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Analysis on the Comparison Exponential Smoothing and Neural Network in Forecasting the Trend of Toddler Nutritions in Community Health Centre

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ABSTRACT

In Indonesia, community health centres (a.k.a Puskesmas) provide integrated services and consultations for the communities, including toddler care services. There is an assumption that the increase of toddler's nutrition status is influenced by toddler's age and parents' economic status. In this study, the exponential smoothing and the neural network methods were used to forecast toddler's nutrition status. The forecastings were then used to test the assumption whether toddler's nutrition status may be influenced by parents' economic status, education, and care status. The forecasting by exponential smoothing with Eviews method and Neural Network Backpropagation method with Matlab were analyzed and compared to determine which forecasting was best for the next three months based on the pattern of the previous trend data. The results of analysis are used to facilitate and assist community health centre officers in forecasting and evaluating the increase in toddler's nutrition status.

Keywords: *Exponential Smoothing, Neural Network Backpropagation, Forecasting, Eviews, Matlab*.

1. INTRODUCTION

Community health centre (Indonesian: Puskesmas) are established and managed to improve community health.[1] Specifically, they have important roles in providing overal, integrated, and sustained healthcare services.[2] Nutritions are organism processes in which foods are consumed to sustain life, nourish the body, maintain normal functions of internal organs, and produce energy.[3]

The analysis on the trend of toddler's nutrition status development was conducted by using previous data forecasting. Forecasting is a process of predicting and determining future outcomes, whereas planning determines what will happen in future. Forecasting is aimed to forecast/predict data. Generally, mean square error is used to minimalize errors in forecasting, measured by mean absolute error.

In Indonesia, Kartu Menuju Sehat (KMS) or Growth Chart is used as a guide in analizing toddler growth status. The number of toddler's nutrition may be acquired based on the Z-score which has been used widely as a reference by Indonesian community health centres. They were published by the Ministry of Health of Indonesia.[4]

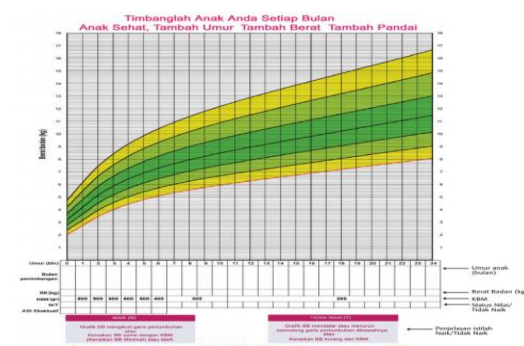


Fig. 1. Growth Chart (a.k.a KMS)

In data regarding toddlers, there is randomness in several aspects such as toddler age and nutrition treatment status. The forecasting on toddler's nutrition status in a community health centre in Banyubiru subdistrict employed the Double Exponential Smoothing method. The method was suggested by Brown, using two smoothing parameters such as α and γ with values between 0 and 1. The method is suitable for forecasting random data and data with trend.[5]

The Exponential Smoothing method was used to forecast toddler's nutrition status based on several factors, namely (1) toddler's age and (2) weights. The forecasting was then related to the assumption regarding several factors influencing toddler's nutrition status, such as (1) parents' economic status, (2) education, and (3) care status. The forecasting was aided with Rapid Miner tools to process the exponential data. The results of analysis were used to forecast toddler's nutrition status and assist community health centre officers in evaluating the increase in toddler's nutrition status in the subdistrict which the centre covers.

2. RELATED RESEARCH

In a study entitled with "The Implementation of the Exponential Smoothing Method on the Forecasting on the Amount of BPJS Kesehatan (or Healthcare Security) claims in Pamekasan", a time series model is investigated.[6] The model used the Double Exponential Smoothing method to forecast the amount of BPJS kesehatan claims in Pamekasan. The analysis process in the study consisted of four parts, such as 1) data identification, (2) modelling, (3) forecasting, and (4) data evaluation using RMSE and MAPE. The forecasting by the exponential method was then compared to the one by the moving average method. The results of study suggested that although both methods performed well because their MAPE values were under 10%, the exponential smoothing method produced RMSE and MAPE values which were lower than the ones of the moving average method.
Another previous, related study is "The Forecasting on Inflation Level in Indonesia by Using the Time-Series Based Neural Network Backpropagation Method.[7] The study employed the neural network backpropagation method to predict the monthly inflation level in Indonesia. The study used 102 records, 80% of them were used as data training while the other 20% were used as data testing with 7 input variables. Based on several testings, input layers of 1,5,7 MSE 0,000529 were acquired. When using the moving average method to predict the input variables, the inflation level in July 2014 was 0,514. Meanwhile, when using the exponential smoothing method to predict the input variables, the inflation level in July 2014 was 0,45. Also, the inflation level of 0,93 was achieved when using the seasonal method. The author also concluded that the neural network backpropagation with seasonal method was better in forecasting compared to the moving average with exponential smoothing method.

3. METHODOLOGY

3.1 Research Method

Proses Data for toddler nutrition status categorization were collected via interviews and questionnaires administered to the parents. The interviewees were community health centre officers and parents. The questionnaires were aimed to collect data regarding (1) toddler's age, (2) weights, (3) parents' economic status, (4) education, and (5) care status. As for the forecasting, the data on the last year were used to identify the development of the trend patterns (in form of graphs).
The scales of measurement in the questionnaires are described as follows:

1) Toddler's age: toddler's age in a scale ratio between 1-60 months.
2) Toddler's weights: the scale ratio of measurement in kilograms.
3) Parents' economic status: the interval scale of income, less= <1.500.000, adequate= 1.500.000 – 2.500.000, more= >2.500.000.
4) Parents' education: types of education taken
5) Care status: Types of care undertaken by carer or non-carer.

The acquired data would be then processed according to the Z-Score table by using values from each attribute of the data in order to categorize the nutrition status data. The category, in turn, would be used for forecasting nutrition status using the Exponential Smoothing and the Neural Network methods by the Community health centre to the community for toddler nutrition advisory purpose.

3.2 Data Analysis Method

The data analysis method used in this study were qualitative and quantitative.[2] A qualitative and quantitative research is aimed to formulate research systematically and accurately on a fact and a nature of particular population.
Double Exponential Smoothing
The Exponential Smoothing model is recommended for forecasting time-series data which tends to be linear.[8] The application of the Double Exponential Smoothing method involves dual smoothing process paths by determining the value of α (alpha).[9] According to [10], the linear exponential smoothing method by Holt is actually in line with Brown's, only if Holt did not use the double smoothing formula directly. Alternatively, Holt smoothed the trend with the parameters differently from the parameters usage in the actual values. The linear exponential forecasting, according to Holt, may employ smoothing constant criteria value between 0 and 1 with three equations:

1) Determining Smoothing (S_t')
$$S_t' = \alpha X_t + (1-\alpha)(S_{t-1} + b_{t-1})$$
2) Determining Trend Rejuvenation (b_t)
$$b_t = \gamma(S_t + S_{t-1}) + (1-\gamma)\, b_{t-1}$$

3) Determining Forecasting Value (F_{t+m})

$F_{t+m} = S_t + b_t(m)$

F_{t+m}	=	Value of forecasting for m forwarding period
m	=	Difference/number of forwarding periods which will be forecast
X_t	=	Actual value of t period
S'_t	=	Smoothing value of t period
α, γ	=	Smoothing constant (1/n), with the value between 0 and 1

To evaluate the result of forecasting, in measuring the error values of forecasting, the MSE equation is used in the Exponential Smoothing method.[9]

Mean Squared Error (MSE)

$$MSE = \frac{\sum(X_t - F_t)^2}{n}$$

$$RMSE = \sqrt{\sum_{t=1}^{n}(X_t - F_t)^2/n}$$

Neural Network Backpropagation

The Neural Network Backpropagation algorithm is often used to handle complicated issues. This network consists of a set of small processing units modeled after or similar to human nervous system. The neural network approach is illustrated as biological nervous system network. The neural network is a set of related input/output units, where each joint has its own weight.[7] The neural network has several characteristics for clustering usage. First, the neural network is an architecture for processing inherent, distributed parallels. Second, the process adjusts the weight to data; it is for normalisation of pattern and action for attributes of extractors to differentiate groups. Third, the neural network processes numeric vectors and needs object pattern to be represented by the qualitative features.

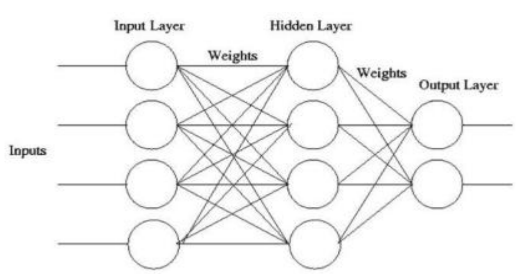


Fig. 2. Simple Architecture of Neural network [11]

Neural Network Backpropagation

Algoritma The backpropagation training algorithm was firstly suggested by Paul Werbos in 1974 and further introduced by Rumelhart and McClelland to be used in neural network. The method, initially, was formulated for feedforward neural network, but the method was developed further and adapted to train other neural network models.[12] There are several paths in the backpropagation artificial neural network. The following is an outline of the backpropagation artifical neural network: (4)

0) Initiation of weights (determined in small random values)
1) If the stop signal is wrong, do step 2–9
2) For each training pairs, do step 3–8

Feedforward

3) Each input unit (x_i, i= 1,2,3…n) receives input signal x_i and then forwards it to hidden units.
4) Each hidden unit (z_j, j= 1,2,3…p) measures weighted input signals,
   $z\_in_{jk} = v_{0j} + \sum_{i=1}^{n} x_i v_{ij}$
   using the arithmetic activation function:
   $Z_j = f(z - in_j)$ (6)
   and send the signals to the output units. (7)
5) Each output unit (y_k, k= 1,2,3…m) menjumlahkan isyarat masukan berbobot,
   $y\_in_k = w_{0k} + \sum_{k=1}^{p} z_i w_{jk}$
   calculates the weighted input signals, by using the calculation activation function,
   $y_j = f(y - in_k)$

Backpropagation:

6) Each output unit (y_k, k= 1,2,3…m) receives pattern target related to the input training pattern. Calculate the information error:
   $\delta_k = (t_k - y_k) f'(y - in_k)$
   Calculate the corrected weight and bias:
   $\Delta\, w_{jk} = \alpha \delta_k x_j$
   $\Delta\, w_{0k} = \alpha \delta k$
7) Each hidden unit (z_j, j= 1,2,3…p) calculates its input delta (from the units in its top report).
   $\delta\_in_k = \sum_{k=1}^{m} \delta_k w_{jk}$
   Calculate the information error
   Calculate the corrected weights and bias

Update the weight and bias:

8) Each output unit (y_k, k= 1,2,3…m) updates the weights and bias (j=0,1,2,3…p)
   $w_{jk}(baru) = w_{jk}(lama) + \Delta\, w_{jk}$
   Each hidden unit (z_j, j= 1,2,3…p) updates the weights and bias (i=0,1,2,3…n)
   $v_{ij}(baru) = v_{ij}(lama) + \Delta\, v_{ij}$
9) Signal testing stops
   The following are explanations for the above steps:

$X…X_n$	= Inputs
$Y_1…Y_n$	= Outputs
$Z_1…Z_n$	= Values of hidden layers

V_{ij} = Weights between input layers and hidden layers
W_{jk} = Weights between hidden layers and output layers
δ = Information errors
α = Continuous constant

4. RESULT AND DISCUSSION

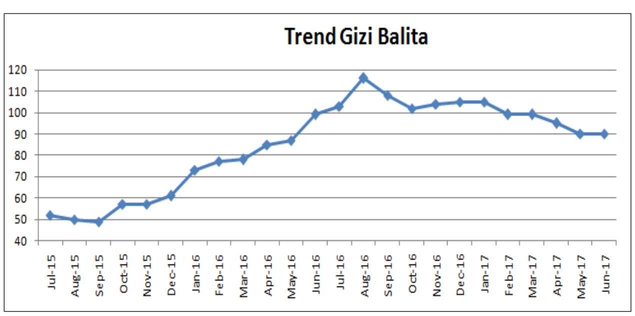
4.1 Data Identification

The initiation and data identification processes for forecasting were done using the Exponential smoothing and the Neural network backpropagation algorithm methods by determining several values which would be related to answer research questions in this study. The data from the table below indicates a trend which can be predicted by comparing both methods. The following is a prediction table during the last two years regarding toddler nutrition in Banyubiru community health centre, Banyubiru subdistrict.

Table 1: Data on the Trend of Toddler Nutrition in the Last Two Years

Number	Month	Qty	Number	Month	Qty
1	Jul-15	52	13	Jul-16	103
2	Aug-15	50	14	Aug-16	116
3	Sep-15	49	15	Sep-16	108
4	Oct-15	57	16	Oct-16	102
5	Nov-15	57	17	Nov-16	104
6	Dec-15	61	18	Dec-16	105
7	Jan-16	73	19	Jan-17	105
8	Feb-16	77	20	Feb-17	99
9	Mar-16	78	21	Mar-17	99
10	Apr-16	85	22	Apr-17	95
11	May-16	87	23	May-17	90
12	Jun-16	99	24	Jun-17	90

Fig. 3. The Graph of the Trend of Toddler Nutrition for 24 months.



4.2 Forecasting Using Exponential Smoothing

Table 2: Analysis Table with the Double Exponential Smoothing Method

P	α	γ	MSE	Results of forecast
P1	0.2	0.3	11.20500	97.21; 94.37; 91.54
P2	0.4	0.5	6.499079	85.50; 82.24; 78.97
P3	0.5	0.7	6.077445	86.02; 83.08; 80.14

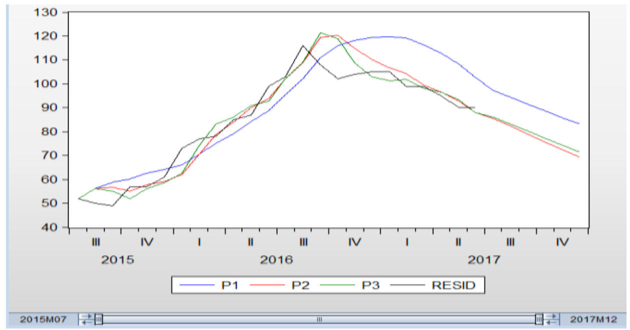


Fig. 4. The Comparison of Three Experiments with Different Parameters

Eviews 8 Tools was used to process the monthly, linear trend data in the forecasting process. With the modified parameter where α = 0.5 and parameter γ = 0.7, here is the results of forecasting using the Double Exponential Smoothing method for period 25 = 86.02, period 26 = 83.08, and period 27 = 80.14. the RMSE value is of 6.077445.

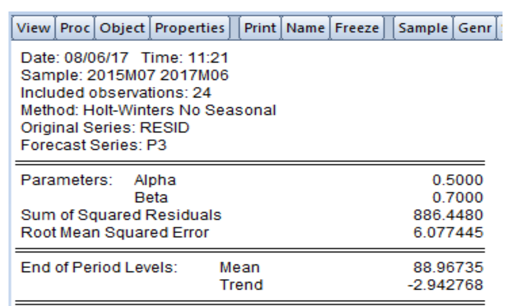


Fig. 5. The Result of Forecasting where alpha = 0.5, beta = 0,7, and MSE = 6.077445

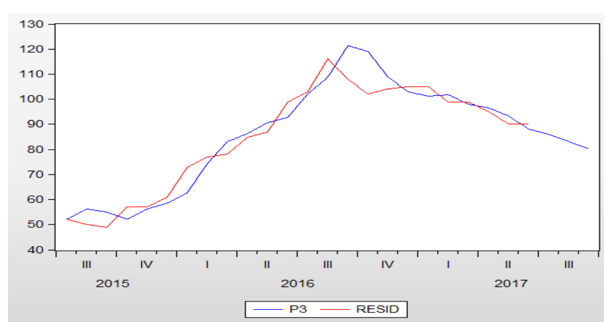


Fig. 6. The Graph of Forecasting in the 3 months exponential smoothing.

4.3 Forecasting with Neural Network Backpropagation

Table 3: Table of Forecasting Using Neural Network with 3 Differents Neurons to Determine the Best Forecasting based on MSE

Neuron	Epochs	MSE	Three months forecast
10	230	0.00099598	97.837; 114.280; 122.808
20	128	0.00096682	92.191; 85.822; 82.169
30	138	0.00098318	74.781; 101.263; 62.438

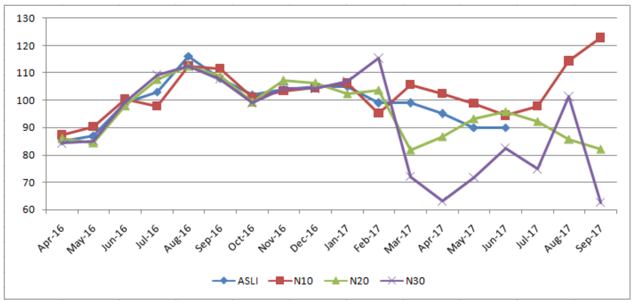


Fig. 7. The Graph of the Results of Forecasting Using the Neural Network Backpropagation.

Matlab R2010a Tools was used to process monthly linear trend data in the forecasting process using the neural network backpropagation. By using 2 hidden layers with total neurons=20, and the hidden layer of the two purelin linear function and training, the results of forecast using the neural network backpropagation method are period 25th = 92, period 26th = 85, period 27th = 82, values of MSE = 0.00096682.

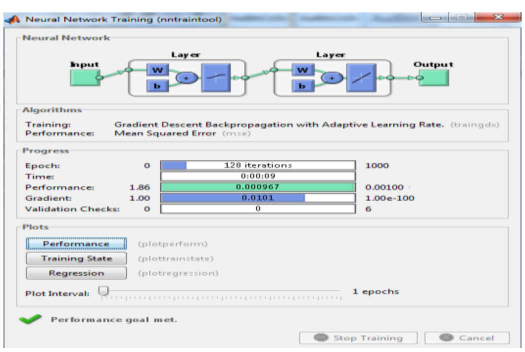


Fig. 8. Training of Neural Network Backpropagation Where Total Neurons = 20, Epochs = 128, and Error Goals=0.0001

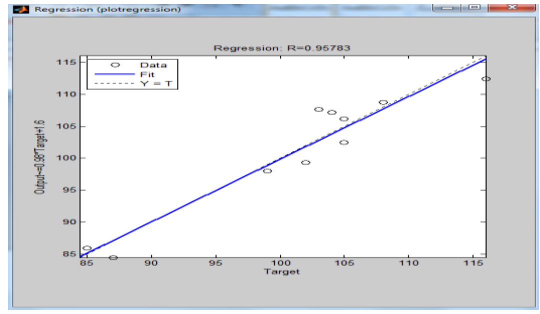


Fig. 9. A Graph of the Result of Regression with the Training Data

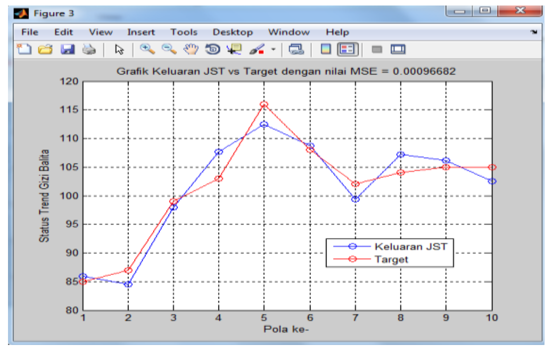


Fig. 10. A graph of the Outputs of the Training Data

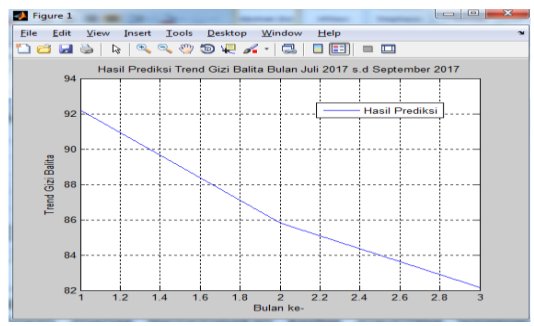


Fig.11. A Graph Predicting Three Months into 25th, 26th, and 27th Periods

4.4 The Comparison Analysis between the Exponential Smoothing and Neural Network Methods

4.4.1 The Analysis of the Forecastings between the Algorithms

The first comparison analysis of the difference in values between the actual data and the 5 months forecasting

Forecasting with the smallest value of SME in the research is identified to be closer to the actual value. The smallest MSE value was acquired from the experiment with the previous parameters. The comparison between the results of the forecasting 5 months before with the exponential smoothing and the neural network backpropagation was acquired by comparing the result of the forecasting with the actual data. The value of comparison from the difference in values of forecasting is closer to the forecasting on actual data by forecasting the last five months during 20th-24th months.

Table 4: Comparison between Toddler Nutrition Trend Forecasting Using Exponential Smoothing (ES) and Experiment with 3 Different Parameters During the Last 5 Months (20th-24th Month).

Actual data	The comparison of forecastings		
	P1	P2	P3
99	123.319	105.332	98.6843
99	126.605	103.961	96.0192
95	129.892	102.591	93.3541
90	133.178	101.220	90.6890
90	136.465	99.850	88.0240

Table 5: The Difference Between Actual Data and the Forecasted Data in Table 5.

Actual data	The difference of distance		
	P1	P2	P3
99	24.319	6.332	-0.315
99	27.605	4.961	-2.980
95	34.892	7.591	-1.645
90	43.178	11.220	0.689
90	46.465	9.850	-1.976

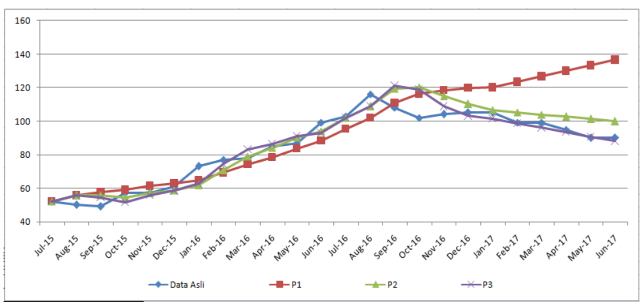


Fig. 12. The Graph of Toddler Nutrition Trend Forecasting using the Exponential Smoothing

Tabel 6: The Comparison Between the Toddler Nutrition Trend Forecasting using Neural Network Backpropagation Method (NNBP) with 3 Different Neurons During the Last 5 Months (Month 20th-24th)

Actual data	Neuron		
	N10	N20	N30
105	135.94	108.62	167.18
99	116.70	100.14	178.84
99	102.86	83.99	195.27
95	104.88	88.37	148.42
90	156.98	108.77	228.42
90	119.72	110.34	214.09

Table 7: The Difference in Values between the Actual Data and the Forecasting in Table 6

Actual data	Difference (Neuron – Actual Data)		
	N10	N20	N30
105	30.94	3.62	62.19
99	17.7	1.14	79.85
99	3.864	-15	96.27
95	9.882	-6.62	53.43
90	66.99	18.77	138.4
90	29.73	20.34	124.1

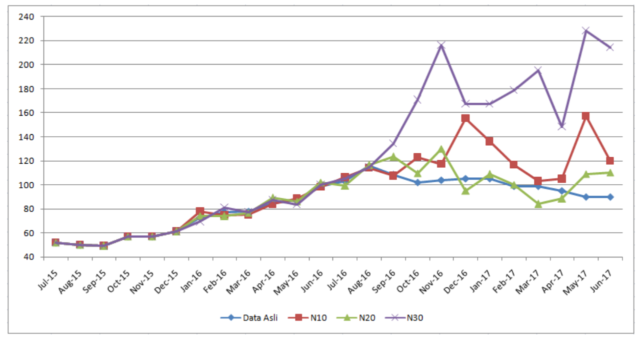


Fig. 13. The Graph of the Toddler Nutrition Trend Forecasting Using Neural Network Backpropagation (NNBP) in Table 6.

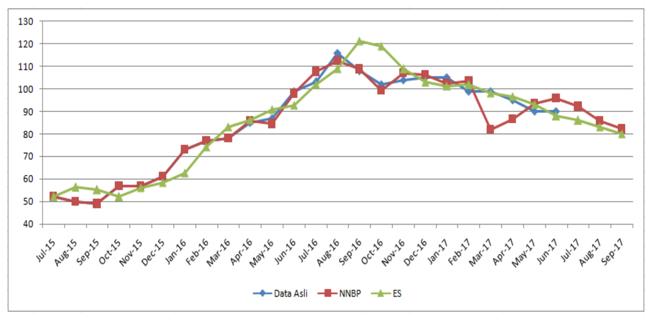


Fig. 14. The Graph of the Comparison between Toddler Nutrition Trend Forecasting by (ES) and (NNBP) using the smallest values of MSE.

Second Analysis: The Comparison of the backward Forecasting

The second testing employed the backward forecastings by the neural network and the exponential smoothing methods. The testing was meant to ensure whether, by backward forecasting from last month to first month, the most suitable method to forecast types of linear data can be identified. Below is its comparison with the exponential smoothing method.

Table 8: The Comparison between the Forecasting by the Exponential Smoothing with Actual Data with the backward Forecasting on the First Six Months

Month	Actual data	Backward Forecasting	
		Forecasting (P3)	Difference in values
Dec-15	61	66.942630	5.942630
Nov-15	57	63.433943	6.433943
Oct-15	57	59.925256	2.925256
Sep-15	49	56.416569	7.416569
Aug-15	50	52.907883	2.907883
Jul-15	52	49.399196	-2.600803

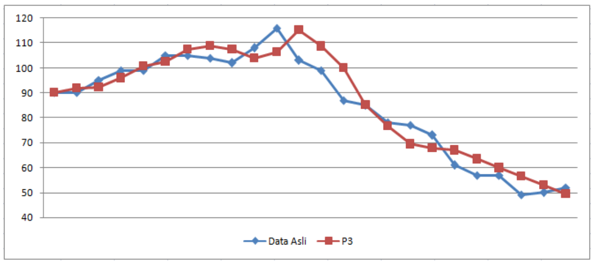


Fig. 15. The Graph of the Comparison of the Forecasting by the Exponential Smoothing Method Based on Table 8.

Table 9: Table of the Forecasting by Neural Network Backpropagation on Actual Data with Six Months Backward Forecasting based on 3 Iteration Settlements.

Month	Actual Data	Epochs		
		Ep. 3	Ep. 5	Ep. 10
Dec-15	61	16.304	200.499	182.8
Nov-15	57	29.278	115.255	54.58
Oct-15	57	29.263	117.058	211
Sep-15	49	25.597	24.167	-34.4
Aug-15	50	44.972	179.824	-11
Jul-15	52	27.759	147.50	74.85

Table 10: Table of the Difference in Values between the Actual Data Forecasting and the First Six Months backward Forecasting in Table 9.

Month	Actual data	Difference in values between Forecasting - Actual Data		
		Ep. 3	Ep. 5	Ep. 10
Dec-15	61	-44.7	139.5	121.830
Nov-15	57	-27.72	58.26	-2.423
Oct-15	57	-27.74	60.06	153.986
Sep-15	49	-23.4	-24.83	-83.394
Aug-15	50	-5.027	129.8	-60.971
Jul-15	52	-24.24	95.51	22.846

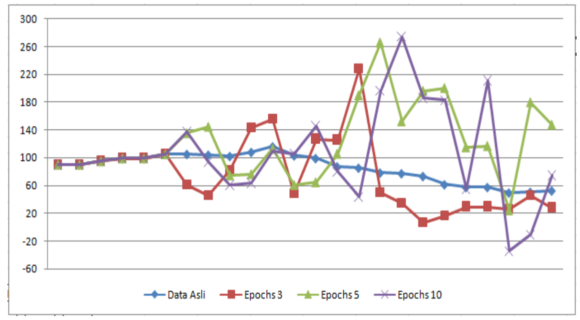


Fig. 16. The Graph of the Comparison between the backward Trend with the Neural Network Backpropagation Based on Table 9.

Analysis on Trend of the Toddler Nutrition Status

Based on the figures of the forecastings by both analysis algorithms described before, it can be concluded that toddler's age and weights significantly influence the increase of the toddler nutrition status. This can be proven by the fact that in Kartu Menuju Sehat (KMS), there is a statement which says the toddler's age must be in balance with toddler's weights. Based on our study involving 152 respondents, it can be concluded that

1. Parents' income (lesser = 57, adequate = 66, higher = 29) did not influence the nutrition status because even though 50% of total respondents have adequate and even higher incomes, the nutrion status still increases.
2. Parents' education, where elementary school = 24, junior high school = 64, senior high school = 59, and undergraduate = 5, did not influence the nutrition status because 50% of total respondents only finished their education under the senior high school. Their awareness on health advices may also influence the trend of the toddler nutrition.
3. Care status owned by parents = 118, and carer = 34 did not influence the nutrition status. Although the toddlers are still cared by their parents, there is still an increase in the nutrition status between zero age till June 2017.

5. CONCLUSIONS

Forecasting used the Exponential Smoothing with parameter α and γ to obtain the trend forecasting which was smoother and closer to the actual values. The forecasting which has smaller MSE may be used as a reference since it is closer to the actual values. In Fig. 4, it can be seen that with the α =5 and γ =0.7, the values of MSE by the exponential smoothing is the smallest.

Comparison between the Neural Network Backpropagation algorithm determines the forecasting with several parameters. The neural network with two hidden layers and 20 neurons to experiment the training and the targets also influenced the weights in the forecasting. In Figure 11, the result of forecasting with 20 neurons is a comparison whose result is closer to the actual values.

Table 11. The Best MSE from Exponential Smoothing and Neural Network Backpropagation Methods.

Methods	MSE
Exponential Smoothing	6.077445
Neural Network Backpropagation	0.00096682

Based on the values of MSE, it can be concluded that the neural network backpropagation is better than the values of MSE by the Exponential Smoothing. The comparison of the MSE neural network is smaller than the one by the exponential smoothing, proven by several testings. The results of MSE can be found in Table 9. The forecasting of the next three months used the neural network, resulting in MSE = 0.00096682, compared to the exponential smoothing which resulted in MSE=6.077445.

The comparison analysis on the forecastings were done using three analytical schemes, 1) forecasting the next three months; 2) determining the difference in values in the comparison between the forecasting and the actual data of the last 5 months; and 3) the inverse forecasting and the determination of Epochs on the neural network. By ignoring the MSE values, the exponential smoothing is better than the neural network. Based on the second analysis which used actual data during the previous five months, the difference in values produced by the exponential smoothing method is smallest. The third analysis using the inverse forecasting also resulted in the exponential smoothing having the smallest difference in values.

The assumption that toddler's weights and age influence toddler nutrition can be seen in the results of questionnaires and KMS. Parents' income and education did not influence the increase in toddler nutrition, since in the graphs the increase progresses along with the increase of toddler's age and weights.

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