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The holt-winters multiplicative model of passengers' traffic forecast of the Nigeria airports

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Abstract
This research work was carried out in response to the need as a result of increase in Nigeria population and the demand for air transport facilities, this research was carried out using the data of the Federal Airport Authority of Nigeria (FAAN) is a federal government agency, set up to manage every commercial airport in the country, as well as making sure that, it provides services to both the airlines and the passengers in the airports. FAAN has a total number of 23 airports out of which four are international airports, seven are domestic airports and twelve are other domestic airports with the total number of 75,879,653 passengers between Jan. 2003 and Dec. 2011. The passengers' traffic of FAAN's data of 2003 to 2011 was collected and forecasted using the NCSS computer package to generate the Holt-Winters multiplicative model with coefficient of determination, R^2 of 91.04 and the models was used to forecast for the years 2012 to 2019 using the model.

Keywords: Passenger's traffic forecast, air transportation, holt-winters multiplicative

Introduction

The Federal Airports Authority of Nigeria FAAN is a federal government agency, set up to manage every commercial airport in the country, as well as making sure that, it provides services to both the airlines and the passengers in the airports. Nigeria has total number of four (4) international airports (Lagos, Abuja, Kano and Port Harcourt), seven (7) domestic airports (Calabar, Enugu, Jos, Kaduna, Maiduguri, Sokoto and Yola) and twelve (12) other domestic airports (Akure, Bauchi, Benin, Ibadan, Gombe, Ilorin, Katsina, Makurdi, Minna, Owerri, Warri and Zaria), summing up to 23 airport in Nigeria. At each airport, records are kept daily, weekly and then compiled into monthly statistical report of passengers (InfoGuide Nigeria, 2020; Adenira, Skanyio and Owoeye, 2018) [11, 1].

The research conducted by Travelstart (2016) [21] revealed that, Nigerian airports lack facilities (59%), general conduct of officers of forces such as immigration, port health, customs (57%) and careless handling of luggage (44%) as the top pain points of travelling through Nigerian airports. Vos (2016) [23] also reflected on the unfavourable conditions of the Nigerian airports as the worst on the continent. Similarly, CNN Travel (2016) [4] ranked Port Harcourt as the worst airport in the world. Travelstart (2016) [21] further suggested to FAAN that in order to improve on the Nigeria airports, the following facilities should be added or improve on: Wi-Fi, air conditioning, customer service and staff training. In view of these problems and the rapid growth in Nigeria population, there is need for FAAN to predict the passengers' traffic bearing in mind these problems.

Predicting the future has been one of the highly desired ambitions of individuals, organizations and even nations. The desire to forecast the future is as old as the human race. A predictor may try to predict where the prey will run, and there are other examples. In ancient times, people relied on prophets, soothsayers and crystals ball. Today we have computers and with them an impressive ever-expanding array of quantitative capacities (Murat, 2014) [15].

Gelper, Roland and Christophe (2008) [7] stated that, Peter Winters generalized Holt's linear method in 1960s to come up with such a technique, now called Holt-Winters method (Triple Exponential Smoothing). It is an extension of exponential smoothing designed for trended and seasonal time series. Holt-Winters smoothing is a widely used tool for forecasting business data that contain seasonality, changing trends and seasonal correlation. A seasonal equation is added to Holt's linear method equations. This is done in two ways, additive and multiplicative model.

According to Makridakis and Wheelwright (1989) [13], Holt-Winters model produces results similar to those of linear exponential smoothing but it has the extra advantage of being capable of dealing with seasonal data in addition to data that have trend. The authors further explained that Winters' linear and seasonal exponential smoothing is based on three equations, each of which smooth a factor associated with one of the three components of the pattern: randomness, trend and seasonality in this respect it is similar to linear exponential smoothing which smooth for randomness and adjusted for trend, however, Winters' method includes an additional parameter to deal with seasonality.

Predicting the future has been one of the highly desired ambitions of individuals, organizations and even nations. The desire to forecast the future is as old as the human race. For instance, in the primitive society, a predictor may try to predict where the prey will run. In ancient times, people relied on prophets, soothsayers and crystals ball. During the last few decades, the study of air travel demand has attracted considerable attention from researchers, alternative methods have been used for modelling and forecasting air passengers demand such as the econometric models (Suryani, Chou and Chen 2010; Aderamo, 2010; Huber, 2010; Profillidis, 2012 and Scarpel 2013) [20, 2, 10, 16, 17], time series models (Samagaio and Wolters, 2010; Min, Kung and Liu, 2010; Xie, Wang and Lai, 2014) [18, 14, 24], artificial intelligence (Alekseev and Seixas, 2009; Kuo, Shiau and Chang 2012; Chen, Kuoa Chang and Wang, 2012) [3, 12, 5] and judgmental approaches and gravity models (Dennis, 2002; Grosche, Rothlauf and Heinzl, 2007 and Sivrikaya and Tune, 2013) [6, 8, 19]. Today we have computers and with them an impressive ever-expanding array of quantitative capacities. According to Karlaftis, (2010) [9] and Tsui, Balli, Gilbey and Gow, (2014) [22], the choice of any methodology is dependent on how successful a model can forecast air passengers' demand.

Methodology

The data for this work were collected from FAAN which has the total number of 23 airports with total number of 75,879,653 passengers between Jan. 2003 and Dec. 2011. At each airport, records are kept daily, weekly and then compiled into monthly statistical report of passengers. Hence, a historical record is generated at any time (t) for a parameter to be used as input. The monthly records were used because, using the data on individual airport or daily or monthly records basis will not yield the expected result as some airport were shut-down for some reasons for a number of months, therefore, all operations at such airports were also closed.

The data from the target population (FAAN) see Table 1 were subjected to Holt-Winters models. According to Makridakis and Wheelwright (1989) [13], "one of the problems accompanying the use of winters method is determining the values for α, β and γ that will minimize MSE or MAD, the approach for doing this manually is trial and error. The search for the values is made by a grid approach where the results using different values for α, β and γ are compared to find the combination that minimizes MSE or MAD. With today's computer statistical packages (Microsoft Excel, SPSS, NCSS, etc), finding the best values of α, β and γ is no longer the problem".

Table 1: Airport Passengers' traffic data (2003-2011)

Months	2003	2004	2005	2006	2007	2008	2009	2010	2011
JAN	422087	769774	649381	573811	766533	870312	907734	1013162	1155534
FEB	368798	630439	651599	537053	605140	709612	833383	932974	1116266
MAR	409208	637620	703403	575451	663107	801311	881514	1009540	1258140
APR	397815	696343	723280	678026	611393	892009	1030886	1116548	1048730
MAY	432962	644540	700510	685223	624286	839736	970442	1106072	1217093
JUN	438920	603808	662364	692077	525647	847083	982455	1103273	1176033
JUL	389859	705917	690873	725483	722781	872444	1059254	1223256	1203799
AUG	501050	720943	786968	773118	776005	1027829	1112405	1297332	1305966
SEP	521221	704563	767004	718594	725295	935087	1061347	1278015	1212442
OCT	522837	656704	714077	774278	783811	868082	1220964	1241689	1369923
NOV	494596	634024	611318	676999	745221	1056987	1178374	1234545	1329764
DEC	556781	752477	649738	798082	860725	1109080	1287706	1425271	1358149

According to Makridakis and Wheelwright (1989) [13], Holt-Winters model is classified as either additive or multiplicative model, but in this research work, the multiplicative model was used.

The Multiplicative Holt-winter's model
Initial

$$L_s = \frac{1}{s}\sum_{i=1}^{s} y_i \quad (1)$$

$$b_s = \frac{1}{s}\left[\frac{y_{s+1} - y_1}{s} + \frac{y_{s+2} - y_2}{s} + \cdots + \frac{y_{2s} - y_s}{s}\right] \quad (2)$$

$$S_s = y_i - L_s, \; i=1,\ldots,s \quad (3)$$

Choose $0 \le \alpha \le 1$, $0 \le \beta \le 1$ and $0 \le \gamma \le 1$

Compute for t > s:

forecast $F_{t+1} = (L_t + b_t) S_{t+1-s}$ (4)

level $L_t = \alpha \frac{y_t}{s_{t-s}} + (1 - \alpha) (L_{t-1} + b_{t-1})$ (5)

trend $b_t = \beta (L_t - L_{t-1}) + (1 - \beta) b_{t-1}$, (6)

seasonal $S_t = \gamma \frac{y_t}{L_t} + (1 - \gamma) S_{t-s}$ (7)

Until no more observations are available and subsequent forecasts

$F_{n+k} = (L_n + k b_n) S_{n+k-s}$ (8)

Where
Level: is the smoothed deseasonalized series.
Trend: is the general direction in which the graph of a time series appears to be going over a long interval of time.
Seasonal: is the identical or almost identical pattern that a time series appears to follow during corresponding months or quarters of successive years.
Makridakis and Wheelwright (1989) [13] suggested that, for a time series, you select the Holt Winters algorithms with the smallest SSE or RMSE or MAPE and also stated the following specific measures of accuracy that can be used with a wide variety of methods:

1. Mean error

$$ME = \frac{\sum_{i=1}^{n} e_i}{n} \quad (9)$$

2. Mean absolute deviation

$$MAD = \frac{\sum_{i=1}^{n} |e_i|}{n} \quad (10)$$

3. Mean squared error

$$MSE = \frac{\sum_{i=1}^{n} {e_i}^2}{n} \quad (11)$$

4. Standard deviation of error

$$SDE = \sqrt{\frac{\sum_{i=1}^{n} {e_i}^2}{n-1}} \quad (12)$$

5. Percentage error

$$PE_t = \frac{X_t - F_t}{X_t} 100 \quad (13)$$

6. Mean percentage error

$$MPE = \frac{\sum_{i=1}^{n} PE_t}{n} \quad (14)$$

7. Mean absolute percentage error

$$\text{MPE} = \frac{\sum_{i=1}^{n} |PE_t|}{n} \quad (15)$$

Passengers' Traffic of Federal Airport Authority of Nigeria Analysis and Result

The NCSS (Trier version) software was used to analyze the data of Table 1 above and the result is as shown below in Table 2.

Table 2: Winter's with multiplicative seasonal adjustment

Number of Observations	96
Mean	790413.1
Coefficient of Determination (R^2)	0.910363
Mean Square Error	4957439000
Mean |Error|	54449.39
Mean |Percent Error|	7.198336
Mean	790413.1
Alpha	0.393743
Beta	0.01924684
Gamma	0.49491
Intercept (a)	379494.4
Slope (b)	9132.579

From Table 2, the results shows that, the multiplicative model explains 91.04% of the variation in the passengers' traffic while the remaining 8.96% can only be explained by chance.
The multiplicative model is.

From Table 2 above, the multiplicative forecast model is given as

$F_{t+1} = L_t + kb_t + S_{t+1-s}$

But $L_t = 0.39374(y_t - S_{t-s}) + 0.60626(L_{t-1} + kb_{t-1})$ (16)

$b_t = 0.01924684(L_t - L_{t-1}) + 0.98075316b_{t-1}$ (17)

$S_t = 0.49491(y_t - L_t) + 0.50509S_{t-1}$ (18)

Therefore, $F_{t+1} = 0.39374(y_t - S_{t-s}) + 0.60626(L_{t-1} + kb_{t-1}) + k(0.01924684(L_t - L_{t-1})$

$+ 0.98075316b_{t-1}) + 0.49491(y_t - L_t) + 0.50509S_{t-1}$ (19)

And the multiplicative forecast model from Table 2 is given as

$F_{t+1} = [0.39374(y_t - S_{t-s}) + 0.60626(L_{t-1} + kb_{t-1}) + k(0.01924684(L_t - L_{t-1}) + 0.98075316b_{t-1})]\ [0.49491(y_t - L_t) + 0.50509S_{t-1}]$ (19)

Hence the multiplicative model.

Forecast for 2012 to 2019 or Out of Sample Forecast

The forecast for the years 2012 to 2019 using the model (equation 19) is depicted in figure 1.
Since the R^2 (coefficient of determination) is very large (0.910363 or 91%), our model gives a good forecast and hence a good model is obtained.

Model Accuracy

A plot of the actual and forecasted values are shown in Fig 1 and the plot of residual (e_t) was made against time (t) and plot appears to show a random behavior of the residuals indicating that there is no heteroscedasticity, thus there is no indication of the model's inadequacy, see Figure 2.

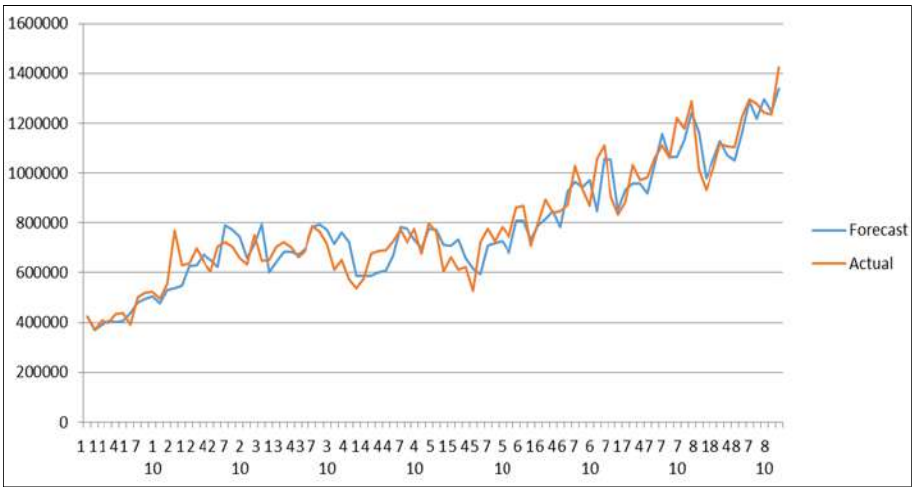

Fig 1: The plot of actual values and predicted values against time of Passengers traffic of Nigerian Airports for Multiplicative Winters' model

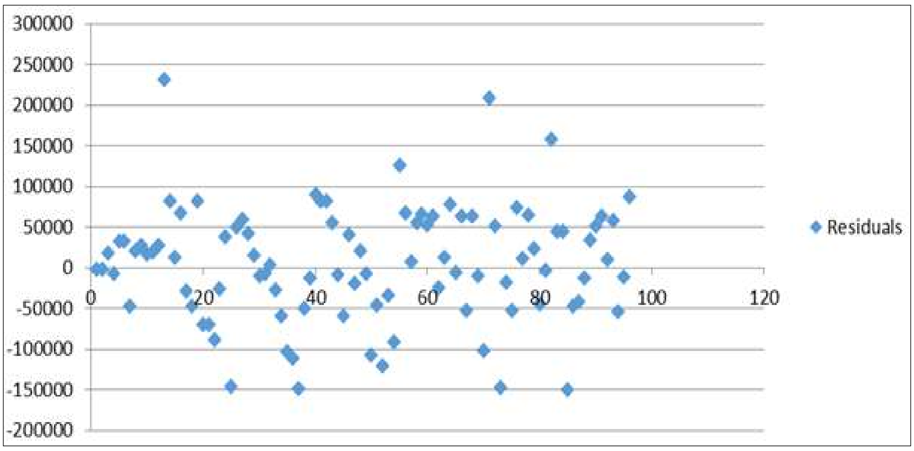

Fig 2: Residual plot of Passengers traffic of Passengers traffic of Nigerian Airports for Multiplicative Winters' model.

Findings

The following findings resulted from this work

1. The multiplicative Holt-Winters model was formulated.
2. The multiplicative Holt-Winters model was used to forecast the FAAN passengers' traffic.
3. The multiplicative Holt-Winters model gives a better fit statistics for the passengers' traffic of the air transport than other types of models.
4. FAAN can use the multiplicative Holt-Winters models in forecasting their passengers' traffic.
5. Any data of this nature can be forecasted using multiplicative Holt-Winters model.

Recommendations

Based on the work done so far on this research, one can make the following recommendations that

- The multiplicative method of Holt-Winters model should be used to forecast the time series data of the passengers' traffic of the air transport.
- The Federal Airports Authority of Nigeria adopts the multiplicative method of Holt-Winters model to predict the traffic of passengers she can expect for the next months or years (up to 20 years).
- The Federal Airports Authority of Nigeria pays attention to the seasonal indexes in order to know the peak and low periods of the traffic of passengers.
- Future researchers should consider individual airport time series data.
- Future researchers should also consider additive Holt-Winters model.
- Any flaw identifiable from this work should be corrected by the future researcher.

Summary and Conclusion

Objectively, this study has been applied to all the laid down procedure to collect, analyze and interpret the data of passengers' traffic of the Federal Airports Authority of Nigeria. While the outcome of the forecasting techniques of the time series has yielded a forecasting model: Holt-Winters multiplicative model for the passengers' traffic of Nigerian Airports. The Holt-Winters multiplicative model the time series yield the best model to forecast the passengers' traffic of the FAAN.

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