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Utilizing Geographic Information Systems to Map Earthquake Disaster Risk in the Citatah Karst Industrial Area

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Abstract

The Lembang fault is located very close to the Citatah industrial area in West Bandung Regency. This location makes the Citatah industrial area highly susceptible to earthquakes caused by the Lembang Fault. The aim of this research is to map the distribution of factories which are part of the earthquake risk, danger and vulnerability zone. The method used is a survey method using the Geographic Information System application. Information on vulnerabilities, hazards and risks is obtained through INARISK, while factory distribution is obtained by direct site surveys. Based on the analysis, it was found that the Citatah karst area has 34 mining factories spread close to the main road. The vulnerability assessment describes that 33 factories are in locations with high vulnerability, while moderate vulnerability consists of 1 factory. The hazard analysis describes that there are 20 factories in the high-risk zone, 10 factories in the medium risk zone and 4 factories in the low-risk zone. The risk of earthquake disasters has three classifications, namely low, medium and high. Based on the analysis, it was found that 26 factories were in the high-risk zone and 8 factories were in the medium zone. This area is close to the Lembang fault, so it is at high and medium risk. The low-risk zone is located at low elevation and the furthest part of the karst area from the Lembang fault. This research can be useful in for spatial planning and mitigation strategies in earthquake-prone areas.

Keywords: Earthquake, Risk, Karst Area, Industrial Area

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1. Introduction

Fault earthquakes are caused by accumulated stress on a fault that is eventually released in a sudden movement. The support forces that build up along faults over time are caused by tectonic shifts of the Earth's plates (Zi et al. 2023). When this pressure exceeds the strength limit of the material, a sudden shift occurs which produces seismic waves (Zhai et al. 2023). Areas around active faults have a high risk of earthquake disasters (Li et al. 2023). Earthquakes cause shifts in the ground that impact surrounding buildings.

The Lembang fault is a type of geological fault where two blocks of land slide horizontally towards each other. Earthquakes caused by fault activity are often called earthquakes due to active fault activity (S. Q. Li 2023) such as the Lembang fault. This earthquake occurs when the accumulated pressure on a fault reaches the limit of material strength, and then a sudden shift occurs along the fault, this is what causes vibrations or shocks that we feel as earthquakes (Du et al. 2023).

When the Lembang fault releases energy suddenly in the form of an earthquake, this energy will propagate as seismic waves in all directions from the epicenter. These waves create vibrations that we feel as earthquake shocks in areas that are relatively close to the epicenter (Wu et al. 2019) even in karst areas. This shaking can cause damage to buildings and infrastructure (Khansefid et al. 2023), and has the potential to threaten human safety (Buonanno, Plevani, and Puca 2023). Earthquakes can also occur in karst areas with geological conditions that support earthquake stimulants (Wu et al. 2019).

The Lembang fault is located very close to the Citatah industrial area in West Bandung Regency. Earthquake disasters in industrial areas can have a significant impact on infrastructure, operations and safety throughout an industrial complex. The risk of earthquake disasters is very important to minimize casualties (Yue, Li, and Zhang 2023). Risk is a combination of danger, vulnerability and disaster capacity. Active structural areas are part of earthquake disaster vulnerability zones (S. Li 2023). Karst areas have the potential for disaster and need mitigation efforts (Zamroni, Trisnaning, and Widiatmoko 2023). Karst areas have variations in disasters that are adapted to geological conditions (Xie and Guo 2017).

Industrial areas often have many buildings, equipment, hazardous materials, and supply networks that can be vulnerable to earthquakes. In several industrial areas there are several factories which have high vulnerability to employees. Factories often have a variety of equipment, building structures, and hazardous materials that can be vulnerable to earthquakes. The Citatah karst area has part of the mining industry activities (Rohaendi et al. 2021). Karst areas are quite identical to industrial areas, because they have mining resources (Yanan and Yuan 2003). In karst areas, the mining product taken is limestone (Reinhart, Putra, and Rafida 2023).

The Citatah Karst area is an industrial area with quite a lot of employees. This industrial area is engaged in limestone or limestone mining. Geospatial information related to assessing the risk, vulnerability and hazard of earthquake disasters is important for providing mitigation and planning efforts. Map products are able to visualize and provide information in an interesting and informative way. The distribution of factories

in the Citatah Karst Area can be visualized and compared with earthquake disaster products. The aim of this research is to map the distribution of factories which are part of the earthquake risk, danger and vulnerability zone. This research can be useful in planning and mitigating earthquake disasters in the Citatah karst industrial area.

2. Method

This research was conducted in the Citatah Karst Area, West Bandung, Indonesia. Based on the digitization results, the Citatah Karst Area has an area of 12,364.67 ha (Figure 1). The Citatah Karst area is located quite close to the active fault earthquake source, namely the Lembang fault. The Karst area is a unique landform and has potential resources that can be exploited, such as mining (Reinhart et al. 2023). Mining activities cause land shifts due to vibrations from the use of heavy equipment. Earthquakes can also cause land shifts, so the potential for disaster in the Citatah Karst Area is very high. The location objects in this research are industrial areas and factory locations which are inhabited by many mining employees.

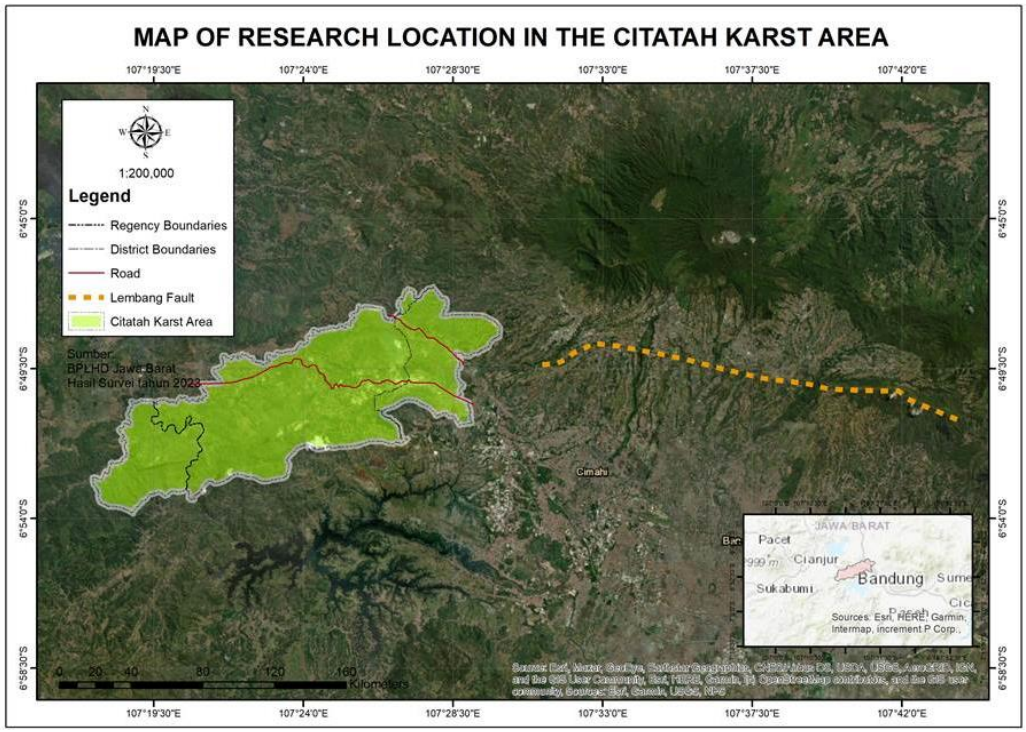

Figure 1. Research Location

The distribution of factories is mapped through direct surveys and geotagging using the Global Positioning System (GPS). The factory location was identified through a survey of the community and geotagging the coordinates of the factory location. The total number of factories mapped are those in the Citatah Karst Area. Geotagging is a technique of adding geospatial information metadata such as coordinates with the addition of other variables. The data taken, apart from coordinates and altitude, is documentation and information related to the identity and specifications of factory products. Survey data will be processed using Geographic Information System (GIS) software for analysis and visualization (Nyimbili et al. 2018).

The earthquake vulnerability assessment scheme follows the regulations of the National Disaster Management Agency (BNPB) (Hizbaron et al. 2024). Earthquake

vulnerability products are processed through metadata which can be freely accessed at https://inarisk.bnpb.go.id/. The type of data obtained is raster with dial number values and BNPB standard vulnerability classification (Kartadireja et al. 2024). The earthquake vulnerability map was analyzed and visualized using Geographic Information System (GIS) software (Mavroulis et al. 2025), which was adapted to the location of the Citatah Karst Area. The vulnerabilities referred to in this study are social vulnerability and physical vulnerability. BNPB's INARISk product is a finished product in raster format, making it easier for users to study earthquake vulnerability (Carol et al. 2023). The planning map product will be overlaid with an intersect on the industrial area, namely the factory location, so that it will be visible where the factory locations are classified as low, medium and high vulnerability. Earthquake disaster vulnerability is very important to minimize the impact of earthquakes on vulnerability values (Shadmaan and Popy 2023).

The earthquake hazard map is adapted from the National Disaster Management Agency (BNPB) product which can be accessed freely at https://inarisk.bnpb.go.id/. Earthquake data is in the form of geospatial data, namely raster data. Raster data is processed, analyzed and visualized using Geographic Information System (GIS) software (Nazirurrahman et al. 2025). Earthquake hazard can be mapped using a spatial approach (Jena et al. 2023). In the processing, we adjust the polygons of the Citatah Karst Area, so that the disaster hazard information presented is limited according to the object. The earthquake hazard obtained from INARISK products is based on the shaking intensity in the bedrock or Peak Ground Acceleration (PGA) as well as the calculation of the Ground Amplification Factor value (Pratama et al. 2022). This model was developed by JICA in 2015 and adapted by BNPB (Afisa et al. 2023). The results of the hazard study will be overlaid in an intersection with the location of the factory, so that it will be known which factories fall into the low, medium and high earthquake hazard classifications.

Earthquake disaster risk is a unity of vulnerability, danger and capacity to face earthquake disasters. The earthquake risk data used in this research is a product of the National Disaster Management Agency (BNPB) which can be freely accessed via https://inarisk.bnpb.go.id/. Disaster risk products are raster data that can be analyzed using Geographic Information System (GIS) software. Earthquake disaster risk studies can be a recommendation in planning studies, as a mitigation effort (Dabiri et al. 2022). Risk information contains low, medium and high classifications. In practice, the earthquake disaster risk product will be compared with the factory location in the Citatah Karst Area, then the status of the factory regarding earthquake disaster risk will be identified.

3. Result and Discussion

A. Factory Distribution Mapping

The Citatah Karst area has a localized mining factory industrial area. Based on the survey results, there are 34 factories in the Citatah karst industrial area. The factory locations are spread along the main road in the central area of the karst area that divides from north to south. The majority of factory locations are on the side of the main road, so accessibility is quite easy. Other factories outside the main road are close to the main road, and have special roads for mining operational vehicles. This condition concludes that the Citatah karst industrial area is located along the main road. Limestone mining

locations are spread close to the factory location. There are several limestone cliffs that are mined, such as cliff 125, cliff 90, and other cliffs. The cliff location is quite close to several limestone processing factories.

The factory location is on a wavy topography, so access to the location winds along the contour. The industrial area in the Citatah karst is an area with medium height compared to non-industrial areas. In the western area, the majority of karst areas are tourism areas and have quite low elevations compared to mining areas. The employees of the Citatah karst mining factory are mostly local people who live in the Citatah area. The distribution of factory locations in the Citatah karst area can be seen in figure 2.

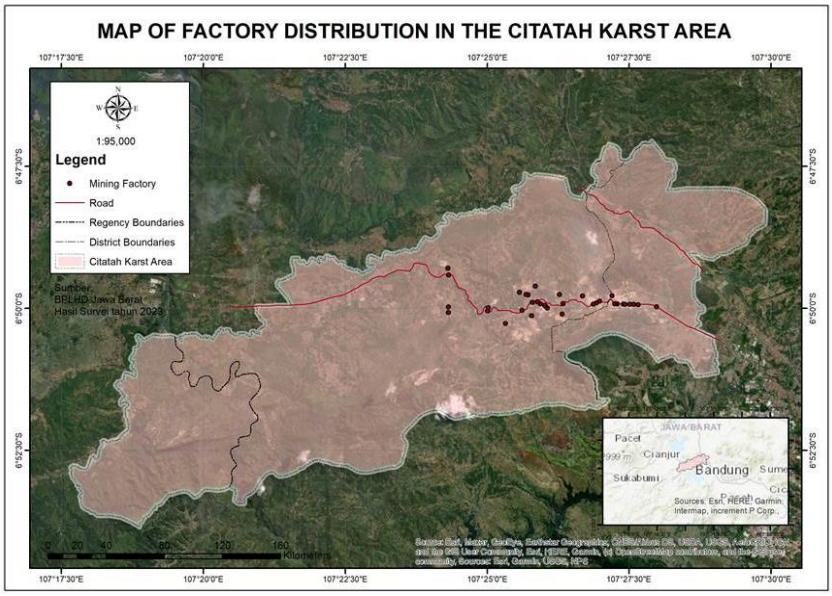

Figure 2. Map of Factory Distribution in the Citatah Karst Area

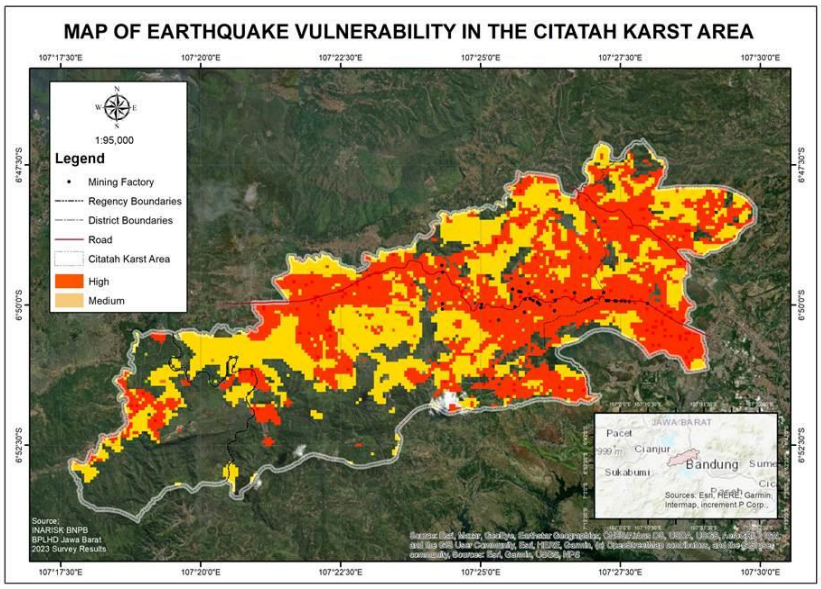

Figure 3. Earthquake Vulnerability Map of the Citatah Karst Area

B. Mapping earthquake vulnerability in factories

The Citatah karst area is an area with high and moderate earthquake vulnerability. Based on INARISK data, it was found that areas of high and moderate vulnerability are spread across the eastern, central, southern and northern parts of the Citatah karst area. The analysis results show that 33 factories are in locations with high vulnerability, while moderate vulnerability consists of 1 factory (table 1). The vulnerability in question is the vulnerability of various aspects, starting from physical and social conditions. Factories with high vulnerability conditions can create earthquake disaster mitigation schemes by implementing an early warning system (EWS). The earthquake vulnerability map with visualization of factory distribution can be seen in figure 3. Areas with colorless patches are areas that are not vulnerable to earthquake disasters:

C. Mapping earthquake hazards in factories

The danger of earthquakes in the Citatah Karst Area is spread across various classifications, namely low, medium and high. This danger indicates the area's resistance to earthquake vibrations, ground vibrations and surrounding geographical conditions. Based on the analysis, it was found that there were 20 factories in the high danger zone, 10 factories in the medium zone and 4 factories in the low zone. Areas with high danger are spread in the eastern area adjacent to the Lembang fault, apart from that there are also in the northwestern area, which is a fragile zone in the karst area. Factories with high hazards are located close to the main road, while the low and medium classifications are quite far from the main road. The earthquake hazard map with visualization of factory distribution can be seen in figure 4.

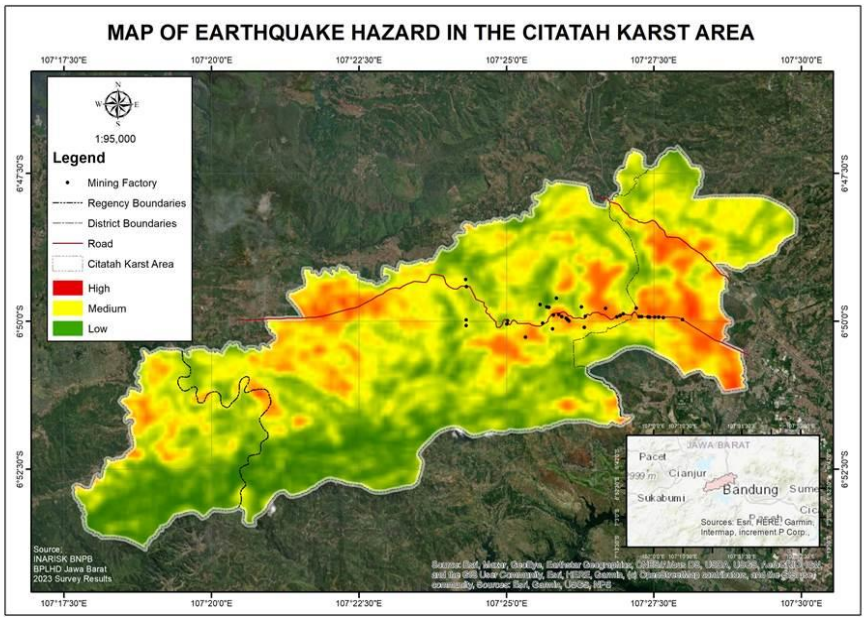

Figure 4. Earthquake Hazard Map of the Citatah Karst Area

D. Earthquake risk mapping in factories

Earthquake disaster risk is a combination of vulnerability, hazard and capacity. The earthquake disaster risk product was adapted from INARISK which was visualized with the distribution of factories in the Citatah Karst Area. The risk of earthquake disasters has three classifications, namely low, medium and high. Based on the analysis, it was found

that 26 factories were in the high-risk zone and 8 factories were in the medium zone. Zones of high and moderate earthquake risk dominate the east, north and southeast. This area is close to the Lembang fault, so it is very rational if it has a high earthquake risk. The risk of earthquake disasters is low in the southwest area of the Citatah karst area. This area is a flat area and is crossed by a large river, namely the Citarum River. Some of these areas have alluvial landforms. The names of factories and locations affected by risks, hazards and vulnerabilities can be seen in table 1.

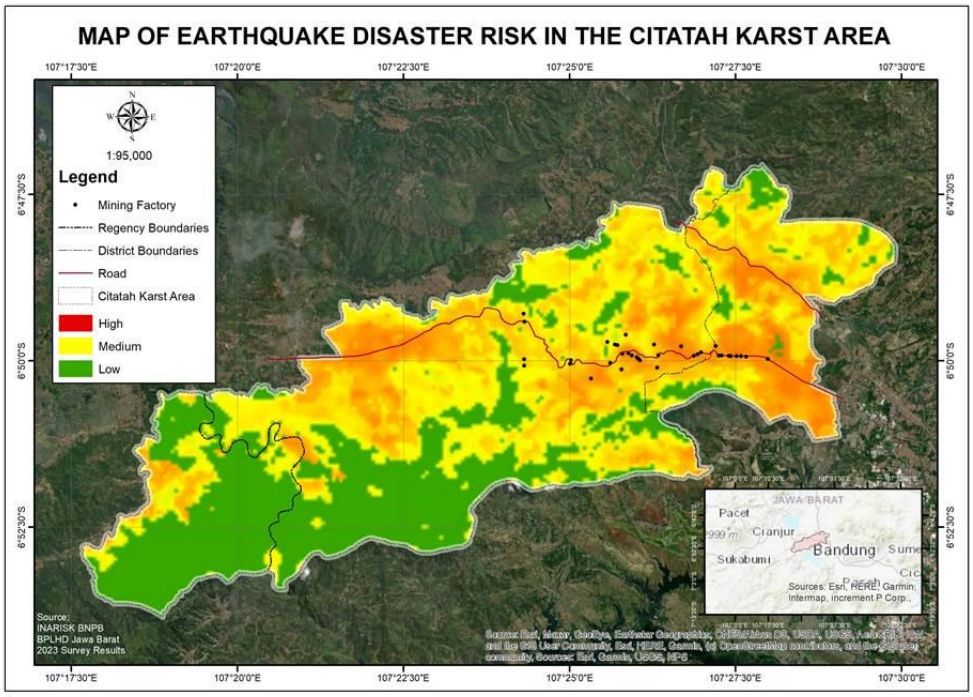

Figure 5. Factory Location in Earthquake Disaster Risk Area

No	Elevation	Lat	Long	Name (Initial)	Type	Vulnerability	Hazard	Risk
1	538.38	-6.83320599608	107.4169700030	PT. Apnd	Factory	High	Low	Medium
2	750.75	-6.83215096593	107.4566699660	PT. BM	Factory	High	High	High
3	663.99	-6.83195399120	107.4389719960	PT. BR 1	Factory	High	Medium	High
4	552.32	-6.83416698128	107.4167799860	PT. BR 2	Factory	High	Medium	High
5	751.24	-6.83210997842	107.4478060190	PT. BWPS	Factory	High	High	High
6	736.98	-6.83173698373	107.4487960060	PT. BMA	Factory	High	High	High
7	677.70	-6.82929198258	107.4378400200	PT. BA	Factory	High	Medium	High
8	473.14	-6.82159001939	107.4051189980	PT. Bmdy	Factory	High	Medium	Medium
9	454.90	-6.82361600921	107.4053660130	PT. EMI	Factory	High	Medium	High
10	752.05	-6.83217703365	107.4571100160	PT. FA	Factory	High	High	High
11	660.29	-6.83328897692	107.4343379770	PT. GN PNPM	Factory	High	High	High
12	623.20	-6.82683197781	107.4307660290	PT. IM	Factory	High	Low	Medium
13	595.80	-6.82943598367	107.4286889940	CV. JI	Factory	High	Medium	Medium
14	727.07	-6.83231499977	107.4610050020	PT. Klst	Factory	High	High	High
15	745.73	-6.83220502920	107.4585200190	PT. KM	Factory	High	High	High
16	759.53	-6.82967101224	107.4533379920	PT. KP	Factory	High	High	High
17	760.89	-6.83208097704	107.4548370110	PT. KAP	Factory	High	High	High

18	583.56	-6.82864800096	107.4261819660	PT. KJMi	Factory	High	Low	Medium
19	625.54	-6.83160102926	107.4299460280	PT. MZ	Factory	High	High	High
20	539.70	-6.83458297513	107.4052840380	PT. Mlvn	Factory	Medium	Medium	Medium
21	654.81	-6.83283903636	107.4338870310	PT. MJ G	Factory	High	High	High
22	757.74	-6.83207100257	107.4541259740	PT. MMA	Factory	High	High	High
23	745.33	-6.83125996962	107.4496610180	PT. MMUT	Factory	High	High	High
24	650.95	-6.83244902641	107.4335430380	PT. Nstr	Factory	High	High	High
25	740.62	-6.83222296648	107.4596550130	PK	Factory	High	High	High
26	603.38	-6.82932299562	107.4280780370	CV. Prtw	Factory	High	Low	Medium
27	674.83	-6.83550003916	107.4297280140	PT. Pmrn	Factory	High	Medium	High
28	603.99	-6.83393597603	107.4268800110	PT. RHJ	Factory	High	Medium	High
29	729.87	-6.83293903247	107.4664180350	PT. SMA	Factory	High	High	High
30	617.82	-6.83781302534	107.4220449940	PT. SS	Factory	High	High	High
31	529.78	-6.83297700249	107.4052810200	PT. SM	Factory	High	Medium	Medium
32	642.74	-6.83201199397	107.4322860040	PT. Srjv	Factory	High	High	High
33	644.55	-6.83147203177	107.4314649960	PT. SJ	Factory	High	High	High
34	697.28	-6.83504397981	107.4386280030	PT. Tns	Factory	High	High	High

4. Conclusion

The Citatah Karst area has a localized mining factory industrial area. Based on the survey results, there are 34 mining factories in the Citatah karst industrial area. The factory locations are spread along the main road in the central area of the karst area that divides from north to south. The earthquake vulnerability study shows that 33 factories are located in locations with high vulnerability, while moderate vulnerability consists of 1 factory. Vulnerability is related to physical and social conditions. The earthquake hazard analysis describes that there are 20 factories in the high danger zone, 10 factories in the medium zone and 4 factories in the low zone. Areas with high danger are spread in the eastern area adjacent to the Lembang fault, apart from that there are also in the northwestern area, which is a fragile zone in the karst area. The risk of earthquake disasters has three classifications, namely low, medium and high. Based on the analysis, it was found that 26 factories were in the high-risk zone and 8 factories were in the medium zone. Zones of high and moderate earthquake risk dominate the east, north and southeast. This area is close to the Lembang fault, so it is very rational if it has a high earthquake risk.

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