https://doi.org/10.1051/itmconf/20246701051

Analysis of socio-economic factors affecting coastal community preparedness using structural equation modeling

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Abstract. Preparedness refers to the actions taken before a disaster to ensure an effective response. In disaster-related research, quantitative studies typically focus on observing direct correlations and regressions. However, directly measuring preparedness can be challenging. To comprehensively analyze variables, researchers often turn to Structural Equation Modeling (SEM), a powerful alternative. SEM is particularly useful when examining complex relationships among multiple variables. In a study focused on coastal communities in the cities of Banda Aceh, Mataram, and Ambon, the SEM method was applied using secondary data. The research considered one endogenous latent variable called "preparedness" and two exogenous latent variables related to social and economic factors, which are involving a collective of 932 participants. The results from the SEM method using GOFI criteria indicated that socio-economic factors significantly influenced coastal community readiness, with an R-squared value of 56.5%.

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1 Page layout

Coastal communities globally are dealing with significant changes due to global climate change, population growth, and vulnerabilities created by human activities [1]. The heightening risks and threats to the coastal areas are caused by environmental changes, the inevitable effects of climate change, and human activities. Therefore, in order to deal with uncertainties related to the pace and magnitude of rising sea levels and other emerging climate-related risks from global environmental change, it is required to take adaptation measures in coastal area management [2,3]. In developing countries, preparedness is often not prioritized, leading to a higher perception of disaster threats [4]. Data from the United Nations reveals that only approximately 17.48% of households are aware of self-rescue techniques during disasters. Similarly, the percentage of households that are knowledgeable about warning signs is only 11.62%. Additionally, household participation in training and simulations remains low, only 1.12% of households have individuals who received training in disaster preparedness and simulations [5].

The indicators used to measure community preparedness as outlined by LIPI-UNESCO/ISDR (2006) are based on five parameters that serve as the main components in a plan of initiatives to address global threats, such as earthquakes and tsunamis in coastal areas. Moreover, apart from being vulnerable to tsunamis, Indonesian coastal areas are also potentially experiencing the consequences of climate change, such as the rise in sea levels [6]. Besides the dangers caused by tsunamis, coastal regions in Indonesia are also extremely vulnerable to the impacts of climate change, specifically the rise in sea levels. The projected 35-40 cm rise in sea level predicted by 2050 will have far-reaching consequences, resulting in substantial harm to coastal ecosystems, communities, infrastructure, and leading to significant economic losses. It is concerning to observe that around 65% of the coastal population in Indonesia faces the threat of being exposed to coastal hazards and the adverse effects of climate change [7].

Quantitative study in disaster field is commonly applied to correlation, regression and other multivariate analysis. However, measuring the preparedness of coastal communities and the factors influencing preparedness cannot be done directly, necessitating the use of appropriate statistical analysis methods for indirect measurement. Structural Equation Modeling (SEM) serves as a potent alternative to multiple regression, path analysis, factor analysis, and covariance analysis. [8]. The application of SEM in data analysis aims to clearly show the relationship between the variables. It can also be used to evaluate and strengthen research models [9]. The primary requirement for the use of SEM is to create a hypothesis model consisting of a structural model and a measurement presented as a path diagram. SEM encompasses a collection of statistical methods that facilitate the simultaneous testing of relationships. It is used when analyzing relatively complex models that are difficult to solve using path analysis methods in linear regression. SEM can estimate multiple relationships between variables, analyzing the error in each observation, making it accurate for analyzing perception-based questionnaire data. SEM can easily modify and improve the model for a better statistical fit and analyze the relationships simultaneously [10].

2 Theorical background and research hypothesis

2.1 Coastal hazard theory

Hazard is an environmental phenomenon that happens when human activities, property, or changes in the environment cause serious disasters. These disasters are a response to natural phenomena in the environment or surrounding area. Hazards can disrupt the lives, behaviors, or activities of coastal communities [11]. The quantity and intensity of natural disasters reported globally have risen in the last decade. The 2018 EM-DAT report shows an increase in the proportion of disasters globally, there were 315 reported disaster events leading to 11,804 fatalities, affecting 68 million individuals, and causing economic losses amounting to USD 131.7 billion. Indonesia accounted for nearly half of the total deaths (47%), while India held the highest rank in the number of people affected (35%). [12]. Oktari et al. (2020) found that the increasing frequency and intensity of disasters worldwide has led countries to prioritize disaster risk reduction and the development of disaster-resilient communities [13].

Hazard, resulting from human activities or environmental changes, triggers serious disasters impacting coastal communities. The global surge in natural disasters, as per the 2018 EM-DAT report, reveals increasing fatalities, affected populations, and economic losses. Coastal areas grapple with challenges from climate change and human actions, focusing on addressing sea level rise and climate-induced risks. The IPCC report underscores coastal regions' vulnerability to flooding and extreme storms due to population growth, economic advancement, and urban expansion. Degradation of coastal ecosystems heightens risks. The combination of climate change, population growth, and human-induced susceptibility poses significant risks like storm surges, erosion, flooding, and tsunamis. With a majority residing in coastal regions, the vulnerability to climate change and coastal hazards is a major concern, especially for cities lacking preparedness and adaptation strategies [14, 15, 16].

2.2 Preparedness theory

Disasters, causing significant disturbance to communities, often occur unexpectedly, leading to wide-scale human, material, economic, or environmental damages. The combination of exposure to hazards, pre-existing vulnerabilities, and insufficient capacity contributes to disasters. Disaster preparedness, crucial for saving lives and limiting damage, involves measures empowering individuals, households, organizations, communities, and societies to respond effectively and recover quickly. FEMA highlights leadership, training, exercises, and support as key elements. Sutton and Tierney emphasize support from cities, communities, states, local governments, tribes, and trained emergency responders. Preparedness, within the disaster risk management framework, aims to build capabilities for handling various disasters, transitioning from response to sustainable recovery. It includes coordination plans, evacuation, public information, and relevant training grounded in risk analysis and integration with early warning systems. Successful implementation requires well-established institutional, legal, and financial resources [17, 18,19, 20,21].

2.3 Research hypothesis

Disaster preparedness involves various actions to ensure an efficient response to hazards, utilizing early warning systems and temporary removal of property from threatened areas. It encompasses prevention, mitigation, and protection measures, engaging all stakeholders—governments, communities, households, and individuals. Stakeholders fall into three primary categories: individuals and households, governments, and school communities. Preparedness, within the disaster risk management framework, builds capacity for managing emergencies and transitioning to sustainable recovery. It relies on proper risk analysis, links with early warning systems, and activities like contingency planning, equipment accumulation, coordination arrangements, evacuation, public information efforts, and relevant training. These efforts require established institutional, legal, and budgetary capabilities [22, 23].

Household attributes significantly correlate with disaster preparedness, with a growing perception of the social and economic damage caused by natural disasters. Socio-economic factors, such as income, education, resource access, and social networks, play a crucial role in influencing preparedness levels. These factors impact decision-making, including evacuation during emergencies. Further studies on the relationship between social and economic status and decision-making in disasters can enhance our understanding of influencing factors on preparedness actions [24-26]. [24, 25, 26]

Given these arguments, the following hypothesis can be stated:

H1. Social (ξ_1) has a positive and significant effect on Preparedness (η).
H2. Economy (ξ_2) has a positive and significant effect on Preparedness (η).

Table 1. Research variables.

Variabel Laten	Simbol	Manifest	Weights
Preparedness (η)	Y_1	Coastal hazard knowledge	(1, 2, 3, 4, 5)
	Y_2	Emergency response plan	
	Y_3	Early warning	
	Y_4	Resource mobilization	
Social (ξ_1)	X_{11}	Amount of household members	(1, 2, 3)
	X_{12}	Beneficiary household	(1, 2, 3, 4)
	X_{13}	Age	
	X_{14}	Family status	
	X_{15}	Education level	
Economy (ξ_2)	X_{21}	Types of house walls	(1, 2, 3, 4)
	X_{22}	Type of house floor	
	X_{23}	Main activity of household head	(1, 2, 3, 4, 5)
	X_{24}	Basic service access	
	X_{25}	Preparedness access	

3 Method

3.1 Research setting

Coastal community preparedness activities were carried out in three coastal cities in Indonesia, specifically Banda Aceh (Aceh Province), Mataram (West Nusa Tenggara Province), and Ambon (Maluku Province). The choice of these cities was based on their representation of the Western, Central, and Eastern regions, aiming to provide a comprehensive picture of Indonesia's coastal areas. Furthermore, these three cities share similar characteristics in terms of hazards along the coast, including earthquakes and tsunamis, rising sea levels, tidal floods, and erosion of coastal areas.

3.2 Research instrument

The research employed a cross-sectional survey design to enhance external generalizability and ensure consistent results. The questionnaire consisted of two sections: the first addressed respondents' demographics, knowledge creation, and retention, while the second included 53 questions. Non-probability voluntary sampling was utilized, with the sample size determined for factor analysis. A cover letter and a publicly accessible Google Form questionnaire were distributed to sub-district heads, contact persons from government agencies, and NGOs in Banda Aceh, Mataram, and Ambon. Data collection took place between October and November 2020, with 932 participants meeting the inclusion criteria—aged 17 to 65, registered residents of the specified cities, and having a minimum residency of three years.

3.3 Data analysis

The research utilized Covariant-Based Structural Equation Modeling (CB-SEM) with six essential steps outlined in SEM analysis. IBM SPSS AMOS version 22.0 facilitated model estimation, testing, and establishing causal relationships [27]. Model validity tests included manifest and convergent validity. Manifest validity was assessed with |*Z-value* (c.r.)| ≥ 1.96 or Pvalue < 0.05, and convergent validity with |standardized loading factors| ≥ 0.30 for data over 350 samples [28]. Reliability was evaluated through Composite Reliability (CR) and Average Variance Extracted (AVE), with AVE ≥ 0.50 and CR ≥ 0.70 indicating good reliability [29]. Data normality tests, both univariate and multivariate, examined skewness and kurtosis values [30].Confirmatory Factor Analysis (CFA) assessed the measurement model's validity through manifest variables, followed by constructing the structural model using path analysis. Model validity was further evaluated using various Goodness of Fit Index (GOFI) criteria, indicating the fit between the hypothesized model and collected data.

4 Results

4.1 Characteristics of respondents

The study encompassed 932 respondents who owned households in Banda Aceh City, 300 respondents (32.2%), Mataram City, 321 respondents (34.4%), and Ambon City, 311 respondents (33.4%).

Table 2. Demograpihcs of respondents.

Characteristics	N	%
Gender		
Male	387	41,52
Female	545	58,48
Age		
26-35	147	15,77
36-45	385	41,31
46-55	249	26,72
> 55	151	16,20
Amount of Household Members		
Small family	653	70,06
Medium family	229	24,58
Big family	50	5,36

4.2 Coastal community preparedness level

The regional distribution of the level of preparedness of coastal communities in the cities of Banda Aceh, Ambon and Mataram is visually presented in thematic maps.

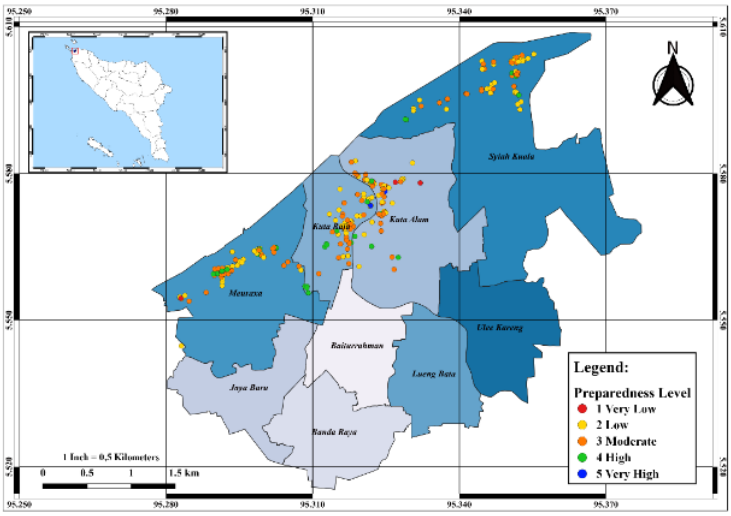

Fig. 1. Distribution of the level of preparedness of coastal communities in Banda Aceh City

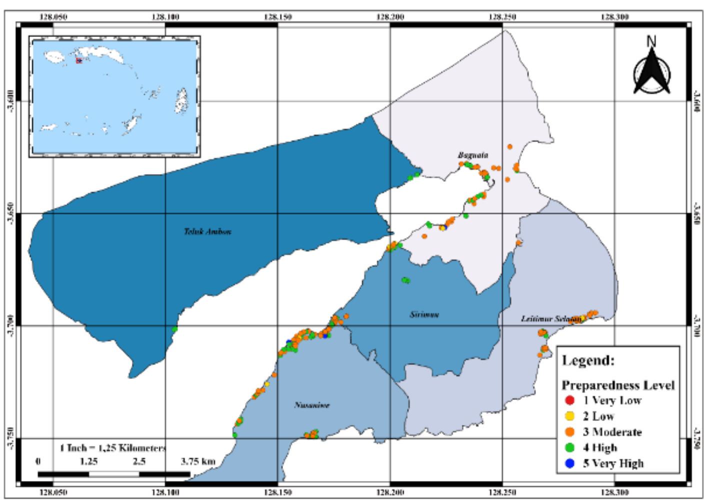

Fig. 2. Distribution of the level of preparedness of coastal communities in Ambon City

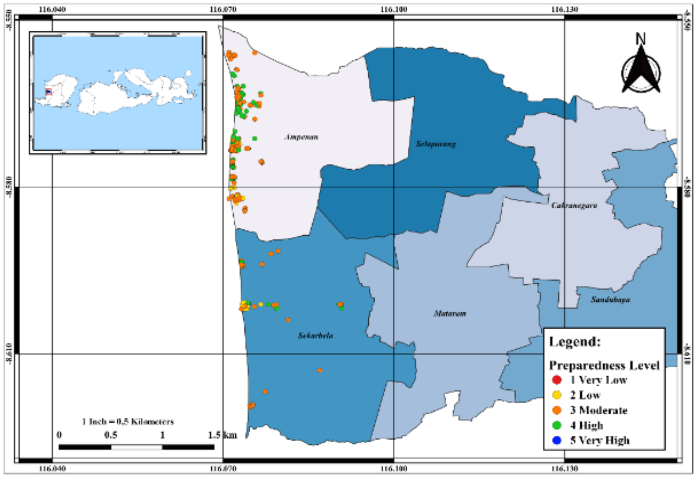

Fig. 3. Distribution of the level of preparedness of coastal communities in Ambon City.

Coastal community preparedness in Banda Aceh City predominantly falls into categories 2 (Low) and 3 (Moderate), as indicated by the consistent point pattern. Similarly, in Mataram City, the preparedness level is characterized by categories 3 (Moderate) and 4 (High). The point pattern in Ambon City also reflects a dominance of categories 3 (Moderate) and 4 (High) in the preparedness level of coastal communities.

4.3 Structural model

The test for multicollinearity shows that the correlation coefficient between the variables is less than 0.90. It can therefore be concluded that there is no multicollinearity between these variables, which means that the data set contains singular values.

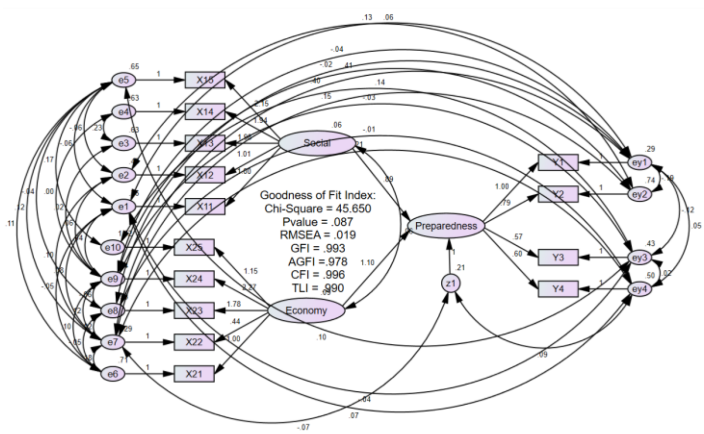

Fig. 4. Goodness of Fit Index Structural Equation Modelling.

$$Y_1 = 1{,}000\ Preparedness\ (\eta) + 0{,}16$$
$$Y_2 = 0{,}968\ Preparedness\ (\eta) + 0{,}39$$
$$Y_3 = 0{,}544\ Preparedness\ (\eta) + 0{,}35$$
$$Y_4 = 0{,}830\ Preparedness\ (\eta) + 0{,}36$$
$$X_{11} = 1{,}000\ Social\ (\xi_1) + 0{,}18$$
$$X_{12} = 0{,}905\ Social\ (\xi_1) + 0{,}47$$

$$X_{13} = 2{,}197\ Social\ (\xi_1) + 0{,}43$$
$$X_{14} = 2{,}147\ Social\ (\xi_1) + 0{,}43$$
$$X_{15} = 1{,}775\ Social\ (\xi_1) + 0{,}55$$
$$X_{21} = 1{,}000\ Economy\ (\xi_2) + 0{,}59$$
$$X_{22} = 1{,}100\ Economy\ (\xi_2) + 0{,}91$$
$$X_{23} = 1{,}346\ Economy\ (\xi_2) + 0{,}45$$
$$X_{24} = 2{,}445\ Economy\ (\xi_2) + 0{,}36$$
$$X_{25} = 0{,}965\ Economy\ (\xi_2) + 0{,}86$$

The parameter estimation results in the measurement model equation all show positive values. This means that all latent variables are reflected by their manifest variables positively.

Table 3. Goodness of Fit Index Modification.

Goodness of Fit Index	Estimasi	Cut of value	Evaluasi Model
Chi-Square	45,650	χ^2 Small value	Good Fit
	0,087	Pvalue > 0,05	
RMSEA	0,019	≤ 0,08	Good Fit
GFI	0,933	≥ 0,90	Good Fit
AGFI	0,978	≥ 0,90	Good Fit
TLI	0,996	≥ 0,90	Good Fit
CFI	0,990	≥ 0,95	Good Fit

$$Preparedness\ (\eta) = 0{,}886\ (\xi_1)\ Social + 1{,}096\ Economy\ (\xi_2) + 0{,}213$$

The parameter estimation results in the structural model equation all show positive values. This means indicates that the greater the socioeconomic level, the greater the preparedness rate.

4.4 Hypothesis test results

Hypothesis testing of structural models is carried out to determine whether the exogenous latent variables that have been formed have a relationship or not with endogenous latent variables. The criteria for rejecting the H0 test if the |*z-value* (c.r.)| ≥ 1,96 or *p-value* < 0,05 is obtained.

Table 4. Hypothesis testing results.

Direction of Influence	*z-value* (c.r.)	*p-value*	Conclusion	R^2
H1 Social (ξ_1) >>> Preparedness (η)	2,308	0,021	Sig.	0,565
H2 Economy (ξ_2) >>> Preparedness (η)	2,619	0,009	Sig.	

The modified SEM model was used to assess direct and indirect impacts, employing standardized regression weights for hypothesis evaluation (Table 5). Results show a significant *z-value* (c.r.) or P-value, indicating that Social (ξ_1) and Economy (ξ_2) have a noteworthy positive correlation with preparedness (η). The coefficient of determination (R^2) for Preparedness (η) is 0.565, suggesting a 56.5% contribution to the variability in coastal communities' preparedness. The remaining 43.5% is attributed to factors not considered in the model. Overall, the analysis confirms a positive and significant relationship between Social (ξ_1) and Economy (ξ_2) with Preparedness (η), emphasizing their influence on coastal communities' preparedness.

5 Discussion

Theoretically, this study focuses on the role of socio-economy in the context of disaster and utilizes the SEM (Structural Equation Modeling) method which is widely used to estimate complex cause-and-effect relationships between various variables. SEM methods are commonly used in research to measure social [31,32,33,34] and economy relationships [35,36,37,38]. The application of SEM methods has now been extended to the public sphere, including in social problem solving and the empowerment of the community as a basic model of knowledge management, especially in the field of disaster. This research will introduce socio-economic theory to improve the preparedness of coastal communities in facing disasters. The research will take cases within three coastal cities in Indonesia, and strives to assess the impact of socioeconomic factors on the preparedness of coastal communities in the face of disasters.

This study shows that socio-economic factors exhibit a positive and significant correlation with the preparedness of coastal communities, especially in the cities of Banda Aceh, Mataram and Ambon, with a coefficient of determination (R^2) of 56.5%. This indicates that 56.5% of the variability in preparedness of coastal communities can be accounted for by the socio-economic factors studied. The remaining 43.5% variation can be attributed to additional factors not incorporated in the model. The findings of this study align with prior research indicating that socioeconomic factors demonstrate a positive and significant effect on disaster preparedness. Socioeconomic factors have contributed to increased vulnerability in some population subgroups, so they tend to experience disproportionate impacts from hazardous events [39]. In contrast, age, disaster experience, and income have been shown to have a relationship with the level of preparation, the correlation between the relationship between preparedness and ethnicity is intricate and demands deeper comprehension. Hence, policymakers should consider initiatives that address socioeconomic and other factors influencing levels of disaster preparedness. [40].

6 Conclusion

This research focuses on coastal community preparedness in the face of disasters, utilizing a socioeconomic approach. The study analyzes essential elements for enhancing preparedness and highlights the crucial role of socioeconomic factors. Notably, socioeconomic variables exhibit a positive and significant correlation with preparedness, particularly in the cities of Banda Aceh, Mataram, and Ambon. The coefficient of determination (R^2) of 56.5% indicates that this percentage of variability in coastal community preparedness can be attributed to the studied socio-economic factors. The remaining 43.5% variation may arise from additional unaccounted-for factors. The conceptual framework proposed in this research aligns with empirical data, confirming the positive impact of socioeconomics on coastal community preparedness.

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