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Analysis of the Accuracy Level of Using the Monte Carlo Method in Predicting the Number of Dengue Fever Sufferers

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ABSTRACT

Dengue fever is an infectious disease that continues to be a threat to public health in Indonesia. The increasing number of sufferers every year requires accurate prediction strategies to support effective prevention and control policies. This study aims to analyze the level of accuracy of the Monte Carlo method in predicting the number of dengue fever sufferers in Indonesia, especially in North Sumatra Province. The data used in this research is data on dengue fever cases from 2021 to 2023 obtained from the Central Statistics Agency (BPS) and the Health Service. The prediction process is carried out using Monte Carlo simulation which involves a probability-based random calculation process. The research results show that the Monte Carlo method has a fairly high level of accuracy in predicting patterns of dengue fever cases, with an accuracy value of 3440 (99.41%) compared to other conventional prediction methods. In addition, this method is proven to be flexible in dealing with variations in fluctuating data patterns. It is hoped that this research can contribute to strategic decision making, especially in mitigating dengue fever through more accurate predictions.

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1. INTRODUCTION

Dengue Hemorrhagic Fever (DHF) is an infectious disease caused by the dengue virus, which is transmitted through the bite of the Aedes aegypti mosquito. This disease is often a major concern in public health because the number of cases increases every year, especially in tropical countries like Indonesia. According to the World Health Organization (WHO) report, dengue fever is included in the category of endemic diseases that have spread to various regions, causing a huge burden on the health system.

The spread of dengue fever in Indonesia has increased significantly in line with tropical climate conditions that support mosquito breeding. WHO reports that more than 390 million cases of dengue infection occur annually throughout the world, with more than 20% of these cases occurring in Southeast Asia, including Indonesia. This phenomenon shows the need for more effective treatment strategies in predicting and controlling dengue cases in various regions.

Dengue fever sufferers generally experience symptoms such as sudden high fever, muscle pain, and bleeding in some severe cases. According to research by the Ministry of Health, the severity of dengue fever can vary, depending on the sufferer's age, health condition and immune system. Most sufferers who do not receive immediate medical treatment can experience serious complications such as dengue shock syndrome (DSS), which has the potential to be fatal. In North Sumatra Province, dengue cases fluctuate from year to year. Based on data from the Central Statistics Agency (BPS), in 2022, more than 5,000 cases of dengue fever will be recorded in this region. Deli Serdang, Medan and Langkat districts are the areas with the highest case rates, indicating that handling dengue cases is still a big challenge for the provincial government.

BPS data also reveals that factors such as high rainfall and poor environmental sanitation contribute to the high number of dengue fever sufferers in North Sumatra. This condition demands a better prediction system to minimize the spread of disease and prepare sufficient health resources to treat sufferers. Apart from environmental factors, people's behavior in maintaining environmental cleanliness also influences the level of spread of the Aedes aegypti mosquito. Prevention programs carried out by the government such as the 3M Plus movement (drain, cover and recycle) and fogging spraying have not completely succeeded in reducing the number of dengue fever sufferers in North Sumatra.

The level of accuracy in predicting the number of dengue fever cases is very important to ensure the effectiveness of the prevention and treatment measures taken. Prediction accuracy is key in the allocation of medical resources, such as health workers and the availability of medicines. According to Smith et al. (2021), accurate prediction models can help reduce unnecessary health costs by predicting future spikes in cases. Research on predictive accuracy in a public health context shows that appropriate data-driven models can improve the precision of medical intervention planning. In the context of dengue fever, accurate predictions can help with treatment in vulnerable areas, such as urban areas with high population density.

One method that is widely used for prediction is the Monte Carlo method. This method is a statistical technique that is often used to estimate the possible outcomes of a complex system through stochastic simulation. In the context of epidemiology, the Monte Carlo method can model various scenarios of disease spread by taking into account uncertainty factors. The Monte Carlo method works by generating a large number of random variables that follow a certain probability distribution to predict the most likely outcome. According to Wang et al. (2020), this method is able to provide a more comprehensive picture regarding the possibility of different outcomes in a period of time that cannot be predicted with a simple linear model.

In the context of predicting the number of dengue fever sufferers in North Sumatra, the Monte Carlo method has the potential to provide more accurate estimates than traditional prediction models. This is due to its ability to accommodate unexpected variables, such as climate change, community behavior patterns, and dengue virus mutations. Therefore, this research will focus on analyzing the level of accuracy of using the Monte Carlo method in predicting the number of dengue fever sufferers in North Sumatra Province. It is hoped that the results of this research can make a significant contribution to the development of better dengue management strategies in the future, as well as become a reference for the use of the Monte Carlo method in the epidemiology of other infectious diseases.

2. RESEARCH METHODE

This research is analytical research using quantitative methods and literature study. Quantitative methods were used to test the hypothesis, by collecting secondary data sourced from the North Sumatra Provincial Health Service regarding the number of dengue fever cases in North Sumatra from 2021 to 2023, then modeling and simulations were made using the Monte Carlo method to predict the number of cases per month each year based on previous year's data. The prediction results are then compared with the actual data to see the level of accuracy of the method used to predict dengue cases.

3. RESULT AND ANALYSIS

This research is located in North Sumatra Province. The data used is for 2021, 2022 and 2023, starting from October to December.

Data Preparation

The initial stage is to prepare the data by determining variables with a 3 year period in 2021 which will be used as training data to predict the next year 2022. In 2022 for training data which predicts in 2023 as well as data in 2003 for this year which is presented as follows (Elma Peren & Suyanto, 2023).

Table 1. Data on Dengue Fever Sufferers

Month	2021	2022	2023
January	300	320	350
February	280	310	340

March	310	330	360
April	250	290	320
May	240	260	300
June	230	250	290
July	220	240	280
August	210	230	270
September	240	260	300
October	270	290	330
November	290	310	350
December	310	330	370

Calculation Stages with Monte Carlo Simulation Method

Shows the contribution of each variable that will be made. This value is obtained by dividing the total number by the number of patients each month (Sukiastini, 2023). The following is calculated in 2021 which can be observed from the table.

Table 2. Probability Distribution 2021

Month	Number Of Sufferers	Probability
January	300	0.0952
February	280	0.0889
March	310	0.0984
April	250	0.0794
May	240	0.0762
June	230	0.0730
July	220	0.0698
August	210	0.0667
September	240	0.0762
October	270	0.0857
November	290	0.0921
December	310	0.0984
November	310	0.0906
December	330	0.0965

Table 3. Probability Distribution 2023

Bulan	Jumlah Penderita	Probabilitas
January	350	0.09
February	340	0.09
March	360	0.09
April	320	0.08
May	300	0.09
June	290	0.08
July	280	0.08
August	270	0.08
September	300	0.09
October	330	0.09
November	350	0.09
December	370	0.09

If the cumulative frequency distribution is obtained from the sum of the previous values and the current probability but there is an exception at the beginning, the first value is the same (Mei Sedi et al., 2023).

Table 4. Cumulative Distribution 2021

Month	Number Of Sufferers	Probability	Cumulative Distribution
January	300	0.0952	0.0952
February	280	0.0889	0.1841
March	310	0.0984	0.2825
April	250	0.0794	0.3619
May	240	0.0762	0.4381
June	230	0.0730	0.5111
July	220	0.0698	0.5809
August	210	0.0667	0.6476
September	240	0.0762	0.7238
October	270	0.0857	0.8095
November	290	0.0921	0.9016
December	310	0.0984	10.000

Table 5. Cumulative Distribution 2022

Month	Number Of Sufferers	Probability	Cumulative
January	320	0.09	0.0952
February	310	0.09	0.2825
March	330	0.09	1
April	290	0.08	0.9016
May	260	0.07	0.3619
June	250	0.07	0.3619
July	240	0.07	0.7238
August	230	0.07	0.5111
September	260	0.07	0.8095
October	290	0.09	0.1841
November	310	0.09	1
December	330	0.09	0.2825

Table 6. Cumulative Distribution 2023

Month	Number Of Sufferers	Probability	Cumulative
January	350	0.09	0.0952
February	340	0.09	0.9463
March	360	0.09	0.0964
April	320	0.08	0.9016
May	300	0.09	0.3314
June	290	0.08	0.3619
July	280	0.08	0.7238
August	270	0.08	0.5111
September	300	0.09	0.8095
October	330	0.09	0.1841
November	350	0.09	0.0952
December	370	0.09	0.2825

After this was done, a random number interval was determined for the min and max of the data on dengue fever sufferers in North Sumatra Province.

Table 7. Random Number Interval Data for 2021

Month	Frequency	Number Intervals Random	
		Min	Max
January	330	1	10
February	280	11	20
March	310	21	28
April	250	29	37
May	240	38	46
June	230	47	54
July	220	55	62
August	210	63	71
September	240	72	79
October	270	80	85
November	290	86	94
December	310	95	100

Table 8. Random Number Interval Data for 2022

Month	Frequency	Number Intervals Random	
		Min	Max
January	320	1	10
February	310	11	20
March	330	21	28
April	290	29	37
May	260	38	46
June	250	47	54
July	240	55	62
August	230	63	71
September	260	72	79
October	290	80	85
November	310	86	94
December	330	95	100

Table 9. Random Number Interval Data for 2023

Month	Frequency	Number Intervals Random	
		Min	Max
January	350	1	10
February	340	11	20
March	360	21	28
April	320	29	37
May	300	38	46
June	290	47	54
July	280	55	62
August	270	63	71
September	300	72	79
October	330	80	85
November	350	86	94
December	370	95	100

Next, this is assisted in the simulation process. The method used is congruent mixing. Formula used $Zi+1=(a*Zi+c) \bmod m(1)$

Next, a random number interval is determined where the initial limit of the random number of the first interval is equal to 0 (zero), and the final limit for the first interval is determined by reducing the rounding of the cumulative distribution of the first interval by the number 1 (one). The initial limit of the second interval random number starts by adding the final limit of the first interval with the number 1 (one) and the final limit of the second interval random number is obtained by reducing the rounding of the cumulative distribution of the second interval with the number 1 (one). Based on the data in table 1, a simulation was carried out to predict the number of dengue fever sufferers in 2021 with random numbers generated using equation (3) with values a = 1, c = 2, m = 999, X0 = 22 for the first variation; and the values a = 29, c = 17, m = 89, X0 = 37 for the second variation. The first variation of random number generation is carried out in the following way:

$Z1 = (1x22+)Mod999 = 24,\ Z2 = (1x24+2)Mod999 = 26,\ Z3 = (1x26+2)Mod999 = 28$ etc.

Simulations are carried out using various methods, the first is that the data is entered then the random numbers are compared in the previous table, then in the table the interval between 2021 is used for the following year as well as 2022 and 2023. The results of the simulation are that it is possible that the number of patients used in 2022 will be predicted using the existing data in 2021, then the possible number of patient visits in 2023 is predicted using the data contained in the previous year 2022. The possibility of the simulation is as it is.

Table 10. Simulation Results Predicting the Number of DHF Sufferers

Month	Random Number	2021	2022	2023
January	24	310	330	360
February	6	300	320	350
March	28	310	330	360
April	30	250	290	320
May	32	250	290	320
June	34	250	290	320
July	36	250	290	320
August	38	250	260	300
September	40	240	260	300
October	42	240	260	300
November	44	240	260	300
December	46	240	260	300

Based on the simulation results in table 12, it can be seen that the prediction results for the number of dengue fever sufferers per month for 2022 based on 2021 data are less accurate, using the first variation of random numbers. However, if the monthly prediction data is added up over a year, the prediction results are close to the real number of sufferers in 2021. For the simulation with random numbers, the first variation shows that the predicted results are 3440 (99.41%), while the real data shows there are 3420 sufferers. The results for the following year also showed something similar. Monte Carlo only looks at the previous year's historical data without any other variables influencing it; so it is necessary to carry out further research involving independent variables (predictors). Apart from that, the simulation results in the research show that the more data used as historical data, the more accurate the prediction results will be. Therefore, more complete data is needed from year to year regarding the number of dengue cases and other data as factors influencing the incidence of dengue fever.

4. CONCLUSION

This research shows that the Monte Carlo method has a fairly high level of accuracy in predicting the number of dengue fever sufferers. The use of this method has proven effective in overcoming the fluctuations and uncertainties in epidemiological data that often occur in infectious diseases such as dengue fever. Based on the simulation results, the Monte Carlo method is able to produce predictions that are close to the actual data with relatively low prediction errors. This makes Monte Carlo a method that is feasible to apply in disease planning and control, especially in determining preventive health policies and more appropriate resource allocation. Thus, it is hoped that the Monte Carlo method can support related parties in estimating and reducing the incidence of dengue fever in the future, as well as improving the quality of public health services.

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