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# A NOVEL HYBRID HOLT INTEGRATED MOVING AVERAGE (HIMA) FOR CONSUMER PRICE INDEX PREDICTION

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**Abstract:**

Holt's method, although successful, has limitations like its limited use for linear trends, seasonal fluctuations, and tendency to overestimate. The Damped Trend Method (DTM) was introduced to address these shortcomings, but still struggles with optimal forecast accuracy. Hence, this study proposes a new hybrid model by integrating the classical Holt's method and the Moving Average Box-Jenkins Methodology known as Holt Integrated Moving Average (HIMA). To evaluate the performance of the new hybrid model, Malaysia Consumer Price Index data from the year 1960 to 2022 was used. The dataset is partitioned using Repeated Time-Series Cross-Validation (RTS-CV). This study has also shown that the HIMA model has improved the forecasting of classical Holt's method and the Damped Trend Method (DTM) for time-series data, which has level and trend components. The results of this study show that HIMA has produced the lowest error measure value (1.5703, 1.1811, and 1.0013 for RMSE, MAE, and MAPE, respectively) and a high percentage of forecast accuracy (99 per cent) compared to other comparative models for CPI forecasting.

**Keywords:**

Holt's Method; DTM; HIMA; Accuracy; RTS-CV

## Introduction

Holt's method, also known as Holt's linear trend method, is an advanced exponential smoothing technique developed by Charles C. Holt in 1957 for forecasting time series data with trends.

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Holt's method uses two smoothing parameters, α for the Level and β for the Trend, based on observed data in non-seasonal data. This method can capture a trend that is increasing or decreasing at a constant rate to forecast future data precisely. Further, as mentioned, Holt's method is simple to implement and understand, thus contributing to its popularity as a forecasting tool. Holt's method has numerous successful applications in economics, information and communication technology (ICT), banking, and healthcare. Studies conducted by Muchayan (2019), Ozsut Bogar and Gungor (2023), and Zaini et al. (2020) show Holt's method has demonstrated superior performance compared to other forecasting methods across various studies. It will help filter out noise to better understand the underlying trends in CPI data and enhance forecasts' accuracy in Malaysia's rapidly evolving economic conditions (Sulaiman and Zulkipli, 2018).

For instance, Holt's method effectively forecasts data conveying a linear trend, including sales, production, inventory, and workforce needs. This method can capture a trend that is increasing or decreasing at a constant rate to forecast future data precisely. Further, as mentioned, Holt's method is simple to implement, and understanding contributes to its popularity as a forecasting tool. Despite the success, Holt's method also has several drawbacks such as the method is only limited to linear trends and can only be used to forecast data that is impacted by seasonal fluctuations (Ellis, 2022; Yapar, Capar, Selamlar, and Yavuz, 2018), and tends to overestimate (over- or -under forecast), especially at longer forecast horizon (Maia and de Carvalho, 2011). Gardner and McKenzie (1985) identified the shortcomings of Holt's method and introduced the Damped Trend Method (DTM) by creating a "dampens" parameter. However, this improved method also has weaknesses preventing the forecast accuracy percentage from reaching its optimal Level.

Therefore, this study aims to introduce a new hybrid model by integrating the classical Holt's method and the Moving Average Box-Jenkins Methodology known as Holt Integrated Moving Average (HIMA). To evaluate the performance of the new hybrid model, Malaysia Consumer Price Index, data from 1960 to 2022 was used. The concept for this new proposed model was derived from a prior study by (Ahmmed Mohammed, 2019; Egrioglu E and Baş W, 2020; Liu and Wu, 2020; Mohammadreza Davoodi and Rabiei, 2022; Yapar et al., 2018) that developed a modified Holt's method. The modified or hybrid Holt's method outperforms the classical Holt's method when the data-generating process involves a trend model. This study breaks new ground by introducing a novel approach, providing fresh insights into time series forecasting, and advancing the current understanding of forecast accuracy. Holt's and Moving Average Box-Jenkins Methodology have certain drawbacks when used alone, and it is important to acknowledge them.

## Literature Review

Time series data is crucial for making decisions and understanding how a variable changes based on historical trends and patterns. It involves analyzing data points collected over time intervals to extract meaningful statistics and characteristics of cyclical variations, seasonality influence, and irregular effect (Siegel, 1997). Jebb et al. (2015) believe that time series allow researchers to use past data to predict future outcomes in forecasting. Additionally, it helps enhance the ability to make well-informed predictions and strategic decisions to anticipate future trends. Time series are utilized across various fields for economic forecasting, sales projections, budget analysis, and healthcare.

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Univariate time series models involve various methods for analyzing and forecasting a single time series variable (Iwok and Okpe, 2016). Exponential Smoothing Model (ESM), Single ESM, Double ESM, Holt's method, Holt-Winter method, and Autoregressive Integrated Moving Average (ARIMA) are commonly used in univariate modelling. Few researchers have explored different univariate models using the Consumer Price Index (CPI) dataset focusing on Malaysia and other countries, shown as in Table 1.

**Table 1: Training and Testing Set for CPI**

| Author (Year) | Data Used | Methods | Findings |
|---|---|---|---|
| Konarasinghe (2022) | CPI in Malaysia, for monthly data from January 2012 until March 2022 | Double Exponential Smoothing (DES) and Holt's Winter's three-parameter additive and multiplicative models. | DES model was the best for predicting short-term forecasts of Malaysia's CPI, indicating a rising trend. It suggests exploring various exponential smoothing methods for better accuracy and calls for further research into modelling CPI in other countries. |
| Khamis et al. (2018) | CPI in Malaysia from January 1972 to August 2016 | ARIMA (1,1,0), ARIMA (0, 1, 1), Simple Linear Regression | ARIMA (1,1,0) was the best model for short-term forecasting of the compared to ARIMA (0, 1, 1) model and Simple Linear Regression. Further research is recommended to explore other models and techniques to improve the precision in forecasting CPI. |
| Aabeyir (2019) | CPI in Ghana from March 2013 to November 2018 | Exponential Smoothing Models (ES: the simple exponential smoothing method, Holt's method, and Winters' method | As a result, Winters' additive method best fits Ghana's CPI. |
| Muhammed et al. (2019) | CPI in Nigeria for monthly data from 1995 to 2017 | Exponential smoothing methods: Holt's method, and Holt-Winters | The findings suggest a gradual increase in Nigeria's CPI over time. The non-seasonal exponential smoothing methods were adopted, and Holt's smoothing exponential method proved to be the best for accurate future forecasting CPI in Nigeria. |

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Generally, Huard et al. (2020) considered Holt's method beneficial for forecasting because it includes trend information, making it ideal for datasets that show a linear trend. It uses a structured approach that considers both the level and trend components of data, which can enhance the precision of forecasts over time. Holt's method is particularly popular for forecasting, demonstrating its practical utility and success in real-world applications. However, Holt's method has some limitations. It may not be effective with datasets that have non-linear trends or abrupt changes. The method depends on choosing specific parameters (α and β) that adjust the smoothing and trend elements for best results.

Gardner and McKenzie (2011) and Sbrana and Silvestrini (2020) discussed the advantages and disadvantages of the Damped Trend Method (DTM) in forecasting. Firstly, the flexibility of DTM enables automatically selecting from various specialized cases during fitting and effectively adjusting to different characteristics of time series data. As a result, it excels in capturing both gradual and abrupt changes in forecasts. Moreover, this adaptability often leads to creating specialized cases rather than confining itself to a single method, enhancing its versatility even further. However, despite its proven accuracy, the use of DTM in forecasting practices has been slow, which limits its widespread adoption and undermines its potential to improve forecast precision. The DTM also cannot be directly applied to model seasonal data, limiting its applicability to time series with seasonal components.

As stated by Makridakis et al. (2020), combining various forecasting models or methods helps to decrease random mistakes, leading to more precise forecasts. Nevertheless, the combined forecasts are not guaranteed to outperform the separate models. Hence, this study will be conducted to verify whether combining two forecasting methods will enhance the forecast accuracy using Malaysia Consumer Price Index data. The Consumer Price Index (CPI) in Malaysia presents statistics on the cost of household goods and services purchased in a specified time from retail outlets in Peninsular Malaysia, Sabah, and Sarawak. The base year for the CPI in Malaysia is currently set at 2010=100, chosen for economic stability and accurate reflection of spending patterns. Based on historical trends, CPI in Malaysia has gradually increased. The CPI is a vital economic gauge that monitors price fluctuations for products and services and can be used to analyze the Trends of future prices (Department of Statistics Malaysia, 2022). Forecasting the CPI for Malaysia is crucial for policymakers to devise appropriate economic policies, ensure stability, and for investors to make well-informed investment decisions based on anticipated inflation trends (Konarasinghe, 2022).

**Proposed Holt Integrated Moving Average Model (HIMA)**

This section describes Holt's method and the Moving Average model from the Box-Jenkins methodology. Then, the proposed HIMA model will be introduced.

***Holt's Method***

Holt's method enhanced the Simple Exponential Smoothing (SES) model to capture time series data with a trend component. This method employs a predictive equation in conjunction with two smoothing equations, Level, and Trend equations. Two smoothing parameters were used, $\alpha$ is the smoothing parameter for Level equation, and $\beta$ is for Trend equation. Both parameters' boundaries are between 0 and 1. Holt's method is no longer employed to produce flat forecast but instead trending. The $m$-step-ahead forecast equals the last estimated Level plus $m$ multiplied by the last estimated trend value. Thus, the forecasts are a linear function of $m$ (Hyndman and Athanasopoulos, 2018).

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Forecast equation : $F_{t+m} = S_t + T_t \times m$ (1)
Level equation : $S_t = \alpha y_t + (1-\alpha)(S_{t-1} + T_{t-1})$ (2)
Trend equation : $T_t = \beta(S_t - S_{t-1}) + (1-\beta)T_{t-1}$ (3)

***Moving Average (MA) from Box-Jenkins Methodology***

An MA model in the Box-Jenkins methodology is a past forecast error (multiplied by a coefficient) in a regression-like model.

$$y_t = \mu - \theta_1\varepsilon_{t-1} - \theta_2\varepsilon_{t-2} - \cdots - \theta_p\varepsilon_{t-q} + \varepsilon_t \quad (4)$$

where $y_t$ is the actual value and $\varepsilon_t$ is the random error, assumed to be identically, independently distributed, with a mean equal to zero and the same variance.

***Proposed Forecasting Model***

The original idea behind the formulation of this proposed forecasting model is the shortcomings of the univariate time-series model. As already known, univariate time-series models only use one variable to form the model. This differs from other multivariate models, such as the Linear and the Logistic Regression models, with one dependent variable, more than one independent variable, and error term (residuals). If the multivariate model being studied is not well fitted (large residuals), independent variables can be added or removed until the error term is reduced. However, this method cannot be applied to univariate time-series models. Therefore, to improve forecast accuracy, a new strategy is introduced where the residual value $e_t$ resulting from the univariate time-series model (in this case, Holt's method) will be used as input variable to the MA model. MA model will be estimated, and the forecast value will be produced. Next, the forecast values from Holt's method and MA model will be combined to produce new forecast values (Refer to Figure 1).

Holt's residual equation : $e_t = y_t - \hat{F}_t$ (5)
HIMA model equation : ${F^*}_{t+m} = (S_t + T_t \times m) \pm (\mu - \sum_{i=1}^{q} \theta_i\varepsilon_{t-i} + \varepsilon_t)$ (6)

There are 3 reasons why the Moving Average (MA) model from the Box-Jenkins methodology is used in the formation of this proposed model. The reasons are: (1) Error correction: MA works to correct any errors produced by the Autoregressive (A.R.) model in producing forecast values. For the model proposed in this study, the MA model will correct any errors produced by Holt's method, (2) Improving Prediction Accuracy: By taking past error terms into account, Holt's method can readjust its predictions accordingly. This will improve the accuracy of the forecast value, especially for time series data that is uncertain or unpredictable, (3) Reducing Residuals: Including past error terms in the model can help in reducing residuals or differences between predicted and actual values. This leads to more efficient and effective models for predicting future values. Figure 1. shows the theoretical framework for the proposed model.

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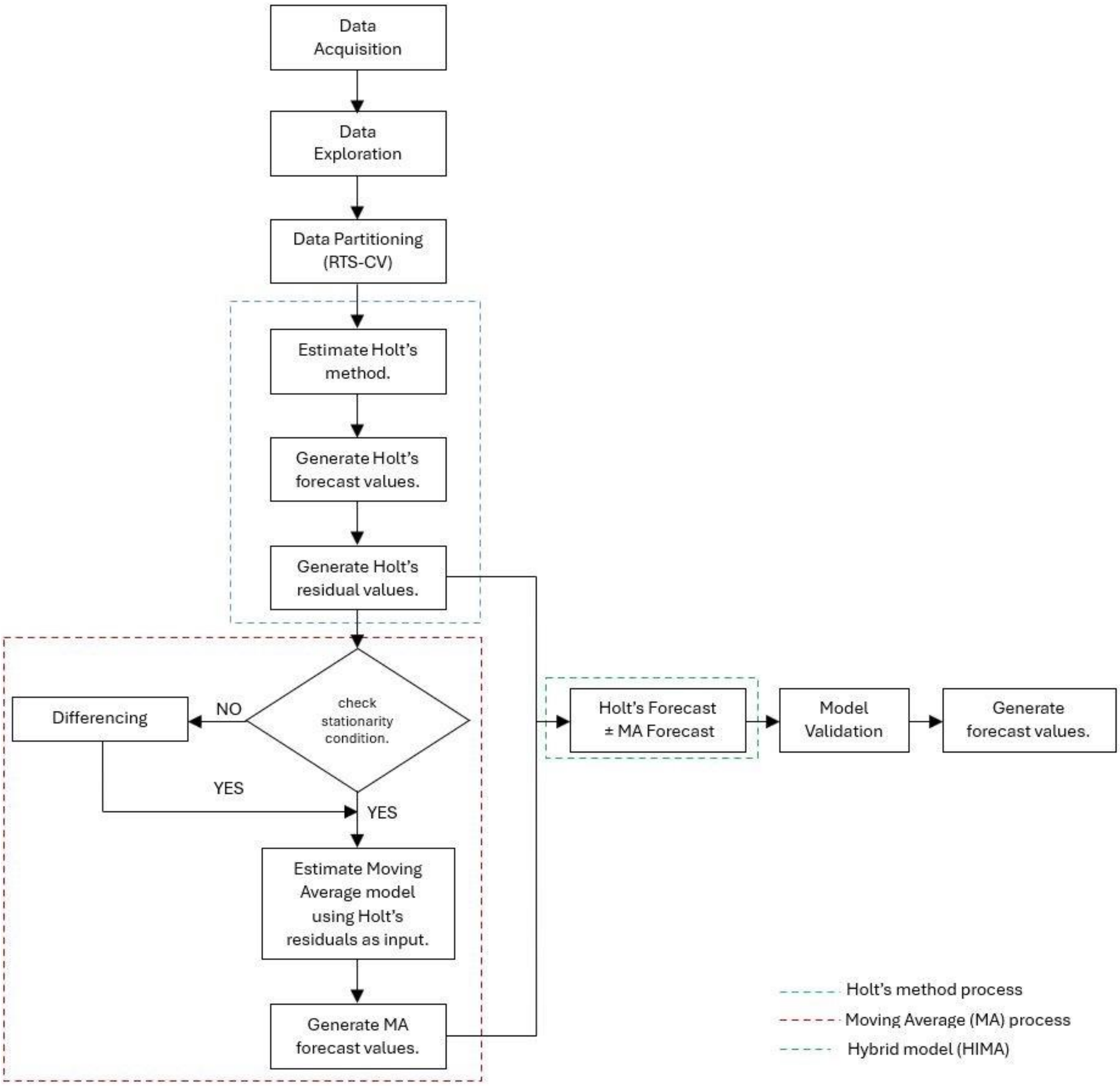


**Figure 1: Theoretical framework of Holt Integrated Moving Average (HIMA)**

**Data Acquisition**

Data consumer price index (CPI) Malaysia was used to evaluate the performance of the classical Holt's method against the proposed hybrid model, Holt Integrated Moving Average (HIMA). The time-series data is obtained from the Department of Statistics Malaysia (DOSM) from 1960 to 2022 on a yearly basis. The data is free from outliers and missing values.

**Data Exploration**

Original time-series plot and decomposition method were applied to determine the presence of time-series components (Trend, seasonal, cyclical, and irregular), investigate the relationship between components, and segregate the components for further analysis.

**Data Partitioning (Training and Testing Set)**

Repeated Time-Series Cross Validation (RTS-CV) was used as a data splitting strategy to ensure data has been trained using several partitioning data sets so that all probabilities were

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considered to determine the best model. For example, for the HIMA model, five models were formed for each set of data partitioning (see Figure 2). Out of the five HIMA models constructed, only one model was selected based on the lowest value of error measures, namely Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE), and Root Mean Squared Error (RMSE). Other than Holt's method, the Damped Trend Method (DTM) and the Autoregressive Integrated Moving Average (ARIMA) models were also used to evaluate the proposed model performance.

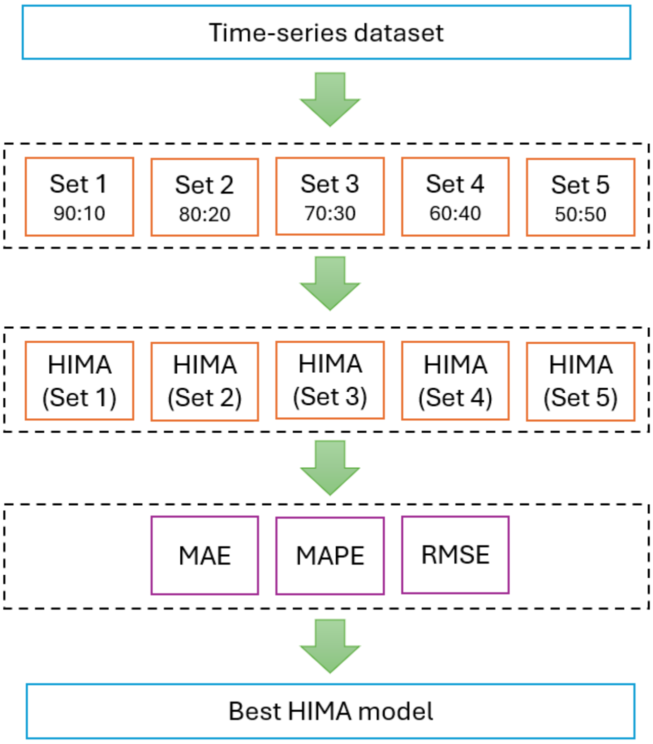


**Figure 2: Data splitting strategies using Repeated Time-Series Cross Validation (Azlan A.A, 2024)**

## Model Evaluation

Error measures were used to differentiate between a poor and a good forecast model. A model that has the smallest error is said to be the best model. Three error measures were used as evaluation criteria:

| | | | | |
|---|---|---|---|---|
| (1) | Root Mean Square Error (RMSE) | : | $\sqrt{\frac{\sum e^2}{n}}$ | (7) |
| (2) | Mean Absolute Error (MAE) | : | $\sum \frac{\lvert e \rvert}{n}$ | (8) |
| (3) | Mean Absolute Percentage Error (MAPE) | : | $\sum \frac{\left(\frac{e_t}{y_t}\right) * 100}{n}$ | (9) |

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(4) Percentage of forecast accuracy : $$\left(1-\left(\frac{|e_t|}{y_t}\right)\right)*100 \quad (10)$$

## Results and Discussion

### *Data Exploration*

Figure 3. shows the original time-series plot for CPI Malaysia from 1960 to 2022. The plot shows the presence of none other than trend component.

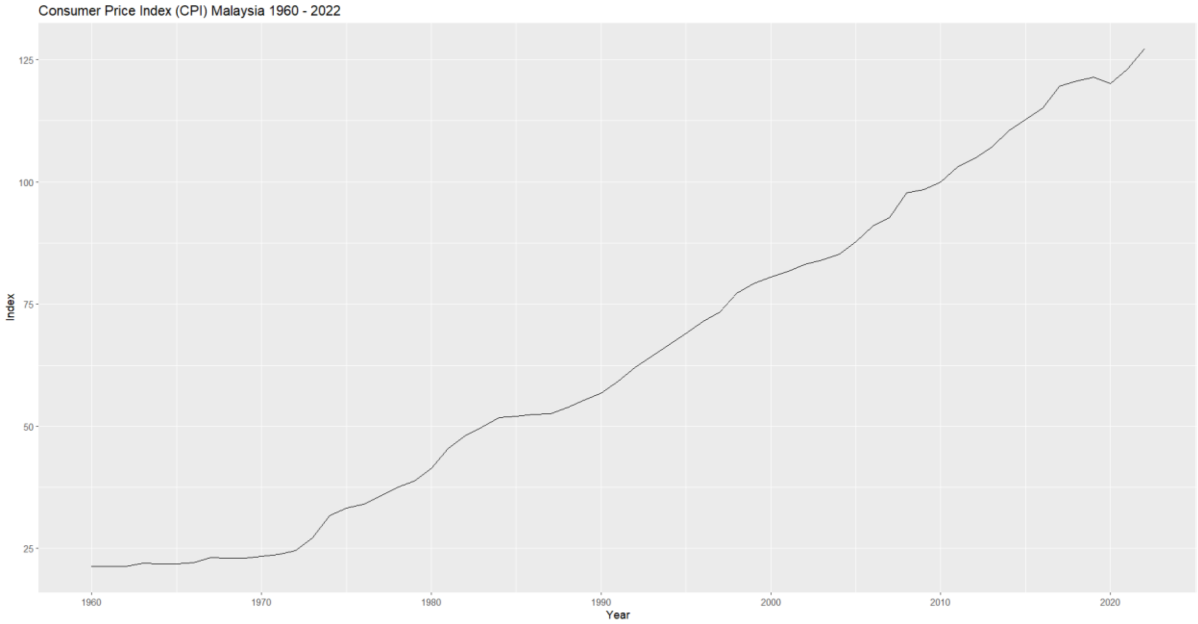


**Figure 3: Original Time-Series Plot**

### *Data Partitioning (Training and Testing Set)*

Table 2. shows the allocation of data for time series forecasting of the CPI, dividing the data into five sets of training and testing data.

**Table 2: Training and Testing Set for CPI**

| Set | | Percentage (%) | Duration | Sample Size |
|---|---|---|---|---|
| Set 1 | Training | 90 | 1960 – 2016 | 57 |
| | Testing | 10 | 2017 – 2022 | 6 |
| Set 2 | Training | 80 | 1960 – 2009 | 50 |
| | Testing | 20 | 2010 – 2022 | 13 |
| Set 3 | Training | 70 | 1960 – 2003 | 44 |
| | Testing | 30 | 2004 – 2022 | 19 |
| Set 4 | Training | 60 | 1960 – 1997 | 38 |
| | Testing | 40 | 1998 – 2022 | 25 |
| Set 5 | Training | 50 | 1960 – 1991 | 32 |
| | Testing | 50 | 1992 – 2022 | 31 |

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***Model Performance***

This section shows the performance of Holt's method and the HIMA model. The HIMA model has two sub-models: HIMA [Holt + MA] and HIMA [Holt - MA]. The three models recorded the lowest error measures and the highest percentage of forecast accuracy in Set 2 with 80 per cent training and 20 per cent testing (as shown in Table 3). The model with the best set has been collected and compared in Table 4. The Damped Trend Method and ARIMA model were also used and compared to find the best model.

**Table 3: Error Measures And Percentage Of Forecast Accuracy For Each Model**

| Model | Set | Training : Testing | MA(*q*) | RMSE (Testing) | MAE (Testing) | MAPE (Testing) | Percentage Forecast Accuracy (Testing) |
|---|---|---|---|---|---|---|---|
| Holt's Method | 1 | 90:10 | - | 2.9574 | 2.3312 | 1.9081 | 98.09 |
| | 2 | 80:20* | - | 1.5892* | 1.2180* | 1.0363* | 98.96* |
| | 3 | 70:30 | - | 14.1531 | 12.4240 | 10.9705 | 89.03 |
| | 4 | 60:40 | - | 2.5967 | 2.0968 | 1.9848 | 98.02 |
| | 5 | 50:50 | - | 14.5461 | 12.8481 | 12.7641 | 87.24 |
| HIMA [Holt + MA] | 1 | 90:10 | MA (2) | 3.0434 | 2.3669 | 1.9360 | 98.06 |
| | 2 | 80:20* | MA (2) | 1.5703* | 1.1811* | 1.0013* | 99.00* |
| | 3 | 70:30 | MA (3) | 14.0779 | 12.3037 | 10.8497 | 89.15 |
| | 4 | 60:40 | MA (5) | 2.5375 | 2.0392 | 1.9284 | 98.07 |
| | 5 | 50:50 | MA (3) | 17.872 | 17.1557 | 15.6519 | 86.74 |
| HIMA [Holt - MA] | 1 | 90:10 | MA (2) | 2.8771 | 2.2955 | 1.8801 | 98.12 |
| | 2 | 80:20* | MA (2) | 1.6204* | 1.2549* | 1.0713* | 98.93* |
| | 3 | 70:30 | MA (3) | 14.2324 | 12.5805 | 11.1338 | 88.87 |
| | 4 | 60:40 | MA (5) | 2.6590 | 2.1544 | 2.0412 | 97.96 |
| | 5 | 50:50 | MA (3) | 18.1041 | 17.4687 | 15.9785 | 87.73 |

* the smallest value (RMSE, MAE, MAPE) and the highest value (Percentage of Forecast Accuracy)

Table 3. and Figure 4. show that HIMA [Holt + MA] outperformed the other models with the lowest error measures of 1.5703, 1.1811, and 1.0013 for RMSE, MAE, and MAPE, respectively. The percentage forecast accuracy is 99 per cent. Therefore, the proposed hybrid model, Holt Integrated Moving Average (HIMA), shows an excellent improvement in predicting time series with trend and level components compared to the classical Holt's method and other univariate models.

**Table 4: Model Comparison For Each Model With Best Set Of Data Partitioning**

| Model | Set | Training: Testing | RMSE (Testing) | MAE (Testing) | MAPE (Testing) | Percentage Forecast Accuracy (Testing) |
|---|---|---|---|---|---|---|
| Holt's Method | 2 | 80:20 | 1.5892 | 1.2180 | 1.0363 | 98.96 |
| DTM | 1 | 90:10 | 2.4153 | 2.0377 | 1.6759 | 98.32 |
| ARIMA (0,2,2) | 4 | 60:40 | 2.232 | 1.7954 | 1.7341 | 98.27 |
| HIMA [Holt + MA] | 2 | 80:20 | 1.5703* | 1.1811* | 1.0013* | 99.00* |
| HIMA [Holt - MA] | 2 | 80:20 | 1.6204 | 1.2549 | 1.0713 | 98.93 |

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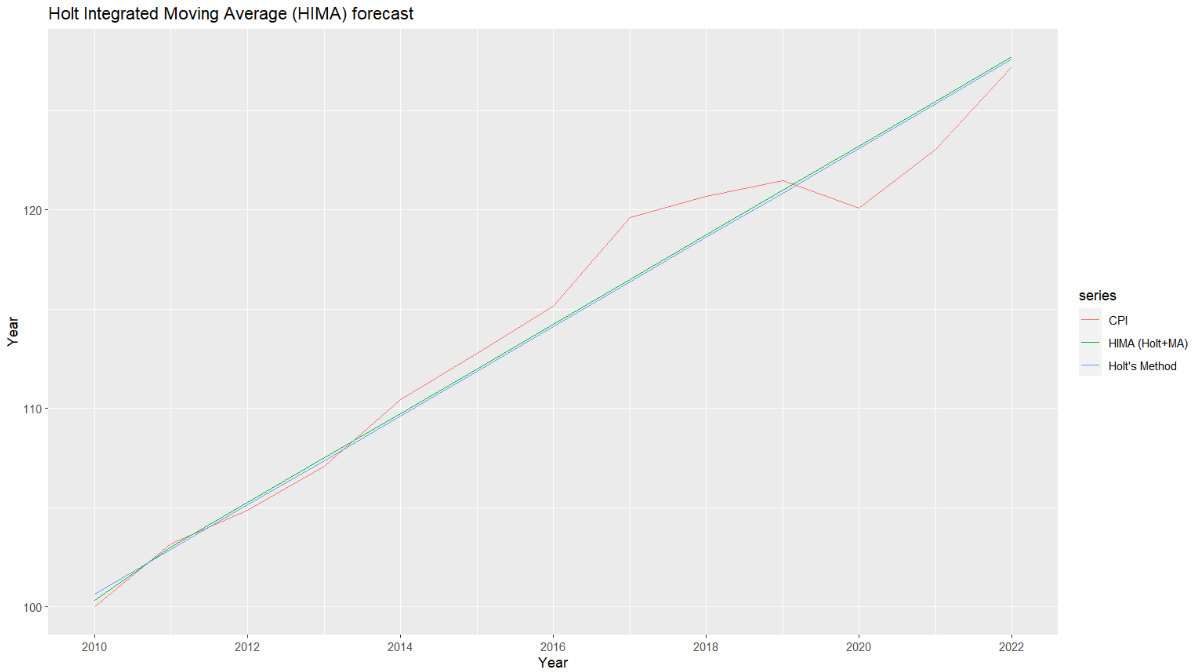


**Figure 4: Holt Integrated Moving Average (HIMA) Performance.**

## Conclusion

This study aims to propose a new hybrid model by integrating the classical Holt's method and the Moving Average Box-Jenkins Methodology known as Holt Integrated Moving Average (HIMA) and improve forecast accuracy for time-series datasets with trend and level components. This study used the Consumer Price Index (CPI) Malaysia from 1960 to 2022 to demonstrate the proposed model's effectiveness.

The results of this study have proven two discoveries in the field of forecasting or time-series analysis. This study has demonstrated that using one set of data partitioning cannot produce the best model and accurate forecast values. This study has adopted the Repeated Time-Series Cross-Validation (RTS-CV) strategy introduced by Azlan A. A (2024). RTS-CV recommends using more than one partitioning data to ensure all possible sets of data partitioning are considered to determine the best model (Abdul Aziz et al., 2018). This study has also proven that a new hybrid model, the Holt Integrated Moving Average (HIMA), has improved the forecasting of classical Holt's method and the Damped Trend Method for time-series data, which has level and trend components. The results of this study show that HIMA has produced the lowest error measure value and a high percentage of forecast accuracy (99 per cent) compared to other comparative models for CPI forecasting.

Other findings from the study found that the consumer price index (CPI) in Malaysia shows an increase every year. The increase in the CPI gives a picture of the challenges and the impact of the cost of living that the people of a country face. Apart from the government's efforts to ease the burden on people's lives through various incentives, the people themselves need to find alternatives to increase income or reduce the cost of household expenses. Among the strategies is growing plants such as mustard, eggplant, chilli, and others by households. Surplus crops can also be sold to the local community, increasing household income. Future studies on the HIMA model are recommended to extend the model to different economic contexts or other

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fields such as agriculture, manufacturing, and services, and compare it with advanced forecasting models.

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