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Determination of Physical and Social Vulnerability Zones in Cisarua District, West Bandung Regency, Using Remote Sensing and Geographical Information Systems

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ABSTRACT

Cisarua is an area in West Bandung that is categorized as prone to earthquakes due to its position close to the Lembang fault. Research in determining physical and social vulnerability zones is needed to reduce the impact of earthquake disasters and determine the relationship between social and physical vulnerability. The research approach uses quantitative analysis with scoring, weighting, and overlay using remote sensing spatial analysis and geographic information systems. Data collection techniques for physical vulnerability variables are secondary data indicators of building density, length of the road network, and the number of permanent buildings, while social vulnerability variables are secondary data indicators of population density, population under five, elderly, women, and persons with disabilities. The results of the study obtained a mapping of the level of physical vulnerability in Cisarua District with a very high score, namely Jambudipa Village, while the lowest scores were in the areas of Pasirhalang Village, Padaasih Village, Tugumukti Village, Sadangmekar Village, and Cipada Village. For mapping the level of social vulnerability in Cisarua District, a very high score was found in the Jambudipa Village area and very low in Tugumukti Village.

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1. INTRODUCTION

Disaster is a series of events that can threaten and disrupt people's lives and livelihoods caused by natural, non-natural, and human factors (Pribudianto et al, 2023; Rahman F, 2019). Natural disasters can result in fatalities, harm to the environment and property, and psychological effects on those who are affected (BNPB, 2012; Ningsih et al, 2023). Indonesia is one country that is vulnerable to natural disasters (Huda, 2021). In 2023, Indonesia was ranked 2nd because it had a risk index of 43,5 out of 100 (World Risk Report, 2023).

Vulnerability is an individual or community group's inability to minimize the impact caused by a hazard, so that when a disaster occurs the government can determine areas that are priorities for disaster mitigation management (Jaswadi et al., 2016; Mantika et al, 2020). Information about disasters spatially is needed, especially information about the level of vulnerability, which is critical to be presented to the community (Choirunisa and Ginarsih, 2016; Mills, 2009). By knowing possibilities and losses, planning focus and implementation integration disaster management becomes more effective (Rumadan and Darwin, 2016).

The purpose of this study was to determine the level of physical and social vulnerability to earthquakes in the Cisarua District, West Bandung Regency, West Java Province, and to find out the relationship between the two physical and social vulnerabilities in the research area as a form of disaster risk reduction (Hapsoro, 2015). Vulnerabilities, according to ADPC 2006, are grouped into five categories (Rahman et al, 2015; Rahman et al, 2018), namely:

1) Physical vulnerability includes the age and construction of buildings, building materials, road infrastructure, and public facilities.
2) Social vulnerability includes perceptions of risk and views of people's lives related to religion, ethnicity, culture, age, social interaction, and gender.
3) Economic vulnerability, including income per capita, poverty, investment, land potential, and potential loss of goods/supplies that arise.
4) Environmental vulnerability, including water, air, soil, flora, and fauna.
5) Institutional vulnerability, including disaster management systems, central/regional government governance, and central/regional government regulations regarding disaster management.

Vulnerability is a pre-disaster condition that has the potential to become a disaster when faced with a hazard (Hossain and Paul, 2018). A vulnerable area that has high vulnerability will result in the element of risk experiencing a more significant hazard and increased disaster risk (Pamungkas and Ningrum, 2022). The elements include settlements, agricultural or plantation productive land, public facilities, and infrastructure (Santosa and Sutikno, 2006). In terms of disaster, what needs to be understood are three important interrelated points: vulnerability and capability with the scale used based on the portion of the level, both at the state, big city, district, and local scale. The understanding of community vulnerability in this research is intended to identify the relationship between physical and social vulnerability in village areas in Cisarua District, West Bandung Regency.

2. METHODS

The research uses quantitative methods, namely weighting, scoring, and overlaying, with the help of ArcGIS 10.8.3 software to determine the level of vulnerability. The approach used in this study is a spatial approach that describes field conditions spatially by using a Geographic Information System as a tool used to process, analyze, and present physical and social vulnerability data for earthquakes in Cisarua District, West Bandung Regency. In essence, spatial analysis is an analysis using geographical references that yields studies on location and all things relevant to distribution patterns (Fachri et al, 2022). Using a spatial

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approach is expected to see the level of physical vulnerability and social vulnerability to earthquake disasters in each village area in Cisarua District, West Bandung Regency (Astari et al, 2021).

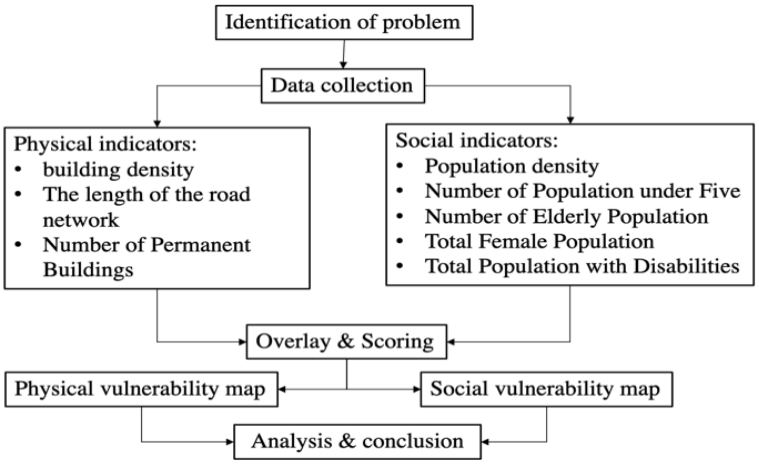

Figure 1. Physical and Social Vulnerability Research Framework

Figure 1 describes the research framework carried out for the stages in determining the level of physical and social vulnerability in Cisarua District, West Bandung Regency, starting from data collection, processing with weighting and scoring, overlaying mapping of geographic information systems and remote sensing from secondary data and data. Satellite imagery to visualize physical and social vulnerability mapping can be analyzed about the relationship between vulnerability types in earthquake disaster studies (Ebert et al, 2009).

The data used in this study is secondary data obtained from various sources, including the Central Bureau of Statistics, in the form of indicators of population density, the number of children under five, the number of older people, and the number of women. Secondary data from the West Bandung Regency Government is in the form of data on the number of people with disabilities and permanent buildings. Secondary data sourced from the Geospatial Information Agency consisting of road network length parameters and data sourced from satellite imagery in the form of population density data.

Table 1. Determination of indicators of Physical and Social Vulnerability to Earthquake Disasters

Type	Indicator	Data Source		Source
		Satellite imagery	Secondary	
Physical Vulnerability	Building Density			Landsat
	Road Network Length			BIG (2000)
	Number of Permanent Buildings			Pemkab Bandung Barat (2018)
Social Vulnerability	Population density			BPS (2021)
	Number of Population under Five			BPS (2021)
	Number of Elderly Population			BPS (2021)
	Total Female Population			BPS
	Total Population with Disabilities			Pemkab Bandung Barat (2019)

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After the data is collected, the next step is data analysis. The analytical method used is scoring and weighting analysis. Scoring analysis gives a score on each parameter used in the study. The scoring and weighting used in this study are based on modified criteria of PERMEN PU No. 21/PRT/M/2007, Kepmen PU No. 378/KPTS/1987, and the modified 2009 Guidelines for Preparing Disaster Risk Zones, as well as Desmonda and Pamungkas references for 2014.

Table 2. Scoring Indicators of Physical and Social Vulnerability Parameters to Earthquake Disasters

Type	Indicator	Score	Criteria
Physical Vulnerability	Building Density	1	< 10
		2	10 – 30
		3	30 – 50
		4	50 – 80
		5	> 80
	Road Network Length (Km)	1	< 8 Km
		2	8 – 16 Km
		3	16 – 24 Km
		4	24 – 32 Km
		5	32 – 40 Km
	Number of Permanent Buildings (Buildings)	1	< 500
		2	500 - 1000
		3	1000 – 1500
		4	1500 – 2000
		5	> 2000 Km
Social Vulnerability	Population density (people/Ha)	1	< 10
		2	10 – 15
		3	15 – 20
		4	20 – 25
		5	> 25
	Number of Population under Five (people)	1	< 2.000
		2	2.000 – 4.000
		3	4.000 – 6.000
		4	6.000 – 8.000
		5	8.000 – 10.000
	Number of Elderly Population (people)	1	< 3.000
		2	3.000 – 6.000
		3	6.000 – 9.000
		4	9.000 – 12.000
		5	12.000 – 15.000
	Total Female Population (people)	1	< 11.000
		2	11.000 – 22.000
		3	22.000 – 33.000
		4	33.000 – 44.000
		5	44.000 – 55.000
	Total Population with Disabilities (people)	1	< 9
		2	9 – 18
		3	18 – 27
		4	27 – 36
		5	36 – 45

Source: Modification of Pedoman Penyusunan Zonan Risiko Bencana; Kepmen PU No. 378/KPTS/1987 and Desmonda and Pamungkas, 2014.

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From the vulnerability scoring categories above, weighting is carried out for each vulnerability by dividing it into 25% physical and 40% social vulnerability. From the results of the weighting of each vulnerability in **Table 3**, then the vulnerability is classified as follows:

Table 3. Scoring of Physical and Social Vulnerability

Vulnerability	Final Score	Class
Physical Vulnerability	1.50 – 1.75	Very Low
	1.76 – 2.00	Low
	2.01 – 2.25	Moderate
	2.26 – 2.50	High
	2.56 – 2.75	Very High
Social Vulnerability	2.40 – 3.19	Very Low
	3.20 – 3.59	Low
	3.60 – 5.59	Moderate
	5.60 – 7.19	High
	>7.2	Very High

Source: Modification of Desmonda and Pamungkas, 2014

3. RESULTS AND DISCUSSION

Physical Vulnerability Level

The base maps for each parameter, namely the Building Density Map, the Number of Permanent Buildings Map, and the Road Network Length Map, were then analyzed using the overlay method to become a Physical Vulnerability Map. The data that has been processed is then distributed into three classes in 8 villages in Cisarua District, West Bandung Regency.

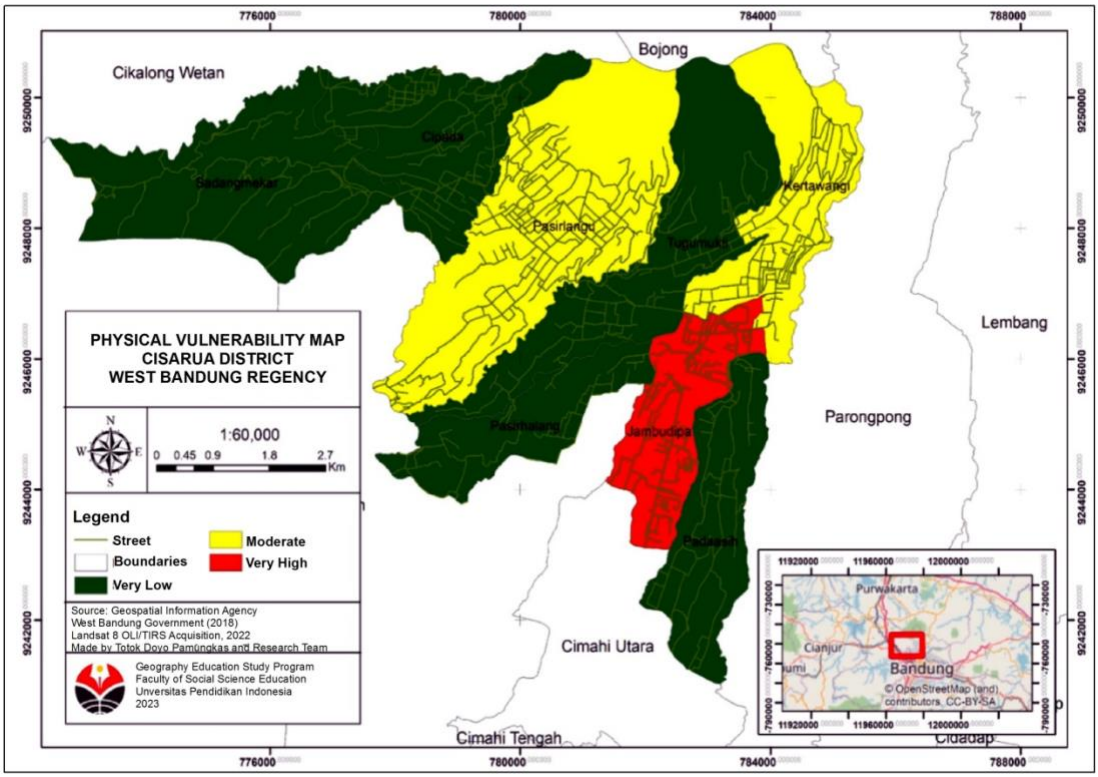

Figure 2. Physical Vulnerability Map of Cisarua, West Bandung Regency

Based on the overlay analysis in **Figure 2**, the results of the vulnerability classification with a distribution of very low physical vulnerability were found in Pasirhalang Village, Padaasih

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Village, Tugumukti Village, Sadangmekar Village, and Cipada Village with a score of 1.5 – 1.75. Meanwhile, the distribution with high physical vulnerability was in Kertawangi and Pasirlangu Villages with a score of 2.5. Then, the distribution with very high physical vulnerability is in Jambudipa Village, with a score of 2.75.

One factor causing the very high physical vulnerability in Jambudipa Village is the building density, which reaches 19 buildings/Ha or a score of 2. Meanwhile, other villages in the Cisarua District have a building density of <10 buildings/Ha. In addition, the number of permanent buildings in Jambudipa Village is the highest compared to other villages in Cisarua District, namely 2408 or getting a score of 5, while in other villages, there are only <2000 permanent buildings.

Level of Social Vulnerability

Social vulnerability analysis uses five leading indicators obtained from West Bandung Regency BPS in 2021 with the parameters obtained are population density, number of children under five, number of the elderly population, and number of women and parameters for the number of people with disabilities from West Bandung Regency Government data in 2019. The five data are then spatialized based on their respective administrative areas, and scoring and weighting are carried out. Then, an overlay analysis was carried out on the five parameter maps.

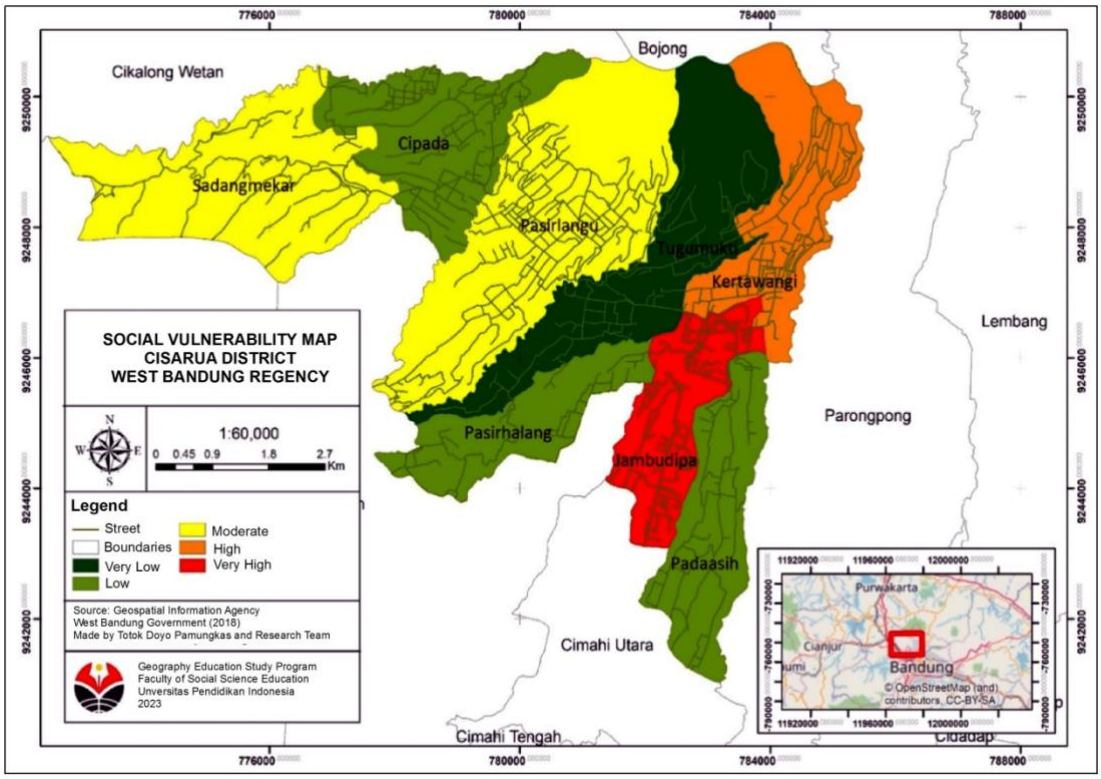

Figure 3. Social Vulnerability Map of Cisarua, West Bandung Regency

Based on the social vulnerability map analysis in **Figure 3**, the overlay results show that Jambudipa Village is the only village in the Cisarua District with a very high social vulnerability score of 7.2. Meanwhile, Kertawangi Village is in the high category with a score of 5.6; Sadangmekar Village and Pasirlangu Village are in the moderate category with a score of 3.6; Pasirhalang Village, Cipada Village, and Padaasih Village are in a low category with a score of 3.2; and Tugumukti Village is in a very low category with a score of 2.4.

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Several factors have caused the level of social vulnerability in Jambudipa Village to be very high, including the high population density of 38 people/ha, in contrast to other villages with a population density of <25 people/ha. In addition, the female population in Jambudipa Village is quite large, namely 8,616 people, compared to the female population in other villages, which is less than 8,000 people. The last parameter that makes the level of social vulnerability in Jambudipa Village high is the high number of older people, namely 1,568 people, compared to other villages, which only number less than 1,000 people.

The analysis of the relationship between the two physical and social vulnerabilities in Cisarua District, West Bandung Regency, shows that the higher the level of social vulnerability in the village area, the higher the physical vulnerability. However, the indicators displayed are different studies. The resulting linear pattern is based on mapping analysis. The geospatial method used for scoring and weighting has a value at the same level as the physical and social vulnerability level related to earthquake disaster studies, especially indicators related to population density and the number of buildings in a village area.

4. CONCLUSION

The research draws conclusions based on the results of the analysis and discussion as follows:

1. The distribution of physical vulnerability level zones in Cisarua District, Kab. West Bandung is very high in the Jambudipa Village area and very low in the Pasirhalang Village, Padaasih Village, Tugumukti Village, Sadangmekar Village, and Cipada Village.
2. Distribution of social vulnerability level zones in Cisarua District, Kab. West Bandung can be categorized as very high in the Jambudipa Village area and very low in the Tugumukti area.
3. The linearity pattern relationship between physical and social vulnerability is where the social vulnerability level affects the physical vulnerability level

5. RECOMMENDATIONS

Recommendation for further research related to earthquake disaster vulnerability needs to be carried out, such as economic and environmental studies to produce a comprehensive and detailed level of disaster vulnerability to follow up in a disaster risk analysis.

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7. REFERENCES

Astari, A. J., Mohamed, A. A. A., & Ridwana, R. (2021). The Role of Geographic Information Science in Achieving Sustainable Development Goals (SDGs) During The Covid-19 Pandemic. *Jurnal Geografi Gea*, *21*(2), 112-122.

Bencana, P. K. B. N. P. (2012). Nomor 02 tahun 2012 Tentang Pedoman umum pengkajian risiko bencana. *Badan Nasional Penanggulangan Bencana (BNPB)*, 4-50.

Choirunisa, A. K., & Giyarsih, S. R. (2016). Kajian kerentanan fisik, sosial, dan ekonomi pesisir samas Kabupaten Bantul terhadap erosi pantai. *Jurnal Bumi Indonesia*, *5*(4).

Desmonda, N. I., & Pamungkas, A. (2014). Penentuan zona kerentanan bencana gempa bumi tektonik di Kabupaten Malang wilayah selatan. *Jurnal Teknik ITS*, *3*(2), C107-C112.

Ebert, A., Kerle, N., & Stein, A. (2009). Urban social vulnerability assessment with physical proxies and spatial metrics derived from air-and spaceborne imagery and GIS data. *Natural hazards*, *48*, 275-294.

Fachri, H. T., Malik, Y., & Murtianto, H. (2022). Pemetaan Tingkat Bahaya Bencana Tsunami Menggunakan Sistem Informasi Geografis di Pesisir Kota Bengkulu. *Jurnal Pendidikan Geografi Undiksha*, *10*(2), 166-178.

Hapsoro, A. W., & Buchori, I. (2015). Kajian kerentanan sosial dan ekonomi terhadap bencana banjir (Studi kasus: Wilayah pesisir kota Pekalongan). *Teknik PWK (Perencanaan Wilayah Kota)*, *4*(4), 542-553.

Hossain, M. N., & Paul, S. K. (2018). Vulnerability factors and effectiveness of disaster mitigation measures in the Bangladesh Coast. *Earth Systems and Environment*, *2*(1), 55-65.

Huda, R. F., & Rahrajo, S. Y. (2021). Analisis Tingkat Kerentanan Bencana Dan Kesiapsiagaan Masyarakat Kecamatan Lembang Terhadap Bencana Letusan Gunung Tangkuban Perahu. *Prosiding FTSP Series*, 500-511.

Jaswadi, R. R., & Hadi, P. (2012). Tingkat kerentanan dan kapasitas masyarakat dalam menghadapi risiko banjir di kecamatan pasarkliwon Kota Surakarta. *Majalah Geografi Indonesia*, *26*(2), 119-149.

Mantika, N. J., Hidayati, S. R., & Fathurrohmah, S. (2020). Identifikasi Tingkat Kerentanan Bencana Di Kabupaten Gunungkidul. *Matra*, *1*, 59-70.

Mills, J. W. (2009). Spatial decision support in a post-disaster environment: A community-focused approach. *Cartographica: The International Journal for Geographic Information and Geovisualization*, *44*(1), 17-31.

Ningsih, R. L., Wulan, P. Y. N., Haq, A. H., Ihsan, F. N., Kusuma, R. W., Farhan, R., ... & Haryono, E. (2023). Multi-Hazard Susceptibility Analysis of Bantul Regency. *Jurnal Geografi Gea*, *23*(1), 8-18.

Pamungkas, T. D., & Ningrum, E. (2022). Analysis of Lembang Fault characteristics based on literatures of geological structure, rock formation and peak ground acceleration probabilistic earthquake analysis. *Jurnal Geografi Gea*, *22*(2), 117-124.

Pribudianto, A. R., Maryani, E., & Darsiharjo, D. Analysis of students' preparednes in public and private high school students for landslide disaster risk in Maja district. *Jurnal Geografi Gea*, *23*(1), 50-59.

Rahman, F. (2019, February). Save the world versus man-made disaster: A cultural perspective. In *IOP Conference Series: Earth and Environmental Science* (Vol. 235, No. 1, p. 012071). IOP Publishing.

Rahman, M. M., Barua, U., Khatun, F., Islam, I., & Rafiq, R. (2018). Participatory Vulnerability Reduction (PVR): an urban community-based approach for earthquake management. *Natural Hazards*, *93*, 1479-1505.

Rahman, N., Ansary, M. A., & Islam, I. (2015). GIS based mapping of vulnerability to earthquake and fire hazard in Dhaka city, Bangladesh. *International journal of disaster risk reduction*, *13*, 291-300.

Rumadan, R., & Darwin, I. S. (2016). Kajian Resiko Bencana Alam Patahan Lembang di Kecamatan Lembang, Parompong, Dan Cisarua Kabupaten Bandung Barat. *Prosiding Perencanaan Wilayah dan Kota*, 365-377.

Santosa, L. W., & Sutikno, S. (2006). Geomorphological approach for regional zoning in the Merapi volcanic area. *Indonesian Journal of Geography*, *38*(1).

Sutedjo, A. G. U. S. (2020). Analisis Tingkat Kerentanan Fisik Dan Sosial Bencana Gempabumi di Sebagaian Surabaya Barat. *Swara Bhumi*, *1*(1).

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