

A literature review: model of disaster risk reduction for decision support system

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Abstract. Disaster is a threat to human life. Many losses are caused by disasters, namely loss of life, injured people, loss of homes, and others. In addition, the frequency and intensity of disasters are also increasing every year. Therefore, research on Disaster Risk Reduction (DRR) is needed both to reduce disaster risk and to manage the disaster. The purpose of this research is to develop an appropriate DRR model in an area to assist decision-making in making policy. This research was compiled based on literature studies from various reputable journals to be used as a reference in the preparation of the right model. Then proceed with the development of a framework to model an efficient and effective DRR. The steps for making a holistic DRR model have been identified and the test design for the model has been determined, namely simulation, validation, and scenario. The recommendation given from this study is the preparation of a DSS (Decision Support System) as a tool for decision-makers to make policies regarding DRR-based regional development. This discussion will be continued in the next research by including case studies in certain urban areas.

1 Introduction

The Sendai Framework for Disaster Risk Reduction 2015-2030 report states that in the last 10 years disasters have become a threat to human life [1]. Disasters have had an impact on human welfare and safety both in the regional and global regions. Impact of the disaster: 700 thousand people lost their lives; more than 1.4 million people were injured and about 23 million were left homeless. From 2008-2012 there were 144 million people displaced by disasters, totaling more than \$1.3 trillion in economic losses.

An increase in the frequency and intensity of disasters occur due to climate change. This has resulted in significant barriers to progress in sustainable development. Evidence shows that exposure to people and assets in all countries is increasing faster than vulnerability decreases, giving rise to new risks and increased disaster-related losses i.e., significant economic, social, health, cultural, and environmental impacts in the short, medium, and long term at both levels local and regional. To overcome this, the United Nations agreed on 7 targets, namely: reduction of disaster mortality, number of affected people, economic losses and disaster damage to critical infrastructure, increasing the number of countries with national and local disaster risk reduction strategies, enhancing international cooperation in support of DRR in developing countries, and increasing availability and access to early warning systems and disaster risk [2].

Based on the description above, efforts are needed for Disaster Risk Reduction, international and regional cooperation forums, development of policies and strategies as well as scientific progress and mutual learning. This will have an important impact on increasing public and institutional awareness, as well as multi-stakeholder decision-making.

2 Disaster Model

Categorizing Disaster Models

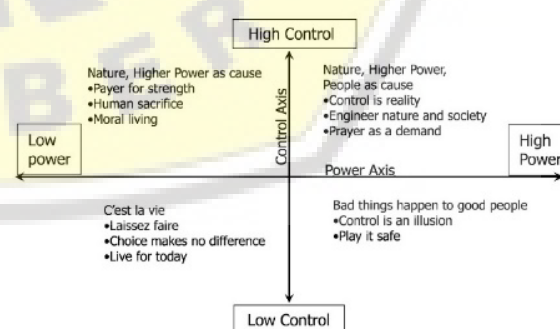


Fig. 1. A Conceptual framework for managing disaster [3].

The model is an application of theory that is a simplified representation of the real world. We need simplifying assumptions to make problems tractable [3]. Simple modeling techniques in disaster management can use quadrants as shown in Fig. 1. This model is effective

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for simple systems. This model makes it easy to evaluate the effect of power and control in disaster management. Good disaster management lies in the upper right-hand quadrant.

In general, disaster management has four pillars of approach, namely:

1. **Mitigation:** actions to reduce the risk of natural disasters.
2. **Preparedness:** planning for disasters and putting in place the resources needed to deal with them when they occur.
3. **Response:** actions were taken after a disaster occurs.
4. **Recovery:** activities to rebuild and restore the community.

However, the model framework above only describes how the disaster was handled. The model still requires the type of disaster that will occur, how much expose the community and how many times occur, and so on. If this model has accurate information regarding the disaster to be faced, then this model can take effective disaster management actions to reduce its impact. Therefore, in this study, we will review several articles that have discussed disaster prediction.

3 Disaster Prediction

Disasters are very difficult to ascertain, how big they will occur when they will occur, how big the impact will be. However, several studies have tried to predict the occurrence of disasters. From various literature studies, information is obtained that several disaster events can be predicted both the events and the impacts that will be caused by exposure to the disaster.

The TOPSIS-multiple linear regression method is an application developed to predict the risk of flooding based on the database in Vietnam [4]. This method is used as an informal assessment tool that can be used by policymakers to clarify the areas most at risk and the losses incurred.

The application of Bayesian Network (BN) theory is becoming a trend in predicting the determination of various technical risks. This risk prediction has also been applied to disaster risk assessment. With BN's ability to determine parameters and correlation between variables in multivariate nonlinear equations, BN is the right consideration to be used as a risk assessment model in natural disasters [5]. Bayesian is also able to contribute to predicting the probability of flood events with good accuracy, can improve the detection of impact assessment and flood disaster management. This Bayesian capability must be supported by complete historical data [6]. The Bayesian method was also used to build a disaster chain hazard assessment model for a series of active volcanoes in China [7]. The Bayesian network combined with ArcGIS can compile a map of the chain and hazard intensity with a fairly good model performance with certain criteria.

The analysis and estimation mathematical methods have been used to predict typhoon disaster prediction and risk assessment. The Analysis method is the upper and

lower limit interval estimation method, while the estimation method uses the average anomaly estimation value. Both methods were applied to the typhoon case study so that it can be used as a tool for disaster prevention and mitigation [8].

At the end of the disaster prediction sub-section, it is necessary to reaffirm the position of disaster prediction and risk assessment. This is necessary as a further step in this study. Disaster prediction is modeling objects that face danger, damage, or loss. While risk assessment models the possibility of future events that can be detrimental. In mathematical modeling, the model for disaster prediction may be an explicit function, while the model for risk assessment may be an implicit function. There are three criteria to assess whether a model is suitable for risk assessment: (i) availability of information, (ii) uncertainty of future conditions, and (iii) modeling is a comparison of the current situation with some known pattern [9]. Disaster probabilistic prediction is just a simplified risk assessment. Whereas disaster prediction can be considered as a special case of risk assessment which is likely to differ from one case to another.

4 Disaster Risk Reduction

Disaster Risk Reduction is the conceptual framework of elements considered with the possibilities to minimize vulnerabilities and disaster risks throughout a society, to avoid (prevention) or to limit (mitigation and preparedness) the adverse impacts of hazards, within the broad context of sustainable development [10]. Based on this understanding, DRR is a concept and good practice in reducing disaster risk, including reducing exposure, vulnerability, and increasing disaster preparedness. This concept must be made systematically based on analysis in formulating sustainable development policies.

Research on DRR is quite diverse because this topic connects and integrates disaster risk reduction with ecosystems through science, engineering, government, policy, and economics [11]. However, the most rapidly developing ones are the implementation of Eco-DRR and Eco-Engineering because they can provide sustainable solutions in reducing disasters with an approach to economic strengthening and social stability.

A study on DRR has been carried out to analyze policies related to code building to protect against earthquakes in Turkey. They used a probabilistic catastrophe-based cost-benefit analysis (CBA) model [12]. This model includes elements of climate change, increased hazard intensity, reduced vulnerability/exposure to assets during the preparation of infrastructure development policies. As well as paying attention to the negative impacts of infrastructure development, namely poor land use, environmental degradation, decreased infrastructure services, overcrowding. So, this model helps them target more efficient and financially effective investments in the implementation of the DRR program before it is implemented.

Another study on the implementation of DRR in the Philippines also shows that the implementation of DRR

must accommodate indigenous knowledge [13]. So far, the implementation of DDR has prioritized scientific knowledge even though the practice that has been carried out for years has naturally been proven to reduce disaster risk. Therefore, it is necessary to facilitate two forms of knowledge to further enhance the power of DDR going forward.

The simplest practice of disaster risk reduction is the study of the provision of disaster protection infrastructure. In a study on the provision of shelters for evaluation in disaster-prone zones in Padang, West Sumatra [14]. This study model the estimation of shelter needs to accommodate refugees during the evaluation process using linear regression models and binary logit. The provision of flood control infrastructure in Surakarta has also been carried out in the context of reducing disaster risk [15]. The provision of flood control infrastructure becomes ineffective if its availability is uneven and capacity decreases.

The concept of DRR in integrated disaster management is to combine the reduction of exposure and vulnerability, with capacity building for disaster preparedness in every policy/management of local and international governments. In infrastructure development, all design/planning, implementation, and implementation of the approach should incorporate DRR on disaster risk management in partnership with local authorities and stakeholders. The social success of DDR is highly dependent on implementation and approaches to adaptation to historical/current/future contexts, governance, and local gradients: urban-rural, inland-coastal landscapes, and rich-disadvantaged populations. While the technical success of DDR is highly dependent on establishing the necessary technical criteria, standards, incentives, and guidelines for participatory and interactive community resilience building across sectors, professions, and populations, it is also important for the successful implementation of this approach [11].

4.1 Hazard

The Hyogo Framework for Action defines that: Hazard is defined in Hyogo Framework for Action as: “A potentially damaging physical event, phenomenon or human activity that may cause the loss of life or injury, property damage, social and economic disruption or environmental degradation. Hazards can include latent conditions that may represent future threats and can have different origins: natural (geological, hydrometeorological, and biological) or induced by human processes (environmental degradation and technological hazards) [16].

In disaster management, it is necessary to know in advance about the potential hazards. Many studies on hazard determination have been carried out. Hazards are conditions that must be taken proactively and collected for future learning processes. Hazard data reporting techniques to be useful are were identified; sharing experiences, organizational learning, extending organizational memory, performance monitoring, and coordinating remedial actions [17]. Hazard determination

using the AHP-Fuzzy method to determine hazard in geo-environmental impact [18].

4.2 Vulnerability

Vulnerability is defined as: “The conditions are determined by physical, social, economic, and environmental factors or processes, which increase the susceptibility of a community to the impact of hazards”. by UN/ISDR Geneva 2004 [10]. And [16] states the types of vulnerability:

- Physical Vulnerability: infrastructure.
- Social Vulnerability: the inability of people, organizations, and societies to withstand adverse impacts to hazards
- Economic Vulnerability: the economic status of individuals, communities, and nations
- Environmental Vulnerability: Natural resource depletion and resource degradation.

Research on decision-making related to infrastructure vulnerability has been carried out. Infrastructure vulnerabilities can be referred to as Critical Infrastructure (CI). Infrastructure failure can lead to dangerous conditions for society, the economy, and even regional and national security. The infrastructure of an area can be networked and can influence each other. Therefore, to measure the vulnerability of infrastructure, we can use the Fuzzy-based DANP (FDANP) method, a hybrid method that combines the Decision Making Trial and Evaluation Laboratory (DEMATEL), Analytic Network Process (ANP), and fuzzy logic theory [19]. This model contributes to the evaluation of decision-making related to CI governance, including protection planning, and management of CI vulnerabilities, and increases the resilience of CI systems and the communities that depend on them.

4.3 Capacity

Capacity has defined a combination of all the strengths and resources available within a community, society, or organization that can reduce the level of risk or the effects of a disaster. Capacity may include physical, institutional, social, or economic means as well as skilled personal or collective attributes such as leadership and management. Capacity may also be described as capability [10].

5 Framework for Model of Regional DRR

The development of a DRR model for an area is very holistic. Many aspects that must be reviewed include how the disaster can be predicted, how much vulnerability the area has, and how much capacity the area has. In this study, a framework for making a DRR model of an area will be developed to obtain the condition of an area that is responsive to disasters by developing a DRR-based area. The concept of the model framework proposed in this study consists of: (i) disaster prediction modeling; (ii) disaster management diagram scheme; and (iii) DRR simulation.

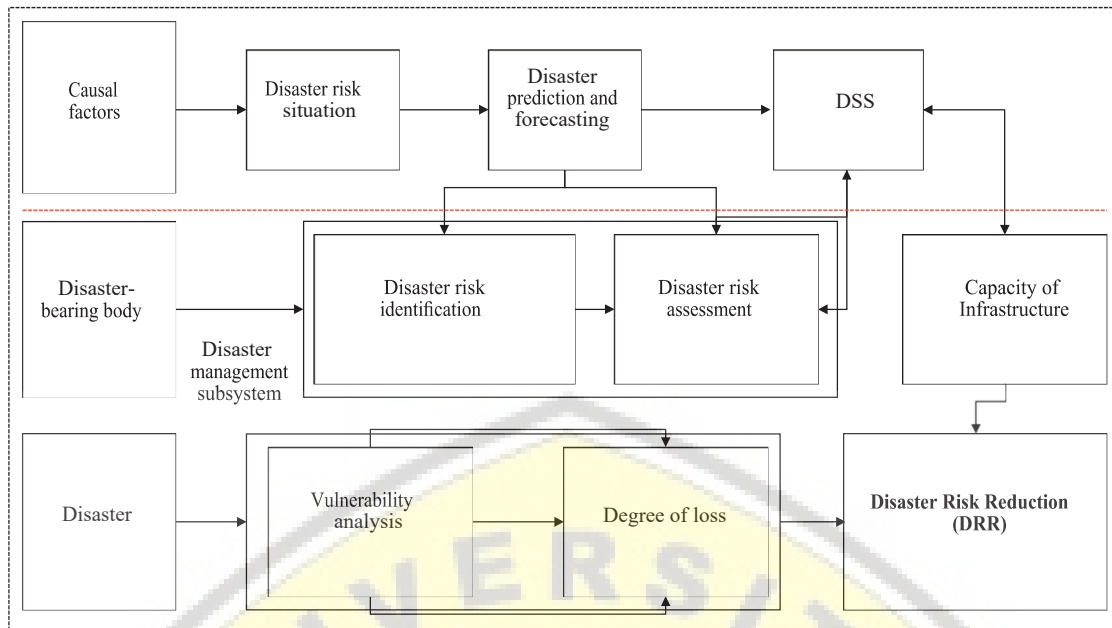


Fig. 3. Schematic disaster system

5.1 Formation of the Modeling Disaster Chain.

Disasters in an area can occur due to various kinds of disasters with various factors. Therefore, a model is needed to predict probabilistically the occurrence of disasters. This prediction is determined by the causal factors obtained from the disaster history data [20]. The chain disaster scheme can be seen in Fig 2.

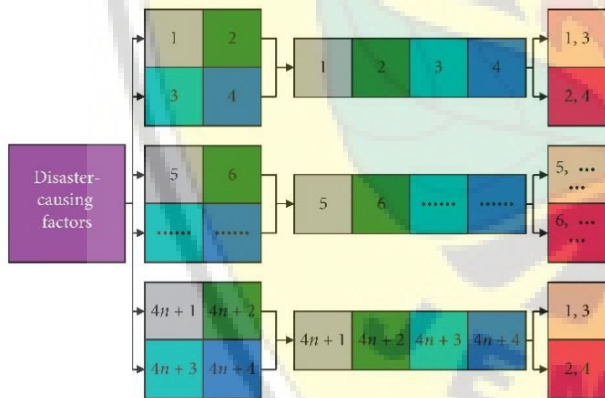


Fig. 2. Schema for chain disaster.

This disaster chain modeling can use several model options, namely bayesian or dynamic bayesian [21], markov-chain [22], artificial intelligence [23], System Dynamic [24], [25] etc.

The Bayesian model uses Bayes’s theory as follows:

$$(\theta|y) = \frac{p(\theta,y)}{p(y)} = \frac{p(\theta)p(y|\theta)}{p(y)} \tag{1}$$

$$p(y) = \int p(\theta)p(y|\theta)d\theta \tag{2}$$

The formula of Markov is as follow:

$$P(X_{t-1} = \frac{j}{x_t} = i) = P(X_1 = \frac{j}{x_0} = i); \tag{3}$$

The form of conditional probability transition matrix can be seen in equation (4):

$$P_{ij}^{(v)} = \begin{bmatrix} P_{00} & P_{01} & \dots & P_{0j} \\ P_{10} & P_{11} & \dots & P_{1j} \\ \vdots & \vdots & \vdots & \vdots \\ P_{i0} & P_{i1} & \dots & P_{ij} \end{bmatrix} \tag{4}$$

The System Dynamic formula is:

$$PG(t) = PG(t - dt) + TPM * dt \tag{5}$$

5.2 Diagram disaster system

In the preparation of the DRR framework for disasters in an area, it is necessary to understand and describe disasters and vulnerabilities. The risk of disaster loss depends on the vulnerability of the hazard carriers, the intensity of the hazard causes, and the disaster risk assessment method. Comprehensive urban infrastructure development must anticipate the prevention and mitigation of urban disaster systems. Therefore, to strengthen urban disaster prevention and mitigation strategies, the following schematic of comprehensive urban disaster prevention and mitigation measures, and increase the city’s ability to withstand disasters (See Fig. 3).

In the first stage, the factors causing the disaster are determined as the basis for determining disaster predictions. The results of this prediction will be decided in the DSS (Decision Support System).

The next stage is the determination of disaster sub management, where at this stage a disaster risk assessment will be estimated based on risk identification data. The results of this identification will be combined in the DSS.

The last step is determining disaster vulnerability. This stage will be combined with capacity and decisions on the DSS will result in DRR action.

5.3 Simulation, Validation, and Scenario of The DRR Model

After all the stages in the preparation of the DRR model are fulfilled, the next step is to create a simulation using existing data. The simulation results will be compared with other existing data to see the validation of the model. If the model meets the validation requirements, it will continue with the model scenario.

Decision-making steps can be taken based on the results of the scenario with the smallest risk value. So that the decisions taken can provide for the management and development of infrastructure in an area.

6 Conclusion

Based on the results of the study above, it can be concluded that the preparation of DRR requires a holistic step, starting with disaster prediction, disaster impact estimation, and determination of regional infrastructure capacity.

Disaster DRR modeling can be done by selecting a model that fits the characteristics of the data, assessing future conditions, and validating using existing data to see how far the model can be accepted. The application of DRR for regional infrastructure that has big data can be modeled using Bayesian or artificial intelligence because both methods can predict cases with complex variables and data uncertainty.

A DSS is needed to simplify and speed up data processing, analysis, and decision-making. The development of this DSS system is carried out by integrating all sub-models in one analysis system.

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