Predicting Potential Cases of Natural Disasters in Indonesia Using the Homogeneous Poisson Process

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ABSTRACT

The potential for natural disasters in Indonesia is very high, because it is located on the Pacific Ring of Fire (an area with a lot of tectonic activity) and the confluence of three large tectonic plates, namely the Indo-Australian plate, the Eurasian plate and the Pacific plate. Predicting potential cases of natural disasters in Indonesia needs to be done, this is an effort to prepare a natural disaster management budget by the government. Therefore, this study aims to predict potential cases of natural disasters in Indonesia. The data used are cases of natural disasters that occurred in Indonesia. The method used is the Poisson Process to analyze the probability of natural disasters that will occur. From the results of the research, the probability of occurrence is obtained by the number of cases of natural disasters that will occur. Based on the research results, it can be used as a basis for the government in preparing disaster management budgets.

Keywords:
Natural Disasters, Homogeneous Poisson Process, Predicting, Mean, Variance

1. Introduction

Indonesia is a country that has the potential for natural disasters with a high intensity of natural disasters (Kalfin et al., 2020a). The potential for natural disasters that occur in Indonesia continues to increase every year. Based on data from the National Disaster Management Agency for the last ten years, every year the same disasters occur again in Indonesia. Even the number of occurrences of several disasters, for example from 2010 to 2020, tends to increase the number of occurrences. Based on this situation, it certainly causes losses, damage to residential areas and casualties that repeat every year in the community (Kalfin et al., 2020b). In addition, the impact of natural disasters causes economic losses for both the community and the government (Kalfin et al., 2021a). Natural disasters are a problem both in big cities and in villages. Natural disasters that occur can cause large losses to human life, in the form of damage to settlements, loss of life and socio-economic impacts (Botzen et al., 2019). As a result of natural disasters experienced by local communities, new problems such as damage to settlements, health problems and others arise (Benali and Feki, 2017).

To minimize the impact of natural disasters, it is necessary to provide understanding to the government and local communities regarding disaster mitigation and management (Kalfin et al., 2021b). Disaster management can be carried out from pre-disaster such as when there is no disaster with disaster risk reduction activities, disaster management planning, prevention, education and training (Kastolani and Mainaki, 2018). In situations of potential disasters that will occur, activities that can be carried out include early warning, mitigation and disaster preparedness (Rozaki et al., 2021). The government's efforts in dealing with natural disasters in Indonesia as regulated in Law No. 24 of 2007, have allocated a budget for disaster management in the APBN/APBD. Unfortunately, the APBN/APBD has limitations in funding for natural disasters. Based on the situation that has occurred in previous years where the prepared disaster management budget is not optimally in disaster management. This is because the budget prepared is not in accordance with the conditions in the field, where the risk of loss due to natural disasters is much greater than the budget prepared. This is because the potential for natural disasters that occur continues to increase and the intensity of the disaster cannot be estimated.

Based on the description of the problem above, this study intends to predict the potential for natural disasters in Indonesia using the homogeneous Poisson process. From the results of the study, it is hoped that it can provide an overview of the potential for natural disasters that will occur in the following year. Thus, from the estimation results, the government can prepare an appropriate natural disaster management budget.

2. Material and Methodology

2.1 Material

The data used in this study is in the form of case data of natural disasters that occurred in Indonesia from 2000-2019. Data obtained from the National Agency for Natural Disaster Management in the form of natural disasters that occurred. In analyzing the data using Microsoft Excel 2010 software and Easy Fit 5.5.

2.2 Poisson Process

The Poisson process is an example of a Point Process, which is a stochastic process with realization in the form of a counting process. That is, during the Poisson process, the process of calculating the number of events in a certain time interval is carried out. The process of calculating $\{X(t),\ t \geq 0\}$ is one of the simplest processes and represents the number of events at time t. The properties that must be met in the calculation process are:

i. $X(t) \geq 0$.
ii. $X(t)$ is an integer without a fraction.
iii. If $s < t$ then $X(s) < X(t)$.
iv. For $s < t$, $X(t) - X(s)$ represents the number of phenomena that occur in the time interval $(s, t]$

Definition 1. (Alawiyah et al., 2021)
The process of calculating $\{N(t),\ t \geq 0\}$ is called a Poisson process with parameter $\lambda > 0$ if it satisfies

i. $N(0) = 0$.
ii. The process has independent increments and stationary increments.
iii. For h short time interval then$P(N(h) = 1) = \lambda h + oh$.
iv. $P(N(h) \geq 2) = o(h)$

Based on Definition 1 for every $t \geq 0$ applies $P_k(t) = P\{N(t) = k | N(0) = 0\}$ with $(k = 0,1,2, \dots)$ which is the probability of occurrence in the time interval $[0, t)$.

$$\sum_{k=0}^{\infty} P_k(t) = 1$$

Since the total probability is 1 by applying the stationary of the Poisson process, we get

$$P\{N(s+t) - N(s) = k\} = P\{N(t) = k | N(0) = 0\} = P_k(t)$$

Untuk sembarang $t \geq 0$ dan $s \geq 0$

Definition 2. (Alawiyah et al., 2021)
The process of calculating $\{N(t),\ t \geq 0\}$ is called a Poisson process with parameter $\lambda > 0$ if it satisfies the following conditions:

i. $N(0) = 0$.
ii. The process has independent increments.
iii. The probability for each k in the interval t is expressed by

$$P\{N(t+s) - N(s) = k\} = \frac{(\lambda t)^k}{k!} e^{-\lambda t},\ k = 0,1,2,3, \dots$$

If each $s, t \geq 0$ then $(N(t+s) - N(s)) \sim POI(\lambda t)$.

So that obtained $E(N(t)) = \lambda t$ and $Var(N(t)) = \lambda t$

3. Results and Discussion

3.1 Descriptive Statistics of Research Data

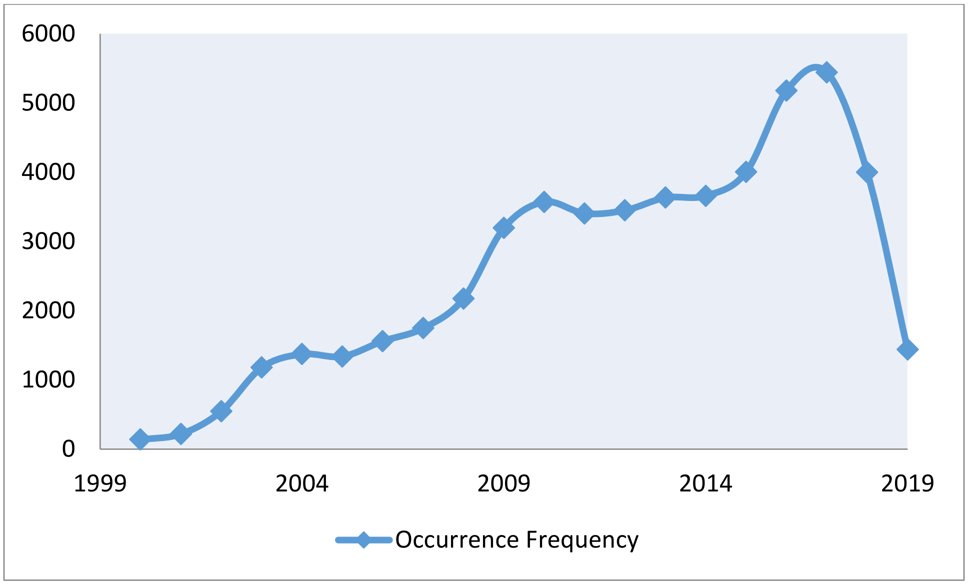

Figure 1. The Number of Cases of Natural Disasters in Indonesia

Based on Figure 1, it can be seen that the highest incidence of natural disasters that occurred in Indonesia occurred in 2017 with the number of natural disasters being 5442. Meanwhile, the smallest number of natural disasters occurred in 2000, with 138 cases. Based on the data in Figure 1, descriptive statistics of the data on the number of natural disasters are given in Table 1 as follows:

Table 1. Descriptive Statistics Data on the Number of Natural Disasters

N	Minimum	Maximum	Mean	Std. Deviation
20	138.00	5442.00	2562.00	1587.41

3.2 Poisson Distribution

Furthermore, based on the data on the number of cases of natural disasters, the Poisson distribution is determined. Checking the Poisson distribution of natural disaster frequency data using Easy Fit 5.5 software. The results of the analysis obtained are given in Tables 2 and 3 as follows:

Table 2. Goodness of Fit - Summary

#	Distribution	Kolmogorov Smirnov		Anderson Darling	
		Statistic	Rank	Statistic	Rank
1	D. Uniform	0.1312	1	4.2454	4
2	Geometric	0.21878	2	1.2272	2
3	Logarithmic	0.5979	5	12.079	5
4	Neg. Binomial	0.35561	3	3.5406	3
5	Poisson	0.5	4	-10.0	1
6	Bernoulli	No fit (data max > 1)			

7	Binomial	No fit
8	Hypergeometric	No fit

Based on Table 2, it can be seen that for the Poisson distribution test on the frequency data for natural disasters, it is ranked 4th using the Kolmogorov Smirnov test, while being in the first rank using the Anderson Darling test. Furthermore, the distribution test can be checked at the significance level for each distribution test. The results of the distribution test analysis are given in Table 3 as follows:

Table 3. Goodness of Fit - Details

Poisson [#5]					
Kolmogorov-Smirnov					
Sample Size Statistic P-Value Rank	20 0.5 3.7876E-5 4				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	0.23156	0.26473	0.29408	0.32866	0.35241
Reject?	Yes	Yes	Yes	Yes	Yes
Anderson-Darling					
Sample Size Statistic Rank	20 -10.0 1				
α	0.2	0.1	0.05	0.02	0.01
Critical Value	1.3749	1.9286	2.5018	3.2892	3.9074
Reject?	No	No	No	No	No

Based on Table 3, it can be seen that using the Kolmogorov-Smirnov test the data on the frequency of natural disasters is not significant at 0.2; 0.1; 0.05; 0.02; and 0.01. However, by using the Anderson-Darling test, the data on the frequency of occurrence of natural disasters is significant at 0.2; 0.1; 0.05; 0.02; and 0.01. This shows that the data on the frequency of natural disasters have a Poisson distribution using the Anderson-Darling test.

3.3 Poisson Process Frequency of Natural Disasters

The first step to determine the number of confirmed cases of natural disasters using the Poisson Process is to determine the rate (λ) by assuming that the data on confirmed cases of natural disasters is valid with time interval $t = [0,20)$.

$$\lambda = \frac{\sum_{i=1}^{n} X_i}{n} = \frac{138 + 218 + \cdots + 1439}{20} = 2.562 \text{ cases/year}$$

Next, determine the expected value and variance from the case data of natural disasters with $t = 20$ years.

$$E\big(N(t)\big) = \lambda t = (2562)(20) = 51240$$
$$Var\big(N(t)\big) = \lambda t = (2562)(20) = 51240$$

Based on the results of the analysis, the expectation and variance of natural disaster events that occurred in Indonesia is 51240. Next, determine the probability of the frequency of natural disasters, which is assumed if there is no increase in natural disaster cases from January 2000-December 2019.

$$P_{x=0}\,(t = 20) = \frac{(\lambda t)^x}{x!} e^{-\lambda t} = \frac{(51240)^0}{0!} e^{-(51240)} = 5{,}63309 \times 10^{-22254}$$

Based on the results of the analysis, it is found that the probability of not occurring cases of natural disasters in Indonesia is $5{,}63309 \times 10^{-22254}$ or close to 0. Therefore, the government needs to increase awareness of natural disasters and prepare a disaster management budget.

4. Conclusion

Based on the results of the analysis, it can be concluded that the potential for non-occurrence of natural disasters in Indonesia is very small. From the results of the analysis, it is found that the probability of not occurring cases of natural disasters in Indonesia is $5{,}63309 \times 10^{-22254}$. From the results of the analysis also obtained the same results for the expectations and variances of cases of natural disasters in Indonesia using the Poisson process method, which is 51240. Therefore, the government and the community need to always increase awareness of natural disasters that will occur. In addition, the government still needs to prepare a disaster management budget as an effort to mitigate natural disasters.

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References

Alawiyah, M., Johar, D. A., & Ruchjana, B. N. (2021). Homogeneous Poisson process in daily case of covid-19. In *Journal of Physics: Conference Series* (Vol. 1722, No. 1, p. 012078). IOP Publishing.

Benali, N., & Feki, R. (2017). The impact of natural disasters on insurers' profitability: Evidence from Property/Casualty Insurance company in United States. *Research in International Business and Finance*, *42*, 1394-1400.

Botzen, W. W., Deschenes, O., & Sanders, M. (2019). The economic impacts of natural disasters: A review of models and empirical studies. *Review of Environmental Economics and Policy*, *13*(2), 167-188.

Kalfin, Sukono, Supian S, and Mamat, M. (2021a). Mitigation and models for determining premiums for natural disaster insurance due to excessive rainfall. In *Journal of Physics: Conference Series*, 1722(1), p. 012058. IOP Publishing.

Kalfin, Sukono, Supian S, Mamat M, and Bon A T. (2020b) Model for Determining Natural Disaster Insurance Premiums in Indonesia Using the Black Scholes Method. *Proceedings of the International Conference on Industrial Engineering and Operations Management* Detroit Michigan, USA, pp. 2376–2385.

Kalfin, Sukono, Supian S, Mamat M, Muljana F, and Bon A T. (2021b) Analysis of Agropolitan Area Planning Based on Natural Disaster Mitigation in West Muna Regency, Southeast Sulawesi, Indonesia. *Proceedings of the International Conference on Industrial Engineering and Operations Management,* Sao Paulo, Brazil, pp. 3592– 3601.

Kalfin, Sukono,, Supian, S., Mamat, M., Bon, A.T. (2020a). A review mitigation efforts and natural disaster insurance schemes in indonesia. *Proceedings of the International Conference on Industrial Engineering and Operations Management*, Harare, Zimbabwe, pp. 1825–1835.

Kastolani, W., & Mainaki, R. (2018). Does educational disaster mitigation need to be introduced In school?. In *SHS Web of Conferences* (Vol. 42, p. 00063). EDP Sciences.

Rozaki, Z., Wijaya, O., Rahmawati, N., & Rahayu, L. (2021). Farmers' Disaster Mitigation Strategies in Indonesia. *Reviews in Agricultural Science*, *9*, 178-194.

Biographies

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Abdul Talib Bon is a professor of Production and Operations Management in the Faculty of Technology Management and Business at the Universiti Tun Hussein Onn Malaysia since 1999. He has a PhD in Computer Science, which he obtained from the Universite de La Rochelle, France in the year 2008. His doctoral thesis was on topic Process Quality Improvement on Beltline Moulding Manufacturing. He studied Business Administration in the Universiti Kebangsaan Malaysia for which he was awarded the MBA in the year 1998. He's bachelor degree and diploma in Mechanical Engineering which his obtained from the Universiti Teknologi Malaysia. He received his postgraduate certificate in Mechatronics and Robotics from Carlisle, United Kingdom in 1997. He had published more 150 International Proceedings and International Journals and 8 books. He is a member of MSORSM, IIF, IEOM, IIE, INFORMS, TAM and MIM.