

Analysis of Fire Risk Level in Demak District Using Analytical Hierarchy Process (AHP) Method

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Received: 03 July 2025; Revised: 02 April 2026; Accepted: 09 September 2026

How to cited this article:

Dewi, S.A.R., Priyanto, B., Amar, T.I.K., Maghfuri, S., (2026). Analysis of Fire Risk Level in Demak District Using Analytical Hierarchy Process (AHP) Method. Jurnal Teknik Sipil, 22(2), 343–355. <https://doi.org/10.28932/jts.v22i2.12419>

ABSTRACT

Demak District in Demak Regency is a city central area that has a high number of fire incidents compared to other districts. Many causes of fires occur due to electrical short circuits, gas leaks, and illegal waste burning. It is necessary to create a map of the fire risk level of Demak District as one of the efforts to overcome fire disasters. There are three parameters in the process of determining the level of fire risk, namely hazard, vulnerability and capacity. Data processing is carried out using the Analytical Hierarchy Process (AHP) method to determine the weight of each variable and utilizes ArcGIS software to create the map by using Overlay tools. Based on the analysis, the variable with the highest weight of each parameter namely the variable of open fire use from the hazard parameter with a weight of 63.33%, building density from the vulnerability with a weight of 49.09%, and fire training and outreach from the capacity with a weight of 61.94%. From the results of data processing on hazard, vulnerability, and capacity parameters, the fire risk level in Demak District shows that there is 1 high-risk area, namely Mulyorejo Village, 8 moderate-risk villages/sub-districts, and 10 other villages with low risk. Therefore, Demak District needs the design or improvement of regional and urban spatial planning systems, as well as the need for the addition of hydrant points or water sources is very important for fire prevention and handling.

Keywords: AHP, Fire, Risk, ArcGIS, Demak District.

ABSTRAK. Analisis Tingkat Risiko Bencana Kebakaran di Kecamatan Demak Menggunakan Metode Analytical Hierarchy Process (AHP). Kecamatan Demak di Kabupaten Demak merupakan daerah pusat kota dengan angka kejadian kebakaran yang tinggi dibanding kecamatan lainnya. Penyebab kebakaran banyak terjadi karena konsleting listrik, kebocoran gas, serta pembakaran sampah sembarangan. Diperlukan pemetaan tingkat risiko bencana kebakaran di Kecamatan Demak sebagai upaya penanggulangan bencana kebakaran. Terdapat tiga parameter dalam proses menentukan tingkat risiko kebakaran yaitu ancaman, kerentanan, dan kapasitas. Pengolahan data dilakukan dengan metode Analytical Hierarchy Process (AHP) untuk mengetahui bobot tiap variabel dan memanfaatkan software ArcGIS untuk memetakan dengan menggunakan tools Weight Overlay. Berdasarkan analisis, variabel dengan bobot tertinggi dari setiap parameter: variable penggunaan api terbuka dari parameter ancaman dengan bobot 63,33%, kepadatan bangunan dari parameter kerentanan dengan bobot 49,09%, sosialisasi dan pelatihan dari parameter kapasitas dengan bobot 61,94%. Dari hasil pengolahan data parameter ancaman, kerentanan, dan kapasitas, tingkat risiko kebakaran di Kecamatan Demak menunjukkan terdapat 1 daerah berisiko tinggi yaitu Desa Mulyorejo, 8 desa/kelurahan berisiko sedang, dan 10 desa lainnya memiliki risiko rendah. Oleh karena itu, Kecamatan Demak memerlukan perancangan atau perbaikan sistem tata ruang wilayah dan kota, serta perlu penambahan titik hidran atau sumber mata air yang sangat penting untuk pencegahan dan penanganan kebakaran.

Kata kunci: AHP, Kebakaran, Risiko, ArcGIS, Kecamatan Demak.

1. INTRODUCTION

A disaster is an event or series of events that threatens and disrupts people's lives and livelihoods (Undang Undang Nomor 24 Tahun 2007 concerning Disaster Management). Based on data from the Pusiknas Bareskrim Polri (2024), fire is the most frequent disaster in Indonesia, recorded from January to early October 2024 as many as 935 cases. In Indonesia, fire disasters often occur on land, forests, industrial areas or densely populated residential areas. According to Rigen in Mustofa et al., (2022), fire is a natural disaster as well as a non-natural disaster due to the emission of fire or due to an uncontrollable explosion that has the potential to cause major losses both in terms of property, and environmental damage, and even can endanger human lives. Fires can occur due to several factors, namely natural disasters, as well as non-natural disasters such as man-made disasters. Natural factors can result from drought due to prolonged dry seasons, volcanic eruptions, or due to lightning strikes. For non-natural factors themselves, it can occur due to human negligence such as littering cigarette butts, illegal burning of wild land, gas leaks, electrical short circuits and many more.

Urban/residential fires generally occur in urban areas that have dense settlements or slums, because the condition of the buildings is not well organized (Kaswara, 2020). Demak Regency, as a region that continues to develop, is not exempt from the risk of fires that can threaten the safety and welfare of its people. There are 14 districts, 6 sub-districts, and 243 villages in Demak Regency which every year are increasingly densely populated by people and new buildings such as settlements, shopping places and other facilities. With rapid population growth and accompanied by the increasing number of residential areas, especially in dense urban areas, fire management facilities are often not in line with the rate of population growth. Therefore, proper fire equipment and fire station facilities with competent officers are needed, especially in urban areas such as Demak District in Demak Regency because they are more vulnerable to fire disasters.

Based on fire incident records from the Polisi Pamong Praja Unit of Demak Regency over the past 5 years, it is known that 2023 is the year with the most incidents, namely 40 fire cases occurred in Demak District. Meanwhile, the smallest number of cases occurred in 2020 with a total of 8 cases in Demak District out of a total of 72 cases throughout Demak Regency. For 2024, there have been 21 cases of fires in Demak District. In the incident record data, many fires occurred due to electrical short circuits in residential houses or stalls/shops, gas leaks and the waste burning that burned a lot of land and surrounding buildings. The lack of hydrant points is one of the obstacles that is quite big when there is a large fire case in Demak District. For this reason, the role of the government is urgently needed in tackling and dealing with this fire disaster, considering the many fire incidents in the Demak District area.

Based on the background, it is known that Demak District has a high frequency of fires. The analysis of fire risk needs to be carried out to find out the level of fire risk in Demak District and what factors affect the fire risk in Demak District.

2. METHODOLOGY

The research was conducted in Demak District in Demak Regency, Central Java. The area of Demak District is 61.56 km² or 6.81% of the Demak Regency area that has 13 villages and 6 sub-districts with the largest region is Turirejo Village (6.28 km²) and the smallest is Singorejo Sub-district (0.87 km²) (BPS, 2024). Figure 1 is the research location.



Figure 1. Research Area (DINPUTARU, 2025)

This research used Analytic Hierarchy Process (AHP) as the method that consisted of quantitative and qualitative data from 2023. According to BNPB Regulation Number 2 of 2012, Analytic Hierarchy Process (AHP) is a measurement methodology through pair-wise comparisons and relies on the assessment of experts to obtain a priority scale. AHP will determine the priorities among the decision criteria when establish within a goal (Salsabila & Anggraeni, 2023). The advantages of this method are flexible, systematic, allows the incorporation of subjective judgment in decision-making with objective data, and the concept is relatively easy to understand and implement.

The data were collected from several agencies such as the Fire Department, namely data of fire incident records, fire station distance, hydrant distance, and fire training and outreach. Data from the Central Bureau of Statistics are the percentage of building quality, population density, and poverty rate ratio. Data from the Office of Public Works and Spatial Planning of Demak Regency such as building density, and qualitative data. The qualitative data is the spatial data of regional administrative boundaries.

Research steps as shown in Figure 2. The first step of AHP process is to create a hierarchy where the goal achieved in this research is to determine the level of fire risk. After that, collect all the required data to achieve the main goal based on a combination of the main criteria factors, namely hazard, vulnerability, and capacity. Each criterion has several sub-criteria such as electricity, stove, open fire use, building density, building quality, population density, poverty rate ratio, distance of fire stations, hydrant distance, and fire training and outreach. The next step is to work on weighting on each criterion.

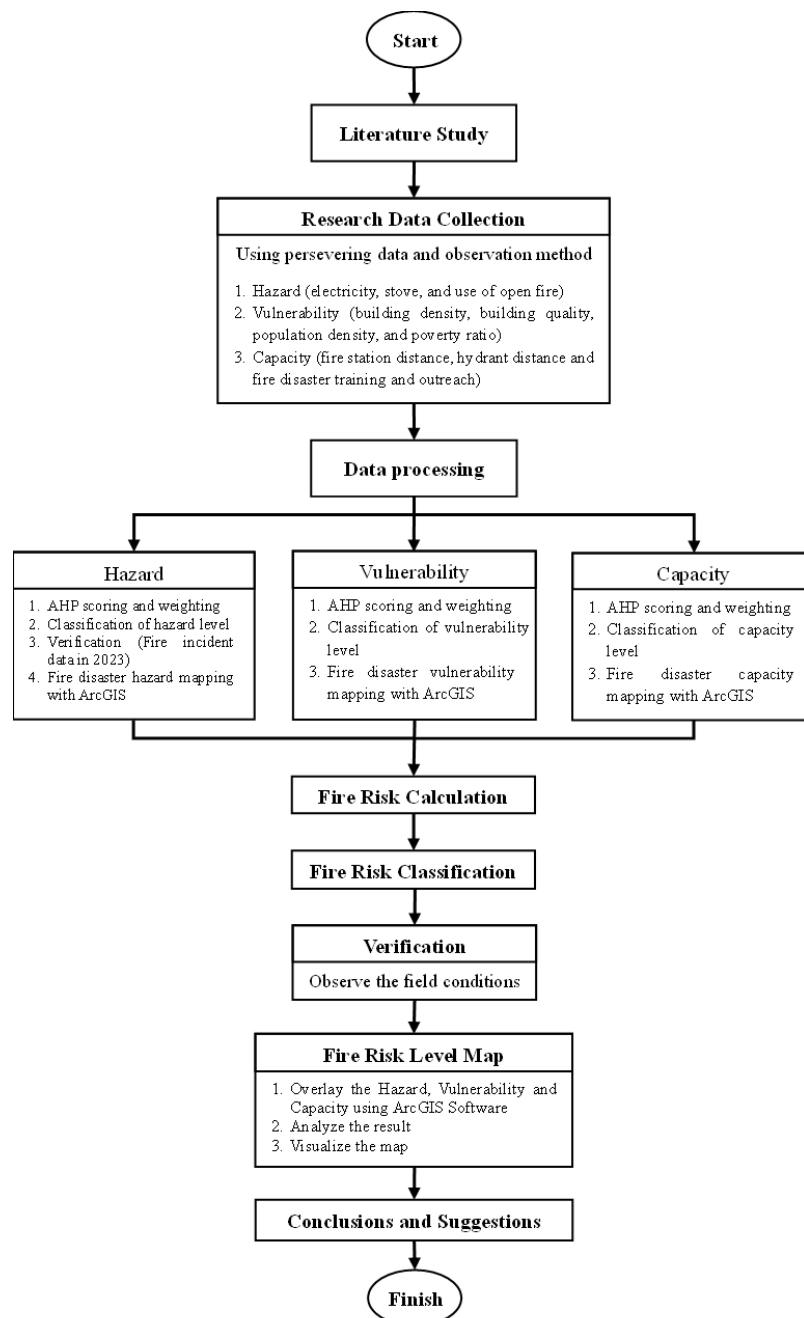


Figure 2. Research Flow Chart

Data processing is carried out in each village and sub-district in Demak District using Microsoft Excel. The risk value based on BNPB Regulation Number 02 of 2012 can be calculated with Formula (1).

$$\text{Risk} = \text{Hazard} \times \frac{\text{Vulnerability}}{\text{Capacity}} \quad (1)$$

Weighting and scoring processing are needed to then be visualized in the form of a map. The mapping was created using ArcGIS 10.8 software with the Weighted Overlay tool.

3. RESULTS AND DISCUSSION

3.1 AHP Weighting Results

The processing of AHP weighting data for each parameter is carried out with Microsoft Excel software with three parameters, namely hazard, vulnerability and capacity. To qualify, the Consistency Ratio (CR) value < 0.1, thus the value is declared to be consistent.

Variables used in the hazard parameter are electricity, stove, and the use of open fires, these three variables are the cause of the most cases of fire incidents in the regency. In Table 1 shows the results of the AHP weighting on the hazard parameter. The variable with the highest weight, which is 63.33%, is the use of open fires because there are 19 cases caused by it in Demak District. Furthermore, there is an electricity variable with a weight of 26.05% with 5 cases and the smallest is a variable stove of 10.62% with 3 cases.

Table 1. AHP Hazard Calculation Results

Hazard Variable	Weight (%)
Electricity	26.05
Stove	10.62
Use of Open Flame	63.33

Vulnerability is a condition that can occur caused by human factors, so that in the management of the vulnerability value calculation four variables are used, namely building density, building quality, population density and poverty rate ratio. In Table 2 that from the results of the calculation of the AHP weighting of vulnerability. The building density has the largest weight, which is 49.09%, followed by population density with 29.13%, building quality with 15.07% and poverty rate ratio with 6.70%.

Table 2. AHP Vulnerability Calculation Results

Vulnerability Variables	Weight (%)
Building Density	49.09
Building Quality	15.07
Population Density	29.13
Poverty Rate Ratio	6.70

There are three variables used in the capacity parameter, namely the distance of the fire station, the distance of the hydrant, and fire training and outreach. In Table 3 the largest weight in the capacity parameter is 61.94% which is the weight of the training and outreach variable, then there is the variable distance of the fire station with a weight of 28.42% and the smallest is the distance of the hydrant with a weight of 9.64%.

Table 3. AHP Capacity Calculation Results

Capacity Variable	Weight (%)
Fire Station Distance	28.42
Hydrant Distance	9.64
Training and Outreach	61.94

The CR values of each parameter are presented in Table 4 where all values have qualified because the value is < 0.1 so that all values are consistent and do not need to be re-judged.

Table 4. CR Value

Parameter	CR
Hazard	0.033
Vulnerability	0.074
Capacity	0.075

3.2 Scoring and Mapping

Scoring is carried out to find out the grade level of each parameter in the village/sub-district. The class level in each parameter is divided into 3 classes, namely low with a score of 1, moderate with a score of 2, and high with a score of 3. Then, mapping is carried out using the calculation of the weight and score of each variable in all parameters with Overlay. After knowing the score of each variable and getting the results of the fire risk level, the next step is creating the maps using ArcGIS 10.8 software with the Weighted Overlay tool.

Hazard

Variables in hazard parameters in the processing of hazard weighting data include variables with categories related to community activities in the area that can trigger fires. Scoring is carried out to get the level of each parameter in the village/sub-district. The class level in each parameter is divided into 3 classes, namely low with score 1, moderate with score 2, and high with score 3. The class interval of the Hazard parameter can be obtained from the most common causes of fires in 2023. Table 5 shows the interval scoring class of hazard.

Table 5. Hazard Score Interval

Variable	Weight (%)	Hazard Score Class		
		Low (1)	Moderate (2)	High (3)
Electricity	26.05	Avoided	The transformer exploded	Electrical short circuit
Stove	10.62	Avoided	Furnace fire	Gas leaks
Use of Open Fire	63.33	Avoided	Land fires	Building fires

From Figure 3, the level of fire Hazard is obtained through the combination of variable values of electricity, stoves, and the use of open fire. From the data processing, it was obtained that Demak District was dominated by moderate hazard level because there were fire incidents in the areas. As for areas with low hazard level, it means that there are no cases of fire incidents according to the variables that occurred throughout 2023 in these areas.

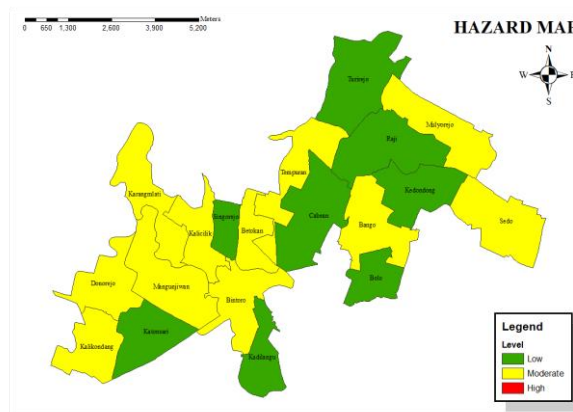


Figure 3. Map of Fire Hazard

Vulnerability

Before making the mapping, the thing that must be done is to determine the score of each vulnerability variable. In the vulnerability parameter, the interval number is obtained from the data of each district in Demak Regency to find a value range using Formula (2).

$$\text{Value range} = \frac{\text{Highest Value} - \text{Lowest Value}}{\text{Number of criteria}} \quad (2)$$

Then to get the classes value where 1 (low) = lowest value + value range, 2 (moderate) = low + value range, and 3 (high) = moderate + value range. Table 6 displays the vulnerability scoring class interval.

Figure 4 is the result of vulnerability mapping obtained by the combination scores and weight of building density, building quality, population density, and poverty rate ratio. Many areas have a high level of vulnerability cause by high scores on the variable with the largest weight, namely building density. Meanwhile, there are only 2 villages with a low level, namely Raji and Sedo which have a moderate and low level of building density and population.

Table 6. Vulnerability Score Interval

Variable	Weight (%)	Vulnerability Score Class		
		Low (1)	Moderate (2)	High (3)
Building Density	49.09	< 394 units/km ²	394-573 units/km ²	> 573 units/km ²
Building Quality	15.07	> 75% consists of permanent buildings	40-75% consist of permanent buildings	< 40% consists of permanent buildings
Population Density	29.13	< 1213 people/km ²	1213-1766 people/km ²	> 1766 people/km ²
Poverty Ratio	6.07	< 1.642	1.642-2.553	> 2.553

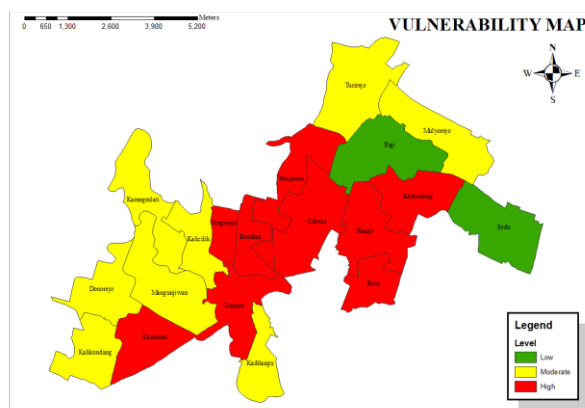


Figure 4. Map of Fire Vulnerability

Capacity

The scoring on the capacity parameter consists of 3 variables, namely, the distance of the Fire Station, the distance of the hydrant, and training and outreach. In the capacity parameter, the interval is obtained based on Peraturan Menteri PUPR No 20 of 2009, SNI and NFPA regulations. Table 7 showing the scoring intervals of capacity.

Table 7. Capacity Score Intervals

Variable	Weight (%)	Capacity Score Class		
		Low (1)	Moderate (2)	High (3)
Fire Station Distance	28.42	> 7500 meters	2500-7500 meters	< 2500 meters
Hydrant Distance	9.64	> 50 m	38-50 m	< 38 m
Training and Outreach	61.94	No	-	Yes

Figure 5 shows that the capacity level in Demak District is dominated by villages/sub-districts with a high level. The capacity level is obtained from a combination of 3 variables, namely the station distance, hydrant distance, and fire training and outreach. For areas that have a high level of capacity because the distance of the fire station is not more than 7.5 km. As for areas with a moderate level of capacity, there is only one area, namely Kedondong Village. The areas with low capacity are in Mulyorejo, Raji, Sedo and Turirejo Villages. The low capacity is caused by the distance of fire stations being far from the area, lack of hydrant facilities, and lack

of outreach and fire training in the area.

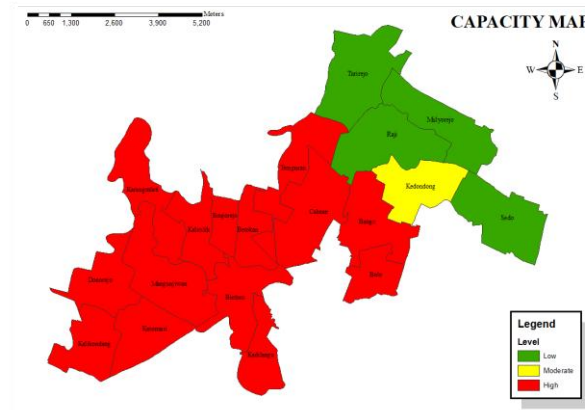


Figure 5. Map of Fire Capacity

Fire Risk

After calculating the final values of each parameter, then calculate the risk with Formula (1). The hazard, vulnerability, capacity, and risk value can be seen in Table 8.

Table 8. Risk Level Assessment

Village/Sub-district	H	V	C	Risk	Level
Bango	2.15	2.56	2.52	2.19	Moderate
Betokan	1.63	2.56	2.52	1.66	Moderate
Bintoro	2.37	2.56	2.81	2.17	Moderate
Bolo	1.00	2.56	2.52	1.02	Low
Cabean	1.00	2.56	2.52	1.02	Low
Donorejo	1.52	2.34	2.52	1.41	Low
Kadilangu	1.00	2.27	2.52	0.90	Low
Kalicilik	1.63	1.78	2.52	1.15	Low
Kalikondang	2.15	2.07	2.52	1.77	Moderate
Karangmlati	1.52	1.85	2.52	1.11	Low
Katonsari	1.00	2.56	2.52	1.02	Low
Kedondong	1.00	2.56	2.24	1.15	Low
Mangunjiwan	2.48	2.07	2.52	2.04	Moderate
Mulyorejo	1.63	1.85	1.00	3.02	High
Raji	1.00	1.49	1.00	1.49	Low
Sedo	1.63	1.00	1.00	1.63	Moderate
Singorejo	1.00	2.56	2.52	1.02	Low
Tempuran	2.27	2.56	2.52	2.30	Moderate
Turirejo	1.00	1.78	1.00	1.78	Moderate

From the calculation above, it is known that villages and sub-districts in Demak District are dominant with low fire risk because many areas do not have fire cases and have high of capacity values which result in low risk level.

There are 8 villages and sub-districts that have a moderate risk level consisting of Bango, Betokan, Bintoro, and Tempuran which have been identified due to the area has 1 or more fire incidents, with estimated losses of approximately from a minimum of 2 million to a maximum of more than 70 million rupiah and have a high vulnerability value. Kalikondang and Mangunjiwan have a moderate vulnerability value with 5 and 8 cases of fire incidents in total, with one of which resulted in estimated losses of approximately exceeding 300 million rupiah, then Sedo and Turirejo because both areas have low-capacity value. Furthermore, Mulyorejo Village is the only area with a high risk of fire level because Mulyorejo Village has a history of fire incident, and has a moderate vulnerability value, but gets a small capacity value because of the remote locations of these areas from fire stations, a lack of hydrant facilities, and insufficient fire safety awareness programs so that the risk value of the area is high.

The risk is obtained after all the values of the hazard, vulnerability, and capacity parameters are known. The higher the hazard value, the greater the potential for dangerous events, then the higher the vulnerability, the easier it is to cause losses if a disaster occurs, and the greater the capacity, the smaller the risk because there is the ability to reduce the impact of fire. Figure 6 is a mapping of the fire risk assessment obtained from the hazard, vulnerability, and capacity combined values.

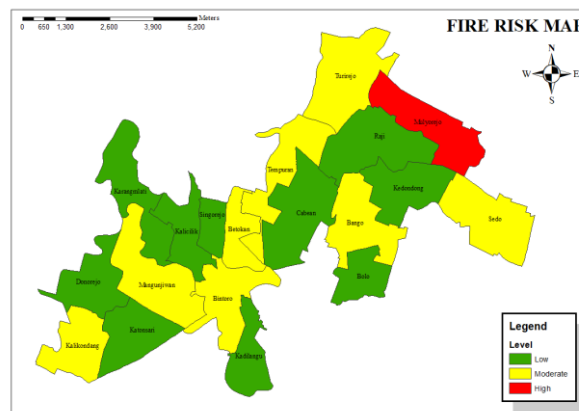


Figure 6. Risk Map

It is known that hazard will not pose a risk if there is no vulnerability, and vulnerability is not a problem if there is no hazard, and capacity is a factor that reduces the impact of the hazard. The greater the capacity, the less risk is generated even though hazard and vulnerability are high.

After the calculation of the fire risk value and mapping that shows on Figure 6, it is known that Demak District has various levels of fire risk. The domination of low fire risk level in 10 villages/sub-districts of 2023, makes Demak District tend to be at low risk level of fire, this is because some these areas have a few records of fire incidents or even didn't have any of it, and

these areas have access quite close to fire station also have been equipped with fire training even though they do not have hydrant facilities.

Among 19 villages and sub-districts in Demak District, there is 1 area that has a high risk of fire, that is Mulyorejo Village. It is because Mulyorejo has a history of a fire incident and has a low level of capacity so that it requires a lot of attention in capacity aspects such as, the distance to the fire station being quite far, no hydrant points, as well as the lack of fire training and outreach. Later, the remaining villages/sub-districts have moderate risk level. There are 8 villages/sub-districts that are at moderate risk, namely Bango, Bintoro, Betokan, Kalikondang, Mangunjiwan, Sedo, Tempuran. and Turirejo. These areas have a high density of buildings and populations with several records of fire cases even though they have already given fire training and outreach and are in areas that tend to be close to fire stations. Therefore, the areas have a moderate level of fire risk.

4. CONCLUSION

Based on the research that has been carried out regarding the risk of fire in Demak District, it is concluded that the factors that affect the level of fire risk in Demak District include, hazard, vulnerability, and capacity factors. In the hazard parameters, the variable of open fire use had the highest weight of 63.33%, followed by electricity and stoves. In the vulnerability parameter, the building density was more dominant than the other variables with a weight of 49.09% followed by the variables of population density, building quality, and poverty rate ratio. Meanwhile, in the capacity parameters, the variables of fire outreach and training was more dominant compared to other variables with a weight of 61.94%, followed by the distance of the fire station, and the distance of the hydrant.

After processing and combining the value of hazard, vulnerability, and capacity, the fire risk level of Demak District was obtained which showed that there was 1 area that had a high fire risk, namely Mulyorejo Village. Mulyorejo has a history of a fire incident and has a low level of capacity so that it requires a lot of attention in capacity aspects such as, the distance to the fire station being quite far, no hydrant points, as well as the lack of fire training and outreach. Then there are 8 villages and sub-districts with a moderate level, namely Bango, Bintoro, Betokan, Kalikondang, Mangunjiwan, Sedo, Tempuran, and Turirejo, as well as the dominance of low fire risk levels in 10 other villages.

From the analysis and discussion that has been conducted, Demak District need to redesign or improve regional and urban spatial systems, and the government can perform additions and periodic maintenance of hydrant points or water sources that are very important for fire prevention and handling. For future research, it is possible to add more research variables and

use different analysis methods to find the fire risk level in urban areas to decide which method has the best analysis. Then can use other software besides Microsoft Excel in weighting calculations and can use other software besides ArcGIS to create the maps.

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