Forecasting and Controlling the Food Supply System in Hospital Using Exponential Smoothing

by Oky Dwi Nurhayati

Forecasting and Controlling the Food Supply System in Hospital Using Exponential Smoothing

Yunila Dwi Putri Ariyanti[1,*], *Mustafid*[2], and *Oky* Dwi Nurhayati[3]

[1]Magister of Information System, School of Postgraduate Studies, Diponegoro University, Semarang – Indonesia 50242
[2]Department of Statistics, Faculty of Science and Mathematics, Diponegoro University, Semarang – Indonesia 50275
[3]Department of Informatics, Faculty of Engineering, Diponegoro University, Semarang – Indonesia 50275

Abstract. The satisfaction of patient care is an indicator of good performance in hospitals, one of which plays a critical role is a logistic serving of food. With the fluctuating number of patients, the hospital should be able to meet the demand for the number of patients each day. This study aims to build the system of forecasting and controlling the food supplies to determine the number of servings of food supplies in the next period. The implementation of Exponential Smoothing method is used to predict the number of servings should be available for the next period. Amount of food raw material is controlled using re-orders point model, it aims to anticipate the occurrence of stockout with the minimum amount of food provides should be available. The data were obtained from the requested amount of food during 212 days for three times, morning, noon, and night. Forecasting values using alpha parameters 0.3 and 0.7 with a minimum forecasting error calculation using MAPE for alpha 0.7 with a value 12.81% for morning time, 11.59% during the day, and 10.96% night time. Forecasting result not only can be used to allocate food supplies but also to control stock of raw material food.

Keywords: **Forecasting Method; Exponential Smoothing; Re-Order Point**

1 Introduction

As a means of health services, hospitals must provide maximum service to patients, patient service satisfaction becomes a good performance indicator for the hospital [1]. Good hospital service quality is needed for handling patients quickly and accurately. The supply chain at the Hospital provides patient care and safety services so that strategies are needed to achieve high performance [2]. High supply chain performance manifests great results and great efficiency [3]. Logistics services take an important role in the entire chain of supply chains in a hospital. Logistics in hospitals include the process of handling physical goods including medicines, medical products operation, medical equipment, sterile goods, food, and others [1].

One of the logistics that plays an important role in improving patient care is food logistics. The availability of food logistics should be able to meet the demands of the number of patients each day. The number of visitors for hospitalized patients is fluctuating, so that the logistics department must prepare the appropriate amount of food portions to meet the needs of food logistics for the patient can be fulfilled. For that with the prediction system and inventory control can anticipate the shortage of food supplies. Until now various methods of prediction have been developed and used in research, some of which are Moving Average (MA), Autoregressive Integrated Moving Average (ARIMA), and one of them Exponential Smoothing [4].

The exponential smoothing method is one of the most important forecasting tools in business and macroeconomics, with this model allowing flexible control, and the exponential smoothing method has been widely used because of its advantages in terms of simplicity, resilience, and precision in forecasting. [5].

Exponential smoothing method is generally single but has strong forecasting, this method is widely used in business for forecasting inventory demand [6]. Forecasting methods such as exponential smoothing are important for building a policy in inventory control, especially in forecasting deployments for future demand. So the inventory policy is given according to the minimum budget owned [7]. The exponential smoothing method forecasting is based on past historical observations data by giving greater weight to the current observations [9], using the value of certain parameters to obtain the smoothing value on which consideration determines the most appropriate method for the forecasting model. In addition to predicting inventory control systems are also required to monitor the current stock conditions [8].

The purpose of this research is to apply prediction systems to determine the amount of food supply in the next day and inventory control model to anticipate the shortage of supplies so that the food logistics department

* Corresponding author: yuniladwipa@gmail.com

can allocate the amount of food that must be available to meet the patient's needs.

2 Literature Review

2.1. Forecasting

Forecasting is a technique of calculation analysis performed with quantitative and qualitative approaches to estimate future events based on references to data in the past [7]. Forecasting is the basis of all planning, long-term forecasting is indispensable for planning and strategies to improve organizational capability and anticipate important changes in the future [10]. Internal business, Forecasting provides many benefits in the field of business and macroeconomics. Forecasting is important to provide an overview of what should be available in the future. In companies engaged in sales, forecasting is useful for inventory control [11].

2.2. Exponential Smoothing Method

Exponential Smoothing Method (ES) is a method of forecasting, which has an approximate weight of past observations, the observations gave are relatively more severe than past observations [9]. Exponential Smoothing for time series forecasting usually depends on three basic methods; single exponential smoothing is used for continuous data types. There is no trend or seasonal trend [12], trend corrected exponential smoothing or also called double exponential smoothing used for trend data types [9] and seasonal variation exponential smoothing or triple exponential smoothing used for type seasonal data such as daily, weekly, or monthly [14].

Single Exponential Smoothing is used for short-term forecasting. The Exponential Smoothing method gives greater emphasis to the current time series through the use of a smoothing parameter. The smoothing parameters range from 0 to 1 [12]. If the parameter is close to 0 then the smoothing effect is greater, whereas if the parameter is close to 1, the smoothing effect is lower or smaller, so we need to add weight to the change [9].

In single exponential smoothing consist of calculating prediction and smoothing value, the forecast value is obtained from the calculation of the predicted value of time to *t* based on the time *t* or based on the previous smoothing level expressed by equation

$$\hat{y}_{t+p|t} = \ell_t$$

$\hat{y}_t$ is the forecast value at time t, p is the distance of the period to be predicted (p=1,2,3, . . .), whereas ℓ_t the level or the smoothing value of the time series t.

Then to calculate the smoothing value is expressed in equation (1).

$$\ell_t = \alpha y_t + (1-\alpha)\,\ell_{t-1} \qquad (1)$$

the observed value at time t is expressed by y_t, whereas α is the smoothing parameter value $0 \le \alpha \le 1$. To calculate the smoothing value, ℓ_t, it can be described as follows

$$\begin{aligned}
\ell_t &= \alpha y_t + (1-\alpha)\ell_{t-1} \\
\ell_1 &= \alpha y_1 + (1-\alpha)\ell_0 \\
\ell_2 &= \alpha y_2 + (1-\alpha)\ell_1 \\
&= \alpha y_2 + (1-\alpha)(\alpha y_1 + (1-\alpha)\ell_0) \\
&= \alpha y_2 + \alpha(1-\alpha)\,y_1 + (1-\alpha)^2\ell_0 \\
\ell_3 &= \alpha y_3 + (1-\alpha)\ell_2 \\
&= \alpha y_3 + (1-\alpha)(\alpha y_2 + \alpha(1-\alpha)\,y_1 + (1-\alpha)^2\,\ell_0) \\
&= \alpha y_3 + \alpha(1-\alpha)y_2 + \alpha(1-\alpha)^2 y_1 + (1-\alpha)^3\,\ell_0
\end{aligned}$$

The smoothing value is counted continuously, so for smoothing ℓ_t can be expressed in the following equation

$$\ell_t = \sum_{j=0}^{t-1} \alpha\,(1-\alpha)^j\, y_{t-j} + (1-\alpha)^t\,\ell_0 \qquad (2)$$

to calculate forecasting can be written with equations

$$\hat{y}_{t+p|t} = \sum_{j=0}^{t} \alpha\,(1-\alpha)^{t-j}\, y_j + (1-\alpha)^t\,\ell_0 \qquad (3)$$

Prior to the calculation of exponential smoothing, first calculation of the initial estimates of the time series on the period t=0 which is defined by ℓ_0 with calculate an average of half of the historical data, ie calculating the amount of food demand with $y_1 + y_2 + y_3 + \ldots + y_n$ and divide by half the data history n, expressed by equation

$$\ell_0 = \frac{\sum_{t=1}^{n} y_t}{n} \qquad (4)$$

Once the value is obtained ℓ_0 then the calculation is done as in the equation (2) and (3).

2.3. Determination of Parameter Values

Calculation of smoothing values requires parameter. The initial parameters that must be known for all exponential smoothing methods are alpha parameters whose values range between $0 \le \alpha \le 1$. The accuracy of a forecasting technique depends on the smoothing parameters used. The smoothing parameter used represents the percentage of forecasting errors [13]. To determine the forecasting value formulated in the equation

$$\alpha = 1 - \left(\frac{n-1}{3n}\right) \qquad (5)$$

$$\alpha = 1 - \left(\frac{\textit{number of history data} - 1\ (\textit{ex.pause time})}{\textit{number of operand} * \textit{number of history data}}\right)$$

Whereas to determine the parameter value for smoothing is formulated with the equation

$$\alpha = \left(\frac{n-1}{3n}\right) - 0 \qquad (6)$$

$$\alpha = \left(\frac{\textit{number of history data} - 1\ (\textit{ex.pause time})}{\textit{number of operand} * \textit{number of history data}}\right) - 0$$

A value of 0 is an extreme value below, and a value of 1 is the upper extreme value of $0 \leq \alpha \leq 1$.

2.4. Forecasting Error

The precision of forecasting is used to measure the suitability between existing data and forecasting data. To calculate forecasting errors using the Mean Absolute Percentage Error (MAPE) calculation method. MAPE is used to evaluate forecasting methods using the smallest selection of error values [12]. MAPE calculation is done by calculating the absolute error in each period or error value obtained from the actual data in the period y_t minus the forecast value $\hat{y}_t$ in each period with an absolute value or all values become positive, then divided by the actual value of observation in that period y_t expressed in the equation

$$Precentage\ Error = \frac{(y_1-\hat{y}_1)}{y_1} + \frac{(y_2-\hat{y}_2)}{y_2} + \ldots + \frac{(y_t-\hat{y}_t)}{y_t}$$

then the error calculated result is divided by the amount of n data to get the average. The MAPE calculation equation is as follows :

$$MAPE = \frac{1}{n}\sum_{t=1}^{n}\left|\frac{(y_t-\hat{y}_t)}{y_t}\right| x\ 100\% \quad (7)$$

2.4. Reorder point

Re-order point (ROP) is an inventory control model that is used for re-stock renewal in order to meet demand requirements by using the reorder point [8]. ROP controls the number of needs that must be prepared to serve a certain portion of food for patients. In this model the inventory system is controlled at the end of each review period, if the stock position is below the re-order point r then a number of portion is ordered. Order quantity received after L time of charge time. Re-order point return is calculated at the end of each period, while order quantity is only counted once for all stock units [14]. To calculate re-order point using variant of exponential smoothing forecasting error, ie Mean Square Error (MSE). MSE is calculated based on actual data difference with forecasting data then squared by the equation:

$$MSE = \frac{1}{n}\sum_{t=1}^{n}(y_t - \ell_t)^2$$
$$MSE_t = \beta\,(y_{t-1} - \hat{y}_{t-1})^2 + (1-\beta)\,MSE_{t-1} \quad (8)$$

β is the value of smoothing $0 \leq \beta \leq 1$. In this equation the constant smoothing value for the MSE procedure is set β =0,25 they reflect the practical values that are commonly used in the context of the application [14]. Then for the ROP calculated based on *Cycle Service Level* (CSL). The cycle is the time period between two consecutive requests, with CSL likely not going to run out of stock during the cycle. The re-order point for period t (at the end of period t-1) is denoted by r_t with equation :

$$r_t = (L+1)\,\hat{y}_t + \varphi^{-1}(CSL)\sqrt{MSE_t(L+1)} \quad (9)$$

L is the waiting time for portion ordering and is the cumulative distribution for demand for each period. φ^{-1} is the cumulative distribution of the service level sought from the normal distribution table.

3 Methods

This study uses data on the number of food portion demand in the hospital for 212 days, starting from August 2017 to February 2018 obtained from the results of observation and interviews at the Hospital. Food portion data is obtained from the amount of data of inpatients and guard doctors at each time. The following is the food portion request data in August shown in Table 1

Table 1. Request the amount of food portion

Month	Date	Morning	Afternoon	Night	Sum
August 2017	1	35	36	36	107
	2	36	32	29	97
	3	29	32	35	96
	4	35	37	36	108
	5	36	39	36	111
...	...	...	...	...	...
February 2018	24	26	31	34	91
	25	32	31	33	96
	26	29	33	35	97
	27	32	45	41	118
	28	38	42	43	123

This research is built through several stages of information system development, the stage consists of input, process, and output. The data of the demand for food portion is used as input, then the process of calculation of prediction and inventory control.

To calculate the prediction in the first analysis of the pattern of food demand data in the hospital. In Method Exponential Smoothing there is three data analysis that can be done. single exponential smoothing used for continuous data types no trend or seasonal trend, double exponential smoothing used for trend data types, and triple exponential smoothing used for seasonal data types such as daily, weekly or monthly. The results of the forecast data pattern analysis determine the design of the system to be created.

In the exponential smoothing calculation, the parameter value is used to calculate the smoothing value, based on the smoothing value can be calculated to get the forecast value for the next period. Then using MAPE can be found the most appropriate alpha value. The next step is to calculate the value of inventory control using reorder point to anticipate the occurrence of stockout. The resulting output is predicted report, reorder point value and fluctuation chart and prediction.

4 Result and Discussion

4.1 Result

The demand for food portion is divided into three serving times: morning, afternoon, and evening. Data was obtained from 212 days. The fluctuating chart of demand for the amount of food portion each time is described as follows

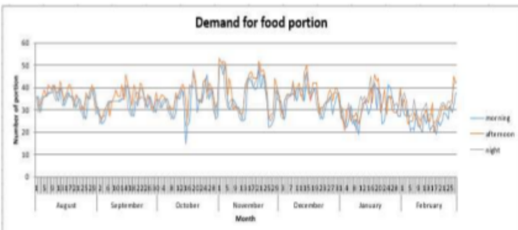

Figure 1. The demand of food portion

Figure 1 shows the pattern of food demand portion data fluctuate, up and down with constant average, so that the forecasting calculation using single exponential smoothing method. To calculate the forecast value, first calculate the initial approximate value as in (4), then equation (1) and (2) calculate the smoothing value with the appropriate alpha. Based on equations (5) and (6) are calculated and the resulting alpha is 0.3 for smoothing and 0.7 for forecasting. Here's an example of smoothing value calculation with alpha = 0.3 for morning time. From the equation (4) the result obtained

$$\ell_0 = 33{,}9905$$

Then from smoothing to 0 can be calculated smoothing to-1 with the equation (1) obtained result

$$\ell_1 = 34{,}2933$$

The results can be seen in the following table

Table 2. Smoothing value calculation

Month	Date	number of portion	Smoothed value	Forecast value
	0		33,99056604	
August 2017	1	35	34,29339623	33,99057
	2	36	34,80537736	34,2934
	3	29	33,06376415	34,80538
	4	35	33,64463491	33,06376
	5	36	34,35124443	33,64463
...	...	...	...	...
February 2018	24	26	26,04120856	26,05887
	25	32	27,82884599	26,04121
	26	29	28,18019219	27,82885
	27	32	29,32613454	28,18019
	28	38	31,92829418	29,32613

In the table above the smoothing value at time 0 or ℓ_0 obtained from calculating half of the total historical data that is a number of 106 data. The smoothing value at time t = 1 is the forecasting value at time t = 2, and so on until t time is reached. The MAPE value is calculated by calculating the average number of original data increments with forecast error, then each alpha value compared to its MAPE value. Showed in Table 3.

Table 3. Calculation of MAPE

Month	Date	Actual	Smoothed value	Forecast value	Forecast Error	Absolute Precentage error
	0		33,990			
August 2017	1	35	34,89	33,990	1,0094	2,8840
	2	36	35,889	34,899	1,1009	3,0581
	3	29	29,688	35,889	6,8899	23,75
	4	35	34,468	29,688	5,3110	15,174
...	...	...	...	...	...	...
February 2018	25	32	31,420	26,205	5,7941	18,106
	26	29	29,242	31,420	2,4205	8,3468
	27	32	31,724	29,242	2,7579	8,6185
	28	38	37,372	31,724	6,2757	16,515
MAPE						12,824

Each time the smoothing value and MAPE are calculated for alpha 0.3 and 0.7 so that the results in Table 4 are obtained.

Table 4. MAPE value for each time

Time	Alpha	Number of portion t = 212	forecast t = 213	MAPE
Pagi	0,3	38	31,9283	14,27 %
	0,7	38	35,9669	12,81 %
Siang	0,3	42	37,2513	12,72 %
	0,7	42	41,7646	11,59 %
Malam	0,3	43	37,6714	12,48 %
	0,7	43	41,8080	10,96 %

From the calculation result table for each time period, the smallest MAPE is obtained for alpha = 0.7, with the sample of morning time from three difference of time as follows

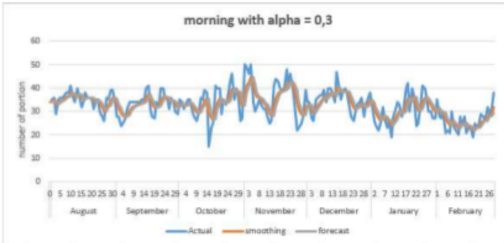

Figure 2. Smoothing value with alpha = 0.3

Figure 3. Smoothing value with alpha = 0,7

The re-order point is calculated using Mean Square Error equation (8) with lead time L of 1, and CSL = 2,05. To calculate the ROP used 3 different service levels to compare the ROP results, the service level used is 90%, 95%, and 98%. The service level is calculated using the cumulative distribution (NORM.S.INV) or normal distribution table, which is denoted by z (service factor) is 1.28; 1.64; and 2.05. So that the results obtained in Table 5.

Table 5. Calculation of service level

CSL	Z (*service factor*)	ROP morning	ROP afternoon	ROP night
90%	1,28	79,53	90,98	90,61
95%	1,64	81,67	93,07	92,58
98%	2,05	84,10	95,46	94,82

The table results explain that a smaller service level will produce a small reorder point, and vice versa. For the Hospital case the fulfillment of the needs must be as maximum as possible, so that the service level used is 98%. For this reason the results of the ROP for each time can be seen in Table 6.

Table 6. Calculation of reorder point

Time	Alpha	Number of portion	Forecast	ROP
Pagi	0,7	38	35,9669	84,10
Siang	0,7	42	41,7646	95,46
Malam	0,7	43	41,8080	94,82

4.2. Discussion

Based on the results of the study can be analyzed that the data of food supply portion vary in fluctuating, there is no trend and seasonal trend seen in figures 1, so to forecats amount of food portion inventory is done using single exponential smoothing method with equation (1). The calculation of the smoothing value is shown in table 2, then each alpha value is calculated by its MAPE to know forecast error as in table 3. By calculating the MAPE value of different alpha values, in table 4 it is known that the best value to forecast is alpha 0.7, so with that value can use to predict the inventory amount of the next period. Prediction accuracy is done by calculating the difference of 100% from the MAPE value.

From the results of these predictions can be calculated inventory control with reorder point shown in table 5. The predicted value of inventories smaller than the reorder point shows the inventory in safe status [8]. By using this model can anticipate the occurrence of stockout. The ROP results are shown in Table 6 that the ROP value is two times greater than the actual portion value and forecasting, this anticipates if there is an increase in the number of patients at a certain time.

5 Conclusion

The forecasting system to determine the number of food portions using the exponential smoothing method helps the Hospital to allocate raw materials and order them in an effective manner. In the exponential smoothing calculation, for forecasting demand in the morning, afternoon, and evening with an alpha of 0.7 the prediction accuracy is 87.19% for morning time, 88.41% during the day, and 89.04% night time. The shortage of inventory stocks can be avoided by re-order point inventory control model by determining the amount of food that must be provided so that it can control food raw material stocks.

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