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Determination of Optimum Smoothing Constant of Single Exponential Smoothing Method: A Case Study

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A B S T R A C T

Exponential smoothing is a sophisticated forecasting method that works based on previous forecast plus a percentage of the forecast error. A key issue of this technique is the proper choice of exponential smoothing constant. In order to minimize forecasting errors, choosing an appropriate value of smoothing constant is very crucial. In this study, a framework is developed for the selection of optimal value of smoothing constant that minimizes a measure of forecast errors like mean square error (MSE) and mean absolute deviation (MAD). Both “trial and error” and Excel based non-linear optimizer “Excel Solver” are used for this purpose. To validate the proposed model, necessary demand data of Ruchi Jhal Muri from years 2010-2016 from Square Food and Beverage Ltd. in Mohakhali, Dhaka were collected. The optimum values of smoothing constant under trial and error method are 0.31 and 0.14 for minimum MAD and MSE respectively whereas for excel solver, values are 0.314 and 0.143 with respect to minimum MAD and MSE. Although both methods provide approximately the same results but excel solver is much easier and requires less time for deriving optimum solution. This study will provide an outline for the forecast planners as well as manufacturers to improve the accuracy of exponential forecasting through using Excel Solver for determining the optimum value of smoothing constant.

Keywords: Smoothing constant, forecast error, trial and error method, excel solver.

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1. Introduction

Forecasting is a planning tool designed to help the management to meet the uncertainty of the future based on previous data and analysis of trends. It is considered as an important and necessary aid to planning which is the backbone of effective operations. History reveals that many organizations have become unsuccessful because of improper forecasting technique on which the company’s entire planning was formed. Effective forecasting helps to reduce unnecessary inventories, improve product availability and level of customer satisfaction. In modern business environment, satisfying customer’s demand at right time and right quantity is

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the main driving force for generating profit. Therefore, to ensure product availability with the lowest possible cost, forecasting with as much accuracy as possible is very necessary.

There are two types of forecasting approaches: qualitative and quantitative. Some forecasting techniques attempt to project historical experience into the future in the form of time series. Single exponential forecasting method is one of the time series forecasts, which is suitable for forecasting data with no trend or seasonal pattern. Exponential smoothing was proposed in Robert G. Brown's work as an OR analyst for the US Navy during WW II [1]. In the late 1950s, Brown modified exponential smoothing for discrete data and developed methods for trends and seasonality [2]. Now, this technique has been widely used for forecasting purposes. Karmaker et al**.** [3] conducted time series analysis including exponential smoothing approach for identifying the most appropriate forecasting technique in order to predict jute yarn demand in Bangladesh. Kabir and Mohsin [4] recommended Simple Exponential Smoothing with an appropriate smoothing constant value for predicting level demand of a retail chain. Jalil et al**.** [5] applied five exponential smoothing methods for electricity load demand forecasting and identified the best one comparing mean absolute percentage error (MAPE) of different approaches.

However, in single exponential smoothing method, an important parameter is the use of smoothing constant (α) which represents the percentage of the forecast error. Forecast values vary with the values of this constant. The accuracy and control of the exponential smoothing technique highly depends on the choice of smoothing constant. Proper selection of smoothing constant improves forecasting technique. The value of constant should be selected in such a way that it will minimize forecast errors. The choice of the smoothing constant can play an important role in defining how reactive the forecast is to the historical data. Low value of constant indicates that the forecast would not be as responsive to the observation. Exponential forecasting method is used for short-range forecast purpose usually one month. So, to use this technique properly, selection of appropriate value of smoothing constant (α) is crucial.

Several researchers have suggested numerous approaches for using different values of smoothing constant. According to Stevenson [6], defining the value of smoothing constant is a matter of judgment or trial and error. He suggested for using forecast errors to guide the decision and determine the optimum one. Stevenson stated that commonly used values of constant range from 0.05 to 0.50. Marzena and Toporowski [7] stated that smoothing constant close to 0 is appropriate for smoothing out unwanted cyclical and irregular components of a time series whereas for value of 1, then, it is good enough for forecasting. Chiang [8] pointed on the use of smoothing constant. The author stated that low value of constant should be utilized when the series show small variations and if the forecast values tend to depend on recent changes in actual values, then high value of constant should be selected. The authors applied Mean Squared Error (MSE) or Mean Absolute Deviation (MAD) as the criterion for an appropriate smoothing constant.

However, random pick up of smoothing constant in range appears to be illogical. Typical values of smoothing constant are ranged from 0 to 1 but a satisfactory value can be generally determined by trial and-error modeling which value minimizes forecast error [9, 10]. Sanjoy [11] used trial and error approach for identifying the optimal value of smoothing constant. He made around 20 trials varying the value of constant and obtained corresponding mean absolute deviation and mean squared error. Then, errors were compared and optimum values were those for which selection criteria were minimized. Cho [12] proposed grid search technique for finding optimal values of smoothing constant. He inspired to choose that value which shows the smallest sum of square errors (SSE) by grid search. Dielman [13] conducted a study for choosing smoothing parameters for exponential smoothing. In the research, the authors used the resulting forecast accuracy for comparing sums of squared and sums of absolute errors.

Salim et al. [14] also proposed for using an exhaustive grid search between the values 0.1 and 1.0 in step sizes of 0.1. Another trial and error method is pattern search strategy which was proposed by William and Friedhelm [15]. In this technique, a series of trial evaluations are conducted and used trial results to decide what to do next. Ravinder [16] used an Excel-based non-linear optimizer (Excel Solver) to determine the optimum values of smoothing constants. In the research, the author made some recommendations on the use of solver. MU'AZU [17] proposed a heuristic algorithm for deriving the exponential constant of the single exponential smoothing method. The contribution of the work is to guide analysts and users of single exponential smoothing model to derive optimum value rather than the arbitrary choice.

In this study, a roadmap has been developed for the selection of optimal value of smoothing constant. The model consists of using two approaches named trial and error and Excel Solver. Although both methods show approximate similar results but Excel Solver is much easier and requires less time for deriving optimum exponential constant.

2. Why Excel Solver?

Excel's Solver add-in provides a powerful tool and recently, it has created urgency for management and practitioners for solving complex optimization problems. The main advantages of it are ease of use, less time requirements etc. This technique provides quick solutions of linear and non-linear optimization problems once their objectives and constraints are implemented in a spreadsheet. For determining optimum value of any decision variables, it is very reliable and quickest methods. Determination of the optimum values of smoothing constant in single exponential smoothing approach is very essential. Previous researchers have mentioned several techniques such as trial and error method, grid search, pattern search, etc. However, most of them take too much time as they rely on doing several trials. In this regard, Excel Solver can provide approximately similar results at the shortest possible time and effort.

3. Materials and Methods

3.1 Sample and measuring technique

The study involves the use of various methods for determining the optimum value of smoothing constant in single exponential smoothing method. For this purpose, relevant data of product "Ruchi Jhal Muri" were collected from a renowned company, namely, Square Food and Beverage Ltd. in Mohakhali, Dhaka, Bangladesh. A written authorization was obtained from the chairman of the company for using the data. The study was conducted from January, 2010 to December, 2016. During this period, demand pattern of company's actual sales data was observed. The actual sales data from 2010 to 2016 were used to estimate several numerical measures such as forecast demand of 84 months, corresponding forecast error, mean absolute deviation (MAD), mean square error (MSE), etc. by using statistical software named Excel.

To determine the optimum values of smoothing constant to minimize MAD and MSE in a single exponential forecasting technique, two types of method named *"Trial and error"* and *"Excel solver"* (excel based non-linear optimization tool) were used. Here, under trial and error method, for different values of exponential smoothing constant, MAD and MSE are calculated. Optimum values of smoothing constant are those for which mean absolute deviation and mean squared error are minimized. In Excel Solver, the first step is to prepare the spreadsheet for representing the model. Once the model is implemented, next step is to call the Solver to find the optimum solution. At third step, the locations (position of cells) of objective function, decision variables, nature of the objective function (maximize/minimize) and constraints are determined.

3.2 Single Exponential Smoothing (SES) method

This sophisticated method is a kind of weighted averaging method which estimates based on previous forecast plus a percentage of the forecasted error. It is easy to implement and compute as it needs not maintaining the history of previous input data. It fades uniformly the effect of unusual data. The equation of SES is as follow:

$$F_t = F_{t-1} + \alpha(F_{t-1} - A_{t-1}). \quad (1)$$

Where,

$F_t = Forecast\ for\ time\ period\ t$
$F_{t-1} = Forecast\ for\ the\ previous\ period$
$A_{t-1} = Actual\ demand\ for\ the\ previous\ period$
$\alpha = Smoothing\ constant\ (0 \leq \alpha \leq 1)$

The accuracy of this technique depends on the value of exponential smoothing constant. The values of constant should be chosen in such a way that forecasts are more accurate. The level of forecasting accuracy is measured in terms of forecasting error which denotes the deviation between actual demand and forecasted demand. The goal is to identify the constant that minimizes the forecast error.

3.3 Measures of forecasting accuracy

Forecasting accuracy plays a vital role when deciding among several alternatives. Here, accuracy refers to forecasting error which is the deviation between the actual value and forecasted value of a given period. In this study, two forecasting error determinants are used: mean absolute deviation (MAD), and the mean squared error (MSE). MAD is the average absolute difference between actual value and value that was predicted for a given period, MSE is the average of squared errors. The formulas used to calculate above stated errors are:

$$MAD = \frac{\sum |D_t - F_t| .}{n} \quad (2)$$

$$MSE = \frac{\sum (D_t - F_t)^2 .}{n-1} \quad (3)$$

Where,

$D_t = Actual\ demand\ for\ time\ period\ t$
$F_t = Forecast\ demand\ for\ time\ period\ t$
$n = Specified\ number\ of\ time\ periods$
$D_t = Forecast\ error = (D_t - F_t)$

4. Results, discussion and recommendation

Actual sales data of “Ruchi Jhal Muri’’ from years 2010-2016 of Square Food and Beverage Ltd. are presented in Table 1. It indicates that demand fluctuates over period to period. The trend of demand of years 2010 to 2016 are quite the same with little fluctuations. Demand was steady until 4 months, and then sharply increased at month March. The increasing trend remained to month August for seven years. At month September, it sharply deceased and continued until December. The lowest and highest values of demand are in Year 2016 which are 48 and 77 packets respectively.

For different values of exponential smoothing constant, MSE and MAD are calculated under trial and error method. Mean squared error for different values of exponential smoothing constant are determined using Eq. (2). Table 2 shows the MSE values for different α.

Similarly, mean absolute error is obtained for different values of smoothing constant. Table 3 presents the measures of different MAD for different α. Here, 20 trials are performed to find out the optimum values. The values of MSE decrease with increasing α up to 0.14 and after the values increase. The corresponding minimum MSE is 53.4288. On the other hand, mean absolute deviation is decreased with increasing smoothing constant up to 0.31 and then, sharply increases.

Table 1. Actual values sales data.

Month	Year						
	2010	2011	2012	2013	2014	2015	2016
January	60	55	65	54	68	71	54
February	62	67	68	49	65	69	58
March	57	61	52	51	57	72	69
April	59	63	49	58	54	75	57
May	68	62	68	69	70	69	71
June	61	59	59	70	71	54	77
July	59	54	57	75	72	59	59
August	72	52	59	71	57	68	58
September	65	58	52	68	55	62	48
October	69	59	51	71	59	63	57
November	63	62	56	70	68	53	71
December	58	63	69	69	54	51	68

Table 2. MSE for different values of α.

Exponential smoothing constant	MAD	Exponential smoothing constant	MAD
0	6.3700	0.31	6.0205
0.05	6.3310	0.32	6.0219
0.07	6.2990	0.33	6.0250
0.09	6.2560	0.4	6.0330
0.1	6.2347	0.5	6.0330
0.2	6.0763	0.6	6.0497
0.21	6.0590	0.7	6.0424
0.24	6.0340	0.8	6.0499
0.27	6.0240	0.9	6.0847
0.3	6.0210	1	6.1205

Table 3. MAD for different values of α.

Exponential smoothing constant	MSE	Exponential smoothing constant	MSE
0	56.4940	0.18	53.4500
0.05	53.5100	0.2	53.4831
0.07	53.4900	0.3	53.7800
0.09	53.4700	0.4	54.2500
0.1	53.4575	0.5	54.8600
0.11	53.4500	0.6	55.5890
0.12	53.4375	0.7	56.5210
0.13	53.4314	0.8	57.7510
0.14	53.4288	0.9	59.4028
0.15	53.4300	1	61.6145

Variations of MSE and MAD with α are portrayed in Figure 1 and 2 respectively. The figures depict that the optimum values of smoothing constant in trial and error method are 0.14 and 0.31 for minimum MSE and MAD respectively.

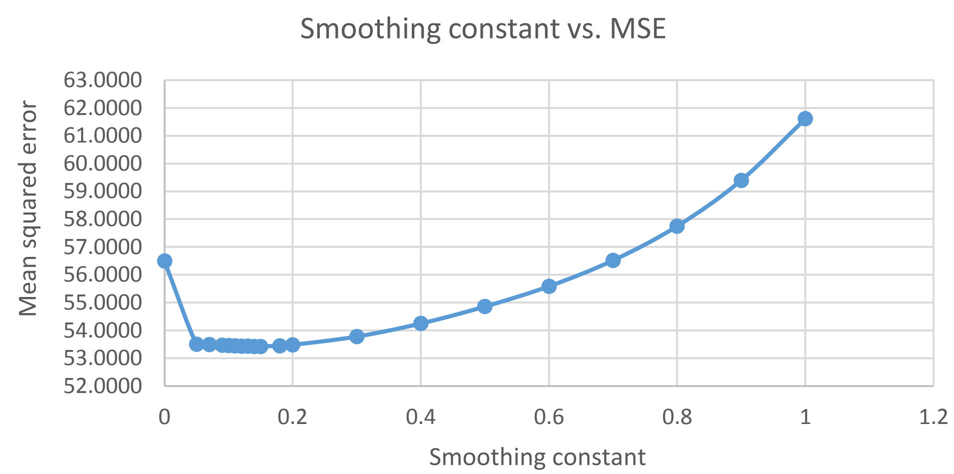

Figure 1. Variation of mean square error for different values of α.

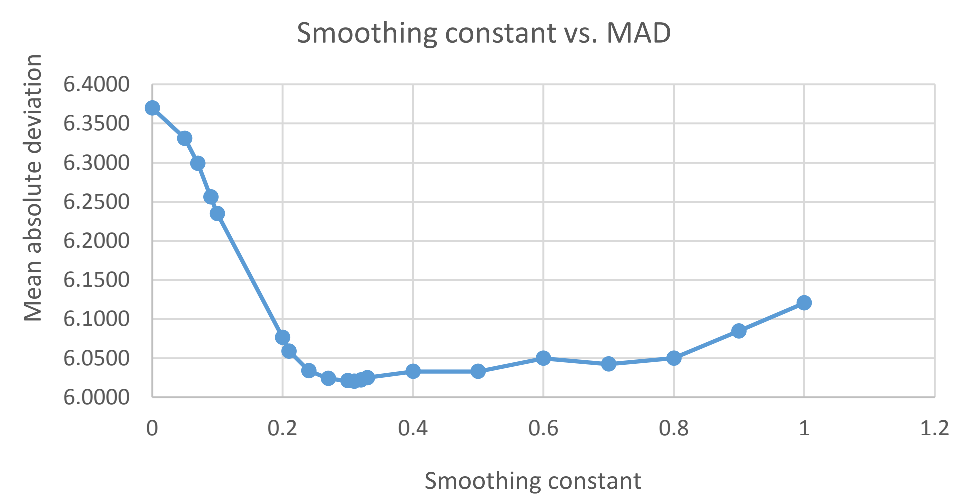

Figure 2. Variation of mean absolute deviation for different values of α.

To calculate optimum values of smoothing constant in Excel Solver, forecasts for all the (past) periods for which demand data are available are calculated using Eq. (1). Then, forecast errors (MSE, MAD) are calculated using necessary equations excluding period 1 putting smoothing constant zero. Table 4 summarizes the actual and forecasted values when smoothing constant is considered zero. Forecasted values are shown in the parentheses; for example, value 60 packets (2^{nd} row, 2^{nd} column) is the forecast value corresponding actual value of 67 packets.

After preparing the spreadsheet, Excel solver is invoked. In the “Set objective field”, the cells containing the value of MAD and MSE are specified for minimizing. In the “By Changing

Variables" cell, the cell having smoothing constant is specified. At last, constraints are defined where constraints are $0 \leq \alpha \leq 1$. The solver provides optimum values of smoothing constant 0.31 and 0.14 for minimum MAD and MSE respectively. Performance measures of two approaches are shown in Table 5.

Table 4. Actual and forecasted values for α=0.

Month	Year						
	2010	2011	2012	2013	2014	2015	2016
January	60 (60)	55(60)	65(60)	54(60)	68(60)	71(60)	54(60)
February	62(60)	67(60)	68(60)	49(60)	65(60)	69(60)	58(60)
March	57(60)	61(60)	52(60)	51(60)	57(60)	72(60)	69(60)
April	59(60)	63(60)	49(60)	58(60)	54(60)	75(60)	57(60)
May	68(60)	62(60)	68(60)	69(60)	70(60)	69(60)	71(60)
June	61(60)	59(60)	59(60)	70(60)	71(60)	54(60)	77(60)
July	59(60)	54(60)	57(60)	75(60)	72(60)	59(60)	59(60)
August	72(60)	52(60)	59(60)	71(60)	57(60)	68(60)	58(60)
September	65(60)	58(60)	52(60)	68(60)	55(60)	62(60)	48(60)
October	69(60)	59(60)	51(60)	71(60)	59(60)	63(60)	57(60)
November	63(60)	62(60)	56(60)	70(60)	68(60)	53(60)	71(60)
December	58(60)	63(60)	69(60)	69(60)	54(60)	51(60)	68(60)
MAD= 6.37 and MSE= 53.49							

Table 5. Summary of results.

Methods	Minimum MAD	Optimum smoothing constant(α)	Minimum MSE	Optimum smoothing constant(α)
Trial and Error	6.0205	0.31	53.4287	0.14
Excel Solver	6.0199	0.314	53.4286	0.143

5. Conclusion

A single exponential smoothing is one of the important forecasting techniques that is widely used by many organizations for predicting the future events. However, difficulties arise as the value of percentage error (smoothing constant) is taken randomly. The accuracy of the technique highly depends on the choice of appropriate value of smoothing constant. The value should be assigned in such a way that it reduces the forecast error. This paper focuses on applying trial and error approach and Excel Solver in order to determine the optimum value. This paper also shows that Excel solver is much easier and less time consumer approach than trial and error method. This study can help the industry as well as other Bangladeshi planners to compute the optimal value of exponential smoothing constant to enhance the accuracy of forecasting. In this paper, only two types of forecasting errors (mean absolute deviation and mean squared error) are minimized. In future, the work can be extended to minimize other forecast error such as mean absolute percent error (MAPE), tracking signal (TS), etc.

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