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Comparison of Ground Motion Prediction Equation (GMPE) Analysis of the Bandung Earthquake 22 January 2022

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Abstract: The value of ground acceleration in an area due to an earthquake that occurs can have different values. One of the factors that influence this is the geological conditions in the area. The purpose of this study was to compare the Peak Ground Acceleration (PGA) values in the area using several Empirical Ground Motion Equation Prediction (GMPE) formulas such as Inan et al. (1996), Katayama (1974) and Peng et al. (1985) with results that are read on the accelerograph. This study uses earthquake data from the and several station networks Meteorology, Climatology and Geophysics Agency (BMKG) in the West Java region. The results of the analysis show that the empirical formula that is close to the readable value on the accelerograph record is the empirical formula of Inan et al. (1996). Thus, the empirical formula is suitable for calculating PGA values in the region.

Keywords: GMPE, Shakemap, PGA

INTRODUCTION

Seismic activity in Indonesia is quite high because it is located at the meeting point of 3 large plates, namely the Pacific Plate, the Eurasian Plate and the Indo - Australian Plate. The West Java region is one of the areas where seismic activity occurs in Indonesia. This is related to the seismotectonic conditions that exist in the area where there are many active faults and the presence of plate subduction in the south of the island of Java. (Ibrahim et al., 2010, Zakaria & Sidarto, 2015).

An earthquake is a phenomenon of the earth's surface vibrating as a result of the release of energy in the earth that occurs instantly marked by the fracture of rocks in the earth's crust. (Lay & Wallace, 1995, Stein & Wysession, 2003, Shearer, 2009). Large and destructive earthquakes have a very large impact on the earth's surface, such as damage to public facilities, buildings collapsing and causing fatalities, marked by a high Modified Mercalli Intensity (MMI) intensity scale so that mitigation measures are needed to reduce the impact of this phenomenon. Earthquake Intensity Scale is a value used to measure the strength of an earthquake based on the level of damage to buildings, environmental damage and the reaction of people due to the earthquake that occurred. (Balassanian et al., 2000). One of the things that can be done is to get information about the ground movement in an area. This information is in the form of the peak ground acceleration value that can be used for the calculation of the Probabilistic Seismic Hazard Alaysis (PSHA), soil characteristics and building planning. (Estrada & Lee, 2017, PuSGeN, 2017).

The peak ground acceleration value is influenced by several factors such as magnitude, epicenter, depth and geological conditions in an area. This causes the PGA value to vary when an earthquake occurs (Bozorgnia & Bertero, 2004, Prawirodikromo, 2012). The price of a PGA is obtained from observations of accelerograph recordings, but due to the limitations of accelerograph sensors in Indonesia, an approach is needed through empirical calculations of

Ground Motion Prediction Equation (GMPE) such as Inan et al. (1996), Katayama (1974) and Peng et al. (1985).

This study aims to compare the results of the calculation of the empirical equation Inan et al. (1996), Katayama (1974) and Peng et al. (1985) with values read on accelerograph recordings with a shakemap of the Meteorology, Climatology and Geophysics Agency (BMKG), geological conditions and validated using a Land Movement Vulnerability Zone Map. Shakemap is a map that provides information in the form of distribution and levels of PGA values and the intensity of shocks caused by the earthquake that occurred (Akkar et al., 2011, Sucuoğlu & Akkar, 2014).

METHOD

The focus of this research is the earthquake that occurred in Bandung and its surroundings on January 22, 2022. This study uses earthquake data and the BMKG station network. The steps taken in this research are as follows:

1. Retrieve earthquake data and station network from BMKG.
2. Convert the magnitude to the Moment Magnitude (*Mw*) to avoid saturation. Saturation is the calculation of ground motion parameters due to earthquakes which tend to be less accurate for earthquakes of a certain magnitude (Kramer, 1996, Shearer, 2009). Some formulas used for magnitude conversion:

$$Mw = 0.781Mb + 1.5175$$
$$Mw = 0.696Ml + 1.7738 \qquad \text{(Suckale et al., 2005)}$$
$$Mw = 1.269Ms - 1.0436$$

3. Calculate the epicenter and hypocenter values using the formula:

$$\Delta = \left(\sqrt{(\varphi_E - \varphi_S)^2 + (\lambda_E - \lambda_S)^2}\right) \times 111\ km$$
$$R = \sqrt{\Delta^2 + D^2} \qquad \text{(Sunarjo \& Pribadi, 2012)}$$

Description:
Δ = Epicenter; φ = latitude; λ = Longitude; R = Hypocenter; D = Depth;

4. Calculate the peak ground acceleration value using several attenuation formulas (Table 1) from the Ground Motion Prediction Equation (GMPE) catalog (Douglas, 2019)
5. Processing the results of empirical calculations and loading them in the form of maps using QGIS software.
6. Analyzing the results of the calculation of the empirical formula with the results that are read on the accelerograph record through the approach of the Land Movement Vulnerability Zone Map, geological conditions and the BMKG shakemap.

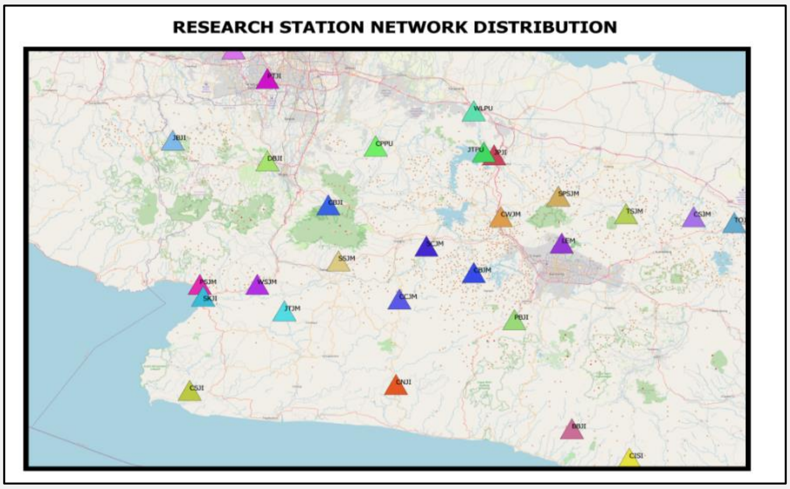
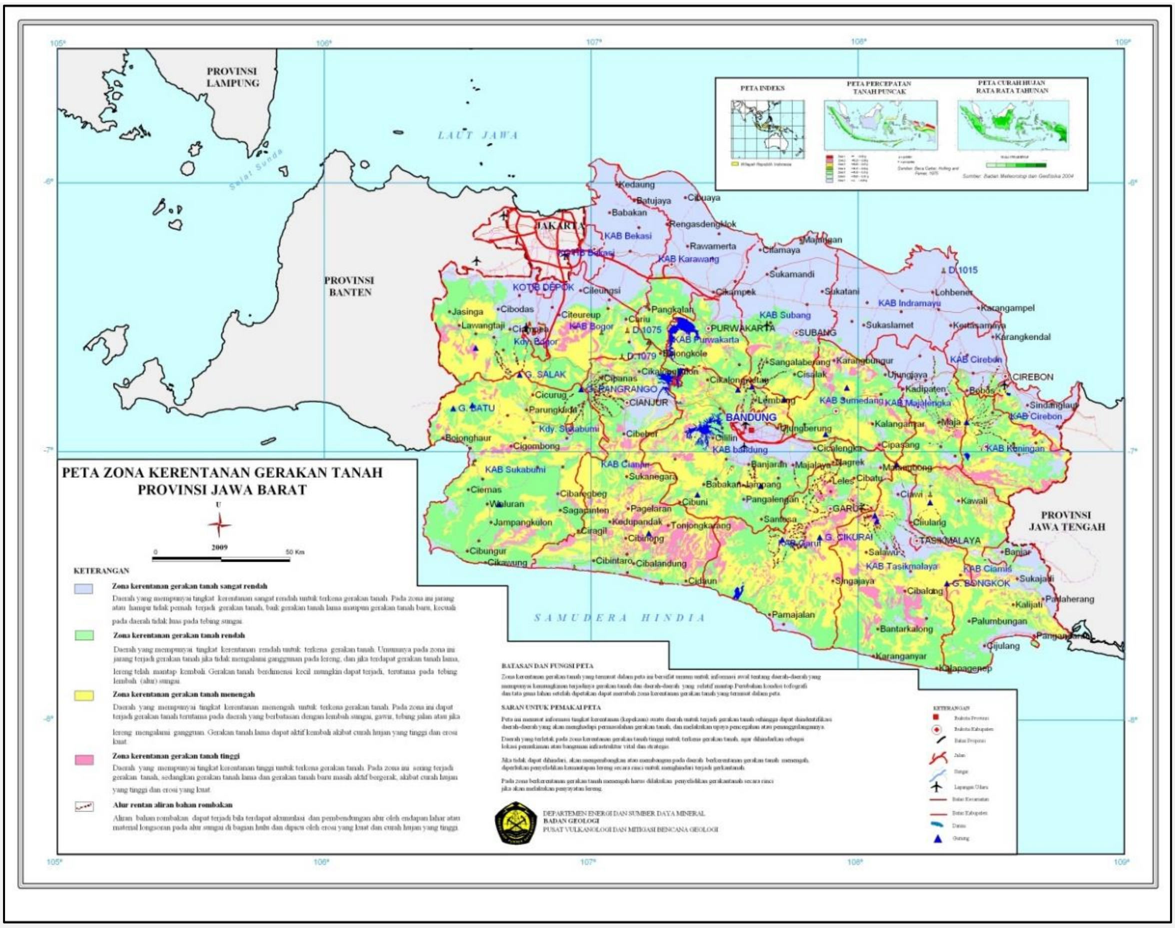


Figure 1. Distribution of Station Network



(a)

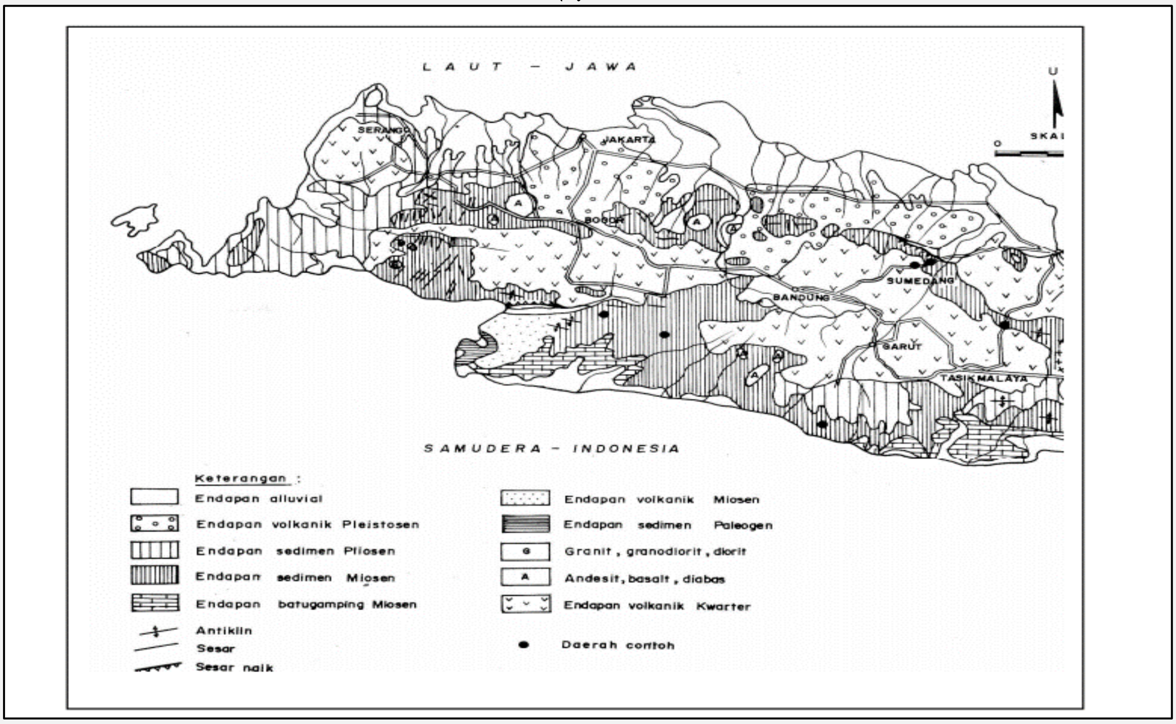


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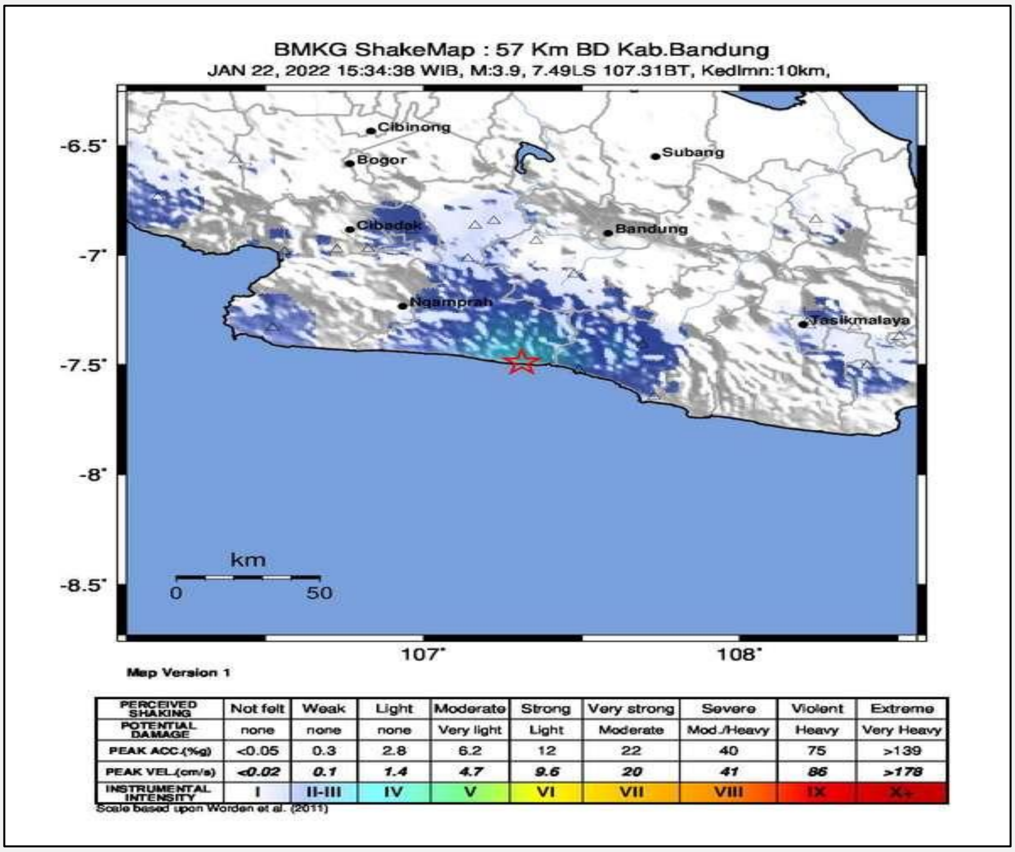
Figure 2.(a) Map of Land Movement Vulnerability Zone (PVMBG, 2022) and (b) Geological Map of West Java (Sampurno, 1976)



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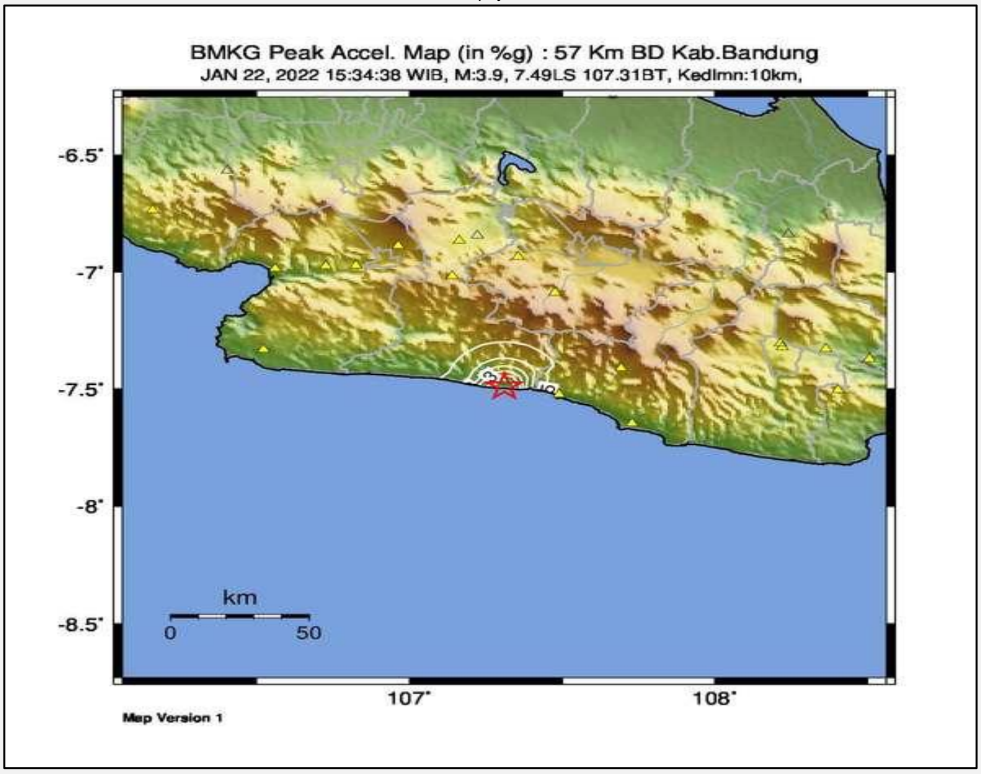

(b)

Figure 3. (a) Shakemap and (b) BMKG PGA Map (BMKG, 2022)

Table 1. Empirical formula used in research (Douglas, 2019)

Name	Formula	Description
Inan et al. (1996)	$\log PGA = aM + blogR + c$	$a = 0.65$ $b = -0.9$ $c = -0.44$
Katayama (1974)	$\log A = c_1 + c_2 \log(R + c_3) + c_4M$	$c_1 = 2.308$ $c_2 = -1.637$ $c_3 = 30$ $c_4 = 0.411$ A = PGA Value
Peng et al. (1985)	$logA_m = a_1 + a_2M - logR - a_3R$	$a_1 = -1.49$ $a_2 = 0.31$ $a_3 = 0.0248$ A_m= PGA Value R = Hipocenter M = Magnitude

RESULTS AND DISCUSSION

In general, there is no significant difference from the calculation results between the empirical formulas of Inan et al. (1996), Peng et al. (1985) with the results of BMKG acceleorgraph calculations. This can be seen in the results of the calculations in Table 2, the shakemap and the BMKG peak gorund acceleration map (Figure 3). The difference in the peak ground acceleration value is very striking on the map based on the calculations of Katayama (1974) the closest location around the earthquake epicenter has an intensity of III - IV MMI with a peak ground acceleration value ranging from 0.35 - 1.1 %g while on the map Inan et al. (1996) had an intensity of II – III MMI with peak ground acceleration values ranging from 0.23 – 0.59 %g and Peng et al. (1985) the closest location around the epicenter had an intensity of I–II MMI with a peak ground acceleration value ranging from 0.002 – 0.315 %g.

Table 2. Comparison of results on accelerograph with calculation of attenuation formula

Sta	Int	Dist (Km)	PGA(%g)			
			Real	Inan et al. (1996)	Katayama (1974)	Peng et al. (1985)
CCJM	3.1	55.8	0.5067	0.337	0.561	0.3714
CSJI	1.9	106.52	0.14545	0.221	0.328	0.0034
SCJM	1.9	107.22	0.0621	0.265	0.417	0.1069
SSJM	1.7	106.96	0.07345	0.252	0.391	0.0079
CBJM	1.3	61.9	0.0733	0.31	0.45	0.0224
BKJI	1	132.4	0.01915	0.152	0.192	0.00015
CIJI	1	101.8	0.03665	0.119	0.284	0.0016
PBJI	1	107.476	0.05575	0.381	0.646	0.0634
PSJM	1	106.56	0.0181	0.196	0.278	0.0014
WSJM	1	106.73	0.0635	0.226	0.337	0.0039

Katayama (1974) calculation is closer to the value read at the CCJM station when compared to the calculation of Inan et al. (1996) and Peng et al. (1985). At the calculation station, Inan et al. (1996) are closer to the values read at CSJI, SSJM, BKJI, PSJM and WSJM stations, while the calculations are closer to the values read at SCJM, CBJM and PBJI stations.

The intensity of the shaking and the value of ground acceleration recorded at the SSJM Station in the Sukabumi area were 1.7 MMI and 106.96 %g. Shock intensity and ground acceleration values are slightly higher at SCJM station which is located in Cianjur area where this location is further from the epicenter when compared to SSJM Station. This is because the geological conditions in the Sukabumi area are dominated by quarterly volcanic deposits compared to the Cianjur area which is dominated by Miocene sediments. This can also be validated with a map of the landslide susceptibility zone (Figure 2a) where the zone at the SSJM Station is located at a higher ground movement susceptibility zone than at the SCJM station.

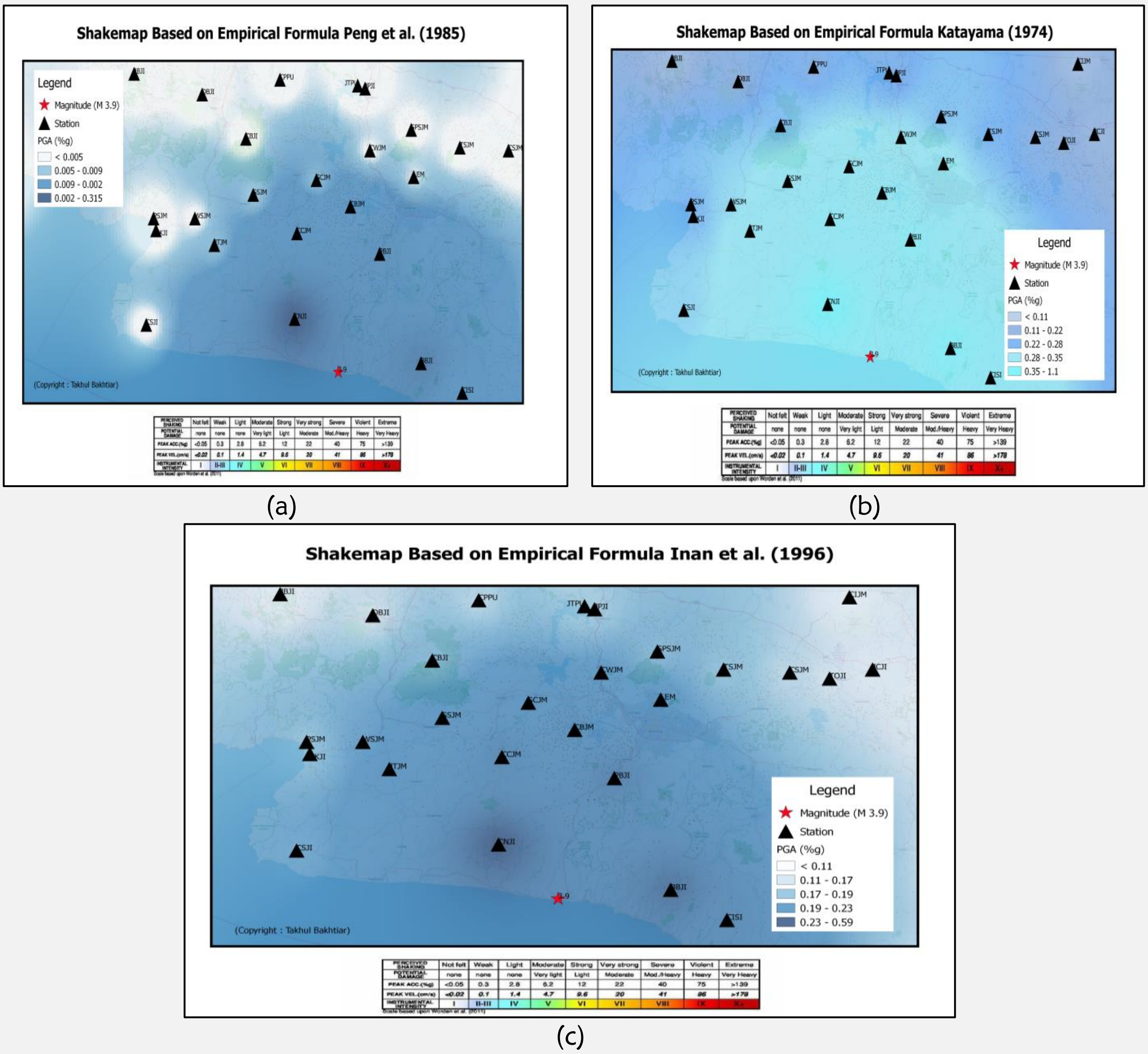

Figure 4. Map based on empirical formula (a) Peng et al. (1985), (b) Katayama (1974) and (c) Inan et al. (1996)

Shock intensity and ground acceleration values recorded at CBJM stations in the West Bandung area were 1.3 MMI and 0.0733 %g at a distance of 61.9 km closer to the earthquake epicenter when compared to CSJI, SCJM and SSJM stations which were farther away from the three stations. This is because the geological conditions in the CBJM station area are dominated by quarterly volcanic deposits, while at the SCJI station the Sukabumi area is dominated by Miocene limestone deposits and the SSJM station in the Sumedang area has a geological character in the form of Miocene sedimentary deposits. This can also be validated through the Ground Movement Vulnerability Zone Map (Figure 2a) where the zone at CBJM Station is located in a lower ground movement vulnerability zone than at CSJI, SCJM and SSJM Stations.

In general, the intensity of the shock at the WSJM station was recorded on the accelerograph around the intensity I MMI equal to the value recorded at the PBJI and PSJM stations. However, the value of ground acceleration at WSJM Station has the greatest value between PBJI and PSJM stations. If you look at the geological conditions in Figure 2b, it can be seen that the location is located in the geological conditions of Miocene sedimentary deposits compared to the geological conditions at the PBJI and PSJM stations which are generally dominated by volcanic deposits so that this causes the acceleration value in the WSJM area to be higher and can validated with a map of the landslide susceptibility zone that the zone is in a higher landslide susceptibility zone than the two locations.

CONCLUSION

Geological conditions in an area and the distance from the station to the earthquake epicenter affect the peak ground acceleration value which causes the peak ground acceleration value to vary. Katayama (1974) calculation obtained an overestimated value compared to the actual value, while Peng et al. (1985) calculation obtained a slightly different value from the actual value, but Inan et al. (1996) calculation is closer to the true value. Thus, the empirical equation that is more suitable to be used is the empirical equation of Inan et al. (1996).

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