NON-MEDICAL RISK ASSESSMENT OF COVID-19 IN PARTS OF CENTRAL AND EAST JAVA, INDONESIA

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Abstract: The impact of the Coronavirus disease 2019 (COVID-19) pandemic varies as each country has a different capacity to stop the virus transmission and apply social distancing. A densely populated country, such as Indonesia, tends to face challenges in implementing social distancing due to population characteristics. The Indonesian government focuses on the medical aspect as this virus is new and has been deadly with a high transmission rate. Meanwhile, the non-medical risk during the pandemic is still unclear. The main objective of this study is to assess the non-medical risk at the village level in two agglomeration cities of Central Java: Greater Surakarta and Surabaya. The methodologies use a risk index, derived from the risk reduction concept. The hazard refers to the death toll, while the vulnerability relates to parameters such as disaster, social and public facilities, health facilities, economics and demography. Further, the parameters were weighted based on expert judgement derived using analytical hierarchy process (AHP). The study found that the disaster aspect had the highest weight (0.38), followed by health facilities (0.31), economics (0.17), social-public facilities (0.11) and demography (0.04). The standard deviations of those parameters were relatively low, between 0.12 and 0.25. A low vulnerability index (0.05–0.36) was observed to be dominant in both study areas. There are 11 villages in Greater Surakarta and 30 villages in Greater Surabaya with high vulnerability index. Disaster-prone areas, low economic growth, lack of health facilities and aged demographic structure significantly added to this vulnerability. Further, a high-risk index (0.67–1.00) is observed in three villages in Greater Surabaya and one village in Greater Surakarta. These villages are relatively close to the city centre and have good accessibility. Furthermore, these four villages experienced the severest impact of the pandemic because the furniture and tourism sectors were their primary industries.

Keywords: COVID-19 pandemic, Central and East Java Indonesia, non-medical risk, analytical hierarchy process

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Introduction

Severe acute respiratory syndrome Coronavirus 2 (SARS-CoV-2), a newly detected infectious Coronavirus which causes Coronavirus disease 2019 (COVID-19), was discovered in Hubei-Wuhan, China, in December 2019 and has spread rapidly across China and to other countries around the world since then (Kabir et al. 2020, Mofijur et al. 2020, Zhou et al. 2020). Like the previous most similar viruses [responsible for causing severe acute respiratory syndrome (SARS) and Middle East respiratory syndrome (MERS)], COVID-19 is a dangerous virus causing pneumonia-like symptoms (Heymann 2020, Holshue et al. 2020). Furthermore, COVID-19 has a rapid transmission rate with both local or international high migration and mobility. As a result, a month after being found in Wuhan, China, there were at least 32 positive cases in China, Hongkong, Macau and Taiwan (US Centers for Disease Control and Prevention 2020). In January 2020, the number of positive cases in China reached 835 with a death toll of around 25 people, and >90% of the patients had undergone intensive medical treatment and monitoring in the referral hospitals.

The virus spread rapidly through droplets and direct contact with COVID-19 positive suspects. Hundreds of thousands of new positive cases associated with COVID-19 have been identified in several countries. The onset of COVID-19 infections started late in Indonesia compared to the other neighbouring countries, such as Malaysia, Thailand, Vietnam, Singapore and Australia. In January 2020, COVID-19 started to spread to Thailand, Vietnam, Singapore and Malaysia. Meanwhile, COVID-19 infected Jakarta, Indonesia, in early March 2020. The first case in Indonesia was confirmed in Depok, Jakarta.

Similar to other countries, the number of people infected by COVID-19 increased exponentially. However, in November 2020, the COVID-19 positive case in Indonesia decreased around 17.1% from the previous week (October 2020). The total number of cumulative cases of COVID-19 was around 412,784. The total number of recovered people was 341,942 or around 82.8%, and the accumulative death toll in Indonesia was around 13,943 people (3.4%). The positive cases were mainly located in several provinces in Indonesia, such as DKI Jakarta, East Java, Central Java, West Java and South Sulawesi. The summary of the COVID-19 outbreak in Indonesia can be seen in Figure 1.

Many research undertakings have been carried out successfully in early January until now in both the medical and non-medical aspects of COVID-19. In terms of the medical aspect, most research tried to discover and develop a vaccine for COVID-19 and to reconstruct the transmission methods to reduce virus transmission. Jeyanathan et al. (2020) discussed a strategy that

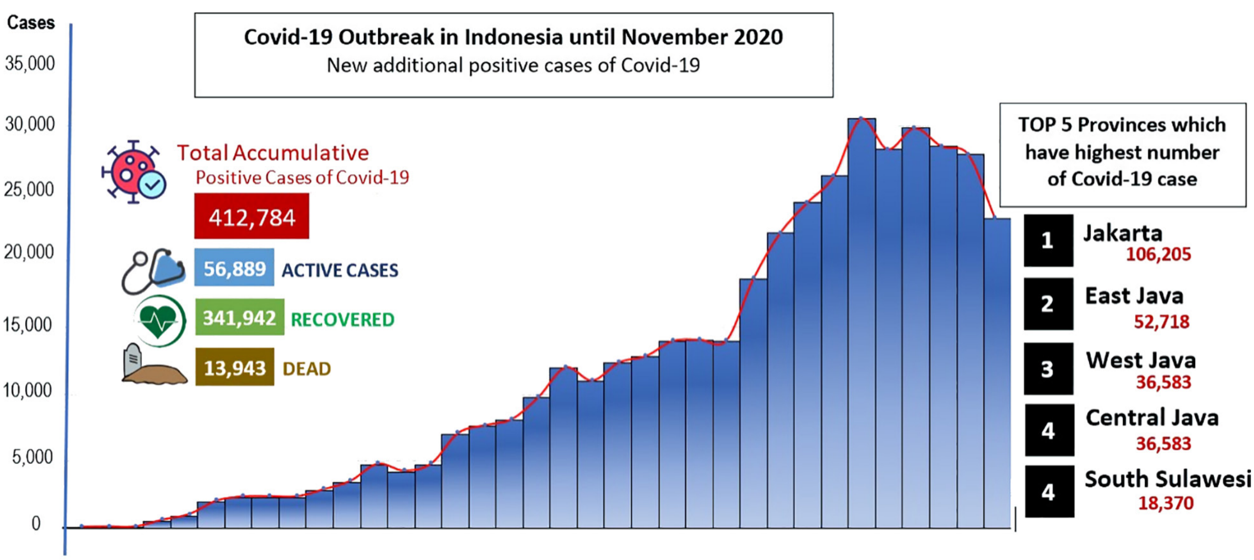

Fig. 1. The COVID-19 outbreak in Indonesia (COVID-19 Response Acceleration Task Force 2020).

can be applied to develop a successful vaccine, both theoretically and practically. The death toll increases significantly after the age of 50 in every country; thus, in general, the fatality rate also increases among the elderly (Crimmins 2020). Based on this condition, every country has its own risk depending on the demographic characteristics. Furthermore, Zhao (2020) found that the population health, medical system and pandemic policies also affect the risk level of every country. Developed countries tend to have a higher risk as they have a contracting population pyramid. On the other hand, developing countries, including Indonesia, who have expanding population pyramids, tend to have a lower risk. However, a bigger problem will emerge as low- and middle-income countries (LMICs) usually have large populations living in dense settlements where the application of 'social distancing' is challenging. Furthermore, the hospital and other healthcare facilities will be flooded with COVID-19 patients (Boong et al. 2020).

The COVID-19 pandemic strongly affected the global economy and will lead to the increase of poverty (Janssens et al. 2021). Increased unemployment, displacement of labour and declining stock markets are just a few of the pandemic's impacts (Mofijur et al. 2020). Further, this condition has caused a 3% drop in global economic growth in 2020. The developing countries will have a severe problem during the COVID-19 pandemic. For example, in Indonesia, the majority of Indonesian people works in the informal sector. According to Statistics of Indonesia (2020), 43.5% or 56.99 million Indonesians work in formal sectors, and 56.5% or 74.04 million Indonesians work in informal sectors. Therefore, when COVID-19 hit Indonesia in February 2020, the informal sector was severely impacted. Several workers from the formal sector were working from home, and several public facilities were closed. The work-from-home policy should be fine for formal sector workers, because they still got their salaries. But the situation was different for the informal sector workers. If they stayed at home, they would fail to provide the basic needs for their family. However, if they kept working outside following the COVID-19 safety procedure, they might get some money to fulfil their family's needs, although the income might decrease significantly.

During the early stage of the COVID-19 global pandemic, Indonesia did not impose travel restrictions on tourists visiting from impacted countries, and also did not provide any special treatment for them (Djalante et al. 2020). Thereafter, Indonesia issued a proclamation pertaining to the initial infection in March 2020 and subsequently applied various policies such as establishing the domestic hospitals as referral hospitals. The Indonesian government has also conducted several studies throughout the COVID-19 period, including risk analysis by the Response Acceleration Task Force. However, the result is too general for the whole of Indonesia. The parameters used were more focused on medical aspects, including epidemiology, healthcare facilities and medical services. Therefore, an integrated analysis using more parameters needs to be conducted both in the medical and non-medical aspects to support the government as it is facing the COVID-19 pandemic. The main objective of this study is to assess the non-medical risk in some parts of Central and East Java, which have a high number of COVID-19 cases. The non-medical aspect consists of disaster, accessibility of medical facility, economy and social and demographic characteristics. This study assessed the risk at the village level, and can support the local government in designing the appropriate mitigation type to implement in their area. Furthermore, the *Bantuan Langsung Tunai,* or cash transfer programme for villages, can be executed more efficiently and accurately on targets.

Overview of the study area

For this study, we assessed the non-medical risk of the COVID-19 outbreak at the village level in two significant regions, namely Subosukowonosraten (Central Java) and Gerbangkertosusilo-Bama (East Java). These two regions are used for the present research because they are included in Indonesia's top five areas with the highest COVID-19 cases. Furthermore, these two regions have similar economic characteristics but are slightly different in terms of social and cultural characteristics.

Subosukowonosraten stands for Surakarta, Boyolali, Sukoharo, Wonogiri, Sragen and Klaten. Subosukowonosraten is also known as

Table 1. The Subosukowonosraten or Greater Surakarta administrative area and GRDP Growth Rate (BPS-Statistic of Central Java, 2020).

Administrative division	Area (km^2)	Population (2019)	The GRDP growth rate at 2010 constant market price			
			2016	2017	2018	2019
Surakarta*	44.03	519,587	5.35	5.70	5.75	5.78
Boyolali	1,015.1	984,807	5.33	5.80	5.72	5.96
Sukoharjo	466.66	891,912	5.72	5.76	5.79	5.92
Wonogiri	1,822.37	959,492	5.25	5.32	5.41	5.14
Sragen	946.49	890,518	5.77	5.97	5.75	5.90
Klaten	655.56	1,174,986	5.17	5.34	5.47	5.57
Karanganyar	800.28	886,519	5.40	5.77	5.98	5.93
Greater Surakarta (Subosukowonosraten)	5,750.49	6,307,821				

* – municipality.

ex-Surakarta Residency or Greater Surakarta. This area consists of a city and six surrounding regencies established as administrative areas during the Dutch Colonial era. In general, Greater Surakarta covers an area of 5750.49 km^2 (Table 1) and hosts around 6,307,821 people, according to the latest of BPS (*Badan Pusat Statistik*)-Statistic 2010. Greater Surakarta was formed based on cultural similarity and the proximity to surrounding areas. Greater Surakarta currently functions as Indonesia's primary extended metropolitan zone and urban agglomeration, and it supports regional economic growth and increases the area's attractiveness in terms of investment, trading and tourism (Putranto 2013). In addition, Greater Surakarta is located close (60 km) to another significant urban agglomeration, Yogyakarta (Fig. 2).

In line with the economic growth of Central Java Province, Greater Surakarta has had positive economic growth from 2016 to 2019. In 2016, 2017, 2018 and 2019, the average economic growth of Greater Surakarta was 5.43%, 5.65%, 5.65% and 5.71%, respectively (Table 1). Meanwhile, the economic growth of Central Java Province was 5.25, 5.26, 5.30 and 5.40 in 2016–2019. The Gross Regional Domestic Product (GRDP) was dominated by industry, trade, construction, agriculture, forestry and fishery sectors. However, during the COVID-19 pandemic, the economic growth in the second quarter of 2020 was depressed. Based on the BPS-Statistic of Central Java, which was issued on 5 August 2020, the economic growth in Central Java decreased by 5.94%. The COVID-19 pandemic affected production activities and the consumption of goods and services. The most impacted sectors in Central Java, including Greater Surakarta, are industry, transportation, storage and tourism (Bank Indonesia 2020a). Therefore, it is necessary to assess the non-medical risk level to aid several areas to survive during the COVID-19 pandemic.

Similar to Greater Surakarta, Gerbangkertosusilo-Bama is an agglomeration region in East Java, centred around Surabaya city. Gerbangkertosusilo-Bama is the abbreviation of Gresik, Bangkalan, Mojokerto, Surabaya, Sidoarjo, Lamongan and Batu-Malang. Gerbangkertosusila was established to accelerate equitable regional development. Gerbangkertosusila, or the Surabaya Metropolitan area of Greater Surabaya, was supported by the provincial government, based on urban land-use plan document and government regulation No. 47/1996, forming part of the national urban land-use plan. The present study also considers two other regencies, namely Batu and Malang, into the analysis. These two other regencies were considered because Batu and Malang were characterised by rapid development and became centres of the crowd and new tourism destinations. Gerbangkertosusilo-Bama covers three cities and six neighbouring regencies, a total area of 5,959.51 km^2 (Table 2).

Greater Surabaya, together with Batu and Malang cities, is located in the eastern part of East Java. The area covers the northern and southern parts of eastern East Java (Fig. 3). Gerbangkertosusilo-Bama was established to increase the economic growth in East Java by developing the potential sectors (Cahyono et al. 2017). The various potential sectors available in Greater Surabaya are manufacturing, mining and agriculture. These three sectors are also in line with the leading sector at the provincial level. In

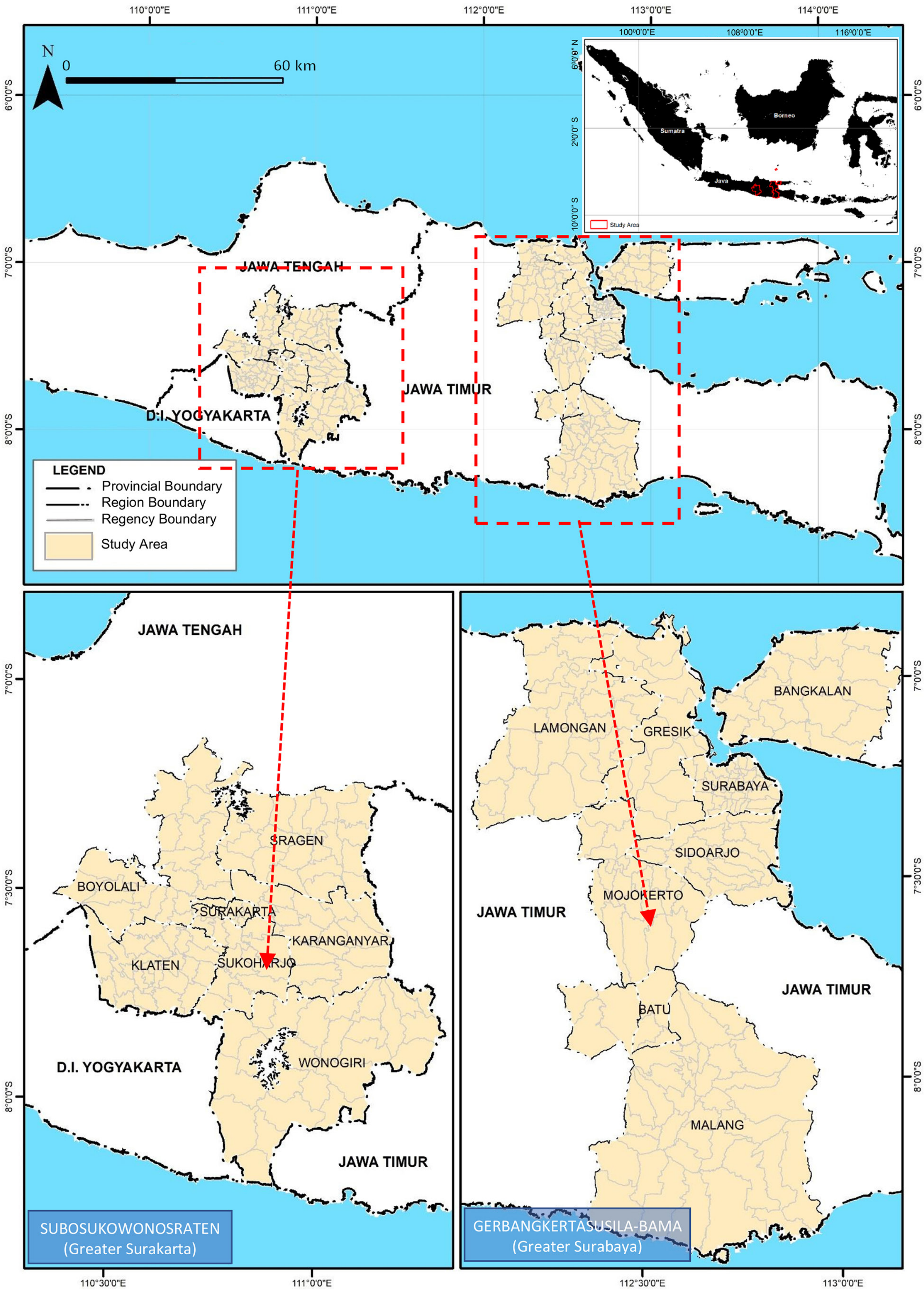

Fig. 2. Administrative map of the study area.

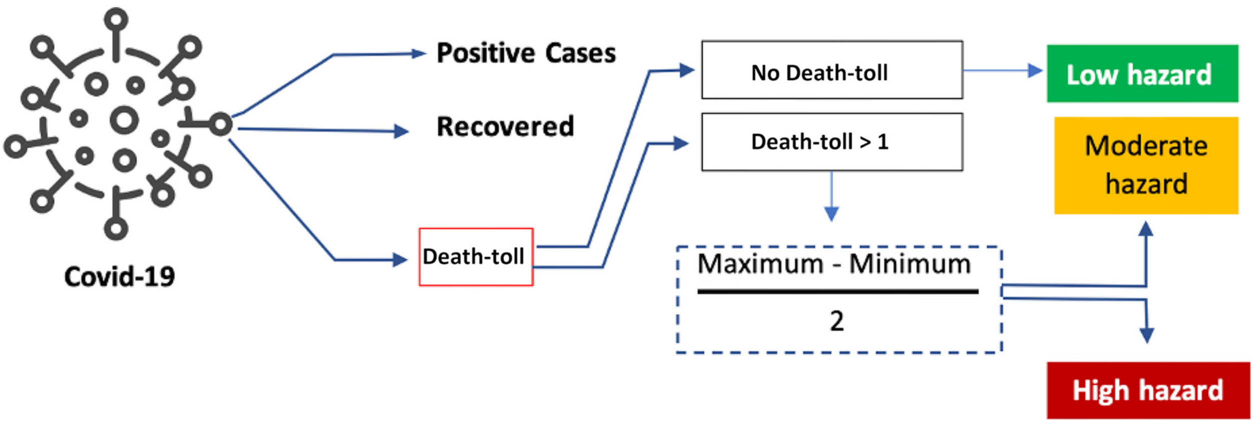

Fig. 3. Fig. 3. Covid-19 hazard analysis.

Table 2. The Gerbangkertosusila-Bama or Greater Surabaya administrative area (BPS-Statistic of Jawa Timur, 2020).

Administrative division	Area (km^2)	Population (2019)
Gresik	1,191.25	1,313,000
Bangkalan	1,001.44	987,000
Mojokerto	717.83	1,118,000
Sidoarjo	634.38	2,249,000
Lamongan	1,782.05	1,189,000
Surabaya *	350.54	2,896,000
Batu *	136.74	207,000
Malang *	145.28	871,000
Greater Surabaya (Gerbangkertosusila-Bama)	5,959.51	10,830,000

2019, at least 30.24% of GDRB originated from the industry and manufacturing sectors, followed by wholesale and retail (18.46%), agriculture, forestry and fisheries (11.43%) (BPS-Statistic of Jawa Timur 2020b).

Like Greater Surakarta, the leading sector in East Java was severely impacted during the COVID-19 pandemic, which was evidenced by a significant decrease in the economic growth of East Java. The economic growth was recorded at −5.90% in the second quarter of 2020 (Bank Indonesia 2020b). This phenomenon occurred because private consumption, investment and foreign and domestic exports decreased due to the large-scale implementation of social restrictions in several areas. Additionally, domestic demand also waned because of the work-from-home policy. The large-scale social restriction caused severe problems for the industry and manufacturing sectors. Most public transportation and department stores were not operating. Some companies were bankrupt and fired their employees, which caused a drop in people's purchasing power. If this condition persists for a long time, then it will cause an extensive economic problem.

Method

Scope of the analysis

The study area is a cluster of Surakarta and Surabaya city. Greater Surakarta covers one city and five neighbouring regencies, while Greater Surabaya covers three cities and five regencies. Both areas have similar economic characteristics, with industry and manufacturing sectors dominating their economies. During the COVID-19 pandemic, Greater Surakarta and Surabaya have been severely impacted, especially the industry and manufacturing sectors, due to the significant decrease in local demand. Thus, this condition directly affected the labourers and factory workers in Greater Surakarta and Surabaya. Furthermore, informal sectors were also affected due to the large-scale social restrictions in several areas.

This research focused on the non-medical impact on the local people's viability during the pandemic at the village level. Therefore, we tried to balance all non-medical aspects, including economic, disaster, social, public and medical facility and demography. The result of this research is the non-medical risk index, which can describe the non-medical risk of people at the village level. Further, the local government can use the risk index before deciding on the type of village mitigation in the COVID-19 pandemic.

Data

The study mainly used secondary data from the government and stakeholders. The online COVID-19 data issued by COVID-19 Response Acceleration Task Force were used to support the COVID-19 hazard analysis in this study. The District in Figures (*Kecamatan dalam angka*), published by Statistics Indonesia, was used to extract the demographic characteristics at the village level. The 2018 village potential data (*PODES/ Potensi Desa*) published by Statistics Indonesia was used to extract non-medical data, including factors such as disaster, social, public and health facility and economic data at the village level. The spatial data, including administrative boundary, road, elevation and other fundamental spatial data, were obtained from Geospatial Information Agency (*Badan Informasi Geospasial*) through the website service of Ina Geoportal. The data used in this research are summarised in Table 3.

The online forum group discussion (FGD) was also conducted to decide the criticality of each parameter in vulnerability assessment. At least 11 respondents representing experts from several scientific disciplines were interviewed. The experts assessed the level of importance of the parameters used in vulnerability analysis by comparing these parameters with each other based on the analytical hierarchy process (AHP) technique. The weight of the parameter and sub-parameter will follow the resultant weight from AHP.

Finally, the expert judgement was analysed through AHP to generate the weights of the non-medical parameters.

Non-medical risk assessment of the COVID-19 pandemic

The non-medical risk of the COVID-19 pandemic was approached following the general concept of risk assessment and reduction. Risk can be expressed by considering the hazard and vulnerability (Westen 2011, Saputra et al. 2020). The general equation used in this research can be expressed as follows:

$$R = H \times V \tag{1}$$

where

- R refers to the non-medical risk of the COVID-19 pandemic,
- H refers to the COVID-19 hazard,
- V is the non-medical vulnerability of COVID-19.

First, we considered H as the number of fatalities in a particular village due to COVID-19. Next, we focused on the non-medical aspect of the disaster, social, public, health facility, economic and demography to assess vulnerability. Finally, we calculated the non-medical risk by applying Eq. (1). A detailed analysis of each stage is provided in the following sections.

Hazard analysis of COVID-19

We focused on the number of fatalities in each village in Greater Surakarta and Surabaya, published online by Pemerintah Provinsi Jawa Tengah (2022) and Pemerintah Provinsi Jawa Timur (2022) at the regency level. We assumed that a significant number of COVID-19 fatalities

Table 3. The data used in the research.

No	Data	Source	Function
1	Data Covid-19	COVID-19 Response Acceleration Task Force	Hazard assessment
2	District in Figures	Statistics Indonesia (2020)	Extract demography data
3	Province in Figures	Statistics Indonesia (2020)	Support the vulnerability assessment
4	Village potential data	Statistics Indonesia (2018)	Vulnerability assessment
5	Administrative boundary, road, river, and elevation (RBI)	Geospatial Information agency (Scale 1:25.000)	Base map of Risk map
6	Expert Judgement	Online FGD	Vulnerability assessment

in a particular village indicated severe problems in handling the pandemic. Thus, we established the hazard assessment at three levels:

1. low hazard (area with zero fatality number),
2. moderate hazard,
3. high hazard.

The moderate and high hazard was decided by Slovin classification based on the maximum and minimum value as shown in Figure 3.

Vulnerability analysis of COVID-19

The vulnerability analysis focused on the five non-medical parameters: disaster, social, health, public facilities, economy and demography. Each parameter has sub-parameters. For instance, the demographic parameter has three sub-parameters: the number of populations, population density and the number of vulnerable people. The analysis was done at the village level, and the vulnerability index was obtained from the weighted overlay analysis. The weights of both parameters and sub-parameters were generated by applying the AHP of 11 experts' opinions through the online FGD. This vulnerability analysis mainly used the village potential data or PODES. Furthermore, the additional demographic data from Statistics Indonesia was also used to generate the vulnerability index. The summary of the vulnerability analysis workflow can be seen in Figure 4.

The parameters were decided based on literature review (disaster (Bottan et al. 2020), social and public facilities-health facilities (Arboleda et al. 2009), economics (Guillaumont 2004), demography (Amoo et al. 2020)). Meanwhile, the sub-parameters were decided through intensive online discussion with the experts. For example, the parameter of disaster, which consists of the number of death toll of a previous disaster (2015–2017), was a meaningful sign that provided a clear description of the economic development and insurance against natural disasters. Usually, more prosperous nations or areas have a fewer death toll due to a disaster because nations with higher economic development can provide better service, health facilities and even insurance to all their citizens.

The characteristic of a health facility in a particular area was also considered an important factor in calculating the non-medical vulnerability. During a disaster event, including the COVID-19 outbreak, the health facility must effectively provide adequate care to the injured or patients (Arboleda et al. 2009). In terms of COVID-19, the health facility becomes an essential aspect for treating the COVID-19 patient to prevent rapid transmission and fatalities in a particular area. Therefore, the absence of health facilities, low accessibility and insufficient electricity, water and transportation network can affect the health facility's performance in controlling the COVID-19 outbreak.

In terms of social and economic characteristics, some particular areas become vulnerable because the majority of its people work in informal sectors. The large-scale social restriction in several areas affected these sectors (CGAP 2020). Informal sector workers, including those engaged in street vending, home-based work, waste picking, domestic jobs and other short-term contracts, often lose their job or contract. They are under higher risk because they lack social protection, access to good public health facilities or even access to sufficient electricity and sanitation. Thus, it is recommended that the villages must try to find other income sources to cover the locals. The village with a higher poverty level becomes more

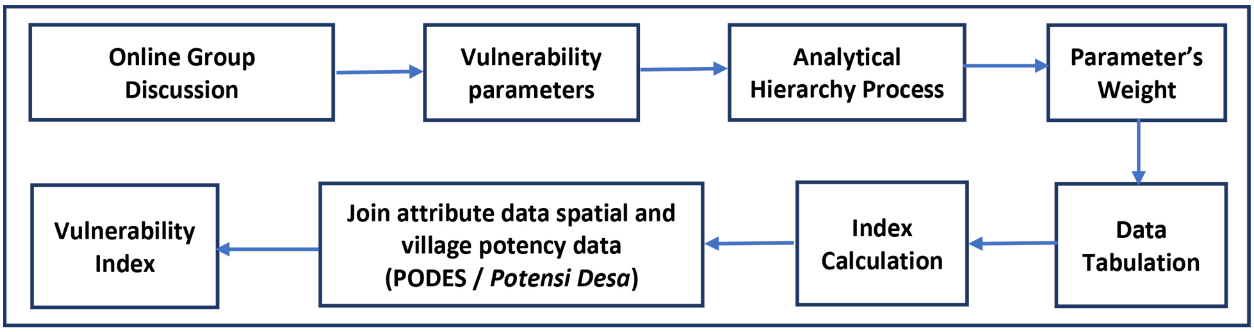

Fig. 4. Vulnerability analysis workflow.

vulnerable in this pandemic era. Contrarily, the village with complete public and social facilities, for instance a sports facility, wide-open space, own social safety network and ordinary criminal effect, should be less vulnerable.

Several groups of the population, such as the elderly (65+), pregnant women and people who have heart, lung, diabetes and other diseases that can affect their immune system, are more vulnerable. Thus, the demographic structure is also considered an important aspect of this study. The summary of parameters and sub-parameters used in this research is provided in Figure 5

Analytical hierarchy process method has been widely used for various fields including COVID-19 pandemic research. Singh and Avikal (2020) used the AHP to analyse the multi-criteria for prioritisation of preventive activities. The AHP compares each parameter head-to-head in a matric form. First, the AHP will be applied in parameter levels, for instance disaster, social, health and public facilities, economy and demography. Next, the AHP will be applied head-to-head on the sub-parameter level (Fig. 5). To avoid researcher subjectivity, we invited experts on disaster, regional planners, planologists, economists, human-social geographers and public health experts. In addition, we also invited several local governments and practitioners from the National

Table 4. The example of AHP matric used in parameters and sub-parameters comparison process.

	Di	SPF	HF	Ec	De
Di		**2 / 1**	… / …	… / …	… / …
SPF	… / …		… / …	… / …	… / …
HF	… / …	… / …		… / …	… / …
Ec	… / …	… / …	… / …		… / …
De	… / …	… / …	… / …	… / …	

Annotation: Di – Disaster; SPC – Social and public facilities; HF – Health facilities; Ec – Economics; and De – Demography. Number '2' and '1' in bold above represent the scale of comparison (Table 6) between parameters Di and SPF.

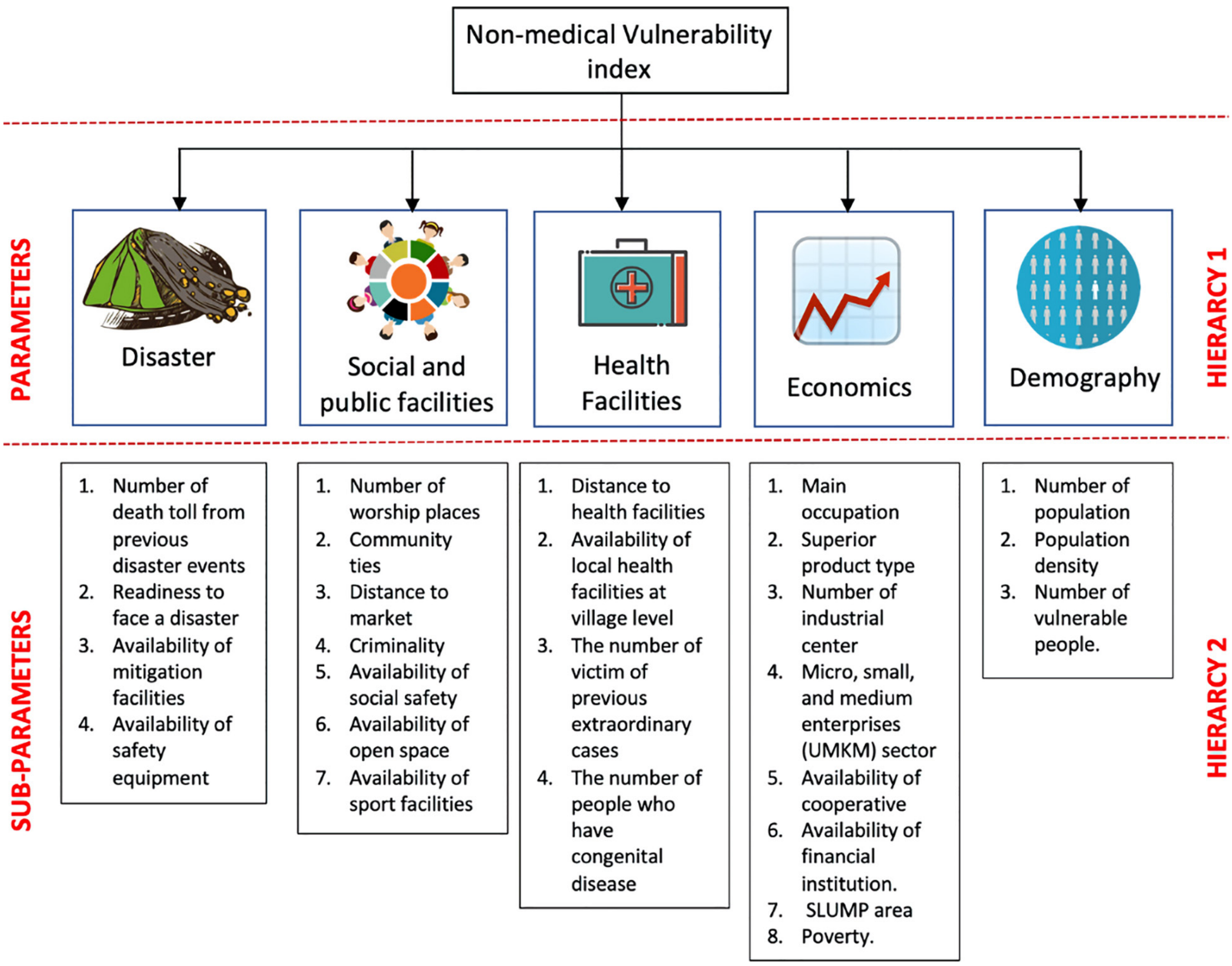

Fig. 5. The list of parameters and sub-parameters used in vulnerability analysis.

Table 5. Scale of AHP (Saaty 1980).

Intensity of importance	Definition
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong or demonstrated importance
9	Extreme importance
2, 4, 6, 8	Intermediate values of importance

Disaster Management Agency. All the experts were asked to judge which parameters are more critical than the other parameters, based on the AHP concept in a matric form (Table 4). Then, all experts needed to decide the importance of each parameter or sub-parameter based on the AHP scale, as provided in Table 5.

Results and discussion

Hazard analysis of the COVID-19 pandemic

This research focused on the death tolls due to COVID-19 to assess the level of hazard at the village level (Fig. 3). The data were obtained from COVID-19 Response Acceleration Task Force at the regency level. Based on the data, we detected some hazardous areas with similar COVID-19 transmission patterns. Greater Surakarta and Surabaya are dominated by villages that have a low level of COVID-19 hazard. Further, Greater Surakarta and Surabaya tend to have a higher hazard index in the municipalities. For example, in Greater Surakarta, some villages in Surakarta city, such as Jebres, Semanggi and Nusukan, have a high death toll due to COVID-19. In October 2020, the number of fatalities was around nine people in Jebres village, and five people each in Semanggi and Nusukan village. The latest data of COVID-19 also showed a similar pattern. These three villages have the highest number of deaths due to COVID-19 in Surakarta city. Jebres village had around 15, Semanggi village around seven and Nusukan village around seven deaths. The other hazardous area in Greater Surakarta is Pabelan village. Administratively, Pabelan village is under the Sukoharjo regency area. However, due to its proximity to the city of Surakarta (5.7 km) with direct access to the downtown, Pabelan village also had a higher COVID-19 fatality number. In October 2020, this area recorded at least four deaths because of COVID-19.

The Greater Surabaya or Gerbangkertosusila-Bama also showed a similar pattern. The areas located in the municipality, except for Batu municipality, tend to have a higher death toll due to COVID-19. The villages, including Mojo, Sidomulyo, Pacar Kembang and Dupak, have a fatality of more than 10 people. Meanwhile, the other villages in Surabaya municipality, such as Kapasan, Pacar Keling, Gundih, Kedung Baruk, Kali Rungkut, Putat Jaya, Tanah Kali Kedinding, Sidotopo Wetan, Simolawang, Sidotopo, Morokrembangan, Ngagelrejo, Tambaksari, Tembok Dukuh, Kedurus, Pagesangan, Rungkut Tengah, Klampis Ngasem, Kertajaya, Gubeng, Ngagel, Manukan Kulon, Banyu Urip, Petemon, Kedungdoro, Bulak Banteng, Ampel, Pegirian and Krembangan Selatan recorded at least five deaths due to COVID-19. The areas in Sukosari in Malang municipality showed a higher death toll number than other villages in Greater Surabaya. Sukosari village recorded at least four deaths due to COVID-19 in October 2020. The complete map describing the hazard level of the COVID-19 pandemic is provided in Figures 6 and 7.

The distribution of COVID-19 both in Greater Surakarta and Surabaya shows similar patterns. Villages in the city tend to have a higher fatality than villages in the rural area. Urban areas usually have specific characteristics in terms of population size, space (land area), population density and socio-economic (Weeks 2010). The large population, high population density and sizeable impervious surface or built-up areas will affect the contact rate in the epidemic process. Furthermore, the contact rate strongly influences the magnitude of the outbreak, the spread and the dramatic effect of the disease or virus (Tarwater, Martin 2001).

The COVID-19 pandemic also struck the capital city of Indonesia, Jakarta. Jakarta has the highest number of positive cases and the highest fatality of COVID-19. Therefore, the urban areas tend to be more prone to the rapid transmission of COVID-19 than the rural areas. In addition, the frequency of contact of the urban dwellers increases with the population density of a particular area. Furthermore, in comparison with those dwelling in rural regions, urban dwellers

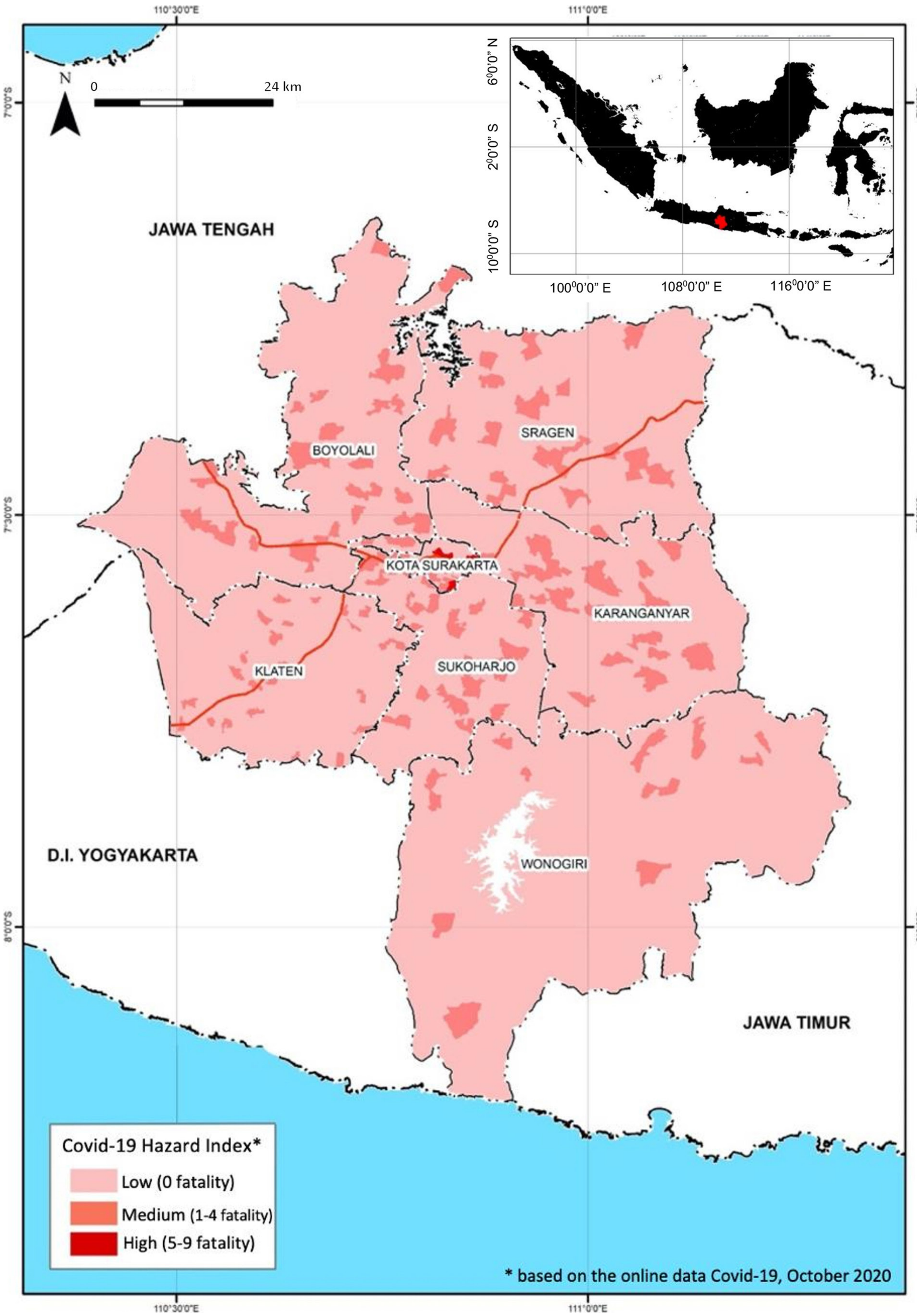

Fig. 6. COVID-19 hazard index of Subosukowonosraten (Greater Surakarta).

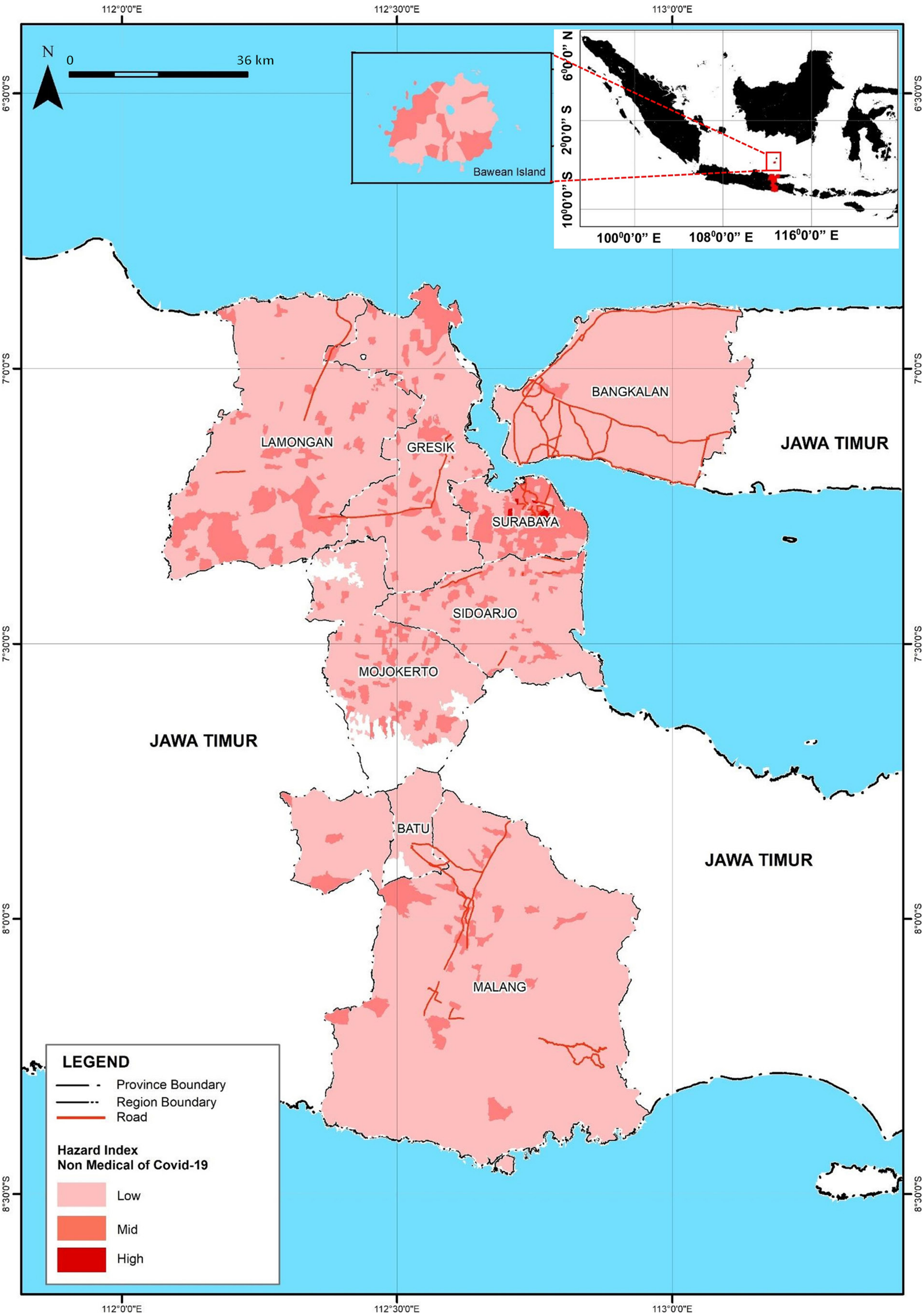

Fig. 7. COVID-19 hazard index of Gerbangkertosusila-Bama (Greater Surabaya).

tend to have more interactions in stores, public transportation, entertainment facilities and offices (Li et al. 2018). Additionally, a recent study by Amoo (2020) revealed the relationship between the population size and the effect of the COVID-19 outbreak. The study found that the population density will amplify the effect of the COVID-19 pandemic (high fatality) and prolong its duration.

Non-medical vulnerability analysis

The non-medical vulnerability index was obtained from the AHP through the pairwise comparison method. We invited 11 experts from several scientific disciplines to assign weight to each parameter and sub-parameter via an online forum group discussion (FGD). The experts consisted of both academics and practitioners. The complete list of experts can be seen in Table 6.

Based on the FGD results, the highest and lowest scores of the first hierarchy parameters are disaster and demography, with an AHP score of 0.38 and 0.04, respectively. The AHP score was obtained by calculating the mean score of each parameter. All the parameters have a relatively low standard deviation value (<0.5), with the highest standard deviation being observed for the disaster parameter (0.22). All the experts have similar perceptions about the parameters' weight as there was only a slight variation of the AHP score of each parameter in terms of non-medical vulnerability assessment. The experts agreed that the disaster aspect was slightly more important than health facilities and significantly more crucial than economic, social and public facilities and demographic aspects. The weight of each

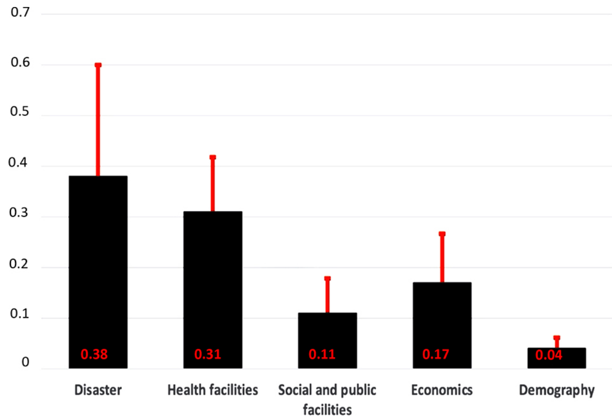

Fig. 8. The weight of each parameter in the first hierarchy.

parameter and the standard deviation is provided in Figure 8.

Furthermore, the AHP score also explained the level of importance of each parameter in the second hierarchy. For example, based on the FGD results, the highest average AHP score in the disaster parameter was the death toll from previous disaster events, with a score of 0.36. Then, the second highest was the availability of mitigation facilities in a particular area (0.27), followed by a preparedness to face disaster events and availability of safety equipment with scores of 0.19 and 0.18, respectively.

The availability of local health facilities at the village level was established as the most critical factor in the second hierarchy of the health facilities parameter, with an AHP score of 0.33. The distance to the health facilities, the number of victims of a previous extraordinary event and the number of people having a chronic disease were scored as 0.30, 0.20 and 0.18, respectively. The deviation among the sub-parameters is in

Table 6. List of experts who were invited to online FGD.

No.	Expert on	Profession	Area
Expert 1	Economic	Academics	Greater Surakarta
Expert 2	Geography of regional development	Academics	Greater Surakarta
Expert 3	Planologist	Academics	Greater Surakarta
Expert 4	Human Geography	Academics and practitioners	Greater Surakarta
Expert 5	Public health	Academics	Greater Surakarta
Expert 6	Disaster management	Academics	Greater Surakarta
Expert 7	Disaster management	Practitioners	Greater Surabaya
Expert 8	Economics	Practitioners	Greater Surabaya
Expert 9	Local government	Practitioners	Greater Surabaya
Expert 10	Public health	Practitioners	Greater Surabaya
Expert 11	Social	Practitioners	Greater Surabaya

the range 0.12–0.25, which means that there is no such variation of the AHP score. In other words, we can assume that all the experts have a similar perception of the issue.

Community ties had the highest score in the second hierarchy of social and public facilities, with an AHP score of 0.25 and a standard deviation of 0.11. The second highest was the distance from the market and was followed by the availability of social security, availability of open space, availability of sports facilities, the number of worship places and criminality, with AHP scores of 0.19, 0.15, 0.13, 0.10, 0.09 and 0.09, respectively. Unlike developed countries, private health insurance (PHI) plays only a minor role in developing countries. Most people in developing countries apply for direct payment (out-of-pocket payment) to cover their needs, which can cause financial insolvency in the case of low-income households (Drechsler, Jutting 2007, Habib et al. 2016). Thus, the availability of Social Safety Net (SSN) or social security in developing countries, including Indonesia, became an essential factor during the COVID-19 pandemic.

In terms of economics, the main livelihood and superior product become the two most important factors, with AHP scores of 0.36 and 0.21, respectively. During the pandemic, the Indonesian government implemented large-scale social restrictions. Most employees were working from home. Thus, the government policy did not significantly affect the salary of people employed in the formal sector. The employees received the same salary when they were working from home. However, the pandemic affected the people who are employed in the informal sector. Their income decreased significantly during the pandemic (CGAP 2020). Further, the two most important sub-parameters' standard deviations were very low, varying between 0.07 and 0.22,

Table 7. The summary of AHP results (green colour – parameters).

Code	Parameter and Sub-Parameters	Average	Standard deviation
D	Disaster	0.38	0.22
D1	Number of the death toll from previous disasters	0.36	0.32
D2	Readiness to face a disaster	0.19	0.10
D3	The availability of mitigation facilities	0.27	0.19
D4	The availability of safety equipment	0.18	0.11
H	Health facilities	0.31	0.11
H1	Distance to health facilities	0.30	0.21
H2	The availability of local health facilities at the village level	0.33	0.25
H3	The number of victims of previous extraordinary events	0.20	0.12
H4	The number of people who have congenital disease	0.18	0.16
S-PF	Social and Public Facilities	0.11	0.07
S-PF1	The number of worship place	0.09	0.06
S-PF2	Community ties	0.25	0.11
S-PF3	Distance to the market	0.19	0.08
S-PF4	Criminality level	0.09	0.05
S-PF5	The availability of a safety net (social security)	0.15	0.07
S-PF6	The availability of open space	0.13	0.09
S-PF7	The availability of a sport centre	0.10	0.11
E	Economic	0.17	0.09
E1	Main livelihood	0.36	0.22
E2	Featured product	0.21	0.16
E3	Number of industrial centre	0.02	0.01
E4	Micro, small, and medium enterprises	0.01	0.00
E5	The availability of cooperative.	0.12	0.09
E7	Slum area	0.14	0.08
E8	Poverty	0.04	0.03
De	Demography	0.04	0.02
De1	Number of population	0.13	0.11
De2	Population density	0.29	0.20
De3	Vulnerable people	0.58	0.21

indicating that all experts had a similar perception of the sub-parameters.

The number of vulnerable people was considered as the vital factor in the demography parameter. Among two sub-parameters, the vulnerable people had the highest AHP score (0.58), with a standard deviation of 0.21. The other demography sub-parameters – population and population density – had AHP scores of 0.13 and 0.29, respectively. During the pandemic, vulnerable people (the elderly and toddlers) play a critical role in the evaluation of the risk level in a particular area. In terms of the COVID-19 transmission process, the elderly had a higher probability of getting exposed to COVID-19 (Crimmins 2020). Furthermore, the number of elderly individuals and toddlers affects the dependency ratio in a particular area, thus affecting the success level of the recovery process after the COVID-19 pandemic. The summary of the AHP score of all parameters and sub-parameters can be seen in Table 7.

Based on the AHP score, it is ascertained that 12 villages have a high non-medical vulnerability for COVID-19 in Greater Surakarta. The three villages that have the highest vulnerability index are Cluntang (Musuk district, Boyolali regency), Laban (Mojolaban district, Sukoharjo regency) and Lemahbang (Jumapolo district, Karanganyar regency), with vulnerability indices of 1.00, 0.99 and 0.99, respectively. These three villages have characteristics similar to those of a disaster-prone area, low economic growth and a lack of health facilities. The list of villages with a high vulnerability index in Greater Surakarta can be seen in Table 8 and the vulnerability map in Figure 9.

On the other hand, in Greater Surabaya, high vulnerability can be found in Sawojajar village (Kedungkandang district), Bandungrejosari village (Sukun district) and Turen village (Turen district). These three villages are located in the same administrative area of Malang municipality. The vulnerability indices for Sawojajar, Bandungrejo and Turen villages are 1.00, 0.998 and 0.953, respectively. They also have similar characteristics, including being disaster-prone areas, having the worst demographic condition and lacking health facilities. The list of villages with a high vulnerability index is provided in Table 9. Meanwhile, the vulnerability map can be seen in Figure 10.

Being a disaster-prone area, having a low economic growth, lack of health facilities and demographic condition are the main problems making an area more vulnerable during the COVID-19 pandemic. Several disasters could occur during the COVID-19 pandemic. Many places (villages or regencies), including places with the high probability of COVID-19 transmission, are in the disaster-prone areas of seasonal flood, landslide, drought and forest fire. In line with previous research, the present study has also found that disaster-prone areas will experience the worst cascading impact between natural disasters and the COVID-19 pandemic. For example, a great earthquake of magnitude 7.0 hit Haiti, causing more than 200,000 deaths and damaging the public sanitation system. This event set up ideal conditions for cholera outbreaks. From a perusal of the literature, we find that the cholera outbreaks that occurred 9 months later, resulting in even more deaths and infections, can be attributed

Table 8. List of villages with the high vulnerability index in Greater Surakarta.

No	Villages	District	Regency or municipality	Index
1	Cluntang	Musuk	Boyolali	1.000
2	Laban	Mojolaban	Sukoharjo	0.995
3	Lemahbang	Jumapolo	Karanganyar	0.994
4	Lemahbang	Kismantoro	Wonogiri	0.994
5	Gawan	Tanon	Sragen	0.992
6	Manjungan	Ngawen	Klaten	0.981
7	Belang Wetan	Klaten Utara	Klaten	0.980
8	Tawang	Weru	Sukoharjo	0.977
9	Gumul	Karangnongko	Klaten	0.976
10	Karangdowo	Karangdowo	Klaten	0.976
11	Granting	Jogonalan	Klaten	0.964
12	Bakulan	Cepogo	Boyolali	0.964

primarily to this natural calamity. (Orata et al. 2014, Quingley et al. 2020).

Another example is the Croatian earthquake that had a magnitude of 5.3, and occurred during the COVID-19 pandemic (19 March 2020). The earthquake caused severe damage to the northern suburbs of Zagreb. At least 59 people required emergency shelters. Thus, during the disaster response, concerns and regulations pertaining to social distancing might temporarily have been abandoned. Consequently, the transmission of COVID-19 showed a potentially increasing trend immediately after the Zagreb earthquake (Quingley et al. 2020). Therefore, it is vital to identify the disaster-prone areas to mitigate the cascading impact of natural hazards and the COVID-19 pandemic.

Low economic growth will worsen the impact of disaster or pandemic conditions. In addition, low economic growth and income instability will affect the resilience level and recovery process. Also, Guillaumont (2004) stated that the loss due

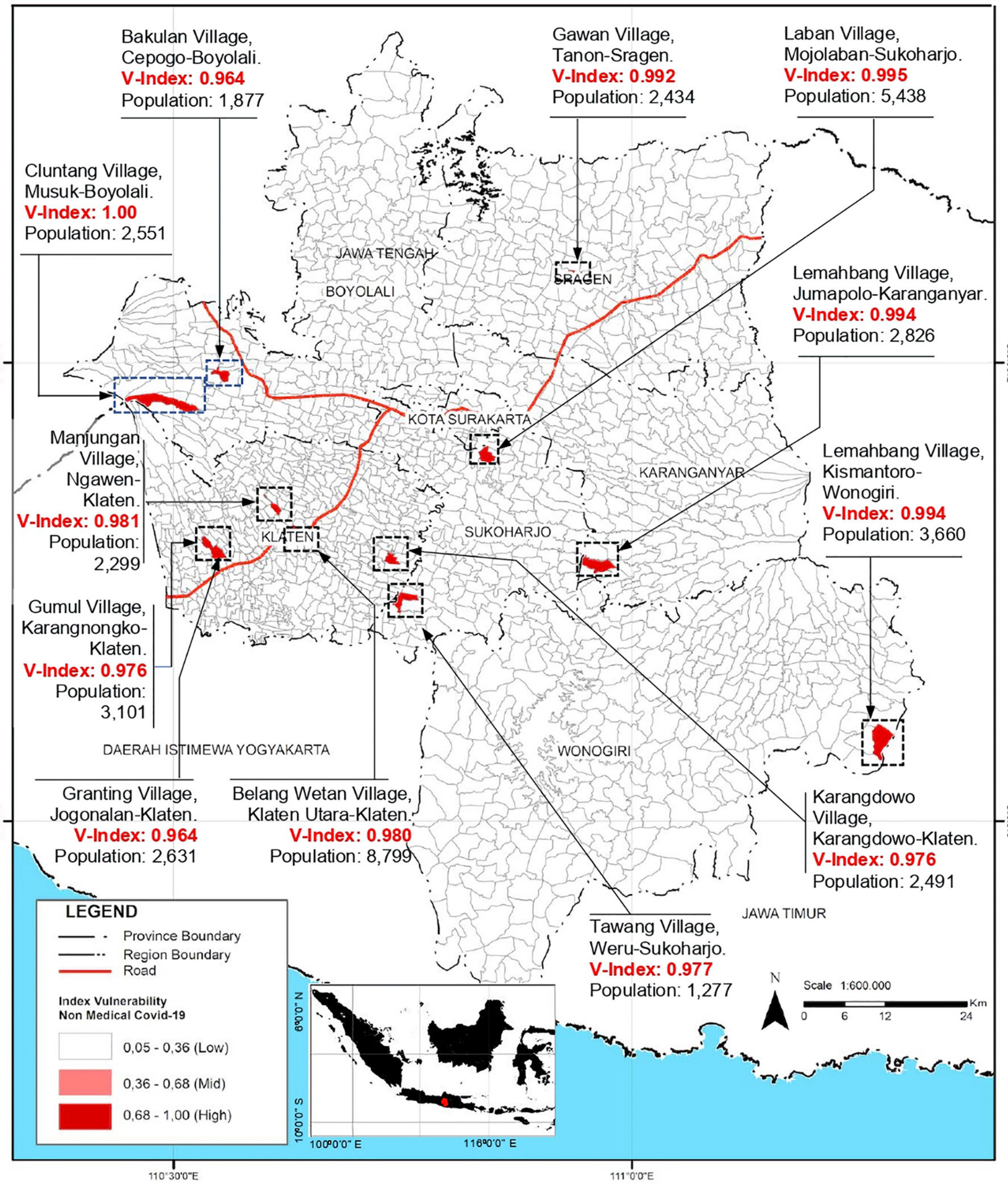

Fig. 9. The high vulnerability villages in Greater Surakarta.

to a particular disaster or shock is associated with low economic growth and income instability, especially in the Least Developed Countries (LDCs). Moreover, the Committee for Development Policy (CDP), Department of Economic and Social Affairs, United Nations established that low economic growth is one of the components of the Environmental Vulnerability Index (EVI). The index is associated with the instability of agricultural production, the concentration of export and goods and the share of manufacturing and modern services in the Gross Domestic Product (GDP). In line with Guillaumont (2004), Bottan et al. (2020) found that economic inequality determined the degree of damage during the pandemic. The results showed that the most prominent effect of the pandemic was on people who were earning less than the national monthly minimum wage. Their jobs were lost because of business closures.

Health facilities play a critical role in the community during the pandemic. Public health can provide sophisticated equipment to contain the COVID-19 outbreak. It focuses on isolating the suspect during the pandemic, quarantine, travel advisories and restriction policy. Public health also plays a vital role in vaccination and medical examinations (Smith, Upshur 2020). Therefore, the lack of public health facilities might be amplifying the negative impact of the COVID-19 pandemic.

Several populations have a higher vulnerability to COVID-19 due to age and health conditions (comorbidity). Thus, the demographic condition is also a significant variable in terms of the COVID-19 outbreak. In addition, the demographic composition (number of elderly individuals) determines the level of social vulnerability, which will affect the risk level in a particular area (Kingma 2011).

Table 9. List of villages with the high vulnerability index in Greater Surabaya.

No	Villages	District	Regency or municipality	Index
1	Sawojajar	Kedungkandang	Malang	1.000
2	Bandungrejosari	Sukun	Malang	0.998
3	Turen	Turen	Malang	0.953
4	Pagentan	Singosari	Malang	0.940
5	Samaan	Klojen	Malang	0.938
6	Candirenggo	Singosari	Malang	0.930
7	Gadingkasri	Klojen	Malang	0.928
8	Balesari	Ngajum	Malang	0.881
9	Petungsewu	Wagir	Malang	0.879
10	Sampangagung	Kutorejo	Mojokerto	0.875
11	Jegreg	Modo	Lamongan	0.874
12	Gadungsari	Tirto Yudo	Malang	0.873
13	Ngadirejo	Kromengan	Malang	0.873
14	Dalisodo	Wagir	Malang	0.873
15	Ngadirejo	Jabung	Malang	0.873
16	Pait	Kasembon	Malang	0.873
17	Kedungpengaron	Modo	Lamongan	0.873
18	Yungyang	Modo	Lamongan	0.873
19	Gedongkulon	Babat	Lamongan	0.873
20	Karanglangit	Lamongan	Lamongan	0.871
21	Mojoasem	Laren	Lamongan	0.871
22	Nguwok	Modo	Lamongan	0.866
23	Slamet	Tumpeng	Malang	0.865
24	Sendangrejo	Ngimbang	Lamongan	0.865
25	Sendangrejo	Lamongan	Lamongan	0.865
26	Mlaten	Puri	Mojokerto	0.864
27	Pengumbulanadi	Tikung	Lamongan	0.863
28	Ngadas	Poncokusumo	Malang	0.859
29	Sumberpucung	Sumber Pucung	Malang	0.858
30	Truni	Babat	Lamongan	0.838

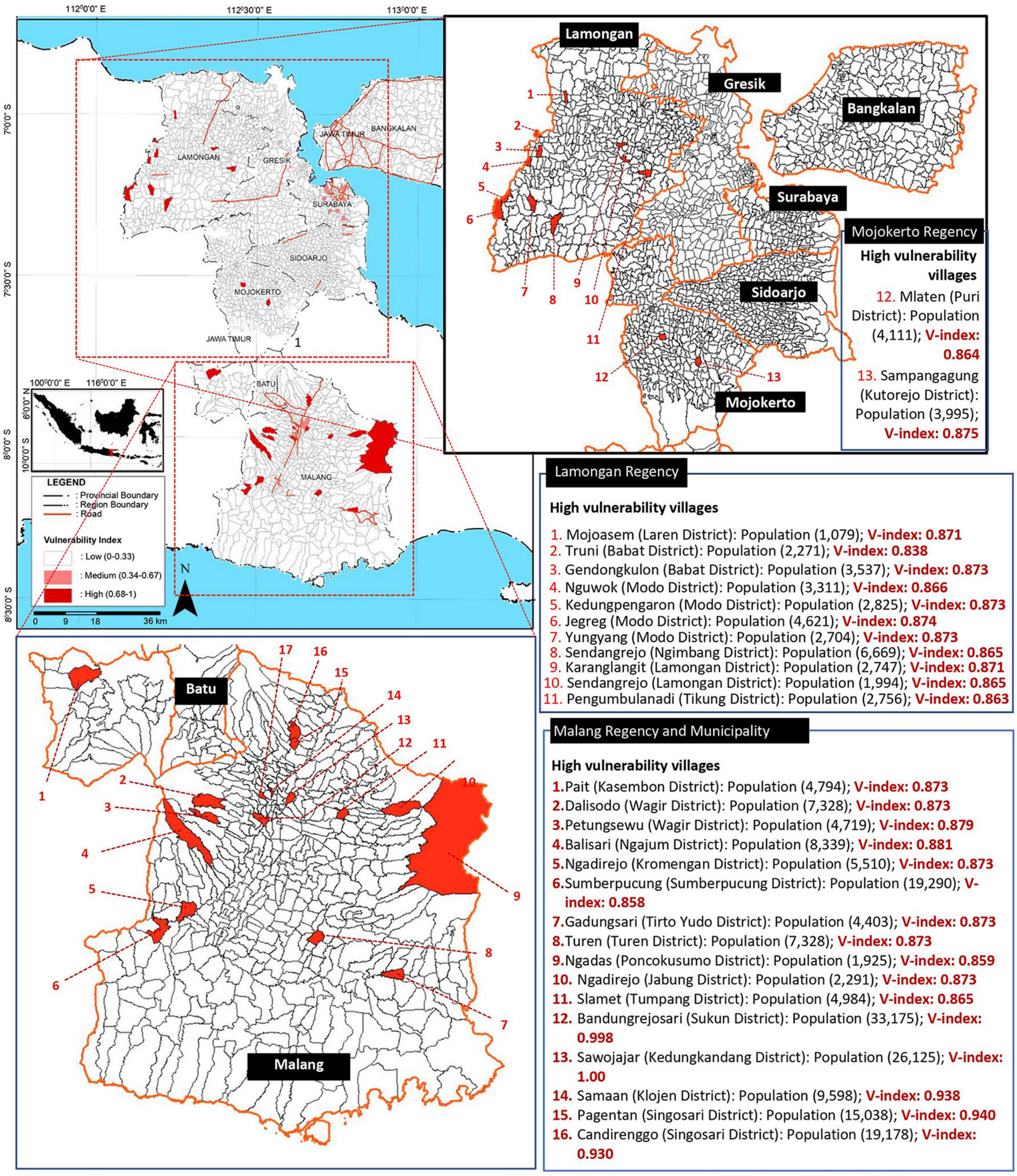

Fig. 10. Villages in Greater Surabaya and Batu-Malang regency/municipality having a high vulnerability index.

Non-medical risk

As mentioned in the methods section, the risk was assessed using the general equation of risk [Eq. (1)]. The hazard referred to the number of fatalities due to COVID-19 at the village level. The vulnerability referred to the disaster, social, public health facility, economic and demographic aspects. Based on the result, the risk index ranges from 0 to 1, where 0 refers to low risk (safe village) and 1 refers to high risk (needing attention). In general, the risk index in Greater Surakarta is 0.65, indicating moderate risk. There is only one village in Greater Surakarta classified as a high-risk village in terms of non-medical risk of COVID-19 outbreaks. This village is Belang Wetan (risk index of 1.00), located in the middle part of the Klaten regency (Fig. 12). This village

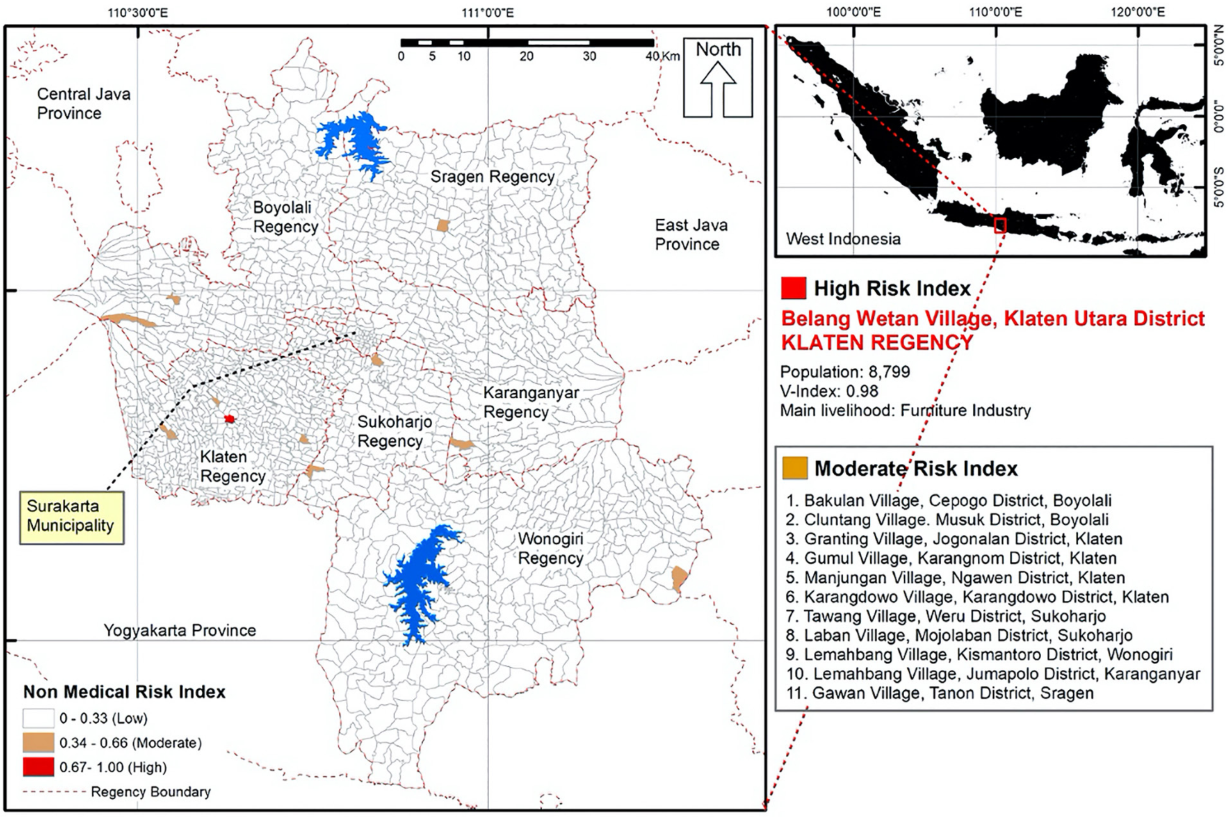

Fig. 11. Non-medical risk index in Greater Surakarta.

has a high vulnerability index (0.980) and medium fatalities (1–4) due to COVID-19.

Meanwhile, at least 11 villages have a medium level of risk with an index of 0.33–0.66. Most of these villages are located in between the east and the middle part of Greater Surakarta. The complete risk index of Greater Surakarta and the list of medium-risk villages are provided in Figure 11.

At least three villages in Greater Surabaya have a high-risk index (>0.66). These three villages are Candirenggo, Singosari district (0.93); Bandungrejosari, Sukun district (0.99); and Sumber Pucung, Sumber Pucung district (0.86). These villages also have a high vulnerability index of 0.930, 0.998 and 0.858, respectively. Moreover, they have a medium hazard level (1–8 fatalities due to COVID-19). Candirenggo village is located in the northern part of Malang regency close to Batu municipality; Bandungrejosari village is located in the centre of Malang regency. In contrast, Sumber Pucung village is located in the western part of Malang regency near the administrative border of central Java (Fig. 12). Moreover, at least 11 villages in Lamongan regency, two villages in Mojokerto regency and 15 villages in Malang regency have a moderate risk index (0.33–0.66). The moderate risk index villages are primarily located in the border areas of the administrative boundary. The complete risk index map is provided in Figure 12.

Based on the results, it can be said that Belang Wetan village has a high-risk index in Greater Surakarta. In addition, Candirenggo, Bandungrejosari and Sumberpucung villages are classified as high-risk villages in Greater Surabaya. This is because these four villages are relatively close to the city centre. Belang Wetan village is only 5 km away or about 11 min from the city centre of Klaten regency. Candirenggo village is located 11 km north of the downtown area of Malang.

Meanwhile, Bandungrejosari village is located 5.4 km south of Malang city centre. On the other hand, Sumberpucung villages is located in the border area between Malang and Blitar regency. Sumberpucung is located 30 km southwest of Malang city centre. In addition, the high-risk villages, both in Greater Surakarta and Surabaya, have high accessibility. Some villages are even

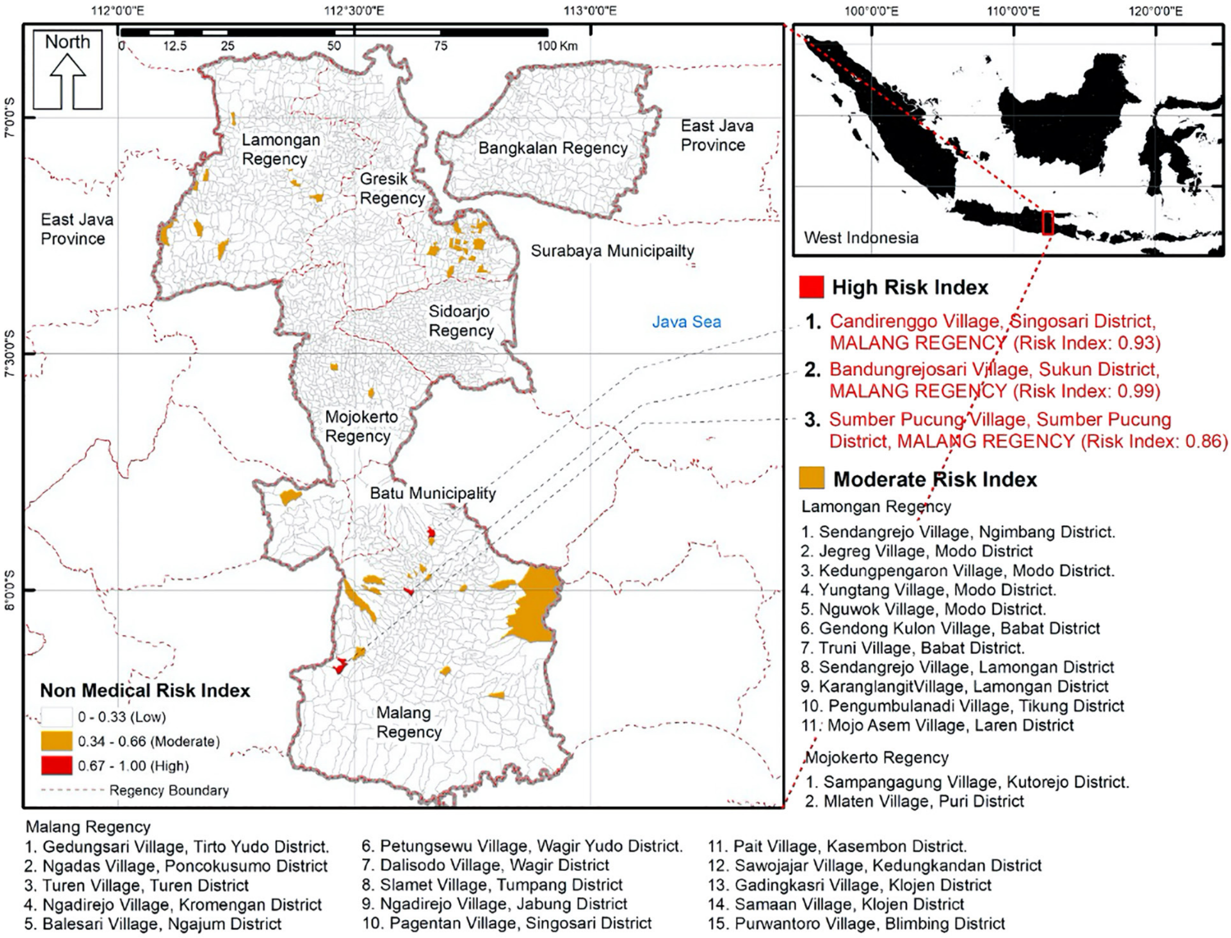

Fig. 12. Non-medical risk index in Greater Surabaya.

located very close (<500 m) to the national road. In terms of COVID-19 outbreaks, the accessibility of particular areas contributes to the degree of spread of infection. The closeness to the city centre and the higher accessibility tend to increase the spreading of COVID-19 towards the community. Furthermore, Pourghasemi et al. (2020) found that the most important predictors were the distance to the bus station, back shop, hospital, mosque, automated teller machine (ATM) and bank, most of which can be found in the city centre.

The inhabitants of the high-risk villages of Greater Surakarta and Surabaya have a similar livelihood. Industrial activities dominate these four villages. For example, Belang Wetan village in Klaten Utara district is famous for its furniture industry. Various types of furniture businesses, from small to big, are located in these villages. Thus, when the pandemic occurred, the demand for various furniture pieces decreased, which affected the production process, including local people who work in this sector. This condition is in line with Bank Indonesia's funding (2020), which reported that industry is one of the most impacted sectors during the COVID-19 pandemic in Central Java. Thus, a detailed analysis is needed to respond to the impact of the COVID-19 pandemic and support local people's recovery.

The scenario is no different in Bandungrejosari and Candirenggo villages, Malang regency. As they are located closer to the city centre of Malang, these villages are dominated by tourism activities. During the COVID-19 pandemic, some tourism spots in Candirenggo and Bandungrejosari villages, including the famous Singasari temple, were closed. This closure caused an economic disruption among local people. Recently, after the Indonesian government applied the new normal policy, some tourism spots have reopened. However, the tourism demand, both domestic and international, is still low. This condition is in tune with that of the tourism industry worldwide. Thus, the pandemic has had a destructive and long-lasting effect on the tourism industry. During the travel restriction, the tourist arrivals declined, and the tourism industry's contribution to the GDP dropped significantly (Skare et al. 2020). Thus, a detailed study about a recovery plan for the high-risk villages is imperatively necessary.

Conclusion

The COVID-19 outbreak represents a continuing pandemic threat, especially in developing countries such as Indonesia. Besides the medical risk study, the non-medical aspect is crucial for an investigation into the risk. A risk reduction concept was used to generate the non-medical risk index. Based on the death toll number, it can be surmised that the municipality and its surroundings tend to have a higher number of dead (more than 10) people associated with the COVID-19 pandemic. Further, the distribution of the death toll number of COVID-19 in study areas shows a tendency for accumulation in villages located in the proximity of cities. The AHP was used to point out the level of importance of each parameter in the vulnerability analysis. The results have shown that the number of victims of a previous disaster has a higher level of importance than the other parameters. Based on the AHP score, the vulnerable villages in Greater Surakarta are Cluntang, Laban and Lemahbang, with vulnerability indices of 1.00, 0.99 and 0.99, respectively. These three villages have characteristics similar to those of disaster-prone areas, low economic growth and a lack of health facilities. In Greater Surabaya, a high vulnerability index is observed in the case of the villages Saqojajar, Bendungrejo and Turen, with vulnerability indices of 1.00, 0.998 and 0.953, respectively. It further highlighted that the Belang Wetan villages, Klaten regency in Greater Surakarta, has the highest risk index of 0.980. Additionally, the results of the study indicate that a high-risk index can be observed in the case of three villages in Greater Surabaya: Candirenggo, Bandungrejosari and Sumber Pocung. Thus, further research is needed to assist the local government in establishing effective recovery planning.

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Author's contribution

A.S., M.A. and W.S. summarised the PODES data. A.S., M.A., W.S., S., R.D. and I.R.N. supported the forum group discussion on vulnerability analysis. A.S. carried out the data analysis and created the map. A.S., M.A. and W.S. interpreted the results. A.S. drafted the manuscript. All the authors read, revised and approved the final draft of the manuscript.

Conflict of interests

We declare that no competing interests exist.

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Availability of data and materials

All data and material except Village Potency (PODES or *Potensi Desa*) in this work are publicly available. The Village Potency data 2018 were provided by *Satuan kerja Balai Penelitian dan Pengembangan Penerapan Teknologi Permukiman, Kementrian Pekerjaan Umum dan Perumahan Rakyat.*

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