



Journal Homepage: - www.journalijar.com
**INTERNATIONAL JOURNAL OF
 ADVANCED RESEARCH (IJAR)**

Article DOI: 10.21474/IJAR01/8450
 DOI URL: <http://dx.doi.org/10.21474/IJAR01/8450>



RESEARCH ARTICLE

THE APPLICATION OF DEMAND FORECAST MODELS IN TEMPORARY SERIES OF THE AIRPORT OF THE CITY OF RIBEIRÃO PRETO IN THE STATE OF SÃO PAULO

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Manuscript Info

Manuscript History

Received: 20 November 2018
 Final Accepted: 22 December 2018
 Published: January 2019

Key words:-

Forecast Demand; Templates; Air variables; Time series.

Abstract

Air transport has the function of stimulating economic relations and the exchange of people and goods, being an active sector in the world economy. The objective of this research is the application of the forecast methods of Holt demand, Smoothing, Winter, Regression and Moving Average at the State Airport Dr. Leite Lopes located in Ribeirão Preto contributing to its operational performance and strategic planning. From the results it is observable which model is relevant the demand of passengers, aircraft and cargoes, with tendency to the growth of the demand through the analyzed years contributing to the air demand.

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Introduction:-

Air transport is a type of modal essential to foreign trade, as it has as an important function to stimulate economic relations and the exchange of people and goods, whether inside or outside the country, besides being considered one of the most active sectors of the world economy and of great importance to the Brazilian transport matrix (Almeida et al., 2007; Azevedo and Ortigoza, 2008).

There are several reasons why the airport system has shown great growth, some of which are: economy growth, inclusion of passengers in classes B and C, cost / benefit ratio, economic stability, among others (Marcos and Ferreira, 2015).

An airport that can be highlighted would be the Dr. Leite Lopes State Airport, located in the city of Ribeirão Preto, because according to Presa and among others (2012) this airport serves not only the city to which it belongs, but also cities located in one radius of approximately 100 km away.

In this case the demands within the air transportation market are always analyzed by statistical reports of the movement of these time series as data sources official government bodies that sustain the exploitation of air data such as passengers, cargo and flights by means of a research method to monitor their longitudinal behavior (ANAC and DAESP, 2018).

The research aims to carry out an application of the methods of forecasting passenger, aircraft and cargo demand at the Dr. Leite Lopes State Airport located in Ribeirão Preto, in the interior of the State of São Paulo, in order to verify and choose which method it has the most suitable result for the airport. The choice of this airport occurred because it is a place responsible for transporting people not only from the city of Ribeirão Preto but also from the

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cities of the region, another important factor was the fact that it is a hub of logistics operators and logistics providers with the tendency and need to set up an international cargo airport.

This study may contribute to the demand analysis of the aforementioned airport as a service offering through the application of five demand prediction methods revealing if it is adequate to its operational demand, and therefore concluding about its capacity to meet the needs of a population dependent on it, as an instrument of strategic urban and regional mobility planning.

**Theoretical reference: -
Demand Forecast**

For a company to realize a forecast of demand is fundamental, since from it it is possible to obtain the accomplishment of a planning and control of all the functional areas, encompassing the sector of logistics, marketing, production and finances. Demand patterns and schedules greatly influence capacity levels, financial needs, and overall business support. In the company, each functional area has its type of problem in relation to the forecast (Ballou, 2009).

As stated by Bortoletto et al. (2016), the forecast of demand is used to verify some events and trends that became indispensable at the time of the strategic planning of the company.

To manage any business environment, you need to calculate estimates or even anticipate future market behavior in order to adjust features and operational strategies. Due to this need, demand planning has become one of the main points where managers centralize efforts to find an optimal solution (Senna et al., 2015).

The forecast of demand can be divided into two methods, being qualitative and quantitative (Almeida, 2010).

The qualitative or subjective forecasting method can be defined using research, comparative techniques, concepts, judgments and experiences of individuals, such as managers, suppliers, suppliers, customers, etc., who generally have the ability to produce quantitative estimates according to the future. (Davis et al., 2001; Ballou, 2009). This method is used when it is intended to predict long-term demand or when difficulties make this process difficult (Chopra and Meindl, 2011), which are: lack of time to collect and analyze data from previous demands, new product launches and end to economic and political instability, which may render data obsolete (Tubino, 2007).

On the other hand, the quantitative or forecasting method is one that uses mathematical models, based on historical data, whose purpose is to estimate future sales (Gaither and Frazier, 2002). This method is subdivided into two genera: causal methods and time series analysis (Moreira, 2008).

The causal method uses historical data associated with several types of independent variables and aims to identify which variables influence the behavior of demand and indicate which relationship is usually applied in the medium and long term (Davis et al. Wanke and Julianelli, 2006, Krajewski et al., 2009, Lelis, 2012). And time-series analysis is a statistical technique applied when historical data is used to project the future of this demand, taking into account that the past patterns of demand have been repeated in the future, and identifying the seasonal trends. This technique is efficient since it is used in a short-term period, with stable and defined variables (Ballou, 2001; Lustosa et al., 2008; Lelis, 2012).

Table 1 presents the authors as the basis for a proposal of demand forecast models.

Table 1:-Definition of demand forecast models

Method	Authors	Models		Definition
Qualitative	Peinado and Graeml, 2007	Prediction	It is to determine what will happen in the future based on subjective data, that is, a bet on how it will be in the future.	
	Peinado and Graeml, 2007	Opinion of the executives	It takes into account the opinion of a small group of high-level executives and is used when no historical data is available.	

	Davis <i>et al.</i> , 2001; Peinado and Graeml, 2007	Delphi method	It is a questionnaire that takes into account the opinion of some individuals, which is done through anonymity so that there is no interference from someone more influential.
	Peinado and Graeml, 2007	Sales team opinion	This is when you directly ask the sales team to provide the estimated sales of a particular product in a given region.
	Krajewski <i>et al.</i> , 2009; Peinado and Graeml, 2007	Market research	It is an organized investigation designed to obtain information so that it is possible to solve some type of problem and increase the consumer's intention to purchase a particular product or service.
	Davis <i>et al.</i> , 2001; Peinado and Graeml, 2007	Analogy with similar products	It is to get historical data of a similar product so that the company can use as the basis for the intended product, which does not have historical data.
Quantitative	Wanke and Julianelli, 2006; Peinado and Graeml, 2007	Simple Moving Average	It is an arithmetic mean of the last periods of observed demand.
	Davis <i>et al.</i> , 2001; Peinado and Graeml, 2007	Weighted Moving Average	It is similar to the simple moving average, but different weights are considered for different periods of demand. The last period of the demand uses a greater weight than the penultimate one and so on.
	Tubino, 2007; Peinado and Graeml, 2007	Mitigation exponencial	It is performed by adjusting the forecast of the current period with the forecast error, where the correction is performed by a weighting weight that goes up exponentially as the periods are more recent.
	Peinado and Graeml, 2007	Linear Regression	Define an equation of the line that makes it possible to extrapolate the projections for the future.
	Wanke and Julianelli, 2006; Peinado and Graeml, 2007	Holt	It is an adaptation of the mitigation exponential, because it uses two weighting coefficients that adjust the level and the trend of the series.
	Wank and Julianelli, 2006; Peiando and Graeml, 2007	Winter	It is used to adjust three weighting coefficients, being the level, the trend and the seasonality of the demand.

Source: Authors.

Measures Of Accuracy

Accuracy measurements are used to verify which demand forecasting method should be chosen according to the best representation of the data series to be forecast, and for that selection to occur, error indicators that measure performance measures (Almeida, 2010, Consul and Werner, 2010, Khoury, 2011). According to Corrêa and Corrêa (2012) there are two types of error indicators that need to be monitored, being they the amplitude and the bias.

The amplitude can be monitored by using the Mean Absolute Deviation (MAD), which is the average of the Absolute Errors calculated in the studied period, followed by the Mean Percent Error (SEM), which is the mean of the errors in percentage calculation and last can be controlled by means of the Mean Absolute Error (MAPE), which is the mean of errors in absolute percentages (Wanke and Julianelli, 2006). For the bias calculation, the traceability signal is used (Correa and Correa, 2012).

Methodology:-

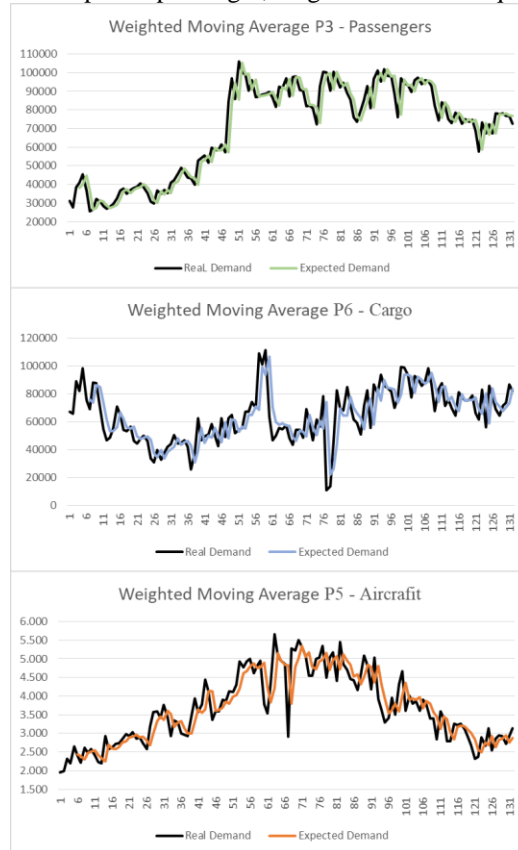
The research has a descriptive, bibliographical, quantitative and applied approach to the airport demands of the Dr. Leite Lopes airport located in the city of Ribeirão Preto, using data from the statistical reports of movement between the 2007 to 2017 longitudinal period of the official entity (DAESP) , (2018).

The descriptive and bibliographic research aims at describing the characteristics of a given population or phenomenon or, therefore, establishing relations between variables and is developed based on already elaborated materials, composed mainly of books and scientific articles (Gil, 2002) . On the other hand, quantitative research using quantification, both in the collection and in the treatment of information, using statistical techniques, aiming at results that avoid possible distortions of analysis and interpretation, allowing a greater margin of safety (Dalfovo et al. 2008). These data were later inserted in @excel, performing the hypothesis tests with the demand prediction methods for each month of each year analyzing the behavior of the time series of the passenger, cargo and aircraft variables and the impact of the progression by the applied methods for the result text and discussion.

Results and discussion:-

From the tabulated data it was possible to perform graphs showing the demands of passengers, cargo and aircraft for the period 2007 to 2017, the trend lines and the equation of the line, as shown in figure 1, the horizontal axis being represented for months and the vertical axis the quantity of each variable in thousands.

Figure 1:-Graphs of passenger, cargo and aircraft requirements



Source: Authors (2018).

Then, the analyzed variables were submitted to the demand prediction methods, being:

The Simple Moving Average according to Peinado and Graeml (2007) is applied to demands that do not show tendency or seasonality, thus using only data that do not present great variation and this model can easily be calculated through its mathematical formula expressed below.

$$P_j = \frac{\sum_{i=1}^n D_i}{n} \quad (1)$$

The Weighted Moving Average is a model that in the words of Peinado and Graeml (2007) resembles the one of Simple Moving Average in the scope of the application of data that do not present tendency and seasonality, but differ since the data values of the nearer periods are considered more important in the definition of the forecast than the distant periods, so this model can be expressed mathematically by the following formula:

$$P_j = (D_1 \times PE_1) + (D_2 \times PE_2) + (D_3 \times PE_3) + \dots + (D_n \times PE_n) \quad (2)$$

$$\text{Sendo } PE_1 + PE_2 + PE_3 + \dots + PE_n = 1$$

The exponential smoothing according to Pellegrini (2000) the time series remains constant above an average level and manifests mathematically in the following expression

$$\hat{z}_{t+1} = \alpha z_t + (1 - \alpha) \hat{z}_t \quad (3)$$

The Holt Method described by Pellegrini (2000) can be applied in time series with a linear tendency, it has two smoothing constants (α and β) that must have values between 0 and 1 and this model is represented by three equations

$$L_t = \alpha z_t + (1 - \alpha)(L_{t-1} + T_{t-1}) \quad (4)$$

$$T_t = \beta(L_t - L_{t-1}) + (1 - \beta)T_{t-1} \quad (5)$$

$$\hat{z}_{t+k} = L_t + kT_t \quad (6)$$

Linear Regression is nothing more than a modeling of a mathematical equation that reproduces the relation between two variables. This method can be expressed through a linear equation according to Rodrigues et al 2013 which has two main characteristics, being they the coefficient of angularity and the linear coefficient of the line at a certain point

$$y_i = \alpha + \beta x_i + \epsilon_i \quad (7)$$

$$\text{Sendo } i = 1, 2, \dots, n$$

The Winter Method according to Graeml (2007) is used when the data present a seasonal behavior. The method can be divided into two groups as per second Pellegrini (2000), which are referred to as additive and multiplicative. In the words of second Pellegrini (2000) the multiplicative model is employed in the modeling of seasonal data so that the amplitude of the cycle varies over time and has its mathematical representation expressed by

$$L_t = \alpha \frac{z_t}{S_{t-s}} + (1 - \alpha)(L_{t-1} + T_{t-1}) \quad (8)$$

$$T_t = \beta(L_t - L_{t-1}) + (1 - \beta)T_{t-1} \quad (9)$$

$$S_t = \gamma \frac{z_t}{L_t} + (1 - \gamma)S_{t-s} \quad (10)$$

$$\hat{z}_{t+k} = (L_t + kT_t)S_{t-s+k} \quad (11)$$

On the other hand, the additive method in the words of second Pellegrini (2000) is also used in the modeling of seasonal data so that the amplitude of the cycle remains constant through time and has its mathematical representation expressed by

$$L_t = \alpha(z_t - S_{t-s}) + (1 - \alpha)(L_{t-1} + T_{t-1}) \quad (12)$$

$$T_t = \beta(L_t - L_{t-1}) + (1 - \beta)T_{t-1} \quad (13)$$

$$S_t = \gamma(z_t - L_t) + (1 - \gamma)S_{t-s} \quad (14)$$

$$\hat{z}_{t+k} = L_t + kT_t + S_{t-s+k} \quad (15)$$

Winter's method cannot be applied to this study because it does not contain data that have a seasonal behavior.

For both the Simple Moving Average and the Weighted Moving Average, two to six periods were used to calculate the mean, since above that, the traceability signal presented a bias well beyond acceptable. In order to improve the value of weights in the Weighted Moving Average and the alpha and / or beta parameters of exponential smoothing and the Holt Method, we used the Excel add-on called Solver, which tends to minimize the Absolute Mean Error (MAE) of the last analyzed period. The Linear Regression Method was calculated from the equation of the line of trend generated in the demand graphs.

After the implementation of the demand forecast models, the performance indicators were applied for each method used, in order to decide which methodology would be the most appropriate for passengers, cargo and aircraft. And for this decision were considered both the breadth and the bias of the errors. Table 1 below shows the result of applying forecasting methods and errors obtained for passengers.

Table 1:-Result of application of forecasting methods and errors obtained for passengers

Method	Median Absolute Error (MAE)	MAD	MPE	MAPE	Traceability Sign
Simple Moving Median – S2	5.372,30	5.221,08	0,33%	8,28%	OK
Weighted Moving Median - P3	4.971,76	4.315,53	0,02%	7,33%	OK
Exponential Mitigation	5.092,37	4.730,50	-0,20%	7,56%	OK
Holt's Method	5.151,71	4.734,47	-0,88%	7,85%	OK
Linear Regression	15.131,77	13.481,35	-7,77%	24,25%	OK

Source: Authors.

In order to forecast passenger demand, it is suggested that the Weighted Moving Average (P3) method be used, because it presents the lowest MAE, MAD, MPE and MAPE, and that its Traceability Signal pointed to a bias within the allowed. In table 2 bellow, is the result for loads.

Table 2:-Result of application of prediction methods and errors obtained for loads

Method	Median Absolute Error (MAE)	MAD	MPE	MAPE	Traceability Sign
Simple Moving Median – S3	10.545,39	10.682,82	-7,37%	21,48%	OK
Weighted Moving Median – P6	9.472,27	8.759,48	-6,43%	19,35%	OK
Exponential Mitigation	10.065,89	9.918,66	5,91%	20,09%	OK
Holt's Method	10.068,78	9.916,22	-6,09%	20,06%	OK
Linear Regression	13.253,64	15.647,56	-12,49%	27,42%	OK

Source: Authors.

Analyzing Table 2, we can recommend the use of the Weighted Moving Average (P6) method, since the error amplitude indices were the lowest and the Traceability Signal is within the allowed parameters. In table 3 below, is the result for aircraft.

Table 3:-Result of application of prediction methods and errors obtained for aircraft

Method	Median Absolute Error (MAE)	MAD	MPE	MAPE	Traceability Sign
Simple Moving Median – S2	344,38	289,67	-0,50%	9,38%	OK
Weighted Moving Median –	322,85	262,15	-0,69%	8,78%	OK

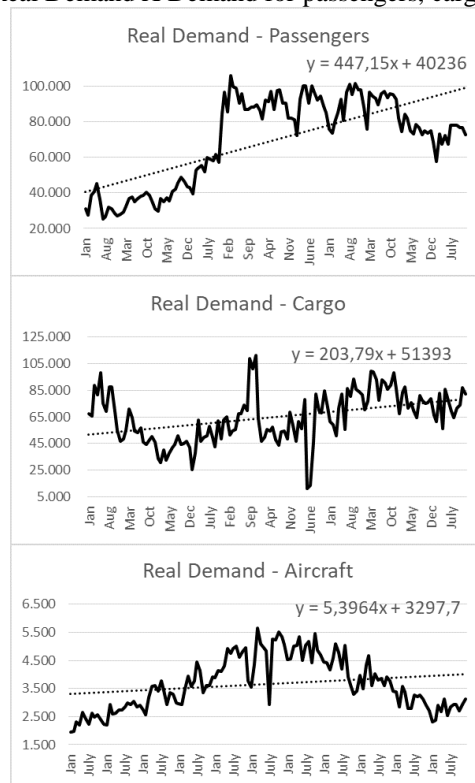
P5					
Exponential Mitigation	337,34	323,07	0,54%	8,95%	OK
Holt's Method	337,46	323,55	-1,43%	9,50%	OK
Linear Regression	778,44	767,61	-5,54%	21,89%	OK

Fonte: Elaborado pelos autores.

Considering Table 3, it is proposed to apply the Weighted Average Mobile Method - P5, because when analyzing the error indicators it is noted that the MAE, MAD and MAPE are smaller than the other models examined and their Traceability Signal is inside of tolerated bias.

After analyzing the five demand forecasting methods for the three variables studied (passengers, cargoes and aircraft) and proposing the best method for each variable, it was possible to visualize the relation between the actual demand and the expected demand.

Figure 2:-Real Demand X Demand for passengers, cargo and aircraft



Source: Authors

It is considered in figure 2 that:

1. Weighted Moving Average P3 - Passengers: the longitudinal periods of major falls are comprised respectively in the months from September to November 2007, February to June 2014, April to June 2015 and April to June 2016 and the discharges are comprised respectively in the months from March to May 2010, June to August 2013, June to September 2014 and June to September 2015, so through an overview we can identify that there was a period of growth of demand in the period from July 2007 to September 2011, and it can be pointed out that the analyzed variables have a marked high period in the year of 2010 between the months of March to July.
2. Weighted Moving Average P6 - Loads: Longitudinal periods of higher falls are comprised respectively in the months from April to August 2008, June to September 2012 and November to December 2013 and the discharge periods are comprised respectively in the months from August to October of 2010, from March to April 2012 and from December 2013 to March, so through an overview we can identify that there was a period of demand growth in the period from August 2010 to December 2015, and it may be pointed out that the analyzed variables have a period high in the years of 2011 and 2012 between the months of November to July and also in the years of 2013 and 2014 between the months of December to March, already abrupt falls related

the variables occur in the years of 2012 and 2013 between the months of June to September 2012 and November to December 2013.

3. Weighted Moving Average P5 - Aircraft: Longitudinal periods of greatest falls are comprised respectively in the months from April to June 2012, August to December 2012 and January to April 2013 and the highs are comprised respectively in the months from June to August of 2012 and December of 2012 to January of 2013, being able to emphasize that the variables analyzed have as characteristic high accentuated periods and abrupt falls related to the analyzed variables, so through an overview we can also identify that there was a period of growth of the demand in the period from November 2007 to April 2013.

Conclusion:-

1. This study aimed to apply the demand forecasting methods for passengers, cargo and aircraft, in order to check and choose which method presents the best result for each variable studied in a period of ten years.
2. By means of the analysis of the collected data, the quantitative methods applied the variables and the error indicators, it was concluded that the methods that obtained the best performance were: Weighted Moving Average - P3 for passengers, Weighted Moving Average - P6 for loads and Weighted Moving Average - P5 for aircraft.
3. Finally, it is suggested that for future research that more data be obtained, other quantitative methods applied such as Box-Jenkins, etc. and the use of qualitative methods is also indicated in order to improve the results obtained.

Abbreviations: -

ANAC: Agência Nacional de Aviação Civil/ NATIONAL AGENCY OF CIVIL AVIATION

DAESP: Departamento Aeroviário do Estado de São Paulo/ Department of Aviation of the State of São Paulo

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