E3S Web of Conferences **359**, 02033 (2022)
ICENIS 2022
https://doi.org/10.1051/e3sconf/202235902033

Risk Level Fire Emergency Handling among Semarang Heritage Area

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Abstract. The revitalisation of Semarang Old Town is considered very necessary and has a positive value. It has a negative impact that must be handled. Revitalisation is expected to increase the tourist attractions of Semarang. In other words, the higher level of activity and occupancy that occurs in Semarang old city and without realising it, the higher the fire risk will happen in the Semarang Old City Area. This study aims to analyse the density of buildings related to fire handling risks and spatially based area fire risk analysis. The Fire Risk Index method was adopted from the ARICA method from Portugal to determine the level of fire risk. The FRI method is a simplification method of the ARICA method, which is devoted to cultural heritage buildings. The FRI method results in the form of the level of building risk, namely low, medium, high, to the extreme. The results of the FRI method and the analysis of building density are presented in the form of mapping using spatial data processing applications. The FRI method in the Old City area obtained the average building in medium and low-risk levels. The risk map gives rise to solutions and handling that can be applied to the region as appropriate disaster mitigation to continue realising an area safe from fire disasters.

1. Introduction

Semarang Old Town experienced a decline in its function as an administrative and financial center in 1980-1990. Since there was no activity, it was increasingly neglected and caused many problems. The problems that occurred were the building condition, socio-culture, environment, infrastructure, and the complexity of other problems. The Semarang Government has not stayed still, but has taken actions, one of which is planning for the revitalization of Semarang Old Town since 2003 to preserve historical buildings that have existed for a long time, revive the function of the old and neglected Semarang Old Town, and grow added value so as to increase its tourist attractions [1]. Although this revitalization is considered very necessary and has a positive value, it also has negative impacts that must be faced. One of the goals of revitalization is to increase tourist attraction, so it will attract many tourists to come to one of the tourist attractions in Semarang. In other words, the higher the level of activity and occupancy that will occur there and without realizing it, the higher the level of fire risk that will happen there.

Fires in Semarang Old Town area had occurred 18-21 times in the 2017-2021 period (BPBD of Semarang) according to Figure 1. It is in an area that is prone to fire incidents. The condition of the cultural heritage buildings consists mostly of wooden materials and is very old, so in the event of fires there, will be a quite high risk. These risks can include the rapid transmission of fire to other buildings, damage to cultural values, loss of property, and even fatalities.

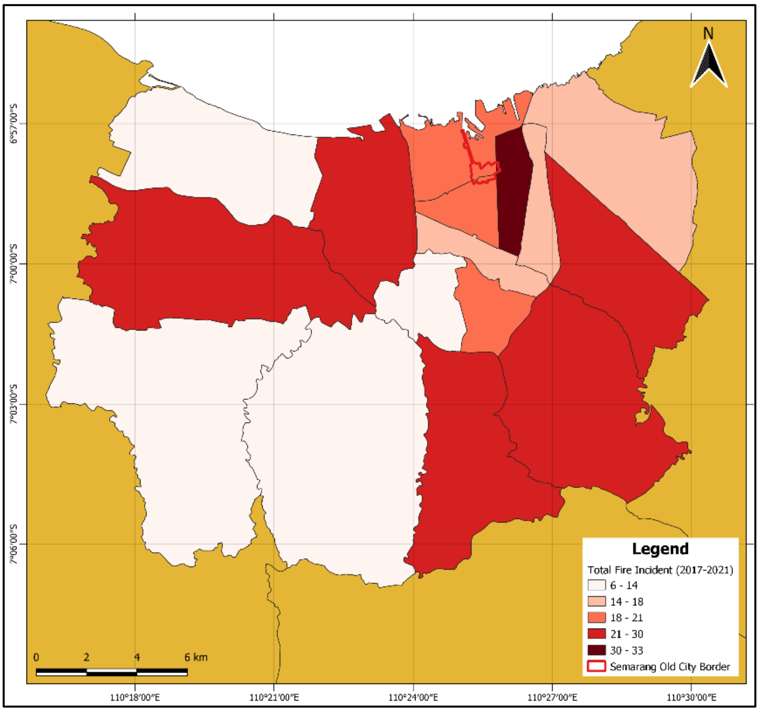

Fig. 1. Semarang Fire Incident Period 2017-2021

One way to avoid or reduce the risks that will occur is the implementation of an Early Warning System (EWS) as an effort to prevent fire disasters from getting bigger and worse. It is the provision of timely and effective information that enables people to take action to avoid or reduce risks that will occur [2]. Several forms of early warning systems include fire sensors, microcontrollers, and SMS gateways. Based on the field observations, Semarang Old Town area has not implemented an early warning system. This is something that needs attention from the Regional Government in the form of regulations regarding the provision of an Early Warning System (EWS) in order to protect the cultural heritage area in Semarang.

2. Research Methods

Fire is still the biggest threat to cultural heritage. The disaster can have an impact on the loss of historical significance in the cultural heritage area [1]. The loss of significance in historical areas will be difficult to restore to its original state.

Based on these problems, this study is conducted to analyze the density of buildings in Semarang Old Town related to the fire handling risks and assess the level of fire risks in the spatially based area. To answer the research objectives, it used the descriptive quantitative research method.

In this study, the data were in the form of primary and secondary data. The primary data were obtained through direct field observation for fire risk assessment and documentation, while the secondary data included spatial data in the form of maps equipped with supporting attributes for assessment and literature study. The spatial secondary data were obtained through One Map Semarang on the Semarang Spatial Planning Service (Distaru) website, Earth Explorer on the United States Geological Survey (USGS) website, and OpenStreetMap. The secondary data from the literature study were in the form of standards and regulations regarding the handling of regional fires and risk assessment.

2.1 Building Density Analysis

Normalized Difference Built-up Index (NDBI) is an algorithm to show the density of *bare soil* [4]. NDBI is very sensitive to built-up or bare soil by calculating multiband raster object to obtain raster with a density index value. The raster data were obtained through Landsat 8 satellite, each Landsat 8 image band has different uses and combinations that can suit the purpose of the analysis presented in table 1.

Table 1. Types and Uses of Bands on Landsat 8

Band	Wavelength (μm)	Use
Band 1 – Coastal Aerosol	0,43–0,45	Coastal/aerosol study
Band 2 – Blue	0,45–0,51	Bathymetric mapping, differentiation of soil from vegetation and miscarriage of canifers
Band 3 – Green	0,53–0,59	Bring up peak vegetation to assess plant health
Band 4 – Red	0,64–0,67	Distinguishing vegetation on slopes
Band 5 – Near Infrared (NIR)	0,85–0,88	Bringing up the biomass content and coastline
Band 6 – Short-wave Infrared (SWIR) 1	1,57–1,65	Distinguishing soil moisture and vegetation, breaking through thin clouds
Band 7 – Short-wave Infrared (SWIR) 2	2,11–2,29	Improved soil water content display, breaking through thin clouds
Band 8 – Panchromatic	0,50–0,68	Resolution 15 meters, sharp image
Band 9 – Cirrus	1,36–1,38	Detection of cirrus clouds with increased resolution
Band 10 – TIRS	10,6–11,19	Resolution 100 meters, thermal mapping and soil moisture forecast
Band 11 – TIRS 2	11,50–12,51	Resolution 100 meters, improved thermal mapping and soil moisture forecast

(Source: Dev Acharya *et al* [5])

 https://doi.org/10.1051/e3sconf/202235902033

Normalized Difference Built-up Index (NDBI) is used to detect building density conditions [6] through equation 1.

$$NDBI = \frac{(\rho_{SWIR1} - \rho_{NIR})}{(\rho_{SWIR1} + \rho_{NIR})} \quad (1)$$

The results of NDBI values are categorized based on Table 2.

Table 2. Categories of Building Density Level from Results of NDBI

Class	NDBI Value	Density Level
1	-1 < NDBI < 0	Bare soil
2	0 < NDBI < 0,33	Medium density
3	0,33 < NDBI < 1	High density

2.2 Fire Handling Risk Level Analysis

The methodology for analyzing the risk level carried out in this study was by using the ARICA method, in a simpler form. The simple ARICA method would form a value called *Fire Risk Index* (FRI). The original methodology is so complex that it makes the analysis much more strenuous and takes a very long time, without producing a significant improvement in the analysis. This has been proven in the research conducted by Vicente *et al.*, 2010. The factors in this FRI method consist of two types, including global risk factors and global effectiveness factors, and there are partial factors from ignition to fire extinguishing as shown in Table 3.

Table 3. Fire Risk Method: Global Factors, Sub-Factors, and Partial Factors

Global Factors	Sub-Factors	Partial Factors
Global Risk Factors (FGR)	Fire Ignition (SF_I) (FGII)	Building Conservation Status (A1) (FEC) Electrical installation (A2) (FIEL) Gas Installation (A3) (FIG)
	Fire Spread (SF_P) (FGDPI)	Vertical Facade Aperture Distance (B1) (FAV) Safety and Security Team (B2) (FES) Fire Detection, Warning and Alarm (B3) (FDI) Fire Compartment (B4) (FCCF) Fire Burden (B5) (FCI)
	Evacuation (SF_E) (FGEE)	Evacuation Route (C1) (FICE) Building Properties (C2) (FIE) Correction Factor (C3) (FC)
Global Efficiency Factors (FGE)	Fire Fighting (SF_C) (FGCI)	Outdoor Fire Extinguisher (D1) (FECI) Indoor Fire Extinguisher (D2) (FICI) Security Team (D3) (FES)

All sub-factors of global factors have the same weight in the FRI calculation, but due to the nature and cultural value in this study, greater attention is paid to reducing the likelihood of occurrence and spread of fires. Therefore, the fire ignition (SF_I) (FGII) and fire spread (SF_P) (FGDPI) sub-factors are given factor values of 1.20 and 1.10, respectively, while the building evacuation sub (SF_E) (FGEE) and firefighting (SF_C) (FGCI) sub-factors are given factor value of 1.00.

The formula of fire risk can be written according to equation 2:

$$\text{Fire risk} = \frac{\frac{(1.20\ x\ SF_I + 1.10\ x\ SF_P + SF_E + SF_C)}{4.0}}{FR_R} \quad (2)$$

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Reference Risk Factor (FRR) is obtained from the consideration of the use of the building and the number of floors in the building, the FRR calculation for the current building can be written according to equation 3:

$$FRR = 0.915 + 0.25 \times F_C^* \quad (3)$$

For industrial buildings, warehouses, libraries, and archives, equation 4 is used:

$$FRR = 1.10 + 0.25 \times F_C^* \quad (4)$$

$^*F_C$ = Correction Factor (Number of floors of the building (C3))

From the fire risk method that has been used in accordance with the above formula, it obtained a value that became the risk level of a building. The limits of the FRI value used are low (0,60–1,00), medium (1,01–1,30), high (1,31–1,65), and extreme (1.66–2.00). If the FRI value is >1.00, the action that must be taken is to minimize the fire risk by complying with applicable requirements. On the other hand, if the FRI value is <1, then the building does not pose a significant problem and complies with the requirements.

The ARICA method cannot evaluate several buildings such as empty or unoccupied buildings, places of worship, and buildings with very low occupancy rates [7] since it includes activities and occupancy in the building.

3. Results And Discussion

3.1 Building Density Analysis

Based on the results of the NDBI raster calculation, Semarang Old Town does not have an area with a high level of building density category with the highest NDBI value of 0.166 which is included in the medium density category. The highest building density is spread in the central location of Semarang Old Town, Tawang Station, and Marabunta. The location of the center of Old Town is the core zone as specified in the Regional Regulation of Semarang Number 2 of 2020 concerning Old Town Building and Environmental Site Plan. The identification of the highest building density is also presented visually in Figure 2.

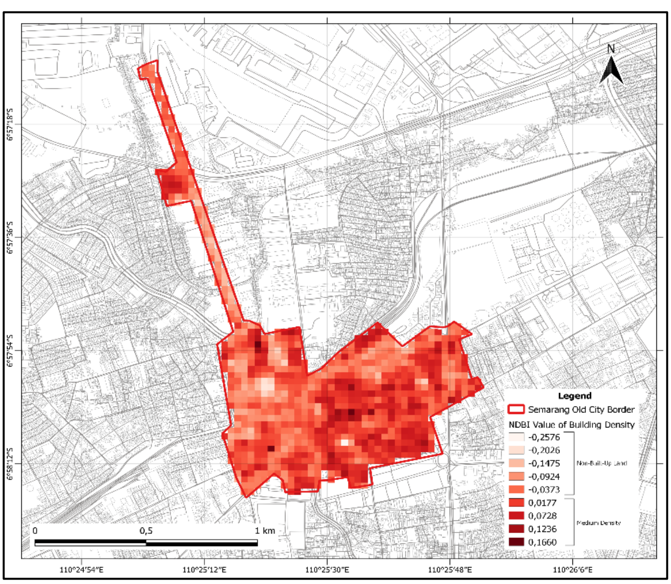

Fig. 2. Identification of Highest Density Location in Old Town Area

3.2 Fire Handling Risk Level Analysis

From the results of risk identification conducted with a field survey of 116 buildings, it obtained buildings with low, medium, to high-risk levels. The number of buildings that can be evaluated is 52 buildings and the remaining 64 buildings cannot be evaluated. The 64 buildings not evaluated are empty or unoccupied buildings, places of worship, and places that do not get a survey permit from the building owner. There are three categories of building that can be evaluated: 14 buildings with low fire risk, 37 buildings with moderate fire risk, and 1 building with high fire risk. The results of identification and calculations are presented in the form of a map according to Figure 3.

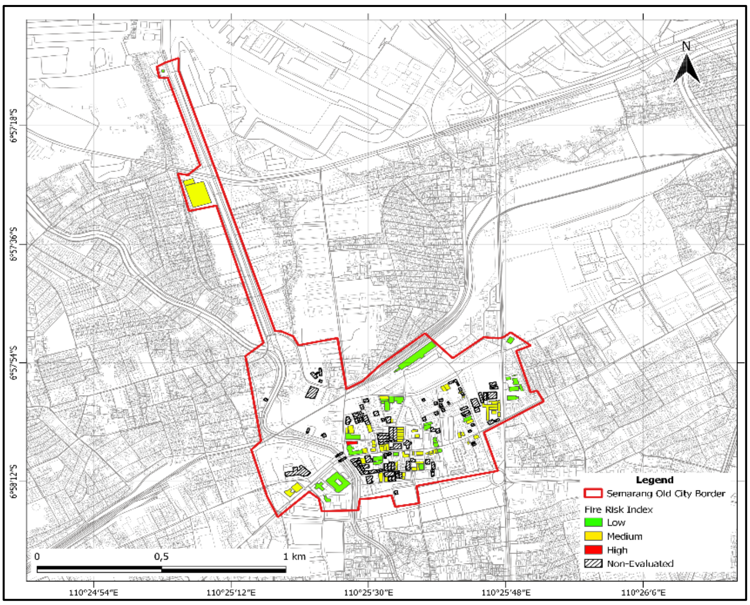

Fig. 3. Identification Mapping of FRI Value in Semarang Old Town

Based on Figure 3, it is found that the building with a high-risk level is PT. Djakarta Lloyd, and the result of FRI calculation is 1.32. The FRI calculation of PT. Djakarta Lloyd obtains the largest average result in the fire suppression sub-factor in the global efficiency factor, so it can be concluded that the handling or control of fire disasters can be minimized by reducing the number of this sub-factor. Disaster control is by procuring fire extinguishers with a minimum number of building floors. Some buildings with a moderate risk level have various sub-factor average scores, fire control can be applied according to the largest value of each partial factor. Fire control is applied to several sub-factors with various considerations, such as costs, building conditions, etc.

3.3 Evaluation of Old Town Area Handling

The map of fire risk level using FRI method obtained previously is then processed into raster data that show the overall risk level of Semarang Old Town Area with IDW interpolation. The interpolation produces a map of the distribution of the fire risk level as shown in Figure 4. The fire risk level map is then overlaid with the results of the road access analysis and compared with the map resulting from the analysis of building density.

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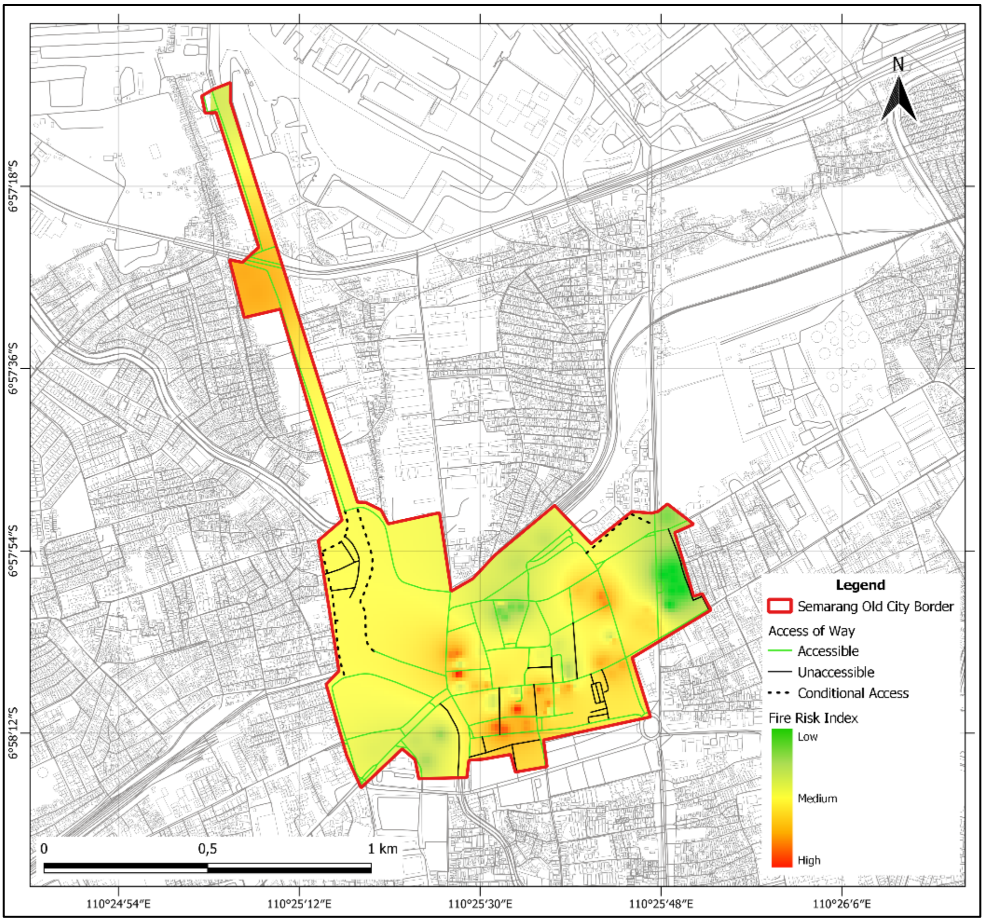

Fig. 4. Comparison of Building Density Analysis and Fire Risk Level of FRI Method

4 Conclusion

The conclusions obtained in answering the research objectives based on the results of the analysis and discussion regarding the fire handling risks in the cultural heritage area of Semarang Old Town are:

- The results of building density analysis using spatial data processing by means of NDBI method obtain several locations that have fairly high density level, including the core zone of Semarang Old Town, the southern part of the buffer zone of Semarang Old Town, Tawang Station, Sleko Street, and Marabunta. The core zone and buffer zone are the zoning of Semarang Old Town site which is determined in the Regional Regulation of Semarang Number 2 of 2020. The areas with a high building density, after being compared with DAMKAR vehicle access road, are areas at risk of being inaccessible, including the southern part of the buffer zone of Semarang Old Town and Sleko Street.
- It is found that there are many areas with moderate and high risk levels in Semarang Old Town based on the results of FRI analysis. Only a few areas are found to be of low risk, such as Saint Joseph Catholic Church Complex, the building on the southern of Pemuda Street (State Finance Building, *Pos Indonesia*, and *Telkom* Johar), and Prau Ladjar Cigarette Factory. The majority of areas with high fire risk level are located on the southern part of the buffer zone of Semarang Old Town which has several roads that

cannot be accessed by DAMKAR vehicles. Kampung Melayu area is also at risk because it has a moderate risk level with roads with conditional access due to road repair works.

Thankful to Diponegoro University for research funding Scheme of Research Development and Implementation (RPP) Year 2022, Basic Research Contract Number 185-47/UN7.6.1/PP/2022.

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