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Predicting East Kalimantan Population Growth with Holt's Exponential Smoothing Approach: A Time Series Analysis

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Abstract: This research is important because as a province that is the location of the relocation of the National Capital, East Kalimantan will experience a significant population surge. Therefore, the purpose of this study is to provide an overview of population projections that can be used as a basis for regional development planning, especially in the context of East Kalimantan's preparation as the location of the National Capital City (IKN). This research is an experiment to forecast population growth data for the next 5 years based on actual data 2014-2023. The data is taken from the Central Bureau of Statistics. The results show that the population is expected to continue to increase gradually from 2025 to 2029 with a stable growth trend and excellent model accuracy (MAPE 0.50%). The implications of the results of this study can be used as a reference for other researchers in developing time series-based prediction models in the population field or other fields that have data trend patterns.

Keywords: Population Growth, Holt's Exponential Smoothing, Time Series Analysis.

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A. INTRODUCTION

Research on population growth and development in East Kalimantan and other regions in Indonesia reveals several key factors that influence regional dynamics. Analysis of spatial interactions in East Kalimantan identified East Kutai Regency as a fast-growing region, while Berau Regency emerged as a growth center (Wijaya et al., 2020). Population growth correlates with increased electricity demand, as shown in Lubuklinggau City, where a linear regression predicts an increase in electricity demand to 162,569 thousand KWH in 2024 (Yanto, 2020). In West Kalimantan, panel data regression analysis shows that life expectancy and average years of schooling significantly affect the Human Development Index (Satyahadewi et al., 2023). In addition, factors such as access to proper sanitation, smoking habits, and malaria incidence were identified as predictors of stunting in children under two years of age across Indonesia (Wardani et al., 2020).

Several methods are used to forecast population growth and related data. GSTARIMA and STARIMA models analyze time series data by considering temporal and spatial factors, and GSTARIMA is suitable for heterogeneous locations (Mubarok, 2024). Demographic analysis examines population trends, distribution, growth, and composition as influenced by fertility, mortality, and migration (Jalaludin, 2020). To predict electricity demand correlated with population growth, multiple linear regression can be used (Yanto, 2020). The Growth Trend regression method in Simple E is used for population forecasting and economic growth calculations, while the Double Log regression method is for estimating electricity consumption (Hasibuan et al., 2022). These various approaches allow us to factor in factors such as time, space, socio-demographic parameters, and economic indicators, thus providing valuable insights for long-term planning and resource allocation. Nurmayanti & Syaharuddin (2022) measured the accuracy level of the double exponential smoothing method in the field of forecasting resulting in a forest plot of modified data of 1.10[0.79, 1.40], while non-modified data showed an accuracy level or forest plot of 1.16[0.86,1.46].

Holt's method, an exponential smoothing technique, has been applied to various forecasting scenarios. This method has shown promising results in the prediction of short-term COVID-19 cases in Brazil although its effectiveness varies by region (Martinez et al., 2020). The performance of this method can be improved by using time-varying smoothing parameters derived from autoregressive models and incorporating a bootstrap approach (Bas et al., 2021). In energy consumption forecasting, the Holt method has been used to predict electricity demand in Colombia, considering factors such as GDP per capita and industrial value added (Salinas et al., 2020). For seasonal Holt-Winters models, proper initialization is essential to produce accurate predictions. A new initialization method has been developed to adapt the traditional single-seasonal approach to multiple seasons with applications in electricity demand forecasting in Spain (Trull et al., 2020).

Kurniawan et al.(2017) compared exponential and logistic models for population growth in Surabaya and found that the logistic model was more accurate. In West Kalimantan, Rosyadi et al.(2023) examined the relationship between population, energy consumption, and economic growth in the new capital city of East Kalimantan and surrounding areas, and found varying impacts in different regions. Wijaya et al.(2020) analyzed spatial interactions and growth patterns in East Kalimantan, identifying East Kutai Regency as a fast-growing region and Berau Regency as a growth center. These studies used various quantitative methods, including time series analysis, panel regression, and spatial analysis, to understand and predict population dynamics as well as economic and infrastructure implications in various regions in Indonesia. In addition, Bas et al.(2021) proposed a modified Holt method with varying smoothing parameters based on an autoregressive model, which showed improved forecasting performance. The purpose of this study is to provide an overview of population projections that can be used as a basis for regional development planning, especially in the context of preparing East Kalimantan as the location of the National Capital City.

B. METHOD

This research applies an experimental quantitative approach with the aim of analyzing and predicting the population growth rate in East Kalimantan Province based on time series data obtained from the Central Bureau of Statistics (BPS) of East Kalimantan. The data used is secondary data, namely annual population growth rates that have been officially published by BPS. The quantitative approach was chosen because this research involves numerical analysis of historical data, while the experimental character is reflected in the application and testing of certain predictive models to evaluate the level of accuracy in estimating future population numbers. The flow of stages in the process of modeling population growth in East Kalimantan Province can be seen in Figure 1.

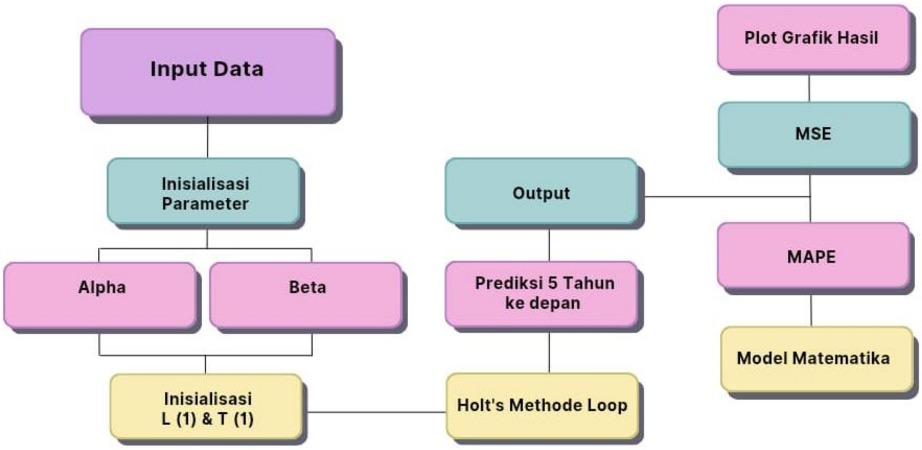

Figure 1. Flow of Population Growth Modeling

Figure 1 shows the stages in applying the Double Exponential Smoothing (Holt) method for forecasting time series data for the next five years. The process begins with entering historical data, then proceeds with determining the parameter values, namely alpha (α) of 0.6 as a level smoother and beta (β) of 0.2 as a trend smoother. After the parameters are set, the initialization of the initial level value (L1) using equation (1) and the initial trend (T1) using equation (2) will be used as the basis in the iterative calculation process. Next, the Holt method is repeated by updating the level and trend values for each period using equation (1). From this process, a prediction value for the next five years is generated. The prediction results are then visualized in graphical form to see the comparison between actual and predicted data. To find out how well the model works, an evaluation is carried out by calculating the Mean Squared Error (MSE) and Mean Absolute Percentage Error (MAPE) shown in Equations (2) and (3). Finally, from the prediction results and parameters used, a mathematical model is formed that represents the data pattern and forecast results.

Level (Lt):

$$L_t = \alpha . Y_t + (1 - \alpha)(L_{t-1} + T_{t-1}) \quad (1)$$

Trend (Tt):

$$T_t = \beta . (L_t - L_{t-1}) + (1 - \beta) . T_{T-1} \quad (2)$$

Forecast (k periods ahead):

$$\hat{Y}_{t-k} = L_t + k \, . \, T_t \quad (3)$$

The number of epochs generated, Mean Square Error (MSE) and Mean Absolute Percentage Error (MAPE) are used in testing the accuracy of the developed network architecture. The MSE and MAPE formulas are shown in Equation (4) and Equation (5):

$$\mathrm{MSE} = \frac{1}{\mathrm{n}} \sum_{\mathrm{i}=1}^{\mathrm{n}} (\mathrm{A_i} - \mathrm{F_i})^2 \quad (4)$$

$$\text{MAPE} = \left(\frac{100}{n}\right) \sum_{t=1}^{n} \frac{|X_t - F_t|}{n} \tag{5}$$

With A_i representing actual data, F_i representing forecasting data, and n representing the amount of data. In the data training and testing stages, the number of epochs, MSE and MAPE generated in each simulation are tabulated to facilitate the interpretation process. These parameters are used to find the best architecture for the prediction stage. The number of epochs is used to measure the length of the training process by the architecture, the MSE (Mean Squar Error) value is used because it produces smaller errors but sometimes produces very large errors, while the MAPE (Mean Absolute Percent Error) is used if the size of the forecasting variable is an important factor in evaluating the accuracy of the forecasting. The lower the MAPE value, the ability of the forecasting model used can be said to be good, and MAPE has a range of values that can be used as a measurement material regarding the ability of a forecasting model, the range of values can be seen in Table 1.

Table 1. Range of MAPE Values

Range MAPE	Meaning
< 10%	Excellent Forecasting Model Ability
10 – 20%	Good Forecasting Model Ability
20 – 50%	Decent Forecasting Model Capability
> 50%	Poor Forecasting Model Ability

C. RESULTS AND DISCUSSION

1. Data Description

The focus of the data used is annual population growth data in the East Kalimantan Province region in Indonesia from January 1, 2015 to December 31, 2024. Rainfall data in the East Kalimantan Province region is obtained on an annual basis from 2014 to 2024 which is obtained annually. The amount of population growth calculated for each year is shown in Table 2.

Table 2. Population Growth Data of East Kalimantan Province from 2014 to 2024

Year	Total Population (Thousand)
2015	3426,6
2016	3501,2
2017	3575,5
2018	3648,8
2019	3721,4
2020	3766
2021	3808,2
2022	3859,8
2023	3909,7
2024	4045,9

Population data for the period 2015 to 2024 shows a consistently increasing trend each year. There is no indication of a decline during this period, indicating that the population continues to grow. The lowest (minimum) value was recorded in 2015, at 3,426.6 thousand people, while the highest (maximum) value occurred in 2024 at 4,045.9 thousand people. The average value of population over the last ten years is in the range of 3,731.3 thousand people. Overall, this data shows a stable and sustainable population growth pattern from year to year. The results of descriptive statistics of population growth data of East Kalimantan Province are shown in Table 3.

Table 3. Descriptive Statistics

	N	Minimum	Maximum	Mean	Std. Deviation
Jumlah_Penduduk	10	3426.60	4045.90	3726.3100	191.81782
Valid N (listwise)	10				

Table 3 shows the results of descriptive statistics of the total population variable analyzed from ten valid data. The lowest (minimum) value of total population was recorded at 3,426.60, while the highest (maximum) value reached 4,045.90. The mean of the total population was 3,726.31, which represents the middle value of the data distribution. Meanwhile, the standard deviation value of 191.82 indicates the level of dispersion of the data from the mean value, which in this case is moderate. In general, the population data has a range that is not too wide and shows a relatively uniform distribution, so it can be concluded that fluctuations in population between periods or categories are not too extreme.

2. Forecasting Results and Decision Making

Based on the results of forecasting using the Double Exponential Smoothing (Holt) method, the estimated population for the next five years is obtained. The following table presents the predicted population from 2025 to 2029.

Table 4. 5-Year Prediction Results

Year	Population Prediction (thousand)
2025	4086.10
2026	4153.28
2027	4220.46
2028	4287.64
2029	4354.82

The data shows the results of population predictions over a 5-year period from 2025 to 2029. Based on the figures shown, there is a steady trend of population growth and a gradual increase each year. In 2025, the population was estimated at 4,086.10 thousand people. This number increased to 4,153.28 thousand people in 2026, then rose again to 4,220.46 thousand people in 2027. This growth continues until it reaches 4,287.64 thousand people in 2028 and 4,354.82 thousand people in 2029. The annual increase ranges from about 67 to 68 thousand people, indicating a linear growth pattern without significant fluctuations. Such a pattern indicates that population projections are consistent and reliable to support medium- and long-term planning, particularly in the aspects of public service provision and regional development.

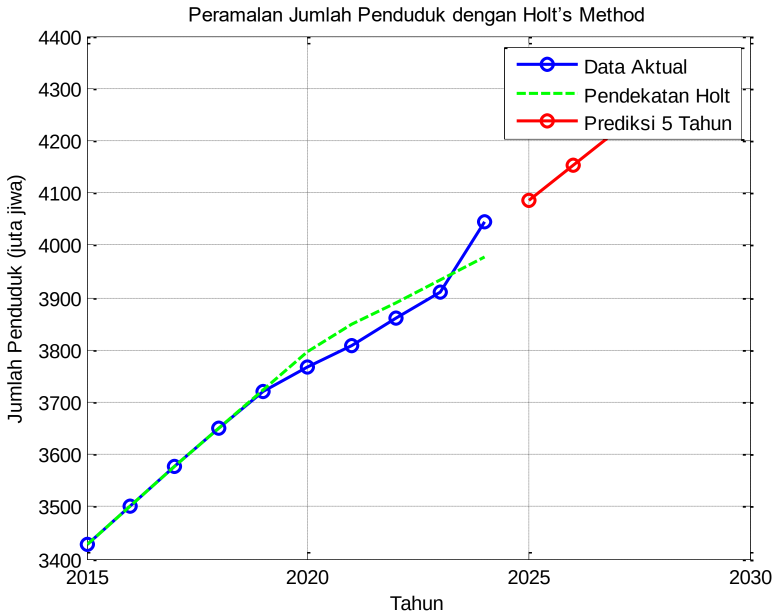

Figure 1. Graph of Prediction Results

Based on the graph of the forecasting results using the Holt's Method model, there are three main elements displayed, namely the actual data (in blue), the results of the Holt's model approach (green line), and the predicted population for the next five years (red line). This graph shows that Holt's model is able to represent the historical trend quite accurately, as indicated by the closeness between the model's approximation line and the actual data. The prediction line shows the continuity of the previously established trend, with the direction of growth tending to increase consistently. The significant discrepancy between the model results and the actual data indicates that the model has a high level of accuracy in projecting data into the future. This visualization can be an effective tool for policy makers to understand the direction of demographic development and develop policies that are responsive to these projections. The results of population growth modeling using the Holt's Method model produced an MSE error value of 861.5104 and a MAPE value of 0.50% which identified the model as very effective in predicting population growth patterns. The prediction math model produced by Holt's Method is like equation (6):

$$Yt = 4018.9201 + 67.1804 * t \tag{6}$$

Based on forecasting results that show a consistently increasing trend in population growth until 2029, anticipatory and planned policies are needed to maintain a balance between population growth and public service capacity. One of the main policies that need to be implemented is strengthening infrastructure and spatial planning, which includes the development of basic facilities such as transportation, clean water, sanitation, and energy, as well as the development of residential areas that pay attention to sustainability aspects. In addition, increasing the capacity of education and health services is crucial, given that the increasing population will have a direct impact on the need for learning facilities, educators, health facilities, and medical personnel. In terms of employment, the government needs to encourage the creation of new jobs through strengthening the productive sector and empowering MSMEs, accompanied by improving the skills of human resources to be in line with labor market needs. On the other hand, policies oriented towards environmental protection must also be strengthened to maintain the carrying capacity of the ecosystem to the rate of population growth. This can be done through monitoring land use, waste management, and environmental conservation. All of these policies need to be supported by an accurate and integrated population information system, so that data-based planning and decision-making processes can be carried out effectively and sustainably.

D. CONCLUSIONS AND SUGGESTIONS

The prediction results using the Holt method show that the population is expected to continue to increase gradually from 2025 to 2029 with a stable growth trend and excellent model accuracy (MAPE 0.50%). The government needs to develop proactive and integrated policies, including improving basic infrastructure, strengthening the education system and health services, creating employment opportunities through the development of productive sectors and MSMEs, and protecting the environment. All of these policies should be supported by an accurate and integrated population information system to support effective and sustainable planning and decision-making processes.

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