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The Role of Exponential Growth Model in Predicting Population Growth: A Study of Demographic Data in NTB Province

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Abstracts: This study aims to apply an exponential growth model in predicting the population of West Nusa Tenggara (NTB) Province based on annual demographic data from 2014 to 2024. By using Winter's exponential smoothing method that includes level, trend, and seasonal components, this model is able to capture population growth patterns that tend to increase consistently from year to year. The calculation results show that the population of NTB is predicted to continue to grow until it reaches 7,253,193 people in 2034. The exponential model is proven to have good accuracy in following historical patterns, as shown by the conformity between the projected graph and the actual data. The advantages of this method lie in the simplicity of the process, the speed of adaptation to the latest data, and its efficiency in producing short-term estimates. The results of this study are expected to be used as a basis for designing more targeted development policies, especially in the education, health, and infrastructure sectors. To improve the accuracy and coverage of the model in the future, it is recommended that future research include additional variables such as migration, birth and death rates, and socioeconomic conditions, as well as compare the exponential model with other forecasting methods such as ARIMA or machine learning approaches. In addition, the integration of prediction results into a geographic information system (GIS) could be a strategic step to support a more interactive and informative presentation of data for policy makers.

Keywords: Exponential Modeling, Population Projection, Ntb, Winter Method, Development Planning.

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A. INTRODUCTION

In the ever-evolving digital era, the ability to predict data plays an important role in supporting planning, policy making, and program evaluation in various fields (Adnyana et al., 2021). Especially in the field of population, estimating the number of people in the future is very vital, especially for local governments in designing long-term oriented development policies (Fejriani et al., 2020). Information on population projections can help estimate the needs of various public service sectors such as education, health, infrastructure, and employment. For this reason, quantitative methods that utilize historical data are an important tool to produce more precise and reliable population predictions.

As the need for predictive analysis in the population field increases, various forecasting methods have been developed to analyze and project population growth data. Commonly used techniques include time series models such as linear regression, moving average, exponential smoothing, as well as advanced statistical approaches such as ARIMA and machine learning algorithms (Pierre et al., 2023). However, in the case of population growth that shows a continuous pattern of increase over time, the exponential growth model is often seen as an efficient method. This model has the advantage of capturing the pattern of

increasing growth trends, in addition to its practicality in application and ease of interpretation of results. Based on these considerations, this study applies the exponential growth model to predict the population in West Nusa Tenggara (NTB) Province using available demographic data (Anggun, 2024).

Several previous studies have shown that the exponential growth model can be used effectively in projecting population numbers. Rahmawati et al., (2020) explained that the exponential model is able to provide accurate prediction results for population growth in Central Java Province within a certain period of time. Rozikin et al., (2021) explained that the exponential model has a relatively low prediction error rate when compared to other simple methods such as linear regression. (Irma Suryani & Nur Khasanah, 2022) emphasized that the suitability of the exponential model is strongly influenced by the stability of historical data trends and the consistency of annual growth. A good understanding of the population growth rate is essential for policy makers, because it can be used as a basis for infrastructure planning and resource allocation, which overall supports the direction of sustainable development in NTB Province (Nurmayanti & Syaharuddin, 2022).

The exponential growth model plays a significant role in predicting population dynamics in NTB Province, by providing a mathematical framework for temporally analyzing demographic data. Several previous studies have utilized this model in forecasting population trends, resulting in important findings regarding the pattern of population change in the region (Syaharuddin et al., 2021). Through the application of demographic transition theory, researchers have identified phases of population growth and decline that are influenced by various factors, including economic development and social conditions (Sudiarta et al., 2021). In addition, population projection methods have been used to evaluate historical patterns of growth, allowing for more accurate predictions of future population conditions (Mandailina et al., 2018). Analysis of demographic data plays an important role in uncovering the main factors that influence these trends, such as birth and death rates.

This research aims to implement the exponential growth model in estimating the population in West Nusa Tenggara (NTB) Province by utilizing historical demographic data. Through this approach, this research is expected to produce a more precise projection of the dynamics of population growth over time. In addition, this study aims to identify patterns of population growth trends and assess the effectiveness of the exponential model in representing progressive growth characteristics. The findings of this study are expected to contribute as a strategic reference in the formulation of regional development policies, especially in terms of resource management and the provision of population data-oriented public services.

B. METHOD

This type of research is quantitative research, using the winter method. Winter's linear exponential smoothing method is used for forecasting if the data has a seasonal component. Winter's method is based on three smoothing equations, namely the overall smoothing equation, trend smoothing, and seasonal smoothing.

The exponential smoothing method is a procedure that repeats the calculation continuously using the latest data based on the calculation of the average exponential smoothing of past data. The advantage of the smoothing method is that it can provide accuracy in short-term forecasting and adjustments can be made quickly and at low cost. Winter,s formula for exponential smoothing can be seen as follows:

$$S_t = (X_t - I_{mt-L}) + (1-a)(S_t + b_{t-1})$$
$$b_t = \gamma(S_t - S_{t-1}) + (1+\gamma)b_{t-1}$$
$$I_{mt} = \beta(X_t - S_{t-1} + (1+\beta)I_{mt-L}$$
$$F_{t+m} = S_t + b_t m + I_{mt-L+m}$$

The explanation of the above equation is St is the overall smoothing variable in period t, while S_{t-1} is the overall smoothing variable in period $t-1$, B_t is the trend smoothing variable in period t, while B_{t-1} is the trend smoothing variable in period $t-1$. BMI is the seasonal smoothing variable in period t, while F_{t+m} is the forecasting variable in period -$T + M.X_t$is the actual data in period ke $t.a, \beta,$, and γ are constants for smoothing, trend, and seasonality. L is the seasonal length (number of months/quarter in 1 year) and M is the number of periods forecaste. The data used in this study is the population growth data of NTB annual period for 10 years, starting from 2014 to 2024 which is the population growth data in NTB.

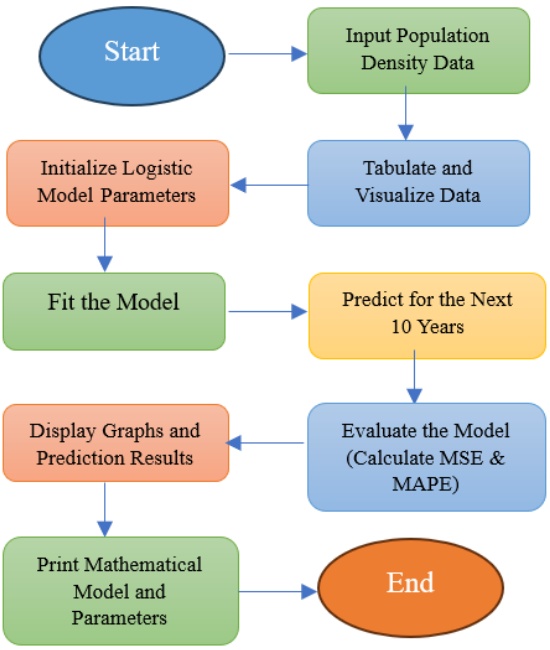

Figure 1. Simulation Data Process Simulation Data Process

Figure 1 describes the systematic process of building and evaluating a growth prediction model using the exponential approach. The process starts with the input of historical data, followed by the addition of tables and data visualization to understand the growth pattern. Next, the exponential model parameters are initialized as initial estimates before the model

fitting process is run to obtain the best parameters. After the model is formed, it is used to calculate the predictions for the next five years and the results are displayed in the form of graphs and tables. Model evaluation is done by calculating the MSE (Mean Squared Error) and MAPE (Mean Absolute Percentage Error) values to measure model accuracy. Finally, the mathematical form of the model and the fitting parameters are displayed, before the process is concluded. This diagram provides a clear and coherent workflow in building predictive models based on historical data.

C. RESULTS AND DISCUSSION

1. Data Description

Population data for West Nusa Tenggara (NTB) Province from 2014 to 2034 shows a positive growth trend that is consistent. In the first two years, 2014 and 2015, the total population was recorded at 4,702,389 people, indicating no increase during this period. However, from 2016 to 2024, there is annual population growth, starting at 4,843,582 people in 2016 and reaching 5,766,000 people in 2024. This growth is gradual, with a notable increase occurring in 2020, when the population jumped to 5,320,092 from 5,042,126 the previous year. For the years 2025 to 2034, the available data are projections, which estimate that the population will continue to increase with a relatively stable and increasing growth pattern, from 5,959,819 people in 2025 to 7,253,193 people in 2034. Overall, over the twenty-year period, the population has increased by 2,550,804 people, or by an average of 127,540 people per year. This growth pattern reflects active demographic dynamics, which are likely to be influenced by various factors such as high birth rates, in-migration flows, and development policies that support a sustainable increase in population.can be seen in Table 1.

Table 1. Data Description

Year	Population (population)
2014	4.702.389
2015	4.702.389
2016	4.843.582
2017	4.911.476
2018	4.977.643
2019	5.042.126
2020	5.320.092
2021	5.428.000
2022	5.538.000
2023	5.651.000
2024	5.766.000
2025	5,959,819
2026	6,091,006
2027	6,225,207
2028	6,362,470
2029	6,502,846
2030	6,646,384
3031	6,793,136

Year	Population (population)
2032	6,943,152
2033	7,096,487
2034	7,253,193

Mathematical Model of Exponential Growth Method

The exponential growth method has a general form:

$P(t) = P_0 \, . \, e^{rt}$

Based on the regression results of the 2014-2024 data, obtained:

$P_0 = 4{,}702{,}389$ $(Initial\ population\ in\ 2014)$

$r = 0.0218\ atau\ 2.18\%\ per\ year$

Thus, the mathematical model of NTB population growth is:

$P(t) = 4{,}702{,}389 \, . \, e^{0{,}0218.t}$

Error parameters (MSE and MAPE)

MSE (Mean Squared Error) = 2943514503.93

MAPE (Mean Absolute Percentage Error) = 0.86%

Furthermore, the figure below illustrates the comparison between the actual population data and the projection results using the exponential model approach:

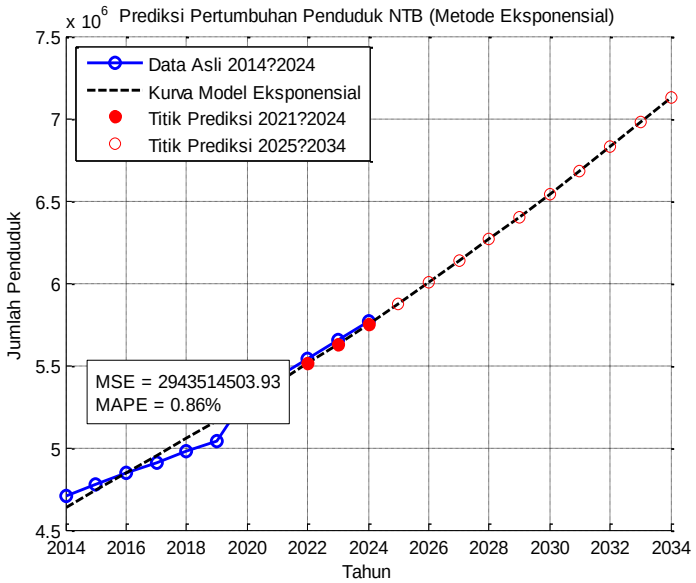

Figure 1. Results Exponential method

The results of the exponential growth modeling graph above applied to the demographic data of West Nusa Tenggara (NTB) Province illustrate the modeling and prediction of population based on actual data from 2014 to 2024 and projections to 2034 using the exponential growth model approach, with actual data marked with blue circles, exponential model curves depicted with black dotted lines, and prediction points for 2021-2024 shown with full red circles and for 2025-2034 with empty red circles. Based on available data, the total

population was recorded at 4,702,389 people in 2014 and 2015, then experienced a gradual increase from 4,843,582 people in 2016 to reach 5,766,000 people in 2024, with a significant spike in 2020 which recorded 5,320,092 people from 5,042,126 people in 2019. Projections for the period 2025 to 2034 show steady growth, from 5,959,819 people in 2025, 6,091,006 people in 2026, 6,225,207 people in 2027, 6,362,470 people in 2028, 6. 502,846 people in 2029, 6,646,384 people in 2030, 6,793,136 people in 2031, 6,943,152 people in 2032, 7,096,487 people in 2033, until reaching 7,253,193 people in 2034. Quantitatively, the exponential model applied has a very good fit to the actual data, indicated by the Mean Squared Error (MSE) value of 294,351,450.93 and the Mean Absolute Percentage Error (MAPE) value of 0.86%, which indicates that this model is able to predict with a very high level of accuracy. Overall, the graph shows that population growth over the period 2014-2034 follows a mild exponential pattern with a steady and sustained upward trend, reflecting active demographic dynamics that are likely to be influenced by factors such as stable birth rates, in-migration flows, and development policies that focus on long-term population growth.

D. CONCLUSIONS AND SUGGESTIONS

Based on the results of the analysis using the exponential growth model on the population data of West Nusa Tenggara (NTB) Province from 2014 to 2024, it can be concluded that the population growth trend shows a consistent upward pattern every year. The exponential model proved to be effective in projecting the population for the next ten years, with predictions reaching 7,253,193 people in 2034. The graph of the projection results shows good agreement between the historical data and the model results, indicating that the model is able to accurately represent the dynamics of population growth. Therefore, this approach can be used as a reliable tool in supporting the data-driven regional development planning process, especially in planning the education, health, infrastructure, and employment sectors.

Future research is recommended to expand the scope of the model by considering other factors that affect population growth, such as migration, birth and death rates, and socioeconomic conditions. In addition, model testing can be extended by comparing the performance of the exponential model with other approaches such as ARIMA or machine learning methods to see a higher level of accuracy. The integration of this modeling system into a geographic information system (GIS)-based platform could also be an innovative step to present the prediction results visually and interactively, making it more informative for policy makers.

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