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Algorithmic Forecasting of Tourist Mobility: Implementation of Fuzzy Time Series in High-Variability Aviation Data

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ABSTRACT

Accurate forecasting of tourist arrivals is a critical determinant for strategic planning and operational efficiency in island destinations. However, forecasting domestic tourist mobility through airport gateways, such as Lombok International Airport (LIA), presents a significant challenge due to the high volatility and non-linear characteristics of aviation data. Conventional statistical models often fail to capture these dynamic fluctuations effectively. To address this issue, this study proposes an algorithmic forecasting framework using the Fuzzy Time Series (FTS) Chen model. The methodology involves processing monthly arrival data through a structured sequence: defining the universe of discourse, partitioning intervals, fuzzification, establishing Fuzzy Logical Relationships (FLRs), and performing defuzzification. The model's performance was rigorously evaluated using the Mean Absolute Percentage Error (MAPE). Empirical results demonstrate that the FTS Chen algorithm is highly effective for stable datasets, achieving a forecasting accuracy with a MAPE as low as 9.23% for foreign tourist arrivals. In contrast, the model exhibited higher error rates for domestic tourist data, attributed to significant seasonal volatility and external shocks. These findings confirm that while the proposed soft computing approach is robust for detecting trends in stable tourism flows, highly fluctuating domestic markets may require hybrid optimization. Practically, this study provides airport authorities with a quantitative tool to anticipate visitor volume and optimize resource allocation in the post-pandemic era.

1. Introduction

Tourism is a sector that contributes greatly to regional economic growth in Indonesia, especially in West Nusa Tenggara (NTB) Province. Lombok Island, as part of NTB, plays an important role as a leading tourist destination that attracts domestic and foreign tourists. The main access to Lombok Island is through Zainuddin Abdul Madjid International Airport (often referred to as Lombok International Airport), which serves as the entry point for air transportation. Official data shows that domestic tourist visits to NTB have increased significantly in recent periods, with the number reaching more than 1.4 million people only in April 2025, an increase of around 35.74 percent compared to the previous month. This indicates the high mobility of domestic tourists to this destination (Iqbal et al., 2023; Sukma et al., 2025).

The increase and variation of domestic tourist visits requires a planned and data-based planning, especially in the management of the tourism and air transportation sectors. Therefore, the projection of

the number of domestic tourist visits becomes very crucial as a supporting tool in decision making. Information on projection results can be utilized by local governments, airport managers, and tourism industry players to formulate strategic policies, increase service capacity, and predict the surge or decline in the number of tourists in a certain period. Various studies have shown that tourism demand projection is an important component in planning and developing sustainable tourist destinations (Hartman, 2021; Scott & Gössling, 2022).

Based on this situation, this study aims to forecast the number of domestic tourist visits to Lombok Island through Lombok International Airport. This forecasting is designed to provide an estimate of the number of visitors in the future period which can be used as a basis for airport operational planning, service capacity management, as well as the preparation of regional tourism sector development policies. The forecast results are expected to help stakeholders in dealing with fluctuations in the number of visitors, so that the decision-making process can be carried out more accurately, efficiently, and data-based (Mustafa & Al-Yozbaky, 2025; Yan et al., 2025; Zhang, Wang, et al., 2024).

This research uses the Chen model Fuzzy Time Series (FTS) method. This method was chosen because it can overcome uncertainty and non-linear changes in time series data, which is in accordance with the characteristics of tourist visit data. Chen's FTS model uses fuzzy logic to build relationships based on language intervals from past data(Devianto et al., 2024; Xian et al., 2024; Yu & Wu, 2025) . This approach does not require certain assumptions about statistical distributions, thus offering greater flexibility than ordinary time series methods(Xian et al., 2024) . Several recent studies have shown that FTS is effective in predicting the number of travelers and passengers at airports.

The advantages of Chen's Fuzzy Time Series model are its ease of application, flexibility in recognizing data change patterns(Kong et al., 2025; Mustafa & Al-Yozbaky, 2025; Palomero et al., 2022) , and its ability to cope with unstable and changing data. This method also produces a model that is quite easy to understand and is able to provide competitive forecasting accuracy, especially on data that has seasonal patterns and erratic changes, such as the number of tourist visits. Assessment of model performance can be done using measures of error in forecasting, such as Mean Absolute Error (MAE) and Root Mean Square Error (RMSE). The purpose of using these measures is to ensure that the forecasting results are reliable.

2. Literature Review

Accurate tourism demand forecasting is a fundamental element in destination strategic planning and airport operational management, especially in island regions that rely heavily on air connectivity. However, tourist arrival data, particularly those through international airport gateways, have non-linear characteristics and high volatility that are often influenced by seasonal factors as well as external shocks(Yan et al., 2025) . This complexity demands forecasting methods that not only rely on linear historical patterns, but are also able to capture the uncertainty inherent in human mobility data .(Devianto et al., 2024; Mustafa & Al-Yozbaky, 2025)

Although conventional statistical methods such as linear regression and SARIMA (Seasonal Autoregressive Integrated Moving Average) have long been the industry standard(Kabbilawsh et al., 2022; Kumari & Muthulakshmi, 2024) , these approaches are often constrained by rigid stationary data assumptions. Soft Computing approaches, particularly Fuzzy Time Series (FTS)(Gunawan et al., 2025; Mustafa & Al-Yozbaky, 2025) , have emerged as a superior alternative. FTS transforms numerical data into fuzzy linguistic sets, allowing models to handle vague and volatile data without requiring strict data normality assumptions (Yu & Wu, 2025).

Variants of the FTS model are able to provide higher prediction accuracy than conventional methods in projecting passenger numbers. FTS is proven to be reliable in mapping seasonal visitation patterns(Bello et al., 2025; Khaira et al., 2023; Wiguna et al., 2026) . Specifically, the FTS algorithm offers an optimal balance between computational efficiency and prediction accuracy through simplifying operations on fuzzy logical relationship groups(Bello et al., 2025; Zhang, Sun, et al., 2024) . Based on this theoretical foundation, this study applies Chen's FTS

algorithm to model the flow of domestic travelers at Lombok International Airport, with the aim of overcoming the challenge of high data variability in the domestic aviation market.

3. Research Methods

This research applies a quantitative approach using Chen's Fuzzy Time Series (FTS) model to predict the number of local and foreign tourist visits to Lombok Island through Lombok International Airport. The research process is neatly organized, starting from data collection to the assessment of prediction results.

The data used is secondary data, namely the number of tourist visits from within the country and from abroad every month obtained from authorized official institutions. The data is organized in a time series format with monthly intervals. In the initial stage, descriptive analysis was conducted to recognize patterns, trends, and changes in the data.

The modeling process is carried out using Chen's Fuzzy Time Series method, which consists of several steps. These steps include determining the scope of discussion, forming intervals, processing data into fuzzy form, forming fuzzy logic relationships, grouping fuzzy logic relationships, and finally, the defuzzification process to produce forecast values in numerical form.

All stages of the research method are summarized in the form of a research flow chart as shown in Figure 1, which illustrates the flow of the research process systematically starting from data collection, time series data preparation, modeling process using Chen's Fuzzy Time Series model, to the model accuracy evaluation stage. A detailed description of each stage of the research method is presented in Table 1 to provide a more structured explanation of the modeling steps performed.

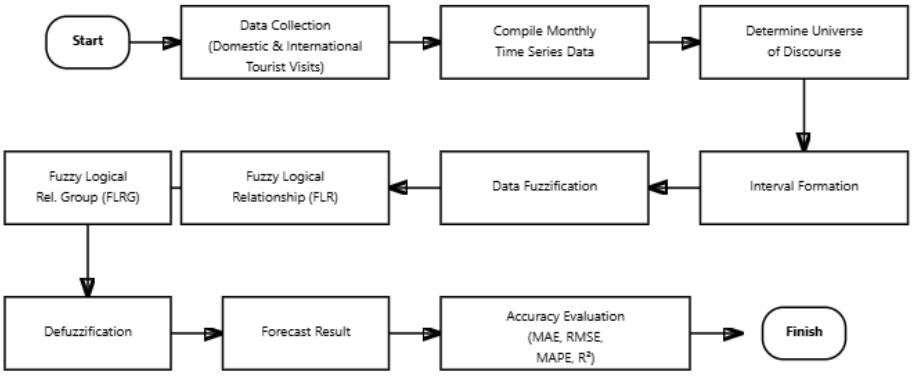

Fig.1. Research Flowchart of Chen Model Fuzzy Time Series (FTS) Method

The research process began by collecting data on the number of domestic and international tourist arrivals using Lombok International Airport. This data is organized in the form of monthly time series, as shown in Table 1. The data is then used to define the universe of speech by taking the minimum and maximum values as the basis for forming intervals. The resulting intervals are then used in the fuzzification process to convert numerical data into fuzzy sets. After the fuzzification stage, the next step is to build a fuzzy logical relationship (FLR) and group the fuzzy logical relationships (Fuzzy Logical Relationship Group/FLRG). This is the basis for generating forecasting values. The defuzzification stage is carried out to convert fuzzy results into numerical values that can be used for forecasting. Furthermore, the forecasting results are assessed using forecasting error measures, namely Mean Absolute Error (MAE), Root Mean Square Error (RMSE), Mean Absolute Percentage Error (MAPE), and coefficient of determination (R^2). These measures are used to measure how accurate the model that has been created is.

4. Results and Discussions

This study uses data on the number of domestic and foreign tourist visits to Lombok Island through Lombok International Airport. The data is organized in monthly time series format. Preliminary analysis shows that the data of domestic visitors experience significant changes, with drastic increases and decreases at certain times. In contrast, the data on foreign tourists shows a more stable and consistent pattern during the observation period. These different data characteristics are important factors that affect the performance of the applied forecasting method. The prediction results of the number of local tourists using Chen's Fuzzy Time Series (FTS) model are shown in Figure 2. The figure shows the comparison between the actual data and the prediction results until 2026. The graph indicates that the forecast results tend to remain consistent after the initial phase, while the actual data shows considerable variation. At certain times, there are significant differences between the actual values and the forecast results, especially in months where the number of visits changes greatly. This indicates that the classical Chen FTS method has limitations in capturing sudden changes in data patterns.

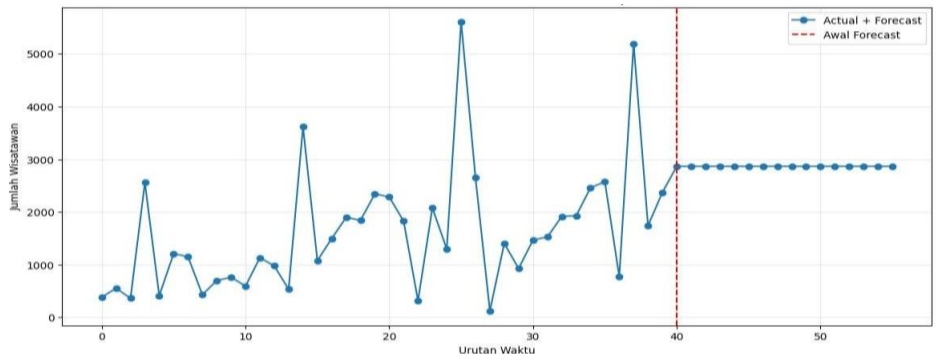

Fig.2. Comparison of Actual Data and Forecasting Results of Domestic Tourists until 2026

Figure 3 shows the comparison between real data and the forecast results of the number of foreign tourists. The predicted number of foreign tourists shows a higher match with the actual data compared to domestic tourists. The fairly consistent data pattern allows Chen's FTS method to build fuzzy logic relationships that better match the past behavior of the data. This results in a more precise forecast.

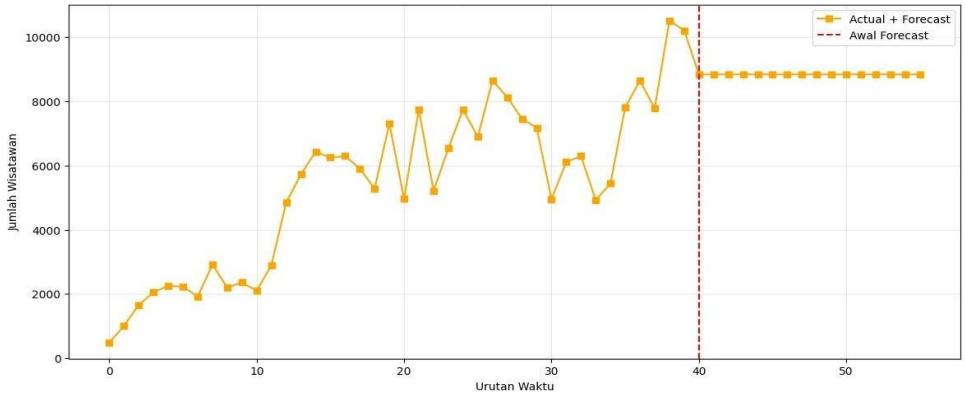

Fig.3. Comparison of Actual Data and Forecasting Results of Foreign Tourists until 2026

The accuracy of the model was evaluated using forecasting error measures, namely MAE, RMSE, MAPE, and coefficient of determination (R^2). The evaluation results show that the MAPE values for foreign tourists are in the low to medium range. The lowest value recorded is 9.23%, which falls into the excellent forecasting category. In contrast, the MAPE value for domestic tourists experienced very significant changes in certain months, especially in August and September. The high error rate in

forecasting indicates that the data used is very unstable, and this is not only due to flaws in the method used.

The comparison of MAPE values between local and foreign tourists shown in Figure 4 shows a clear difference in model performance. The MAPE value for foreign tourists is consistently lower and remains stable compared to local tourists. The results of this study show that the properties of the data have a great impact on the performance of the Fuzzy Time Series method developed by Chen. This research offers a new approach by using Chen's FTS method as a base model to forecast the number of tourist visits to Lombok Island. In addition, this study also compares the performance of the model using two types of data that have different characteristics.

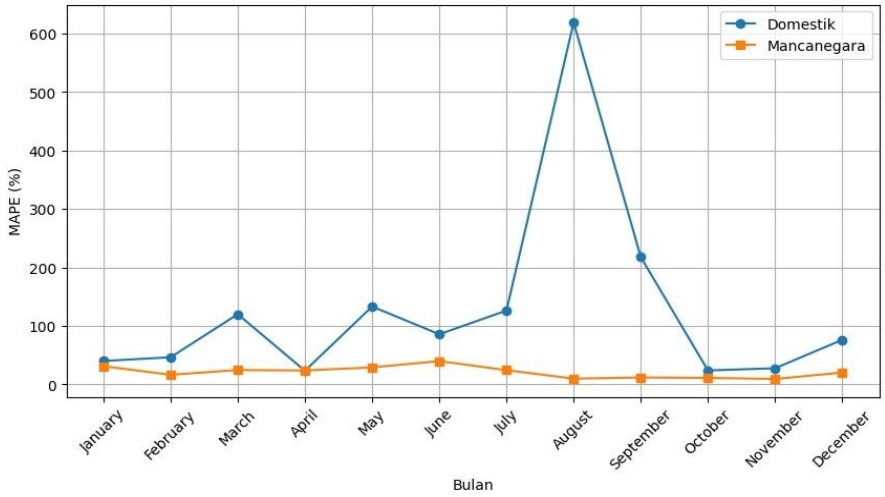

Fig.4. Comparison of Mean Absolute Percentage Error (MAPE) Value of Domestic and Foreign Tourists

5. Conclusion

This study aims to predict the number of local and foreign visitors who come to Lombok Island through Lombok International Airport using the Fuzzy Time Series (FTS) method of the Chen model. The results showed that Chen's FTS method can produce good forecasting for foreign tourist visit data which has a stable and consistent pattern. The low to moderate Mean Absolute Percentage Error (MAPE) values in most observation periods indicate that these forecasting results can be taken into good consideration in tourism sector planning**.** In contrast, the prediction results for local tourist data show that there is a greater error rate and is not stable in certain months. This condition occurs because domestic tourist data has an unstable nature and the number of visits can change drastically at certain times. This research reveals that the effectiveness of forecasting methods is highly dependent on the properties of the data, especially on the level of stability and patterns that already exist in the data being analyzed. Therefore, Chen's FTS method is more suitable for data that has a fairly stable pattern, rather than data that has experienced many changes.

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