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Study Modeling Population Growth using a Logistic Model to Analyze and Predicting Population Density in NTB Province

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Abstract: This study aims to analyze and predict population density in West Nusa Tenggara (NTB) Province using an experimental quantitative approach through a logistic model. Secondary data were obtained from the NTB Central Bureau of Statistics (BPS), including population and area during the period 2014-2023. The research stages include tabulation, data visualization, logistic model building with MATLAB, and accuracy evaluation using MSE and MAPE. The analysis results showed a stable population growth trend with an average of 272.8 thousand people and a standard deviation of 11.21. The model projected density until 2028 with high accuracy (MAPE 1.25%; MSE 18.82), and estimated the maximum capacity of the area at 298.56 people/km². The findings show that the logistic model is able to effectively represent population dynamics and can be used as a basis for development planning. The practical implications of this study include support for spatial policy making, density control, and preparedness for environmental pressures. In the future, integration of spatial data and socio-economic variables is recommended to improve the accuracy of the model in supporting adaptive and sustainable regional development.

Keywords: Population Growth, Logistic Model, Population Density

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A. INTRODUCTION

Residents are people who live in an area that is bound by applicable rules and interact with each other continuously or continuously (Fejriani et al., 2020). Population density is an indicator that shows how many individuals occupy an area per unit area, usually calculated in people per square kilometer (Nisa, 2019). This concept is crucial in demographic studies because it provides an overview of population pressure on the environment and resource availability. In West Nusa Tenggara (NTB) Province, which includes areas such as Lombok and Sumbawa Islands, the distribution of population density is uneven. Understanding this condition is necessary for development planning, infrastructure provision, and equal distribution of welfare.

In predicting population, there are a number of commonly used approaches, such as linear regression models, exponential growth, ARIMA methods, and artificial intelligence-based techniques (Stephani, 2015). However, for regions such as NTB where resources are limited, the logistic model is more relevant. This model considers that there is a maximum population limit that can be accommodated by the environment and shows that the growth rate slows down near that point. Therefore, the logistic model provides more realistic predictions in the context of long-term population growth (Anggraeni et al., 2020).

Population growth in NTB continues to increase, especially in urban areas which are heavily influenced by economic factors and migration flows. Research over the period 2010 to 2022 shows that population increase is not entirely influenced by economic development, but also by other factors such as poverty levels and investment into the area (Anggun, 2024). Population density has an impact on economic activities, particularly in agriculture and livestock production, which are vital to NTB's economy (Adnyana et al., 2021). NTB's demographic composition shows a large number of young people, especially in the adolescent age group, as well as a gender distribution that shows a tendency for women to dominate certain sectors, such as health services (Nariswari et al., 2022). These findings are important to inform decision-making on public services and social development.

The logistic model provides a mathematical approach to describe population growth that slows down as the region approaches its maximum capacity. Development of this model, such as integration with gray systems, has improved its accuracy (Wijay, 2021). In NTB, the ARDL method was used to predict the number of poor people in 2019 with a result of 718,059 people and a MAPE of 3%, showing the potential of forecasting as a basis for policy (Rahmasari et al., 2019). Previous research conducted by Nurmadhani & Faisol (2022) found that the logistic model has the highest accuracy with the lowest MAPE value, estimating the population capacity of 1,141,132 people and predicting the population in 2040 of 1,127,591 people. Research results Kurniawan et al., (2017) also shows that of the two population growth models obtained, the more accurate model for estimating the population of Surabaya City is the logistic model.

The use of logistic models in population projection is still limited, especially in regions such as NTB that have unique geographical and social characteristics. Most of the previous studies only used linear or exponential models without considering the carrying capacity of the environment. This research aims to fill the gap by applying a logistic model to analyze and predict the population density of NTB, in order to support more appropriate and sustainable development planning.

B. METHOD

This research falls into the experimental quantitative category, as it utilizes numerical data to analyze and predict population dynamics without intervening in the variables. The quantitative approach is used to formulate a logistic model that mathematically and empirically represents population growth patterns. The equation for the logistic model follows:

$$P(t) = \frac{K}{1 + \frac{K - P_0}{P_0} e^{-rt}}$$

The data used is secondary and obtained from the Central Bureau of Statistics (BPS) of West Nusa Tenggara Province, including information on population and area from 2014 to 2023. This data is used to calculate the annual population density which is the basis for the modeling and forecasting process.

This research begins by collecting population density data in West Nusa Tenggara (NTB) Province for the period 2016 to 2023. The data is then processed through tabulation and

visualization processes to identify population growth patterns. Next, a logistic model was built and implemented using MATLAB software to predict population density for the next five years. Evaluation of model performance was carried out using the Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) parameters as a measure of prediction accuracy. The evaluation results show that the applied logistic model can represent population dynamics well and support the data-based development planning process. The complete procedure is in Figure 1.

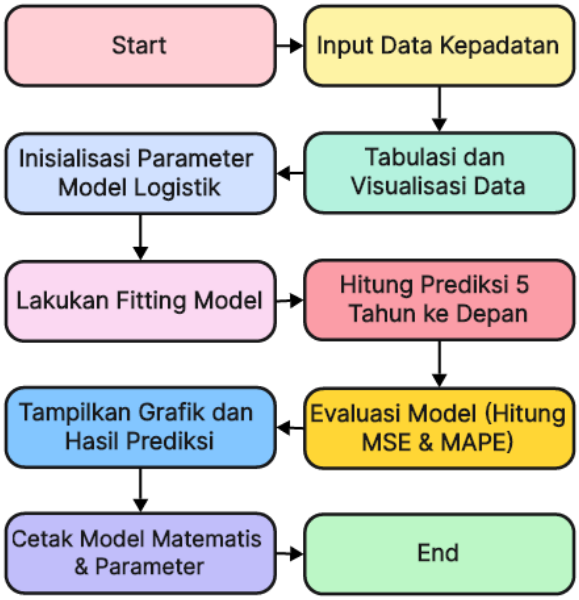

Figure 1. Computing System Design Procedure

C. RESULTS AND DISCUSSION

1. Data Description

Based on the results of descriptive statistical analysis of the population data of NTB Province from 2014 to 2023, it is known that the population showed an increasing trend during the period. The smallest value was recorded at 257 thousand people, while the highest value reached 290 thousand people, with an average of 272.8 thousand people. Meanwhile, the standard deviation of 11.21 indicates that data fluctuations between years are relatively small. Overall, this data illustrates that population growth tends to be consistent throughout the period. Further information on the data characteristics can be seen in Table 1.

Table 1. Data Description

Data Descriptive Statistics	Value
N (Number of Years)	10
Minimum	257
Maximum	290
Average (Mean)	272,8
Standard Deviation	11,21

2. Forecasting Results and Decision Making

The logistic modeling that has been carried out produces a projection of the population density of West Nusa Tenggara Province for the next five years, which is shown in the following table.

Table 2. Predicted Population Density of NTB in 2024 - 2028

Year	Population Density Prediction
2024	287
2023	289
2024	290
2025	291
2026	292

The figure below illustrates the comparison between the actual population density data and the projection results using the logistic model approach:

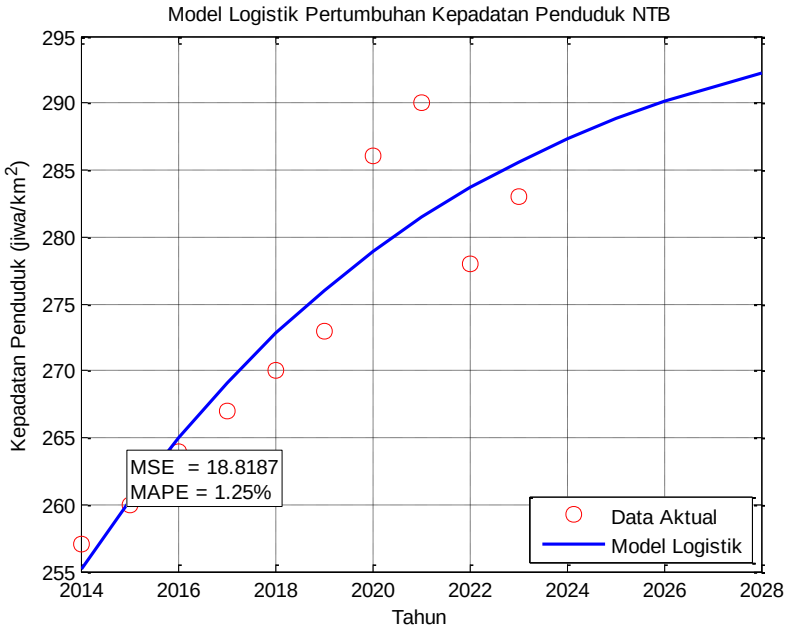

Figure 2. Actual and Predicted Data Approach

Based on the results of modeling with a logistic approach, it is predicted that population density in West Nusa Tenggara Province will increase gradually throughout the period 2024 to 2028. The model estimates a maximum carrying capacity of 298.56 people per km², with a growth rate of 0.147. The mathematical model used is formulated as follows:

$$P(t) = \frac{298{,}5561}{1+0{,}1701.e^{-0{,}1470.t}} \quad (2)$$

This model reflects a logistic growth pattern that tends to approach the maximum value in the long term. The accuracy of the model is high, indicated by the low MAPE value of 1.25% and MSE of 18.82, so it can be concluded that this model is quite representative in describing the dynamics of population density growth in the region.

D. CONCLUSIONS AND SUGGESTIONS

Based on the results of statistical analysis and logistic modeling of population data of West Nusa Tenggara (NTB) Province during the period 2014 to 2023, it was found that the population experienced stable and sustainable growth. The average population was recorded at 272.8 thousand people with relatively small annual variations, indicated by a standard deviation of 11.21. Projections for the next five years (2024-2028) using the logistic model showed a gradual increase in population density, with an estimated maximum capacity of 298.56 people per km² and a growth rate of 0.147. The low prediction error values (MAPE 1.25% and MSE 18.82) are even better compared to the study by (Rozikin et al., 2021) The MAPE of 2.1% confirms that the model has a good level of accuracy in describing population growth trends in the region.

However, there are still opportunities to deepen the research, especially in terms of integrating spatial aspects and socio-economic variables into the model used. This limitation suggests the need for further research that combines geospatial approaches with predictive models in population density analysis. In the future, it is important to develop research on topics that focus on the integration of multidisciplinary approaches in sustainable population planning. Such studies are expected to contribute significantly to regional planning that is more adaptive and responsive to the dynamics of population growth.

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