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# A Holt-Winter Approach to Forecasting Admission in the Psychiatric Department

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**Abstract:** Psychiatric admissions predictive modeling is a crucial step in hospital resource and service management. Prediction models are essential for medical facilities to account for patient arrival fluctuations that could potentially overextend their resources. The present study used the Holt-Winters method to forecast psychiatric admissions at Hospital Universiti Sains Malaysia (HUSM). The estimation and evaluation phases are based on historical admission data from 2017 to 2024 to extract trends, seasonal and level components. The dataset was split into training and testing phases to ensure robust model selection. Mean Absolute Scaled Error (MASE), Root Mean Squared Error (RMSE) and Mean Absolute Percent Error (MAPE) are used to compare the performance. This paper examines two forms of the Holt-Winters model: additive and multiplicative. The results reveal that the Additive Holt-Winters model consistently has the lowest error across all performance metrics. Thus, it is the best for predicting psychiatric patient admissions. The forecasting results indicate an overall increase in admissions with variations driven by seasonal factors. An accuracy assessment reveals that most predictions match actual admissions to some extent, suggesting the model is reliable. These include certain months that demonstrate standout differences, suggesting that other confounding factors may be influencing admission rates. It demonstrates the robustness of Holt-Winters' forecasting methodology in healthcare and its implications for hospital administrators seeking to improve efficiency in the deployment of resources. Future work might also focus on combining other predictive tools to improve forecast quality.

**Keywords:** *Admission, Forecast, Holt winter, Psychiatric, efficiency*

## 1. Introduction

The global COVID-19 pandemic has profoundly impacted various aspects of healthcare systems worldwide, including the mental health sector. (Yıldırım et al., 2022). Psychiatric disorders, which are influenced by both environmental and biological factors, have seen a notable rise in prevalence due to the stress, uncertainty, and isolation associated with the pandemic. Thus, understanding the trends and patterns of psychiatric admissions is crucial for effective resource allocation, policy formulation, and intervention planning (Boldrini et al., 2021; Hambleton et al., 2022; Xiang et al., 2020).

Research into psychiatric admissions has demonstrated that the pandemic triggered a surge in mental health issues, including anxiety, depression, and substance use disorders. Studies have also documented an increase in emergency department visits for mental health crises, especially during periods of lockdown and social restrictions (Dong et al., 2020; Mendez-Lopez et al., 2022; Mustikasari et al., 2022). For instance, research in various regions revealed a marked increase in admissions related to acute stress and suicidal ideation. On the other hand, some studies have paradoxically reported a decline in psychiatric admissions during the initial phases of the pandemic, potentially due to fear of contracting the virus and restricted access to healthcare facilities. While these findings underscore the profound impact of COVID-19 on mental health, they also highlight the complexities and inconsistencies in patient admission trends, warranting further investigation (Jones et al., 2021; Nearchou et al., 2020).

Despite these efforts, there remain significant gaps in understanding the long-term trends and patterns in psychiatric admissions during and after the pandemic. Previous studies have often focused on short-term observations or specific subpopulations, limiting their generalizability. Additionally, few studies have employed robust statistical forecasting methods to predict future trends, leaving healthcare planners without reliable tools for anticipating demands in psychiatric services (Herrera et al., 2023; O'Donoghue et al., 2022; Rodrigues et al., 2022). Therefore, addressing these gaps is essential for developing proactive strategies to meet the growing mental health needs of populations worldwide.

This article seeks to address these gaps by applying the Holt-Winters exponential smoothing method to analyze and forecast the number of psychiatric admissions. The research focuses on examining the temporal patterns in psychiatric admissions before and after the COVID-19 outbreak, identifying key inflection points and seasonal variations. The objectives of this study are twofold: first, to provide a comprehensive analysis of the changes in psychiatric admission trends influenced by the pandemic, and second, to develop a reliable forecast model using the Holt-Winters approach. This model, which incorporates both seasonal and trend components, offers valuable insights for healthcare policymakers and practitioners. By bridging the gap between current observations and future projections, this study contributes to advancing knowledge in psychiatric epidemiology and healthcare forecasting. Ultimately, it aims to support data-driven decision-making and enhance the capacity and preparedness of psychiatric departments to address emerging mental health challenges.

## 2. Literature Review

Forecasting hospital admissions, particularly in psychiatric departments, is crucial for efficient resource allocation and management. The COVID-19 pandemic has underscored the significance of accurate forecasting models for adapting to sudden changes in healthcare demand. A study examining admissions to psychiatric hospitals before and during the pandemic highlighted the effectiveness of various forecasting models, including machine learning and time-series models, in predicting admissions. The study revealed that time series models, such as exponential smoothing, were particularly adept at adjusting to the shock effects of the pandemic, outperforming simpler models like the seasonal naive forecast (Wolff et al., 2021). This underscores the need for robust forecasting methods that can handle both regular patterns and unexpected disruptions.

Forecasting hospital admissions is essential for ensuring that resources are available to meet fluctuating patient needs. The COVID-19 pandemic has further underscored the importance of accurate forecasting models that can respond to sudden and unprecedented changes in healthcare demand. Previous studies have highlighted the rise in psychiatric admissions linked to stress, anxiety, and other disorders during the pandemic, while also noting short-term declines in service use due to restricted access and fear of infection (Hay et al., 2021).

Psychiatric admissions present unique forecasting challenges, as they are influenced by clinical needs, social, cultural, and external events. During COVID-19, psychiatric hospitals experienced inconsistent patterns: some reported surges in demand, while others observed temporary declines due to access restrictions (Boldrini et al., 2021; Tarricone et al., 2023; Reece & Sams, 2022). Understanding long-term patterns beyond the pandemic requires robust forecasting techniques that integrate both trend and seasonality.

The ability to accurately forecast patient inflow can enhance resource allocation and improve patient care. Research has demonstrated that the Holt-Winters method can effectively model seasonal variations in healthcare data, allowing hospitals to prepare for fluctuations in patient numbers (Mohd Lip et al., 2020; Mahmoodpour-Azari et al., 2023). For instance, studies have demonstrated the successful application of the Holt-Winters approach in forecasting healthcare utilization, which is critical for planning staffing and resource management (Valsamis et al., 2019). Moreover, the method's ability to provide short-term forecasts makes it particularly valuable in dynamic environments such as psychiatric departments, where patient needs can change rapidly (Erişen et al., 2017; Oral, 2019). The integration of Holt-Winters with other forecasting techniques, such as artificial neural networks, has also been explored, suggesting that hybrid models may further enhance predictive accuracy (Rodriguez et al., 2016; Ortiz, 2016).

The Holt-Winters method, a classical time-series forecasting technique, has been widely used for its ability to model seasonality and trends effectively. The method incorporates three recursive processes to estimate the level, growth rate, and seasonal parameters, making it suitable for various applications, including hospital admissions (Kays et al., 2020). A study on the application of the Holt-Winters method for forecasting hospital admissions in cities like St. Petersburg demonstrated its effectiveness in rapidly changing situations, such as those caused by the COVID-19 pandemic. The study justified the use of the Holt-Winters method for its ability to adapt to dynamic processes and provide reliable forecasts (Klyapko, 2021). This adaptability is crucial for psychiatric departments, where patient admission patterns can be influenced by numerous external factors.

The Holt-Winters approach exhibits patterns of growing or decreasing trends with seasonality. There are two variations of the Holt-Winters smoothing method, depending on whether the seasonal pattern in the series is represented in an additive or multiplicative manner. According to Djakaria and Saleh (2021), they used Holt-Winters exponential smoothing to forecast the COVID-19 pandemic for a given period, with the result indicating that the pattern of COVID-19 cases in Gorontalo Province will not end anytime soon, as the model does not indicate a decreasing trend. Furthermore, Lima et al. (2019) compared the precision of Holt-Winters models (additive and multiplicative) for forecasting economic time series and also brought new perspectives about the methods used through this technique, with the five measures of evaluation calculated and discovered that the multiplicative model has high accuracy and forecast performances of the e-commerce retail sales time series of Portugal.

The Holt-Winters model, also known as triple exponential smoothing, has been widely documented in the literature and has been demonstrated to be successful in projecting energy consumption with high accuracy. (Almazrouee et al., 2020). However, Bridge et al. (2020) Used the Holt-Winters forecasting model for the same study and observed no significant change in the level or trend of suicide after the show was released for both overall and by gender. Furthermore, Rostami et al. (2019) Used the Holt-Winters' multiplicative smoothing approach to investigate the changes in monthly suicide rates in Iran's most inhabited western region, discovering a significant seasonal variation in suicide with a record high in August.

The application of Holt-Winters exponential smoothing methods in forecasting has gained significant attention across various fields, including healthcare. The Holt-Winters method, which incorporates seasonality, trend, and level, is particularly suitable for time series data that exhibit these characteristics. This method has been widely validated in the literature, demonstrating its robustness across contexts, including economic indicators, tourism, and healthcare utilization (Atoyebi et al., 2023; Mohd Lip et al., 2020). The adaptability of the Holt-Winters model allows for capturing complex seasonal patterns, which is essential for understanding patient flow in psychiatric settings where admissions may vary significantly due to seasonal factors or external events, such as public health crises (Mahmoodpour-Azari et al., 2023; Valsamis et al., 2019).

The literature suggests that the Holt-Winters method, with its ability to model seasonality and trends, is a valuable tool for forecasting admissions in psychiatric departments. Its effectiveness in adapting to sudden changes, as demonstrated during the COVID-19 pandemic, makes it particularly suitable for healthcare settings where demand can fluctuate unpredictably. By incorporating dynamic adjustments, the method can further enhance forecasting accuracy, providing psychiatric departments with the insights needed for efficient resource management and planning. As healthcare systems continue to face challenges, adopting robust forecasting models, such as the Holt-Winters method, will be essential to maintaining optimal patient care and operational efficiency. Despite its success in other sectors, Holt-Winters has not been systematically applied to psychiatric admissions in Malaysia, especially in the post-pandemic context. This study addresses this gap by demonstrating how Holt-Winters can capture both long-term upward trends and seasonal variations in psychiatric admissions, providing hospital administrators with evidence-based insights for resource allocation and planning.

## 3. Methodology

### Data Description

Secondary data were collected from the Psychiatric Department of Hospital Universiti Sains Malaysia (HUSM) from January 2017 to December 2024. A total of 96 admissions each month were recorded. The data series had been split into estimation and evaluation sections before further work on the model could be performed. It is a common procedure to divide all available labelled data into estimation and evaluation, with a 75 % estimation and a 25 % evaluation part. The predicted values will be compared to the original values retained in the evaluation section.

### Holt-Winter

The Holt-Winters method is frequently referred to as an approach to exponential smoothing. Multiplicative Seasonal Method (Multiplicative Seasonal Method), used for seasonal variation of data that has raised or reduced (fluctuation), and Additive Seasonal Methods, which are used for continuous seasonal variation, are

the two sections of this method. (Pongdatu & Putra, 2018). For a model with a linear trend and an exponential trend, the additive models are used. For data with trend and seasonality that do not get larger and larger, the Holt-Winters additive model is adequate. (Talkhi et al., 2021). Assuming that there is a multiplicative relationship between these elements, the equations are written as follows:

**Additive Holt-Winters Model**

The Additive Holt-Winters Model is presented in the following equations:

Level: $L_t = \alpha\left(Y_t - S_{t-s}\right) + \left(1-\alpha\right)\left(L_{t-1} + b_{t-1}\right)$, (1)

Trend: $b_t = \beta\left(L_t - L_{t-1}\right) + \left(1-\beta\right)b_{t-1}$, (2)

Seasonal: $S_t = \gamma\left(Y_t - L_t\right) + \left(1-\gamma\right)S_{t-s}$, (3)

Forecast: $F_{t+m} = L_t + b_t m + S_{t-s+m}$. (4)

The initials for Holt-Winters Additive Model are:

$$L_s = \frac{1}{s}\left(Y_1 + Y_2 + \ldots.. + Y_s\right), \quad (5)$$

$$b_s = \frac{\sum\left(Y_{s+1} - Y_t\right)}{s^2}, \quad (6)$$

$$S_s = Y_i - L_s, \quad (7)$$

$$F_{t+1} = L_t + b_t + S_{t+1-s}. \quad (8)$$

**Multiplicative Holt-Winters Model**

The Multiplicative Holt-Winters Model is presented in the following equations:

Level: $L_t = \alpha\left(\frac{Y_t}{S_{t-s}}\right) + \left(1-\alpha\right)\left(L_{t-1} + b_{t-1}\right)$, (9)

Trend: $b_t = \beta\left(L_t - L_{t-1}\right) + \left(1-\beta\right)b_{t-1}$, (10)

Seasonal: $S_t = \gamma\left(\frac{Y_t}{L_t}\right) + \left(1-\gamma\right)S_{t-s}$, (11)

Forecast: $F_{t+m} = \left(L_t + b_t m\right)S_{t-s+m}$. (12)

The initials for Holt-Winters Multiplicative Model are:

$$L_s = \frac{1}{s}\left(Y_1 + Y_2 + \ldots.. + Y_s\right), \quad (13)$$

$$b_s = \frac{\sum\left(Y_{s+1} - Y_t\right)}{s^2}, \quad (14)$$

$$S_s = \frac{Y_i}{L_s}, \quad (15)$$

$$F_{t+1} = \left(L_t + b_t\right)S_{t+1-s}, \quad (16)$$

Where denotes an estimate of the level of the series at time $t$, $b_t$ denotes an estimate of the trend of the series at time $t$, $S_t$ is an estimate of the seasonality at time $t$, and is the seasonality length, which is the number of weeks in a year ( $s$ =52). Meanwhile, $F_{t+m}$ is the forecast for the $m$ time ahead and $F_{t+1}$ is the forecast within the data set.

**Model Validation**

Goodness of fit is a measure of the accuracy of a forecast model compared to the actual values. Mean Absolute Scaled Error (MASE), Root Mean Squared Error (RMSE) and Mean Absolute Percent Error (MAPE) are model accuracy measurements based on the time series data used to create the model. The best model was chosen by comparing the results of the statistical test with the lowest error measures.
The model forecast accuracy was measured by the following criteria:

Mean Absolute Error (MAE): $\frac{\sum |e_t|}{n}$, (17)

Root Mean Square Error (RMSE): $\sqrt{\frac{\sum e_t^2}{n}}$, (18)

Mean Absolute Percentage Error (MAPE):

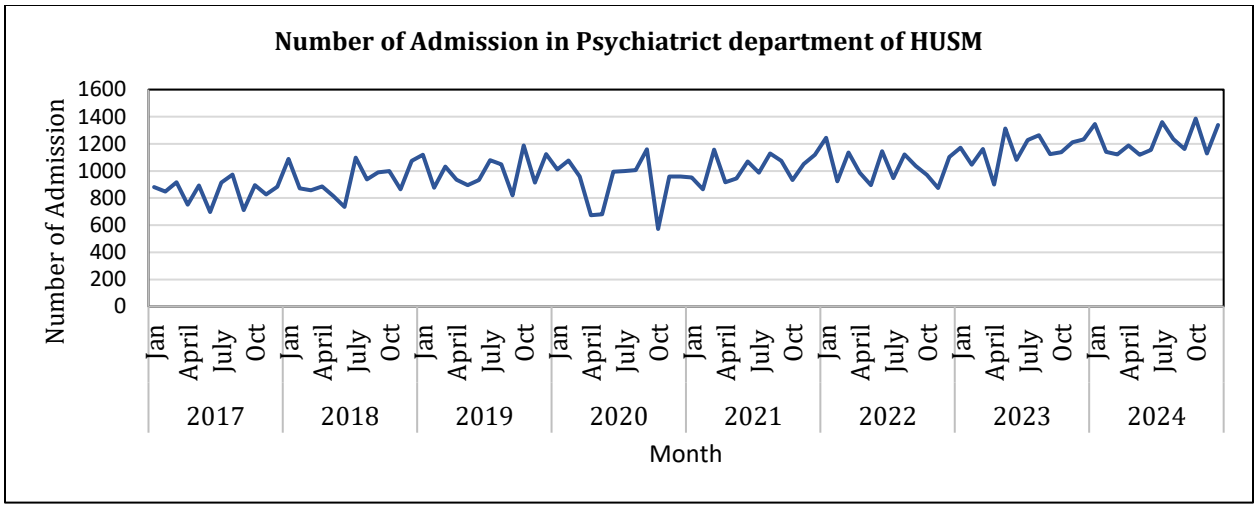
$$\left(\frac{1}{n}\sum\left|\frac{e_t}{Y_t}\right|\right)(100), \quad (19)$$

Where the forecast error is $e_t$, and it is calculated by subtracting the forecast value from the series' actual value, $Y_t$. Here $n$ Is the number of effective observations used to match the model? Minimum values of these accuracy measures provide the best fitting models.

**4. Result and Discussion**

The figure illustrates the monthly number of admissions in the Psychiatric Department at HUSM from January 2017 to October 2024. The data indicates fluctuations over the years, with admissions generally increasing. Notable drops are observed around mid-2020, potentially reflecting the impact of external factors like the COVID-19 pandemic. After this period, admissions gradually rise, displaying an upward trend from 2021 onward. The highest admissions occur in 2024, suggesting a steady increase in demand for psychiatric services over time.

**Figure 1: Monthly Number of Admissions in Psychiatric Department in HUSM**




**Data Analysis and Results Presentation**

In this study, the data were divided into two parts: estimation (75%) and evaluation (25%). In the estimation part, the data selected are from January 2017 (n = 1) to December 2022 (n = 72). Data from January 2023 (n = 73) to December 2024 (n = 96) were used in the evaluation part. The data used for estimation were used to identify the level component, the trend component, and the seasonality component. The forecast values were calculated during the evaluation. R software was used to determine the best combination of $\alpha$ , $\beta$ and $\gamma$ , as outlined in Table 1.

**Table 1: Measurement Errors of the Holt-Winters Model's Parameters**

| Model | $\alpha$ | $\beta$ | $\gamma$ |
|---|---|---|---|
| Multiplicative Holt-Winters | 0.12 | 0 | 0.43 |
| Additive Holt-Winters | 0.12 | 0.04 | 0.39 |

**Table 2: Measurement errors of the Holt-Winters Models**

| Model | MAE | | RMSE | | MAPE | |
|---|---|---|---|---|---|---|
| | Estimation | Evaluation | Estimation | Evaluation | Estimation | Evaluation |
| Multiplicative Holt-Winters | 98.9864 | 100.9005 | 137.6300 | 137.3795 | 11.0508 | 8.2131 |
| Additive Holt-Winters | 96.7523 | 96.7688 | 134.0152 | 132.8561 | 10.8117 | 7.8476 |

The table presents measurement errors for the Multiplicative and Additive Holt-Winters models using three error metrics, MAE, RMSE, and MAPE, in both the estimation and evaluation phases. The Additive Holt-Winters model consistently produces lower errors across all metrics than the Multiplicative model. Specifically, the Additive model has lower MAE (96.7523 in estimation, 96.7688 in evaluation), RMSE (134.0152 in estimation, 132.8561 in evaluation), and MAPE (10.8117 in estimation, 7.8476 in evaluation), indicating better forecasting accuracy for psychiatric admissions. This suggests that the Additive Holt-Winters model performs better in this context, making it a preferable choice for forecasting. The predicted monthly number of attendances at HUSM's Psychiatric Department is based on data from the evaluation part in 2024, which were computed using the best model selected as summarized in Table 3.

**Table 3: Predicted Number of Attendances at the Psychiatric Department of HUSM**

| Month | Predicted Number of Attendances | Actual Number of Attendances | Accuracy (%) |
|---|---|---|---|
| January | 1561 | 1345 | 86.16 |
| February | 1384 | 1142 | 82.51 |
| March | 1526 | 1121 | 73.46 |

| | | | |
|---|---|---|---|
| April | 1372 | 1187 | 86.52 |
| May | 1334 | 1120 | 83.96 |
| June | 1488 | 1154 | 77.55 |
| July | 1461 | 1360 | 93.09 |
| August | 1562 | 1234 | 79.00 |
| September | 1496 | 1161 | 77.61 |
| October | 1412 | 1386 | 98.16 |
| November | 1431 | 1130 | 78.97 |
| December | 1575 | 1340 | 85.08 |

The table presents the predicted and actual attendance figures for each month, alongside the calculated accuracy percentages. Accuracy varies throughout the year, with the highest being in October (98.16%) and July (93.09%), indicating close alignment between predictions and actual numbers. On the other hand, March recorded the lowest accuracy at 73.46%, reflecting a significant gap. Most months, including January (86.16%), April (86.52%), and December (85.08%), achieved accuracies in the mid-80% range, indicating relatively reliable predictions. However, lower accuracies were noted in June (77.55%), August (79.00%), and November (78.97%), suggesting moderate prediction discrepancies for those months. Overall, the predictions yield a reasonably high level of accuracy, with most months exceeding 75%. This suggests that the forecasting model is effective at estimating patient attendance, though some months exhibit greater deviations between predicted and actual values. The variation in accuracy indicates potential seasonal or external factors influencing psychiatric attendance.

The predicted number of psychiatric admissions at HUSM in 2025 was computed using the selected best model, as outlined in Table 3.

**Table 4: Predicted number of psychiatric admissions at HUSM in 2025**

| Month | Predicted Number of Psychiatric Admissions |
|---|---|
| January | 1581 |
| February | 1383 |
| March | 1371 |
| April | 1436 |
| May | 1372 |
| June | 1416 |
| July | 1563 |
| August | 1585 |
| September | 1461 |
| October | 1501 |
| November | 1550 |
| December | 1610 |

Table 4 presents the predicted number of psychiatric admissions at HUSM for the year 2025. Predictions ranged from 1,371 in March (the lowest) to 1,610 in December (the highest). The first half of the year generally yields lower predicted values, ranging from 1,371 to 1,436. In contrast, the second half of the year reflects a rise in predictions, with admissions ranging from 1,461 in September to a peak of 1,610 in December. This indicates a gradual increase in predicted psychiatric admissions as the year progresses, with a noticeable surge toward the end of the year.

## 5. Conclusion and Recommendations

The analysis of psychiatric admissions at HUSM between 2017 and 2024 highlights a general increase in patient numbers, with notable fluctuations observed over the years. A sharp decline in mid-2020 corresponds with a period of significant global disruptions, which may have influenced hospital attendance. However, an upward trajectory is evident from 2021 onwards, culminating in the highest recorded admissions in 2024. To better understand and predict future trends, forecasting techniques were applied, with the Holt-Winters model used to generate estimates. Two variations of the model were assessed, and performance was measured through MAE, RMSE, and MAPE. The Additive Holt-Winters model demonstrated superior predictive capability compared to its Multiplicative counterpart, as indicated by consistently lower error values across all assessment metrics. Monthly forecasts for 2024 were compared with actual data, revealing generally high prediction accuracy, particularly in October and July, which recorded alignment rates of 98.16% and 93.09%, respectively. Conversely, March exhibited the lowest accuracy at 73.46%, highlighting possible seasonal influences or external factors affecting patient attendance. Despite variations, most months presented prediction accuracy exceeding 75%, indicating the forecasting approach is largely effective. Using the most reliable model, psychiatric admissions for 2025 were projected, revealing a gradual increase over the year. The lowest expected admission rate is in March (1,371), while the highest is in December (1,610), suggesting an upward trend as the year progresses. The first half of the year maintains relatively stable figures. In contrast, the latter months exhibit a notable rise, potentially signalling an increase in demand for psychiatric services toward the year's end. These findings reinforce the growing need for psychiatric care and the importance of accurate forecasting methods in resource planning and hospital management. While the predictive model provides valuable insights, some discrepancies suggest that further refinement could enhance reliability. At the same time, factors such as seasonal trends, external events, and institutional policies may influence patient numbers, and incorporating these variables into future models could improve forecast accuracy. The continuous rise in psychiatric admissions underscores the necessity for ongoing capacity expansion, staffing considerations, and policy adjustments to accommodate increasing patient needs effectively.

In conclusion, applying a Holt-Winters approach to forecast admissions in the psychiatric department of HUSM offers a promising avenue for enhancing operational efficiency and patient care. The method's established efficacy across multiple domains, coupled with ongoing advances in its optimization, underscores its potential utility for healthcare forecasting. By leveraging the strengths of the Holt-Winters model, HUSM can better anticipate patient admissions, ultimately leading to improved resource management and patient outcomes. Therefore, future research should focus on validating these forecasting models within the specific context of psychiatric care, exploring the integration of additional variables that may influence patient flow, and assessing the impact of accurate forecasting on clinical operations. (Ponziani, 2021; Fauzi et al., 2020).

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