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Human Development Index Forecasting with Moving Average, Simple Exponential Smoothing and Naïve Method

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ABSTRACT

The purpose of this research is to forecast the Human Development Index (HDI) using the moving average (MA) method, the simple exponential smoothing method and the naïve method. The region forecasted for its HDI is North Lombok Regency, for which it has the lowest HDI in West Nusa Tenggara, Indonesia. The data used for this research is the HDI from 2010 to 2022. The selection of these methods is due to the limited amount of data and the popularity of MA, SES, and Naïve method in the world of forecasting until this day. The results of this research is the MA method which consists of MA MA3, SMA MA5, WMA MA3, WMA MA5, EMA MA3, EMA MA5, and SES tested value α=0.1 and α=0.9 and Naïve method have a high degree of accuracy that can be seen in the Mean Absolute Percentage Error (MAPE) value which is below 10%. However, the chosen method is the best method with the smallest MAPE which is Naïve method with MAPE 1.32% where MAPE is below 10% indicating that the model used is Highly accurate and the result of North Lombok Regency HDI in 2023 is 65.7 which means that the HDI in North Lombok Regency has not changed. HDI in North Lombok Regency stay on middle level.

Keywords: Forecasting; IPM; Human Development Index; Moving Average; Simple Exponential Smoothing; Naïve Method; MAPE; Best Model

INTRODUCTION

Human is the real nation's resources[1]. Economic development viewed from the side of trade, investment, and technology sees humans as a tool to achieve growth, not as the purpose of development[2]. Human development have seen all the issues in society simultaneously: the balance between economic growth, environment quality and social welfare[3] also cover the other important issue, which is gender[4]. Therefore, human development pays attention to the social sector, and is a comprehensive approach from all sectors[2]. *United Nations for Development Programme (UNDP) introduced the measurement of human development in 1990*[5]. UNDP introduced a new idea for measuring human development, the Human Development Index (HDI). Since then, HDI has been publicized periodically in the annual Human Development Report (HDR). HDI explained how the public can access development results in obtaining income, health, education, etc. According to UNDP, Human Development Index (HDI) measures human

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development achievement based on some basic life quality components. As the measurement of life quality, HDI is built through a basic 3-dimensional approach. These dimensions include: 1. a long and healthy life; 2. knowledge; and 3. a decent standard of living[2][6][7].

The measurement of HDI is also performed in Indonesia, both at the country, provincial, and regency/city levels. West Nusa Tenggara's (NTB) HDI level is on the 29th out of 34 provinces in Indonesia[8]. The NTB province consist of 10 regencies/cities[9]. The lowest HDI is occupied by North Lombok Regency (KLU)[8], so it is interesting to forecast to assist the government in determining policy. Based on the HDI category set by[5], KLU's HDI is in the medium category[10]. One of the steps that can be taken to determine a policy related to HDI is to forecast the HDI value[11]. Based on [12] forecasting is a prediction about what will happen in the future using past and present data, while according to [13] forecasting is the result of prediction from future events that can be obtained from systematic process or intuition, thus it can be concluded that forecasting is a prediction of future events by processing the data of past and present time.

There are many methods of forecasting[14]. Some initial steps to determine the right forecasting method are considering the amount of data, making the data plot to see the data or performing a preliminary analysis of the data[15].There are 13 past data on North Lombok Regency's HDI data[16], so there are several methods to forecast the HDI which is moving average (MA), simple exponential smoothing (SES) and Naïve method that can be used to forecast the future data with the limited amount of the past data. Furthermore, these methods have the advantage, which is the simplicity of forecasting calculation[17][18]. For example, the Naïve method that can forecast the tomorrow data only with one data today because in the Naïve method, tomorrow forecast is the actual value today. Moving average (MA), simple exponential smoothing (SES), or Naïve method have been used on the previous researches to forecast the HDI value. The previous researches were conducted by Mandailina et al in 2018[19], Sucipto et al in 2018[20], and Irawan et al in 2019[21]. In the research conducted by [15],[16] and [17] have the *Mean absolute percentage error* (MAPE) under 10%, even below 2%, dimana metode dengan MAPE yang dibawah 10% indicating that these methods is suitable and has high accuracy to forecast the HDI.

The of this research is to forecast North Lombok Regency's HDI using the Moving Average (MA), simple exponential smoothing (SES) and Naïve methods. The smallest MAPE will select the best method from these three methods. The best method will be used to forecast the North Lombok Regency's HDI value. It is expected that the HDI forecasting value in the coming year will assist the local government of North Lombok Regency in increasing the effectiveness of Policy-making associated with health, education and decent life society to increase the value of the regional HDI.

METHODS

Data Time Series

Time series data consists of the variables collected according to time sequence in a certain period for a certain category or individual. When time is seen as discrete (time can be seen as continuous), the collecting frequency will always the same (*equidistant*). In discrete case, the frequency can be in seconds, minutes, hours, days, weeks, months, years, etc[22].

This research will try to forecast the future data of North Lombok Regency's HDI by using the time series data of North Lombok Regency's HDI from 2010 until 2022, using three methods, which is Moving Average (MA), Simple Exponential Smoothing (SES) and Naïve method. The three methods' accuracy will be compared using Mean Absolute Percentage Error (MAPE). The method with the smallest MAPE will be chosen as the best, which will be used later to forecast the North Lombok Regency's HDI in 2023.

Moving Average (MA) Method

Moving Average method is the forecasting method which is done by taking a group of observation values to find the average value as the predition for the next period. This method is called the moving average because every time new data is available, a new average is calculated and used as the forecast value[23][24]. The advantage of this method is that it is very easy to understand and use in forecasting calculations compared to using trendline analysis, while the disadvantage is that the moving average method is slow to respond to data changes that often occur in the market[25].

There are several types of moving average methods:

- **Simple Moving Average (SMA)**
  Simple Moving Average (SMA) is the simplest Moving Average and does not use weighting in forecasting calculations. Even though it is simple, SMA is effective enough to determine the trend that happened in the market. Even the data is convenient to read. Simple Moving Average (SMA) is calculated by collecting the average values from the HDI over a certain period of time[23].

$$SMA(F_t) = \frac{1}{n}\sum_{i=t-n}^{t-1} X_i \quad (1)$$

  [26][27].
  Description:
  X_t = actual data from a certain period (t)
  n = amount of data

- **Weighted Moving Average (WMA)**
  Weighted Moving Average (WMA) is an enhanced form of Simple Moving Average (SMA) which is giving more wight (W_i)to newer data than the older data. Means that the most recent data is more influential than older data in determining forecasting values. The weight factor is calculated from the number of days used in the time series data, also known as the number of digits[23][28].

$$WMA(F_t) = \frac{\sum_{i=t-n}^{t-1}(X_i \times W_i)}{\sum_{i=t-n}^{t-1}(W_i)} \quad (2)$$

  [23][28].
  Description:
  X_i = actual data from a certain period (i)
  W_i = weight of every X_i

- **Exponential Moving Average (EMA)**

The newest data in EMA get the highest weight and every data values get less weight when we go back chronologically. It means that the most recent data is more influential than older data in determining forecasting values, but unlike WMA, in EMA, the weight for each old data point decreases exponentially, so it never reaches zero[23].

$$EMA(F_t) = \left(\beta \times (X_{t-1} - F_{t-1})\right) + F_{t-1} \quad (3)$$

[23][29].
Description:
$\beta = \frac{2}{t+1}$
t = period of EMA
X_{t-1} = actual data from period $t-1$
F_{t-1} = previous EMA value

Simple Exponential Smoothing (SES)

Unlike the moving average, simple exponential smoothing put more pressure on the current time series through the use of a smoothing constant. Smoothing constant is possibly larger from 0 but smallest than 1. The value that closer to 1 put most pressure to the current value, while the value that closer to 0 put more pressure to the previous data point [23][30].

$$SES\ (F_t) = a \times X_{t-1} + (1-a) \times F_{t-1} \quad (4)$$

[30][31][32].
Description:
a = smoothing constant
SES = the forecasting value on period t
F_{t-1} = the SES value on period t-1

Naïve Method

Naïve method is a simple forecasting method. whereas this method is often used as a comparison, because of the convenience in obtaining forecasting results.

$$F_t = X_{t-1} \quad (5)$$

[23][33][34].
Description:
Naïve Method = Forecasting value on period t

Accuracy Measurement of the Forecasting Method

Data is often divided into two parts in time series analysis; data in sample and data out sample. The best model is the model with the minimum error. It is certainly expected to be the best model to fitting data in sample and also the good model to forecast data out[35].
According to[36], the accuracy measurement of the model can use the calculation of *Mean Absolute Percentage Error* (*MAPE*) with the following equation[37]:

$$MAPE = \frac{1}{n}\sum_{i=1}^{n}\left|\frac{X_i - F_i}{X_i}\right| \times 100\% \quad (6)$$

Table 1. Accuracy Measurement of the Model Scale

MAPE Value	Valuation of Measurement Scale
$< 10\%$	Highly accurate
$11\% - 20\%$	Good forecasting
$21\% - 50\%$	Reasonable forecasting
$> 51\%$	Not accurate

[38].

The Forecasting Algorithm

The algorithm used in this forecasting is as follows:

1. Collecting and tabulating data
2. Forecasting the HDI data with:
   i. Simple Moving Average (SMA) (use equation number 1)
   ii. Weighted Moving Average (WMA) (use equation number 2)
   iii. Exponential Moving Average (EMA) (use equation number 3)
   iv. Simple Exponential Smoothing (SES) (use equation number 4)
   v. Naïve Method (use equation number 6)
3. Choosing the best method based on the smallest MAPE value (use equation number 1)
4. Forecasting the HDI value of North Lombok Regency in 2023 using the best method.

RESULTS AND DISCUSSION

Data Tabulation and Descriptive Statistics

The discussion will being with tabulating data and making descriptive statistics as follows:

Table 2. North Lombok Regency's HDI Data in 2010-2022

Year	2010	2011	2012	2013	2014	2015	2016
HDI	56.13	57.13	58.19	59.2	60.17	61.15	62.24
Year	2017	2018	2019	2020	2021	2022	
HDI	63.04	63.83	64.49	64.42	64.77	65.7	

Table 3. Descriptive Statistics of North Lombok Regency's HDI in 2010-2022

Mean	61.57
Standard Error	0.88
Median	62.24
Standard Deviation	3.16
Sample Variance	10.01
Kurtosis	-1.18
Skewness	-0.43
Range	9.57
Minimum	56.13

Maximum	65.70
Sum	800.46
Count	13.00

The information obtained from the table 2 is North Lombok Regency's average HDI value is 61.57, where the data spread by 3.61 from the average. The lowest HDI in North Lombok Regency is 56.13 and the highest is 65.70, with the kurtosis value -1.18, so it can be said to be a platykurtic curve, which is a destribution that has an almost flat peak (kurtosis value < 3). On a platykurtic curve, the peaks of the curve are below the normal distribution, so that it can be said that the frequency of the modus values are close to the minimum or maximum frequency values.

Skewness also showed negative value -0.43 or the values is concentrated to the right side (located on the right side of Mo), so that the curve has a tail that extend to the left, its mean the average value is smaller than the mode value.

Moving Average (MA) Method

- **Simple Moving Average (SMA)**
  The method used in this research is SMA MA3 and SMA MA5.
  SMA MA3 forecasted the HDI today by calculating the average value of 3 time series of the past HDI:

$$SMA\ MA3(F_t) = \frac{X_{t-1} + X_{t-2} + X_{t-3}}{3}$$

  while SMA MA5 is the SMA method that forecasted the HDI values today by calculating the average values from 5 HDI's data in the past:

$$SMA\ MA5(F_t) = \frac{X_{t-1} + X_{t-2} + X_{t-3} + X_{t-4} + X_{t-5}}{5}$$

  For example if we want to forecast value at 2015 using SMA MA3 we have to calculating the average actual data from 2012 to 2014. But if we use SMA MA5 we have to calculating the average actual data from 2010 to 2014.
  The results of forecasting and MAPE SMA MA3 and SMA MA5 is as follows:

Table 4. Forecasting and MAPE results from SMA MA3 and SMA MA5 Method

Year	HDI (X_t)	F_t		$\left\|\frac{X_t - F_t}{X_t}\right\|$	
		SMA MA3	SMA MA5	SMA MA3	SMA MA5
2010	56.13				
2011	57.13				
2012	58.19				
2013	59.20	57.15000000		0.034628378	
2014	60.17	58.17333333		0.033183757	
2015	61.15	59.18666667	58.164	0.032106841	0.048830744
2016	62.24	60.17333333	59.168	0.033204799	0.049357326
2017	63.04	61.18666667	60.190	0.029399323	0.045209391
2018	63.83	62.14333333	61.160	0.026424356	0.041829861
2019	64.49	63.03666667	62.086	0.022535794	0.037277097
2020	64.42	63.78666667	62.950	0.009831315	0.022819
2021	64.77	64.24666667	63.604	0.008079872	0.018002161
2022	65,70	64.56000000	64.110	0.017351598	0.024200913
MAPE SMA MA3				0.024674603	
MAPE SMA MA5					0.035940812

- **Weighted Moving Average (WMA)**
  The WMA method that being used is WMA MA3 dan WMA MA5, using the equation (2). The difference of WMA MA3 and WMA MA5 is the amount of data used on forecasting. WMA MA3 used 3 past data, while WMA MA5 used 5 past data. This is the forecasting calculation (F_t) of HDI 2015 using WMA MA3 (and WMA MA5:
  HDI forecasting in 2015 using WMA MA3:
  (use a multiplier with a decreasing numerator of 3/6, 2/6 and 1/6. The value 6 in the denominator is obtained from the addition of 3+2+1)

$$F_{2015} = \frac{3}{6}X_{2014} + \frac{2}{6}X_{2013} + \frac{1}{6}X_{2012}$$

$$\Leftrightarrow F_{2015} = \frac{3}{6} \times 60.17 + \frac{2}{6} \times 59.2 + \frac{1}{6} \times 58.19$$

$$\Leftrightarrow F_{2015} = 59.18666667$$

  HDI forecasting in 2015 using WMA MA5:
  (use a multiplier with a decreasing numerator of 5/15, 4/15, 3/15, 2/15 and 1/15. The value 15 in the denominator is obtained from the addition of 5+4+3+2+1)

$$F_{2015} = \frac{5}{15}X_{2014} + \frac{4}{15}X_{2013} + \frac{3}{15}X_{2012} + \frac{2}{15}X_{2011} + \frac{1}{15}X_{2010}$$

$$\Leftrightarrow F_{2015} = \frac{5}{15} \times 60.17 + \frac{4}{15} \times 59.2 + \frac{3}{15} \times 58.19 + \frac{2}{15} \times 57.13 + \frac{1}{15} \times 56.13$$

$$\Leftrightarrow F_{2015} = 58.84066667$$

  The complete results of forecasting and MAPE from WMA MA3 and WMA MA5 are listed on this table:

Table 5. Forecasting and MAPE results from WMA MA3 dan WMA MA5

Year	HDI (X_t)	F_t		$\left\|\frac{X_t - F_t}{X_t}\right\|$	
		WMA MA3	WMA MA5	WMA MA3	WMA MA5
2010	56.13				
2011	57.13				
2012	58.19				
2013	59.2	57.49333333		0.028828829	
2014	60.17	58.51833333		0.027450003	
2015	61.15	59.51666667	58.84066667	0.026710275	0.037765059
2016	62.24	60.49833333	59.836	0.027983076	0.038624679
2017	63.04	61.53166667	60.86	0.023926607	0.034581218
2018	63.83	62.45833333	61.81	0.021489373	0.031646561
2019	64.49	63.30166667	62.7	0.018426629	0.027756241
2020	64.42	64.02833333	63.50133333	0.006079892	0.014260582
2021	64.77	64.345	63.99133333	0.00656168	0.012022027
2022	65.70	64.60666667	64.38	0.016641299	0.020091324
MAPE WMA MA3				0.020409766	
MAPE WMA MA5					0.027093461

- **Exponential Moving Average (EMA)**
  The MA method that used on this research are EMA MA3 and EMA MA5. The first calculation of F_t is using the equation (1) and followed by using the equation (3) to determine F_t on EMA method, both on MA MA3 and MA MA5.

  ✓ EMA MA3

  HDI forecasting in 2013 on the Ft EMA MA3 column using MA MA3:

$$F_{2013} = \frac{X_{2010} + X_{2011} + X_{2012}}{3} = 57.15$$

  HDI forecasting in 2014 using EMA MA3:

$$F_{2014} = \left(\frac{2}{3+1}\right)(X_{2013} - F_{2013}) + F_{2013} = 58.175$$

  ✓ EMA MA5

  HDI forecasting in 2015 on the Ft EMA MA5 column using MA MA3:

$$F_{2015} = \frac{X_{2010} + X_{2011} + X_{2012} + X_{2013} + X_{2014}}{5} = 58.164$$

  HDI forecasting in 2016 using EMA MA5:

$$F_{2016} = \left(\frac{2}{5+1}\right)(X_{2015} - F_{2015}) + F_{2015} = 58.9105$$

Table 6. Forecasting and MAPE results from EMA MA3 and EMA MA5 Method

Year	HDI (X_t)	F_t		$\left\|\frac{X_t - F_t}{X_t}\right\|$	
		EMA MA3	EMA MA5	EMA MA3	EMA MA5
2010	56.13				
2011	57.13				
2012	58.19				
2013	59.2	57.15		0.034628378	
2014	60.17	58.175		0.033156058	
2015	61.15	59.1725	58.164	0.032338512	0.048830744
2016	62.24	60.16125	58.9105	0.03339894	0.053494537
2017	63.04	61.200625	59.742875	0.029177903	0.05230211
2018	63.83	62.1203125	60.56715625	0.026785015	0.051117715
2019	64.49	62.97515625	61.38286719	0.023489591	0.048180072
2020	64.42	63.73257813	62.15965039	0.010670939	0.0350877
2021	64.77	64.07628906	62.72473779	0.010710374	0.031577308
2022	65.70	64.42314453	63.23605334	0.019434634	0.037502993
MAPE EMA MA3				0.025379034	
MAPE EMA MA5					0.044761647

Metode Simple Exponential Smoothing (SES)

This method used two α value, which are $\alpha = 0.1$ and $\alpha = 0.9$. On SES method with $\alpha = 0.1$ (closer to 0) means the forecast put emphasis on the past data point. On the contrary, SES method with $\alpha = 0.9$ (closer to 1) means the forecast put emphasis on the newest data point. The calculation of this method used the equation (4).

HDI forecasting in 2012 using SES $\alpha = 0.1$:

$$F_{2012} = a \times X_{2011} + (1 - a) \times F_{2011}$$

$$\Rightarrow F_{2012} = 0.1 \times 57.13 + 0.9 \times 56.13$$

$$\Rightarrow F_{2012} = 56.23$$

HDI forecasting in 2012 using SES $\alpha = 0.9$:

$$F_{2012} = a \times X_{2011} + (1 - a) \times F_{2011}$$

$$\Rightarrow F_{2012} = 0.9 \times 57.13 + 0.1 \times 56.13$$

$$\Rightarrow F_{2012} = 57.03$$

(in the example above the SES method with different alpha values will give different forecasting results)

The results of forecasting and MAPE from SES method:

Table 7. Forecasting and MAPE results from SES $\alpha = 0.1$ dan SES $\alpha = 0.9$

Year	HDI (X_t)	F_t		$\left\|\frac{X_t - F_t}{X_t}\right\|$	
		SES $\alpha = 0.1$	SES $\alpha = 0.9$	SES $\alpha = 0.1$	SES $\alpha = 0.9$
2010	56.13				
2011	57.13	56.13	56.13	0.017503938	0.017503938
2012	58.19	56.23	57.03	0.033682763	0.019934697
2013	59.2	56.426	58.074	0.046858108	0.01902027
2014	60.17	56.7034	59.0874	0.057613429	0.017992355
2015	61.15	57.05006	60.06174	0.067047261	0.017796566
2016	62.24	57.460054	61.041174	0.076798618	0.019261343
2017	63.04	57.9380486	62.1201174	0.08093197	0.014592046
2018	63.83	58.44824374	62.94801174	0.0843139	0.01381777
2019	64.49	58.98641937	63.74180117	0.085340063	0.011601781
2020	64.42	59.53677743	64.41518012	0.075802896	7.48197E-05
2021	64.77	60.02509969	64.41951801	0.073257686	0.005411178
2022	65.70	60.49958972	64.7349518	0.079153886	0.014688709
MAPE SES $\alpha = 0.1$				0.014307956	
MAPE SES $\alpha = 0.9$					0.06485871

Naïve Method

The calculation of Naïve method forecasting results using the equation (5), which is the today forecasting results is the actual value of yesterday. The following is the results of forecasting and MAPE from North Lombok Regency's HDI using Naïve method.

Table 8. Forecasting and MAPE results from Naïve Method

Year	HDI(X_t)	Forecasting (F_t)	$\left\|\frac{X_t - F_t}{X_t}\right\|$
2010	56.13		
2011	57.13	56.13	0.017503938
2012	58.19	57.13	0.018216188
2013	59.2	58.19	0.017060811
2014	60.17	59.2	0.016120991
2015	61.15	60.17	0.016026165
2016	62.24	61.15	0.017512853

Year	HDI(X_t)	Forecasting (F_t)	$\left\lvert\frac{X_t - F_t}{X_t}\right\rvert$
2017	63.04	62.24	0.012690355
2018	63.83	63.04	0.012376625
2019	64.49	63.83	0.010234145
2020	64.42	64.49	0.001086619
2021	64.77	64.42	0.005403736
2022	65.70	64.77	0.014155251
	MAPE		0.013198973

Choosing the Best Method

The following is the list of method with the MAPE value, sorted from the method with the smallest to the highest MAPE.

Table 9. MAPE list from MA, SES and Naïve Method

No	Model	MAPE	MAPE (%)
1	Naïve Method	0.0132	1.32
2	SES α=0.9	0.0143	1.43
3	WMA MA3	0.0204	2.04
4	SMA MA3	0.0247	2.47
5	EMA MA3	0.0254	2.54
6	WMA MA5	0.0271	2.71
7	SMA MA5	0.0359	3.59
8	EMA MA5	0.0448	4.48
9	SES α=0.1	0.0649	6.49

On the table 9, it can be seen that all of the methods has MAPE below 10%. This means that based on the category from table 1, the accuracy measurement scale on all of the nine method can be classified as highly accurate because of having MAPE below 10%. However, the Naïve method has been chosen as the best out of the nine methods because this method obtained the smallest MAPE. Thus, Naïve is used to forecast the HDI of North Lombok Regency in 2023.

North Lombok Regency's HDI Forecasting in 2023

Forecasting value F_t of North Lombok Regency's HDI based on Naïve equation method is:

$$F_t = X_{t-1}$$

$$\Rightarrow F_{2023} = X_{2022} = 65.7$$

Time Series Plot of Actual HDI Data vs Data According to the Naïve Method

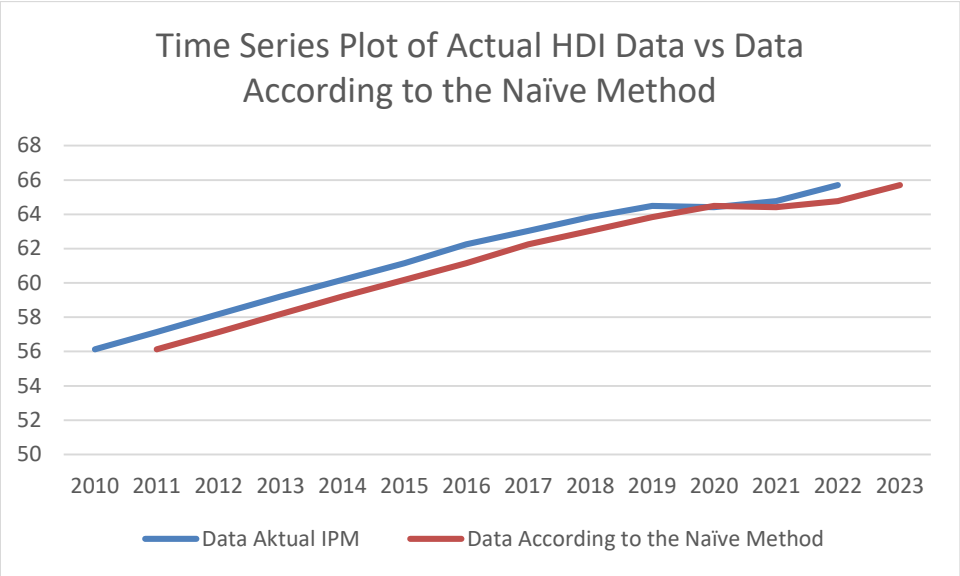

Figure 2. Time Series Plot of North Lombok Regency's HDI in 2010-2022, Data According to HDI in 2010-1022, and forecasting result in 2023 using Naïve method

CONCLUSIONS

The best method to forecast HDI in North Lombok Regency is the method with the smallest MAPE, which is Naïve method with 1.32% as the amount of MAPE. This method is in the model category with high accuracy because it has a MAPE below 10%. The results of HDI in North Lombok Regency in 2023 using Naïve method generate a forecast of 65.7 which means that the HDI in North Lombok Regency has not changed. HDI in North Lombok Regency stay on middle level. It is necessary to adopt a policy that can increase the level of HDI in North Lombok Regency.

REFERENCES

[1] B. S. Alkire, O. Poverty, H. D. Initiative, and S. Lecturer, "The real wealth of nations," *Econ. (United Kingdom)*, vol. 403, no. 8791, pp. 30–31, 2012, doi: 10.2469/dig.v42.n4.11.

[2] Badan Pusat Statistik Kabupaten Humbang Hasundutan, *Indeks pembangunan manusia*. Doloksanggul: BPS Kabupaten Humbang Hasundutan, 2020.

[3] T. Hák, S. Janouˇsková, and B. Moldan, "Sustainable Development Goals : A need for relevant indicators," *Ecol. Indic. j*, vol. 60, pp. 565–573, 2016, doi: https://doi.org/10.1016/j.ecolind.2015.08.003.

[4] L. Carlsen, "Gender inequality and development," *Sustain. Sci.*, vol. 15, no. 3, pp. 759–780, 2020, doi: 10.1007/s11625-019-00767-9.

[5] UNDP, *Human Development Report 2021/2022*. New York: United Nations Development Programme, 2022.

[6] J. Hickel, "The sustainable development index: Measuring the ecological efficiency of human development in the anthropocene," *Ecol. Econ.*, vol. 167, no. May 2019, p. 106331, 2020, doi: 10.1016/j.ecolecon.2019.05.011.

[7] N. Lind, "A Development of the Human Development Index," *Soc. Indic. Res.*, vol. 146, no. 3, pp. 409–423, 2019, doi: 10.1007/s11205-019-02133-9.

[8] BAPPENAS, "Capaian indikator utama pembangunan tahun 2022," *Kedeputian bidang pengembangan regional - kementerian PPN/Bappenas*, 2022. https://simreg.bappenas.go.id/home/pemantauan/ipm (accessed Dec. 15, 2022).
[9] Pemprov NTB, "Profil daerah," *Diskominfotik NTB*, 2019. https://www.ntbprov.go.id/profil-daerah (accessed Dec. 15, 2022).
[10] Badan Pusat Statistik Provinsi Nusa Tenggara Barat, "[Metode Baru] IPM Kabupaten/Kota 2020-2022," *Badan Pusat Statistik*, 2022. https://ntb.bps.go.id/indicator/26/133/1/-metode-baru-ipm-kabupaten-kota.html (accessed Dec. 15, 2022).
[11] I. O. Kirana, Z. M. Nasution, and A. Wanto, "Proyeksi indeks pembangunan manusia di Indonesia menggunakan Metode Statistical Parabolic dalam menyongsong revolusi industri 4.0," *J. Pendidik. Teknol. dan Kejuru.*, vol. 16, no. 2, p. 202, 2019, doi: 10.23887/jptk-undiksha.v16i2.18178.
[12] K. R. Moran *et al.*, "Epidemic forecasting is messier than weather forecasting: The role of human behavior and internet data streams in epidemic forecast," *J. Infect. Dis.*, vol. 214, no. Suppl 4, pp. S404–S408, 2016, doi: 10.1093/infdis/jiw375.
[13] J. B. Lewis, R. J. McGrath, and L. F. Seidel, *Essentials of applied quantitative methods for health services managers*. Sudbury: Jones and Bartlett Press, 2011.
[14] K. C. Green, A. Graefe, and J. S. Armstrong, "Forecasting Principles," 2010.
[15] R. Satyarini, "Menentukan Metode Peramalan Yang Tepat," *Bina Ekon. Maj. Ilm. Fak. Ekon. Unpar*, vol. 11, no. 1, pp. 59–70, 2007, doi: https://doi.org/10.26593/be.v11i1.670.%25p.
[16] Badan Pusat Statistik Kabupaten Lombok Utara, "Indeks Pembangunan Manusia (IPM) Kabupaten Lombok Utara, 2010-2021," *Badan Pusat Statistik*, 2022. https://lombokutarakab.bps.go.id/subject/26/indeks-pembangunan-manusia.html#subjekViewTab3 (accessed Dec. 16, 2022).
[17] G. B. Wendrian, "USULAN PERSEDIAAN OPTIMAL DENGAN METODE PERAMALAN PERMINTAAN DI CV. SUMBER PASIR UTAMA," Universitas Atma Jaya Yogyakarta, 2021.
[18] S. P. Khan, W. Wahyudin, S. M. Ayuningtyas, W. Rohmah, Z. I. Vindari, and A. G. Azzahra, "Analisa Perbandingan Nilai Akurasi Exponential Smoothing dan Linier Regresion pada Peramalan Permintaan Part Joint Brake Rod KTMY.," *J. Serambi Eng.*, vol. 8, no. 1, 2023, doi: https://doi.org/10.32672/jse.v8i1.
[19] V. Mandailina and D. Pramita, "Analisis tingkat akurasi fsm dalam peramalan IPM Indonesia menggunakan GUI matlab," *J. Pemikir. dan Penelit. Pendidik. Mat.*, vol. 1, no. 2, pp. 58–67, 2018.
[20] L. Sucipto and S. Syaharuddin, "Konstruksi forecasting system multi-model untuk pemodelan matematika pada peramalan indeks pembangunan manusia provinsi nusa tenggara barat," *Regist. J. Ilm. Teknol. Sist. Inf.*, vol. 4, no. 2, pp. 114–124, 2018, doi: 10.26594/register.v4i2.1263.
[21] R. Y. Irawan, W. L. Yuly Saptomo, and S. Setiyowati, "Penerapan Metode Double Exponential Smoothing Untuk Peramalan Tingkat Indeks Pembangunan Manusia Berbasis Sistem Informasi Goegrafis Di Provinsi Jawa Tengah," *J. Teknol. Inf. dan Komun.*, vol. 7, no. 2, pp. 18–28, 2019, doi: 10.30646/tikomsin.v7i2.437.
[22] D. Rosadi, *Analisis runtun waktu dan aplikasinya dengan R*. Yogyakarta: Gadjah Mada University Press, 2014.
[23] A. Kumila, B. Sholihah, E. Evizia, N. Safitri, and S. Fitri, "Perbandingan Metode Moving Average dan Metode Naïve Dalam Peramalan Data Kemiskinan," *JTAM | J. Teor. dan Apl. Mat.*, vol. 3, no. 1, p. 65, 2019, doi: 10.31764/jtam.v3i1.764.

[24] L. Wang, H. An, X. Liu, and X. Huang, "Selecting dynamic moving average trading rules in the crude oil futures market using a genetic approach," *Appl. Energy*, vol. 162, pp. 1608–1618, 2016, doi: 10.1016/j.apenergy.2015.08.132.

[25] Khoiri, "Tiga Kelebihan dan Kekurangan Moving Average," 2020. https://www.khoiri.com/2020/12/3-kelebihan-dan-kekurangan-moving-average.html (accessed Aug. 22, 2023).

[26] O. Chantarakasemchit, S. Nuchitprasitchai, and Y. Nilsiam, "Forex Rates Prediction on EUR/USD with Simple Moving Average Technique and Financial Factors," in *17th International Conference on Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology, ECTI-CON 2020*, 2020, pp. 771–774. doi: 10.1109/ECTI-CON49241.2020.9157907.

[27] K. Storm, "Introduction to construction statistics using Excel," in *Industrial Process Plant Construction Estimating and Man-Hour Analysis*, 2019, pp. 1–21. doi: 10.1016/b978-0-12-818648-0.00001-6.

[28] P. Sulistyanto, O. Wahyunggoro, and A. I. Cahyadi, "Pengolahan Isyarat Load cell Menggunakan Metode Simple Moving Average Tingkat Dua dan Weighted Moving Average Tingkat Dua untuk Pencarian Titik Referensi," in *Seminar Nasional Aplikasi Teknologi Informasi 2015*, Yogyakarta: Jurusan Teknik Informatika Fakultas Teknologi Industri Universitas Islam Indonesia, 2015, pp. 31–35.

[29] M. Aslam, M. Azam, and C. H. Jun, "A new exponentially weighted moving average sign chart using repetitive sampling," *J. Process Control*, vol. 24, no. 7, pp. 1149–1153, 2014, doi: 10.1016/j.jprocont.2014.05.001.

[30] A. M. Maricar, "Analisa Perbandingan Nilai Akurasi Moving Average dan Exponential Smoothing untuk Sistem Peramalan Pendapatan pada Perusahaan XYZ," *J. Sist. dan Inform.*, vol. 13, no. 2, pp. 36–45, 2019, [Online]. Available: https://www.jsi.stikom-bali.ac.id/index.php/jsi/article/view/193

[31] C. Bergmeir, R. J. Hyndman, and J. M. Benítez, "Bagging exponential smoothing methods using STL decomposition and Box-Cox transformation," *Int. J. Forecast.*, vol. 32, no. 2, pp. 303–312, 2016, doi: 10.1016/j.ijforecast.2015.07.002.

[32] M. Nakano, A. Takahashi, and S. Takahashi, "Generalized exponential moving average (EMA) model with particle filtering and anomaly detection," *Expert Syst. Appl.*, vol. 73, pp. 187–200, 2017, doi: 10.1016/j.eswa.2016.12.034.

[33] L. Sanny and S. Haryadi, "Peramalan Jumlah Siswa/I Sekolah Menengah Atas Swasta Menggunakan Enam Metode Forecasting," *Forum Ilm.*, vol. 10, no. 2, pp. 198–208, 2013.

[34] C. J. Lynch and R. Gore, "Application of one-, three-, and seven-day forecasts during early onset on the COVID-19 epidemic dataset using moving average, autoregressive, autoregressive moving average, autoregressive integrated moving average, and naïve forecasting methods," *Data Br.*, vol. 35, p. 106759, 2021, doi: 10.1016/j.dib.2021.106759.

[35] D. Rosadi, *Analisis Ekonometrika&Runtun Waktu Terapan dengan R*. Yogyakarta: C.V ANDI OFFSET, 2011.

[36] Aswi and Sukarna, *Analisis Deret Waktu: Teori dan Aplikasinya*. Andira Publisher, 2006.

[37] A. de Myttenaere, B. Golden, B. Le Grand, and F. Rossi, "Mean Absolute Percentage Error for regression models," *Neurocomputing*, vol. 192, pp. 38–48, 2016, doi: 10.1016/j.neucom.2015.12.114.

[38] C. D. Lewis, *International and Business Forecasting Methods*. Butterworths, 1982.