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Factors Affecting the Response of Bali's Society to Earthquake Information Using Structural Partial Least Squares Equations

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Abstract: Bali is a region prone to earthquakes caused by plate collision activity and back-blows from the subduction process of the Flores Ascending Fault. The geological structure of the Flores Ascending Fault in Northeast Bali triggered a large earthquake followed by a tsunami in June 2019 that spread across the south and north of the island. Due to the high potential for earthquake occurrences in Bali, a strategic planning is required to the level of earthquakes preparedness and give the earthquake information to the tourist visiting Bali. Community preparedness is, in fact, part of ensuring the safety and comfort of tourists. This research will examine the factors that affect the preparedness of the Balinese people responding to earthquake information issued by the Meteorology, Climatology, and Geophysics Agency. Data analysis was carried outusing the Structural Equation Modeling-Partial Least Square (SEM-PLS) approach. The results of this study indicate the factors of the earthquake risk belief, community participation, critical awareness, social trust, earthquake knowledges, earthquake experience, participation in disaster education and training, and knowledge of disaster mitigation had a significantly positive effect on the preparedness of the Balinese people for earthquake disasters.

Keywords: earthquake, preparedness, Structural Equation Modeling, Partial Least Square.

使用结构偏最小二乘方程的影响巴厘岛社会响应地震信息的因素

摘要：巴厘岛是一个容易发生板块碰撞活动和弗洛雷斯登高断裂俯冲过程引起的反吹地震的地区。巴厘岛东北部弗洛雷斯上升断层的地质结构引发了一场大地震，随后在 2019 年 6 月发生了海啸，波及整个岛屿的南部和北部。由于巴厘岛发生地震的可能性很高，因此需要对地震的准备水平进行战略规划，并将地震信息提供给来巴厘岛旅游的游客。实际上，社区准备是确保游客安全和舒适的一部分。这项研究将研究影响巴厘岛人民应对气象，气候和地球物理机构发布的地震信息的准备程度的因素。使用结构方程模型-偏最小二乘（扫描电镜）方法进行数据分析。这项研究的结果表明，地震风险信念，社区参与，批判意识，社会信任，地震知识，地震经验，参与灾害教育和培训以及减灾知识对减灾准备工作具有显着积极影响的因素。巴厘岛人民遭受地震灾害。

关键词：地震，准备，结构方程建模，偏最小二乘。

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Introduction

Indonesia is one of the countries that has a complex tectonic arrangement so that it is one of the countries with the most active seismic frequencies in the world. Alarge number of tectonic activitiesoccurred since Indonesia is surrounded by a Pacific ring of fire that extends from Aceh, Sumatra, Java, Bali, Nusa Tenggara, Sulawesi, Maluku, and North Maluku to Papua. It influences the confluence of four tectonic plates: the Eurasian Plate, the Pacific Plate, the Indo-Australia Plate, and the Philippine Sea Plate. The interaction of the meeting of the four plates causes a high frequency of earthquake activity in Indonesia.

Study [1], which covered 11 years (2009—2019) recorded 71,628 earthquakes spread across 34 provinces in Indonesia with an average tectonic earthquake activity of 6,512 earthquake events per year, 543 earthquake events per month, and 18 earthquake events per day. The results of sorting and visualizing the monthly earthquake charts for each province showed that the highest number of monthly earthquakes occurred in West Nusa Tenggara Province in August 2018, totaling 1,658 events. In line with this research, [2] examined the potential for earthquake-prone areas in the Regional Center 3 (RC3) area, including Bali and Nusa Tenggara, using cluster analysis. The results additionally show that Bali and West Nusa Tenggara are potentially prone to earthquake with high magnitude caused by plate collision activity and back-blows from the subduction process of the Flores Ascending Fault [3].

Paper [4] described the existence of a plate subduction zone in South Bali that substantially impacted the occurrence of several large earthquakes due to subduction activity. The earthquake occurred on May 13, 1857, in the North Bali region with a magnitude of 7.0 on the Richter scale and an epicenter at sea. This earthquake triggered a tsunami that killed 36 people. On January 21, 1917, another earthquake occurred, this one with a magnitude of 6.6 and the epicenter located in Southeast Bali. The death toll was 1,500, and it damaged 64,000 houses and palaces, destroyed 10,000 rice barns, and damaged 2,431 temples [5]. According to [6], this earthquake triggered a tsunami in Klungkung and Benoa of a height of up to two meters. The next earthquake occurred on October 13, 2011, with a magnitude of 6.8 and the epicenter located 143 km southwest of Nusa Dua. Felt in areas including Mataram, Malang, and Yogyakarta. This earthquake damaged several houses in Bali, Jember, Banyuwangi, and Lumajang, and also injured dozens of people in Denpasar, Kuta, and Nusa Dua. Then, on July 16, 2019, an earthquake with a magnitude of 6.2 occurred in southern Bali. It was centered on the sea, 80 km south of Kota Negara, Jembrana Regency. This earthquake was categorized as intermediate depth caused by the subduction activity of the Indo-Australian Plate, which infiltrated the Eurasian Plate. The results of an analysis of the source mechanism show that this earthquake was generated by rock deformation with an *oblique thrust fault* [7]–[9].

Based on this background and the lack of public knowledge on disaster preparedness, it is necessary to conduct research related to earthquake prediction that requires intensive scientific effort to meet community needs and social demands. Although seismic research has been conducted for more than a century, research on earthquake predictions continues to be an exciting area of study [10].

A wide body of research exists on earthquakes, for instance, in Nepal [11]–[13], Indonesia [1], [2], [4], [14], and Christchurch [15]–[17]. However, not all research focuses on earthquake preparedness. However, Adhikari, Paton, Johnston, Prasanna, and McColl researched the modelling of earthquake hazard preparedness predictors in Nepal. They made a structural model and analyzed it with the SEM-PLS method. The study shows that the level of belief in earthquake risk among Nepalese individuals, communities, and institutions can be used to predict earthquake risk preparedness [11]. Earthquake preparedness modelling research was also carried out by [18] and [19] in the Canterbury Region of New Zealand. The research was based on an earthquake with a magnitude of 7.1 in New Zealand which destroyed more than 370,000 buildings, caused infrastructure damage and resulted in 185 deaths. The results showed that preparedness for survival was influenced by negative outcome expectations, community participation, critical awareness, earthquake belief/knowledge [20].

1 Research Design

The research design used the Structural Equation Modeling-Partial Least Square (SEM-PLS) approach with latent variables from research in [15] which are negative outcome expectancy, community participation, critical awareness, social trust, and earthquake knowledge. And we add 3 variables from [21] which are earthquake experience, participation in disaster education and training, and knowledge of disaster mitigation.

The measurement of the SEM-PLS model is a measurement of a formative model with two layers of measurement, which include measures at the construct level (latent variables) and efforts at the indicator level (manifest variables). In Figure 1, there are six latent variables, namely risk belief, community participation, critical awareness, belief, earthquake knowledge, and knowledge about earthquake disaster mitigation measured using a formative model. The remaining two variables, namely earthquake experience, participation in disaster education, and training, are single constructs that can be measured directly. The formative examination in Figure 1 can be carried out in two stages.

We are using formative and single construct (not reflective), so the step by step SEM PLS can be seen in Figure 2.

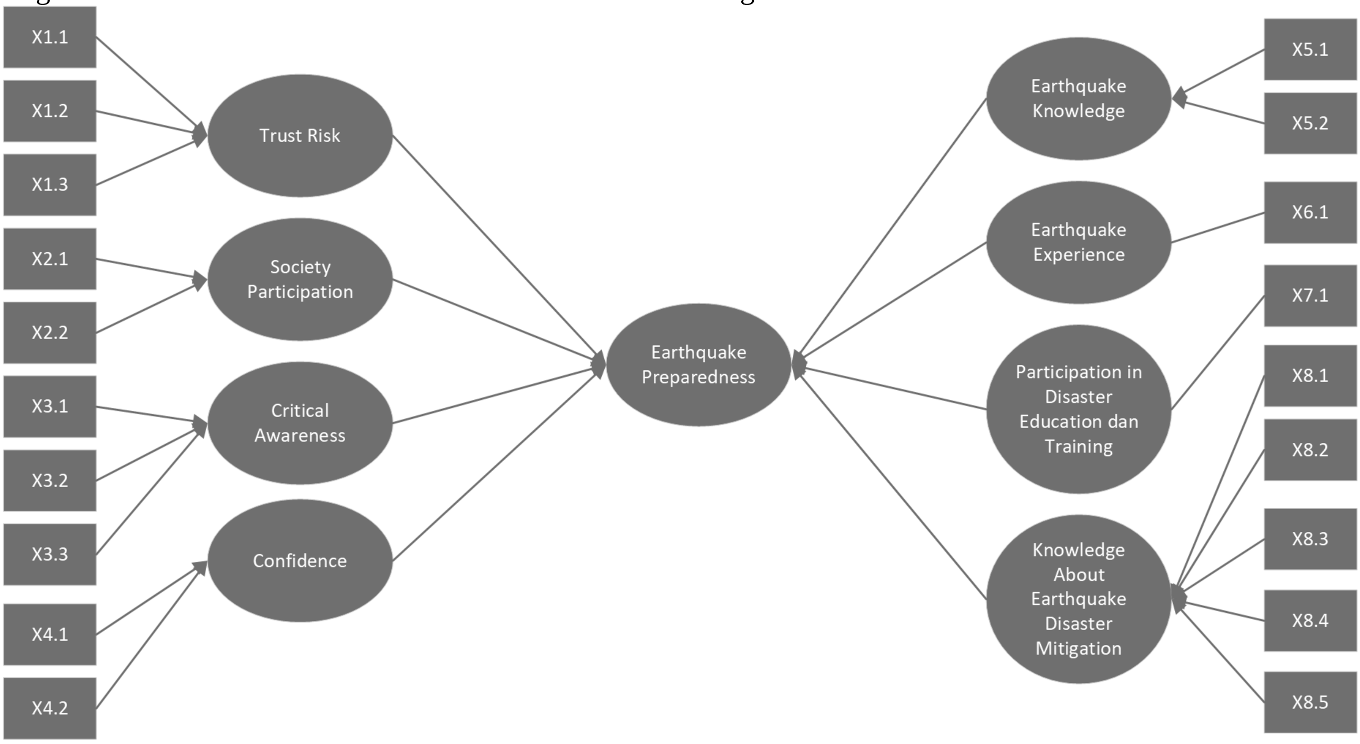

Fig.1 Smart PLS Model Framework

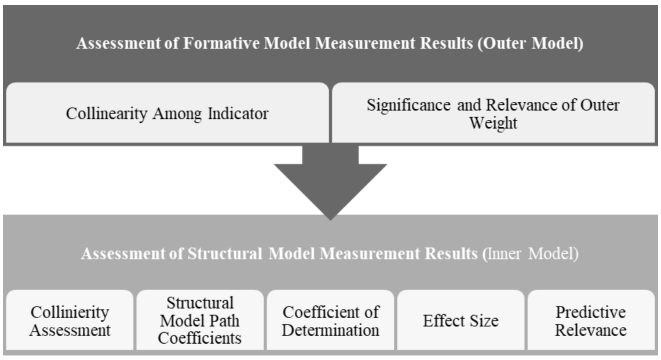

Fig.2 Research Conceptual Model

In the first stage, a collinearity check is carried out using the variance inflation factor (VIF) value and checking the significance of the outer weight. After the examination of the outer model is complete, it is followed by an assessment of the measurement results of the structural model (inner model). There are five stages: Collinearity Assessment (using VIF), Structural Model Path Coefficients (using the t-test), Coefficient of Determination (using R2), Effect Size (using f2), and Predictive Relevance (using Q2) [22].

2 Analysis Results

2.1. Assessment of Formative Model Measurement Results (Outer Model)

The first step is to find the VIF value from the outer model. This is done to see whether there is multicollinearity between indicators in a latent variable.

Table 1. VIF Outer

Indicator	VIF	Indicator	VIF
X1.1	2.410	X4.1	2.126
X1.2	2.319	X4.2	2.126
X1.3	2.216	X5.1	1.504
X2.1	1.272	X5.2	1.504
X2.2	1.272	X8.1	2.581
X3.1	1.272	X8.2	2.555
X3.2	1.297	X8.3	2.532
X3.3	1.334	X8.4	2.486
		X8.5	2.650

Based on Table 1, the VIF value for all indicators is less than 5, which shows that there is no indication of multicollinearity in each formative indicator. Thus, this model can be continued in examining the significance and relevance of outer weights with the condition that the p-value Outer Weight> alpha (0.05); however, if the value of the relevance of outer weights is not met, then the value can be used Outer Loading > 0.5 and p-value Outer Loading > alpha (0.05).

Table 2. Significant Outer Weight

Formative Indicators -> Latent Variable	Outer Weight	P-values
X1.1 -> X1 (Trust Risk)	0.346	0
X1.2 -> X1 (Trust Risk)	0.303	0
X1.3 -> X1 (Trust Risk)	0.471	0
X2.1 -> X2 (Society participation)	0.658	0
X2.2 -> X2 (Society participation)	0.508	0
X3.1 -> X3 (Critical Awareness)	0.444	0

X3.2 -> X3 (Critical Awareness)	0.457	0
X3.3 -> X3 (Critical Awareness)	0.389	0
X4.1 -> X4 (Confidence)	0.613	0
X4.2 -> X4 (Confidence)	0.461	0
X5.1 -> X5 (Earthquake Knowledge)	0.475	0
X5.2 -> X5 (Earthquake Knowledge)	0.647	0
X8.1 -> X8 (Knowledge About Earthquake Disaster Mitigation)	0.245	0
X8.2 -> X8 (Knowledge About Earthquake Disaster Mitigation)	0.218	0
X8.3 -> X8 (Knowledge About Earthquake Disaster Mitigation)	0.343	0
X8.4 -> X8 (Knowledge About Earthquake Disaster Mitigation)	0.199	0.001
X8.5 -> X8 (Knowledge About Earthquake Disaster Mitigation)	0.151	0.014

Table 2 shows that all formative indicators have a p-value < 0.05, so these indicators are suitable for measuring their latent variables.

2.2. Assessment of Structural Model Measurement Results

2.2.1. Assessment of Structural Model Measurement Results

Table 3 VIF Inner

Variable	Y1 (Earthquake Disaster Preparedness)
X1 (Trust Risk)	2.323
X2 (Society participation)	1.784
X3 (Critical Awareness)	1.566
X4 (Confidence)	2.362
X5 (Earthquake Knowledge)	1.820
X6 (Earthquake Knowledge)	2.547
X7 (Participation in Disaster Education and Training)	2.013
X8 (Knowledge About Earthquake Disaster Mitigation)	2.396

Table 3 shows all inner VIF values <5, which means that there is no multicollinearity in all predictor variables.

2.2.2. Structural Model Path Coefficients

The structural model coefficient analysis is used to determine which variables have a significant effect. The assumptions are used to measure the level of significance of the variables using the standard p-value. If the p-value <α (0.05), then the relationship is significant, and if the p-value ≥ α (0.05), then the relationship is not significant.

Table 4Coefficients Inner Model

	Coefficient	P-values
X1 (Trust Risk) -> Y1 (Earthquake Disaster Preparedness)	0.156	0.000
X2 (Society participation) -> Y1 (Earthquake Disaster Preparedness)	0.092	0.000
X3 (Critical Awareness) -> Y1 (Earthquake Disaster Preparedness)	0.075	0.000
X4 (Confidence) -> Y1 (Earthquake Disaster Preparedness)	0.163	0.000
X5 (Earthquake Knowledge) -> Y1 (Earthquake Disaster Preparedness)	0.103	0.000
X6 (Earthquake Experience) -> Y1 (Earthquake Disaster Preparedness)	0.231	0.000
X7 (Participation in Disaster Education and Training) -> Y1 (Earthquake Disaster Preparedness)	0.160	0.000
X8 (Knowledge About Earthquake Disaster Mitigation) -> Y1 (Earthquake Disaster Preparedness)	0.213	0.000

Table 4 shows that risk belief, community participation, critical awareness, belief, knowledge of earthquakes, earthquake experiences, participation in disaster education and training, as well as knowledge of earthquake disaster mitigation, have a significant positive effect on the preparedness of the Balinese people in facing earthquake disasters.

2.2.3. Coefficient of Determination

The coefficient of determination is used to measure the accuracy of the SEM-PLS model in predicting factors that affect the preparedness of the Balinese people in the face of earthquakes. The results of the coefficient of determination (R^2) can be seen in Table 5. The R^2 value of 0.75 is a value with great predictive accuracy. An R^2 value of 0.50 is considered to have moderate predictive accuracy, and an R^2 value of 0.25 is considered to have weak predictive accuracy.

Table 5 Coefficient of Determination

Variable	R Square (R^2)
Y1 (Earthquake Disaster Preparedness)	0.898

Based on the results of Table 5, the R^2 value is 0.898, this indicates that the Balinese people already have an understanding of preparedness in the face of an earthquake.

2.2.4. Effect Size

To evaluate the coefficient of determination of all endogenous variables, the effect size (f^2) can be used. The difference between f^2 and R^2 is that f^2 is more specific for each exogenous variable. The results of the f^2 test can be seen in Table 6. In general, the effect size value is divided into three, namely a value of f^2 less than 0.05 has a small effect size, f^2 between 0.05-0.30 has a medium effect size, and f^2 greater than 0.30 has a large effect size.

Table 6 Effect Size

	Y1 (Earthquake Disaster Preparedness)
X1 (Trust Risk)	0.103
X2 (Society participation)	0.047
X3 (Critical Awareness)	0.035
X4 (Confidence)	0.110
X5 (Earthquake Knowledge)	0.057
X6 (Earthquake Experience)	0.205

X7 (Participation in Disaster Education and Training)	0.125
X8 (Knowledge About Earthquake Disaster Mitigation)	0.185

Based on the f^2 value in Table 6, community participation and critical awareness have a relatively small effect size (f^2 less than 0.05) on earthquake disaster preparedness. Meanwhile, risk belief, knowledge of earthquakes, earthquake experience, participation in education and training about earthquake experiences and knowledge of earthquake disaster mitigation have a moderate effect size (f^2 between 0.05 and 0.30).

2.2.5. Predictive Relevance

To evaluate the value of R2 as a criterion for predictive accuracy, this study uses the Stone–Geisser's Q^2 value. The value of Q^2 was obtained using a blindfolding procedure. The predictive relevance criterion (Q^2) is that if a Q^2 value less than 0.05 is considered to have little predictive relevance, then Q^2 between 0.05 and 0.30 has moderate predictive relevance, and Q^2 greater than 0.30 has large predictive relevance. The results of predictive relevance can be seen in Table 7.

Table 7. Predictive Relevance

Variable	SSO	SSE	Q² (=1-SSE/SSO)
Y1 (Earthquake Disaster Preparedness)	400	52.131	0.870

Table 7 shows the predictive relevance value for earthquake disaster preparedness, which is very large with a Q^2 value of 0.870. This indicates that the variables of earthquake risk belief, community participation, critical awareness, belief, earthquake knowledge, earthquake experience, participation in disaster education, and training as well as knowledge about earthquake disaster mitigation is very influential on the Balinese people in earthquake disaster preparedness.

2.3. Discussion

Based on the results of the (SEM-PLS) analysis, it can be asserted that the more people believe in the risk associated with an earthquake, the more prepared they are for earthquake disasters and the greater the community's participation will be. The greater the critical awareness, the higher one's confidence. The more knowledge people have about earthquakes, the more prepared they will be. This confirms the research conducted by Adhikari, Paton, Johnston, Prasanna dan McColl [11], and Paton, Anderson, Becker and Petersen [15].

The more experience people have with earthquakes, the more often people will participate in disaster counseling and training. Additionally, the more people understand earthquake disaster mitigation, the more they are prepared for earthquake disasters. This is a new finding developed from Kristanti's research [21], which discusses the variables of earthquake experience, participation in disaster education and training, and knowledge about disaster mitigation and earthquake preparedness. However, it does not measure the impact of earthquake experience, participation in disaster education and training, and knowledge about disaster mitigation on earthquake preparedness.

3 Conclusion

Based on the results of the SEM-PLS analysis, the predictive relevance value for Q^2 earthquake disaster preparedness is equal to 0.870. This shows that the variables of risk confidence, community participation, critical awareness, belief, earthquake knowledge and experience, participation in disaster education and training as well as knowledge about disaster mitigation significantly affect the Balinese people's earthquake preparedness. In other words, the more people believe, are critical and responsive to risks, the more prepared they are in the face of a disaster.

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