivation of inactive fire wells
		Utilization on the source of water in Ampel Mosque
	Firefighting resources do not reach the buildings located in the middle of the Ampel region	Propose a wider road to connect roads which are wider than 3.5 meters but are blocked by narrower roads
		The purchase of adapters to connect different types of fire hoses
		Adding the number of fire hoses brought to the site can be an alternative strategy
		Vulnerable buildings can be remodeling to make the building stronger using inflammable materials with keeping the value of the cultural landscape
2	Resources for evacuation cannot accommodate all the population	Preparing evacuation route to the closest open space areas
	The open space buffer does not cover the area on the north side	
	Open space inside Kampung Ampel cannot accommodate all the population	

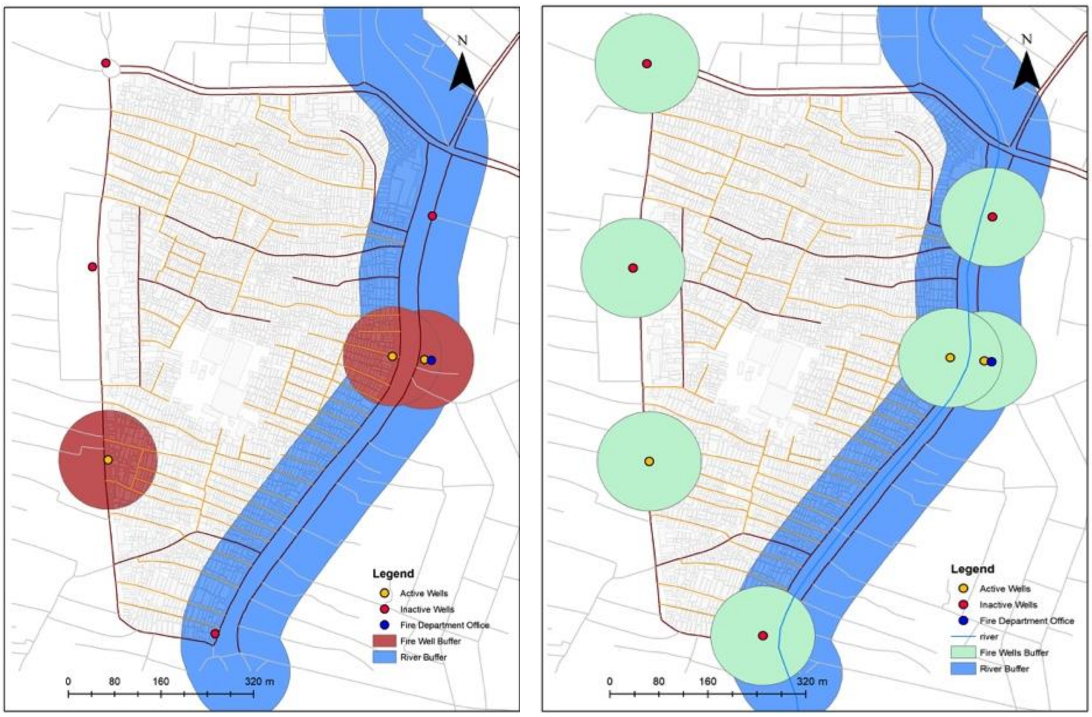

Figure 2. Comparison of fire resources buffer before and after reactivation of inactive fire wells

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Figure 3. Source of water inside Ampel Mosque area

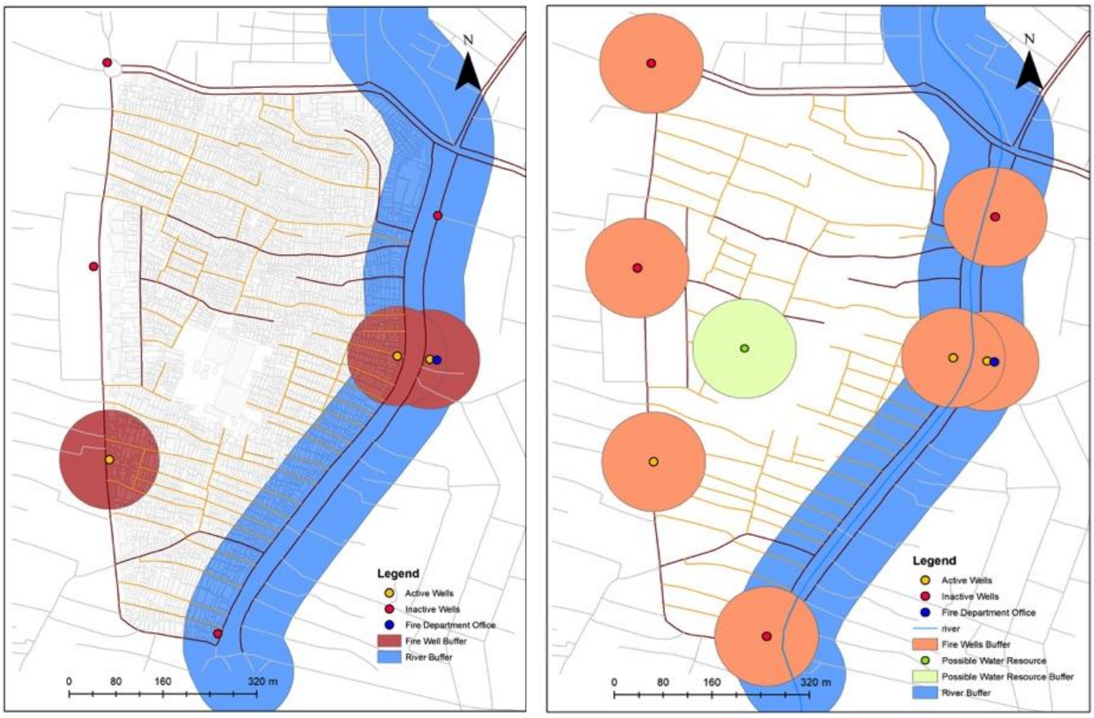

Figure 4. Comparison of fire resources buffer before and after the added source of water from Ampel Mosque and reactivation of inactive fire wells

1) Propose a wider road to connect roads wider than 3.5 meters but are blocked by narrower roads.

On the west side of *Kampung* Ampel, two roads' lines actually have a width of more than 3.5 meters (Jl. Petukangan Utara and Jl. Petukangan Tengah I). Still, they have not added buffers because smaller roads block the roads' entrance access from the main street. Therefore, if it is possible to propose a wider road, the buffer areas will be bigger, thus covering wider areas (Rijanto, 2010; Miadinar, 2009; Rusli, 2011; Sujatmiko, 2012; Adi et al., 2013; Latifah & Pamungkas, 2013; Rahman et al., 2015). The illustration of the buffer area after road widening is displayed in Figure 5 (the target of road widening is inside the black circles).

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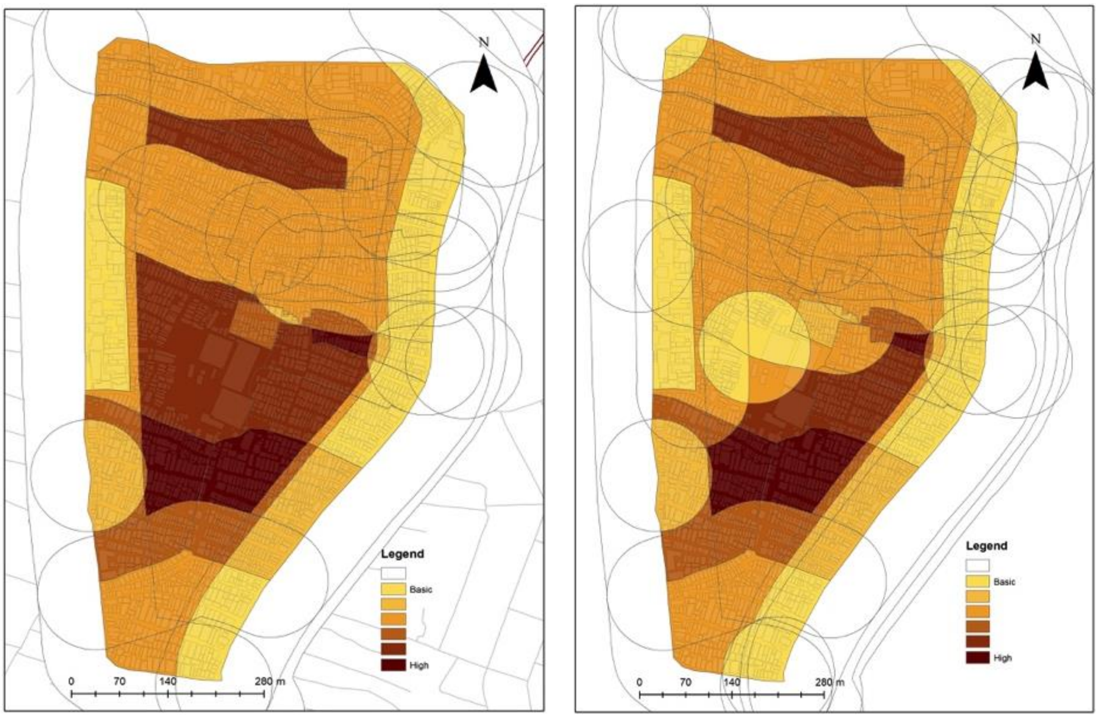
Figure 5. Comparison on fire hose range buffer before and after road widening

Afterward, to see the comparison of risks and resources between before and after the application of proposed solutions above (Figure 6):



Before: High-risk area 26.6%

After: High-risk area 16.6%

Figure 6. Comparison of the map of risks and resources before and after proposed solutions

The above map was obtained by combining the risk of fire spreading with several recommendations: [1] reactivation of inactive fire wells; [2] utilization of water source from Ampel Mosque; [3] road widening to connect blocked road with the main road. The map shows that after some suggestions are applied to the study site, the areas that can be covered by firefighting resources are wider. Therefore, the high-risk area is decreasing from 26.6% to 16.6%.

2) The purchase of adapters to connect different types of fire hoses

According to Surabaya City Fire Department, in each fire fighting action, each fire truck carries 6 outdoor hoses sized 2.5 inches and six indoor hoses sized 1.5 inches, each of which has a length of 20 meters. To connect both types of fire hoses, the purchase of adapters can be an effective solution. After adapters connect both types of fire hoses, the calculation on the fire hose range will be as follow:

$$\text{Fire hose range} = \frac{\text{Length of fire hose}}{\sqrt{2}} = \frac{240\text{m}}{\sqrt{2}}$$

$$= 169.70\text{m} = 169\text{m}$$

Thus, a buffer of 169m was created along the roads with a width of 3.5 meters and more. The comparison of fire hose range buffer before and after installing fire hose adapters shows a big difference in the coverage area, as shown in Figure 7. Because of the increased radius of fire hose range due to the installation of fire hose adapters, the same buffer will be applied to fire infrastructure elements, namely river and fire wells, including the inactive fire wells, with the assumption that the inactive fire wells will be reactivated. The map illustrates a significant difference between the before and after coverage areas (see Figure 8).

Figure 7. Comparison of fire hose range buffer before and after the installation of the fire hose adapter

Then, both maps of fire hose range buffer and fire infrastructure above will be overlaid with a map of risk of fire spreading to see the comparison of risks and resources between before and after installing fire hose adapters. The map shows that after some suggestions are applied, the high-risk area decreases from 26.6% to 3.4%. (see Figure 9). Furthermore, to treat the remaining 3.4% high-risk area, the possible solution is to utilize the water source from Ampel Mosque. When the water source is utilized using fire hoses after

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installing adapters (a buffer of 169 meters will be added), the high-risk area decreases to 0.2% (see Figure 10).

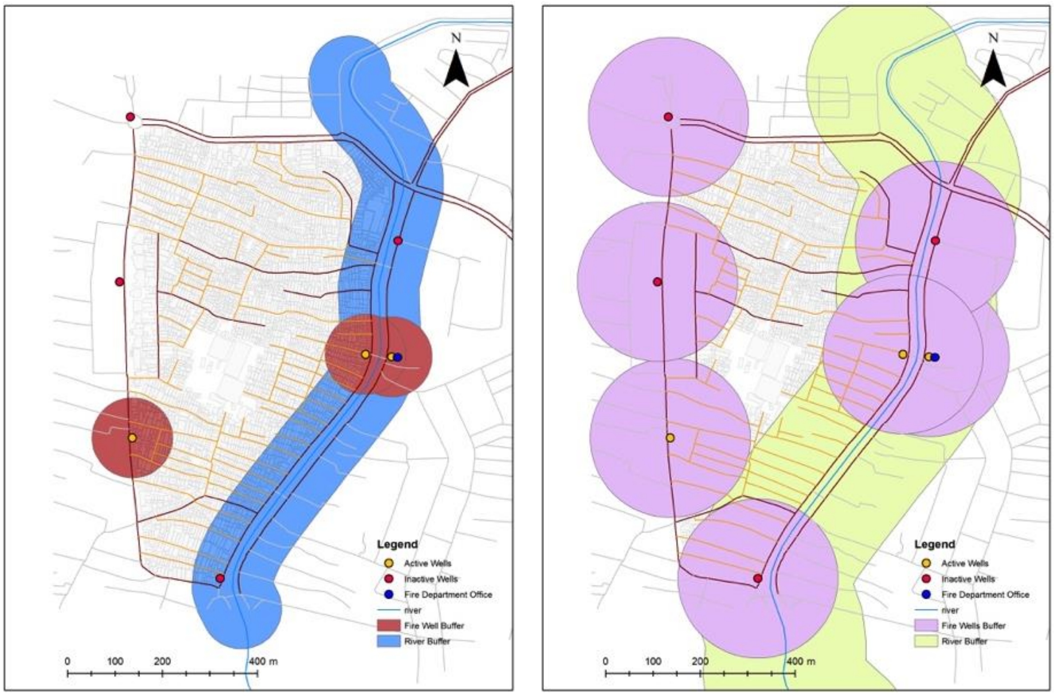
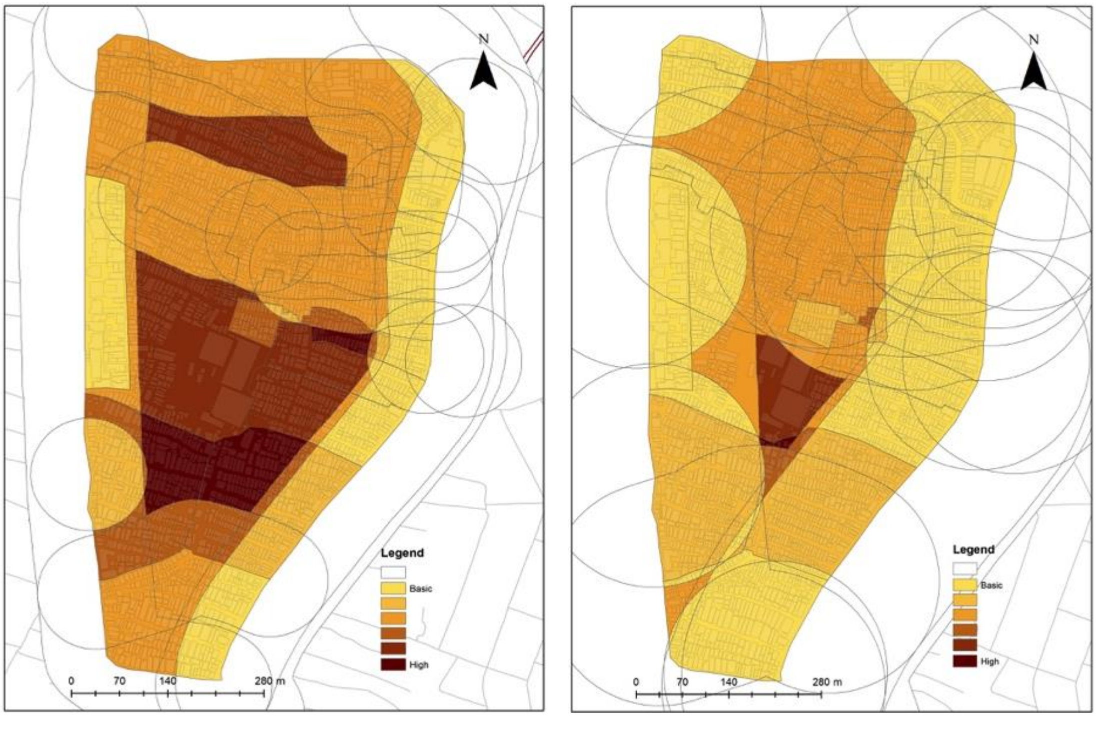


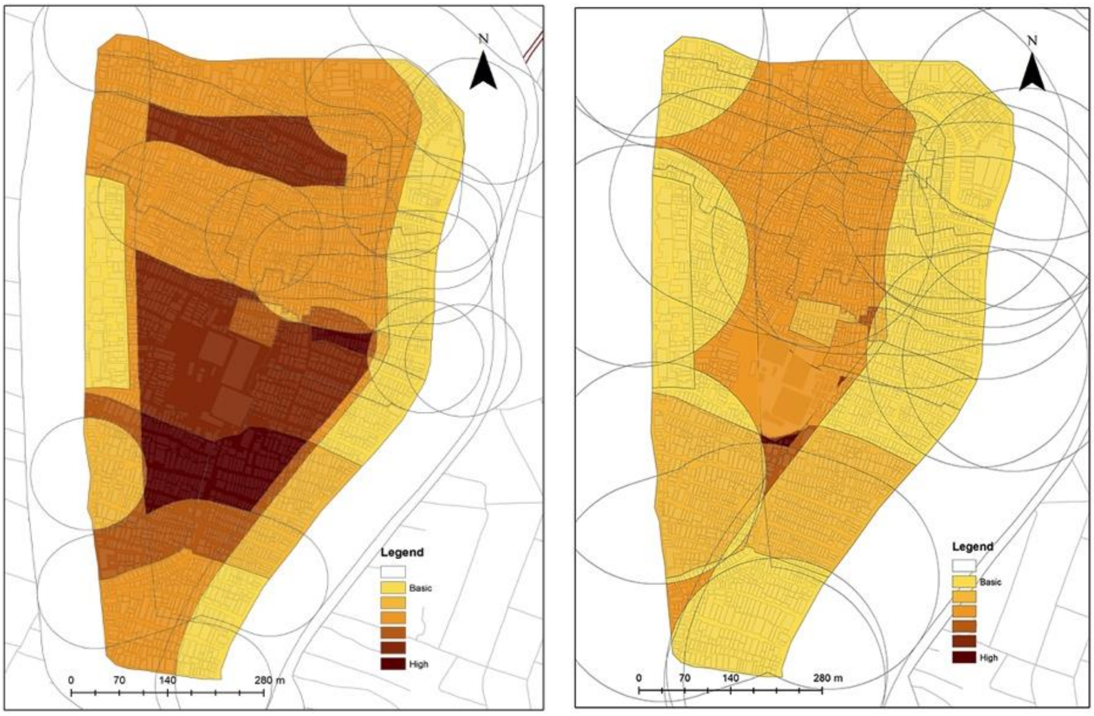
Figure 8. Comparison of fire resources buffer before and after reactivation of inactive fire wells and installation of the fire hose adapter



Before: High-risk area 26.6%

After: High-risk area 3.4%

Figure 9. Comparison on the map of risks and resources before and after reactivation of inactive fire wells and installation of the fire hose adapter



Before: High-risk area 26.6%   After: High-risk area 0.2%

Figure 10. Comparison on the map of risks and resources before and after reactivation of inactive fire wells, installation of fire hose adapter, and utilization of water source from Ampel Mosque

3) Adding the number of fire hoses brought to the site can be an alternative strategy.

As can be seen from the recommendation on the installation of the fire hose adapter above, a buffer of 169 meters was added. The result of this proposed solution shows that a large area categorized as high risk has decreased to lower levels. Only a few areas remain in the high-risk category. The total number of fire hoses brought by the Surabaya City Fire Department to the fire scene is 12 units. Therefore, to cover the entire area with firefighting resources, providing additional fire hoses can be an effective solution. However, to cover a wider area than 169 meters, the number of fire hoses must be above 12.

4) Preparing the evacuation route to the closest open space area.

Evacuation route is obtained from the most visited tourist area to the nearest open space. In this case, the most visited tourist area is the Mosque and Tomb of Sunan Ampel. There are four possible routes as follows (see Figure 11):

a. From Mosque and Tomb of Sunan Ampel to Open Space 2 with a length of 415 meters (yellow line);
b. From Mosque and Tomb of Sunan Ampel to Open Space 2 with a length of 423 meters (purple line);
c. From Mosque and Tomb of Sunan Ampel to Open Space 3 with a length of 452 meters (red line);
d. From Mosque and Tomb of Sunan Ampel to Open Space 4 with a length of 1068 meters (green line).

The preparation of these evacuation routes illustrates which road is important for facilitation and maintenance to accelerate evacuation, especially for tourists. Facilitation can be done by providing signage, clearance path of illegal or non-permanent stalls, or route socialization.

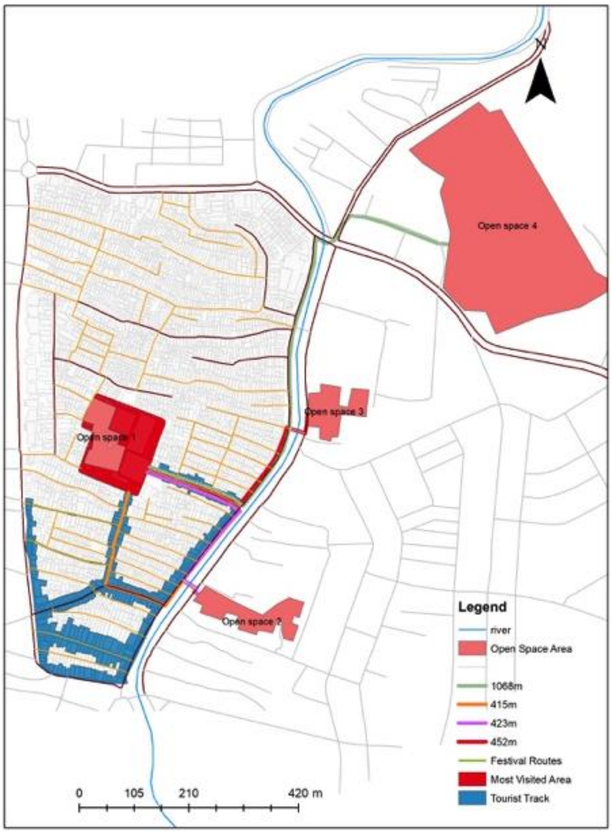


Figure 11. Possible Evacuation Routes

5) Keeping a portable fire pump in Ampel Mosque for a faster fire handling

In Surabaya, the fire pump is carried to the location of fire only by the firefighters. Therefore, as Ampel Mosque is the most visited cultural heritage in *Kampung* Ampel, keeping the fire pump in Ampel Mosque can speed up the residents' fire handling before the firefighters reach the site considering that there are no major access routes to Ampel Mosque.

The research conducted by Rahmawati et al. (2016) produces a fire risk map by taking into account three variables, namely fire hazard, vulnerability and capacity. This research not only produces fire risk maps but also fire disaster risk reduction scenarios that can be carried out to preserve cultural heritage.

4. CONCLUSION

Like the way we preserve our ancestors' treasure, cultural heritage has such sanctity and needs protection. It is essential to mitigate the risks of disasters, resulting in the loss of irreplaceable artistic and cultural assets. *Kampung* Ampel, as a cultural heritage area, has several cultural heritage objects that need to be preserved. The high number of fire incidents in the area becomes a challenge in preservation means. Therefore, spatial analyses to assess the risks and resources of the area to fire hazards need to be performed. The results of the analyses consist of challenges and possible solutions. The condition and challenges can be concluded as follow resources for firefighting cannot cover the entire area of *Kampung* Ampel. Resources for evacuation cannot accommodate all the population, including the visitors.

Reactivation of inactive fire wells owned by Surabaya City Fire Department is an effective solution for fire risk reduction because out of seven fire wells located in the vicinity of the Ampel area, three are active, while four are inactive. The existence of holy water inside the Ampel Mosque can be an alternative water resource to secure the area. However, since the Fire Department does not own it, the water resource volume in this mosque is unknown. Besides, it should also be investigated whether it is possible to be utilized in an emergency. Proposing wider road to connect roads which are wider than 3.5 meters but are blocked by narrower roads facilitates the accessibility of fire engines to get deeper into the site, thus expanding the coverage area of firefighting resources. The purchase of adapters to connect different types of fire hoses can be a very effective solution because it can expand the firefighting resources' coverage area. Previously, the number of fire hoses is only six units, but the number can be doubled to twelve units with the installation of adapters. Adding the number of fire hoses brought to the site can be an alternative strategy. Similar to the installation of fire adapters, an addition to the number of fire hose will definitely expand the coverage area of firefighting resources. To cover a wider area than installing adapters, the number of fire hoses ideally more than twelve units. Vulnerable buildings can be remodeling to make the building stronger using inflammable materials by keeping the cultural landscape's value. Preparing evacuation routes to the closest open space areas will illustrate which road is important for facilitation and maintenance to accelerate evacuation, especially for tourists. Facilitation can be done by providing signage, clearance path of illegal or non-permanent stalls, or route socialization.

The application of reactivation of inactive fire wells, utilization of water source from Ampel Mosque, and proposing wider roads for blocked roads can reduce the high-risk area from 26.6% (before application) to 16.6% (after application). The installation of a fire hose adapter and reactivation of inactive fire wells can reduce the high-risk area from 26.6% (before application) to 3.4% (after application). The installation of a fire hose adapter, reactivation of inactive fire wells, and water source utilization from Ampel Mosque can reduce the high-risk area from 26.6% (before application) to 0.2% (after application). Keeping a portable fire pump in Ampel Mosque can speed up the fire handling, which can be done by the residents.

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6. REFERENCES

Adi, Wahyu, T. J., & Mirnayani. (2013). *Probabilistic Modeling to Predict Fire Risk Using Hirid BBN-Kriging (219K)*. Konferensi Nasional Teknik Sipil 7 (KoNTekS 7).

Akasah, U. H. (2011). *Jejak Sejarah dan Budaya Kampung Arab (4)*. Retrieved from http://catatanakasah.blogspot.jp/2016/04/jejak-sejarah-dan-budaya-kampung-arab-4.html

Al-Irsyad. (2016). *Sejarah Rumah Sakit*. Retrieved from http://rs-alirsyadsurabaya.co.id/menu/konten/sejarah-rumah-sakit

Azad, T. A., Hasan, I., & Saha, M. K. (2018). *Risk of Fire Disaster : Consequences on Industry Sectors in Bangladesh*. (January).

BPS. (2015). Surabaya Dalam Angka Tahun 2015. *Surabaya: BPS Kota Surabaya*.

Coburn, A. W., Spence, R. J. S., & Pomonis, A. (1994). Mitigasi Bencana Edisi II-Program Pelatihan Managemen Bencana. *UNDP & DHA*.

IS. (2014). *Masjid Sunan Ampel*. Retrieved from http://inilahsurabaya.blogspot.jp/2014/04/masjid-sunan-ampel.html

Jigyasu, R., & Arora, V. (2014). *Disaster risk management of cultural heritage in urban areas: a training guide: a training guide for conducting courses in disaster risk management for cultural heritage in urban areas*. Kyoto, Japan: Research Center for Disaster Mitigation of Urban Cultural Heritage, Ritsumeikan University.

Latifah, R. N., & Pamungkas, A. (2013). Identifikasi Faktor-Faktor Kerentanan terhadap Bencana Kebakaran Hutan dan Lahan di Kecamatan Liang Anggang Kota Banjarbaru. *Jurnal Teknik POMITS*.

Mantra, I. B. G. . (2005). Kajian Penanggulangan Bahaya Kebakaran Pada Perumahan (Suatu Kajian Pendahuluan di Perumahan Sarijadi Bandung). *Jurnal Permukiman*, *3*(61).

Mappaturi. (2015). Konstruksi Ekologis Arsitektur Mesjid Ziarah Nusantara, Studi kasus: Mesjid Ziarah Ampel Surabaya. *Jurnal RUAS*, *13*(1), 14–25. [Crossref]

Miadinar, A. (2009). Wilayah Rawan Kebakaran di Kota Yogyakarta tahun 2008. *Universitas Indonesia*.

Moga, J. (2002). Disaster mitigation planning: the growth of local partnerships for disaster reduction. *Regional Workshop on Best Practices in Disaster Mitigation--Lessons Learned from the Asian Urban Disaster Mitigation Program and Other Initiatives*, 24–26.

Okubo, T. (2003). Proposal: Environmental Water Supply System (EWSS) for Protection of Cultural Heritage from Earthquake Fire. *Water and Cultural Diversity*, 103–112. Kyoto, Japan: United Nations Educational, Scientific and Cultural Organization.

Pedersoli Jr, J. L., & Michalski, S. (2016). *A Guide to Risk Management of Cultural Heritage*. Canada: ICCROM.

Price, O., & Bradstock, R. (2014). Landscape and Urban Planning Countervailing effects of urbanization and vegetation extent on fire frequency on the Wildland Urban Interface : Disentangling fuel and ignition effects. *Landscape and Urban Planning*, *130*, 81–88. [Crossref]

Rahman, N., Ansary, M. A., & Islam, I. (2015). GIS Based Mapping of Vulnerability to Earthquake and Fire Hazard in Dhaka City, Bangladesh. *International Journal of Disaster Risk Reduction*, *13*, 291–300. [Crossref]

Rahmawati, D., Pamungkas, A., Aulia, B. U., Larasati, K. D., Rahadyan, G. A., & Dito, A. H. (2016). Participatory Mapping for Urban Fire Risk Reduction in High-density Urban Settlement. *Procedia - Social and Behavioral Sciences*, *227*(November 2015), 395–401. [Crossref]

realita.co. (2014). *Di Ampel, Ada Hotel Kuno Rp 75 Ribu/Malam*. Retrieved from http://www.realita.co/di-ampel-ada-hotel-kuno-rp-75-ribumalam

Rijanto, B. (2010). *Fire and Building Planning*. Jakarta: Mitra Wacana Media.

Rusli. (2011). Faktor-Faktor Penentu dalam Analisis Sistem Proteksi Kebakaran dalam Suatu Kawasan (Studi Kasus: Kota Parigi) – [Determinants in The Analysis of Fire Protection Systems in An Area – Study Case: Parigi City]. *Jurnal SMARTek*, *Vol. 9*(No. 3), 196–211.

Sagala, S., Adhitama, P., & Sianturi, D. G. (2013). Analisis Upaya Pencegahan Bencana Kebakaran di Permukiman Padat Perkotaan Kota Bandung, Studi Kasus Kelurahan Sukahaji. *Resilience Development Initiative*.

Setiawan, B., & Wiguna, A. (2012). *Analisa Potensi Ancaman Kebakaran di Kawasan Permukiman Pesisir Kota Tarakan*. Online),(http://digilib. its. ac. id/public/ITS-Master-21737-chapter1pdf~….

Silas, J., Setyawan, W., Ernawati, R., & Okitasari, M. (2012). *Kampung Surabaya Menuju Abad 21 - Kajian Penataan dan Revitalisasi Kampung di Surabaya [The Kampungs of Surabaya Entering The 21st Century - Planning and Revitalization of Kampungs in Surabaya]*. Surabaya: Badan Perencanaan Pembangunan Kota - Pemerintah Kota Surabaya.

Sivakumar, C., Malathy, R., & Sivaprakash, P. (2018). A Study on Fire Safety on Residential and Commercial Construction Sites. *Archives of Civil Engineering*, *64*(2), 161–174. [Crossref]

Stovel, H. (1998). *Risk Preparedness: A Management Manual for World Cultural Heritage*. Via di San Michele 13, 00153, Rome, Italy: ICCROM.

Sujatmiko, R. (2012). Kejadian Kebakaran Permukiman Kota Bekasi Tahun 2010. *Universitas Indonesia*.

Sulistiowati, T. E. (2000). *Tinjauan Eksistensi Standar-Standar Proteksi Kebakaran Dan Penerapannya Dalam Mendukung Implementasi Peraturan Keselamatan Bangunan*. Retrieved from http://www.triekosulistiowati.com/2016/11/makam-muhammad-bin-idrus-alhabyi.html#

Suprapto. (2008). *Tinjauan Eksistensi Standar-Standar Proteksi Kebakaran Dan Penerapannya Dalam Mendukung Implementasi Peraturan Keselamatan Bangunan*. Bandung: Departemen Pekerjaan Umum.

surabaya.go.id. (2015). *Kunjungi Tempat Bersejarah, Peserta Ampels Heritage Walk 2015 Kenakan Kostum Pejuang*. Retrieved from http://www.surabaya.go.id/pemerintahan/7299-kunjungi-tempat-bersejarah,-peserta-ampels-heritage-walk-2015-kenakan-kostum-pejuang

Twigg, J., Christie, N., Haworth, J., Osuteye, E., & Skarlatidou, A. (2017). *Improved Methods for Fire Risk Assessment in Low-Income and Informal Settlements*. (February). [Crossref]