Application of Forecasting Methods in the Planning Process of Supply and Demand in Aviation

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ABSTRACT: The aim of forecasting is gathering of knowledge, experiences and ideas about the future, which can be gained by rational approaches and logical thinking. The methods of forecasting can be used in solution of tasks, algorithms and intuitive prediction of future trends in the areas of supply and demand in transport aviation. It is not only a set of theoretical actions based on intuition and experience, but also a scientific branch based on mathematical analysis and processing of knowledge and information that can be used in the process of planning and control of operations in aviation in some future time frame. The scientific level of forecasting of demand and supply in aviation transport is given mainly by its complexity, completeness, synopsis and multirole use.

The aim of the article is to present the possibilities of application of forecasting methods in computation of prediction of the number of aviation passengers in a certain time frame. These methods can be also used for computation of forecasts during peak times during a day, week or year. The methodology results from estimation and precision of demands in logistic processes of future trends in supply and sales of goods and services on the market of transport aviation. The content of the article also includes a brief description of application of certain statistical and predictive methods in the area of creation of a general plan, economic, technical and organizational development of airports and airport companies. Possible fluctuations due to political, social, economic or weather factors are not considered in computation of forecasts of the number of air transported passengers.

INTRODUCTION

Only these companies that can efficiently and quickly satisfy the needs of their customers can achieve success on the aviation transport market. This relates not only air transport companies, but also to airports and airport companies, which need to adapt to the needs of transport companies. Highly professional approach and the supply of qualitative logistic services form the base of economic growth in aviation transport. This can result in increase of safety, efficiency and also the volume of the supplied transport services. This is a long term and difficult process, base of which is formed not only by qualitative employees and modern technological base, but it also demands a thorough planning process. The creation of prognostic plans, analytic studies and the ability to adapt to actual needs of the market and changes in legislative, technical, technological, safety and organizational structures all belong into this area [1],[10].

The base for strategic, tactic and operative decisions of the accepted measures is also represented by forecasting of demand for air transportation. It is about planning of new flight lines and destinations, forecasting of the amount of the transported passengers, fulfillment of seating capacities or tonnage of transported goods and so on. Air companies as well as airports; have to be personally technically and organizationally prepared for it. Possible scenarios of future development and the creation of a forecasting plan has to come from relevant and real materials, basis of which is formed by reliable information, consistency, results of analysis, simulations and modeling [2],[9],[10].

Helpful tools in the process of demand and sales forecasting in air transportation can be certain mathematic forecasting/prognostic methods, by use of which demand for air transportation can be forecasted and evaluated in a time frame of several years [8].

1 SIMPLE MOVING AVERAGE METHOD

It is a relatively simple method of a time series, base of which is represented by statistical data. Their obtaining and evaluation by solution of a specific decision making problem like the prognosis of the air transported passengers for the upcoming year is not trivial. Statistic data, which are at disposal have to be put into a statistic order, while the data have the character not only as section data, but also time series data expected in the following periods.

The method can also be used to forecast a number of air passengers in a certain period or to predict the number of passengers (tons of cargo) for a certain flight route, or seat utilization of a certain aircraft.

The formula for estimation of the forecast for demand of air transport by passengers (cargo, utilization of a route, line) for t+1 time period $P_{t,t+1}$ in t-th period has the following form:

$$\boldsymbol{P_{t,t+1}} = \frac{\sum_{i=0}^{n-1} S_{t-i}}{n}, \qquad (1)$$

where $\boldsymbol{S_{t-i}}$ is the number of transported passengers (tonnage of cargo, utilization of a line) during the previous $\boldsymbol{n}$ periods.

This method is however complicated to use for predictions in case of seasonal fluctuations in air transport, for example during one year, week or day. Such forecasts computed by the method of moving averages do not diverge from the total mean when looking at a larger time span (e.g. 5 and more years) [3].

2 THE NAIVE MODEL

The naïve model represents a hypothesis of relation between two values of the same variable (seating utilization of the chosen aircraft type for a certain route), which we observe in several consequent periods. This type of model can also be used for comparison of precision with other forecasting models, for example the regression models [4].

In one of the naïve models, we start from the assumption that the predicted value of a variable in the following period Y_{n+1} is best represented by a value from some common period Y_n. At the same time we assume that the error of the created formula is a stochastic element of the model with zero mean value and a constant dispersion. This model can include seasonal and trend fluctuations like the number of passengers traveling during a peak. The formula of the model is the following:

$$\boldsymbol{Y}_{n+1} = \boldsymbol{Y}_{n-3} \; \frac{Y_n - Y_n - 4}{4} \qquad (2)$$

The average value for the last four terms can be added to the term value of a certain variable (like a single year), thus adding the estimation of trend into the model.

3 WEIGHTED MOVING AVERAGE METHOD

By using the method, average values of a certain variable from a certain chosen number of empirical values from a time series can be computed. The computed average value is added to the mean period of the moving part of the time series [3].

During the calculation of prediction of air transport passengers (tons of cargo, seating utilization), the basis is formed by real weighted demands for passengers transport in real time and the transported passengers during a certain time period in the past.

We start from the formula:

$$\boldsymbol{S_{t+1-n} = P_{t,t+1}} \qquad (3)$$

After inclusion:

$$\boldsymbol{P_{t+1,t+2} = P_{t,t+1}} + \frac{1}{n}\boldsymbol{(S_{t+1} - S_{t+1-n})} \qquad (4)$$

It holds that:

$$\boldsymbol{P_{t+1,t+2} = P_{t,t+1}} + \frac{S_{t+1} - P_{t,t+1}}{n} \qquad (5)$$

If we include for $\frac{1}{n} = \alpha$ into the formula we obtain

$$\boldsymbol{P_{t+1,t+2} = (1 - \alpha) P_{t,t+1} + \alpha S_{t+1}} \qquad (6)$$

while it holds, that the coefficient $\alpha = \frac{1}{n}$, where n is the number of time periods.

The calculation using the weighted moving averages can be combined with algorithmic processing. The selection of the correction factor in algorithmic calculation is quite problematic, this is the value which will need to be added or subtracted to obtain realistic results. If the correction factor equals 1, it means that the estimation of prediction of passengers in the following time periods is based on real transported passengers in the last (real) period. As the value of the correction factor gets smaller than 1, the prediction will be closer to the simple weighted average and will be less susceptible to actual changes in passengers numbers in the closest upcoming period [7].

The correct selection of α solves the compromise between elimination of random fluctuations and adjustment towards the actual state of the transported passengers, while the coefficient does not have to be constant. Methods, which can help to adjust the correction factor α are called adaptive methods [6].

4 THE COMBINATION OF WEIGHTED MOVING AVERAGES AND SEASONALITY

To improve the resulting value of the prediction (estimation) in numbers of potentially air transported passengers during a certain period, it is necessary to correct the predictions. This is mainly relevant in computation of seasonal fluctuations in the demand. Analyses unambiguously show that the density of air transportation and number of passengers is higher in summer months compared to winter months. This is mainly caused by climatic factors and vacations during summer periods, which is more attractive to tourism. Seasonal fluctuations in air transport are evident in peaks during a day or a week. The density of air transport in the morning and hours before lunch is several times higher than evening and night flights.

The algorithm of computation of the weighted averages and seasonality is done as follows:

1. the method of moving averages is applied describing the whole development trend of the researched time series,
2. seasonal indexes based on moving averages are computed describing the seasonal fluctuations according to the formula:

$$I_s = \frac{S_t}{\overline{\overline{S_t}}}, \tag{7}$$

where $\overline{S_t}$ is weighted average for the t-th period.

Correction of the forecast for seasonal fluctuations of air transportations during a year (week, day) is then computed as

$$P_{t,t+1} = I.\,\overline{S_{t+1}} \tag{8}$$

5 EXPONENTIAL SMOOTHING

This method represents an application of the weighted moving average method. In forecasting of the number of air transported passengers with application of such smoothing, the coefficients $\alpha \in \langle 0,1\rangle$ are computed. The values of the coefficients are derived from exponential division. Higher importance in this case have the most current (actual) statistical data about the number of dispatched passengers during a certain time period.

The formula for computation of the prediction from *n* historical data by application of the base relation for weighted average the equation for the exponential smoothing has the following shape:

$$P_{t+1} = \alpha S_t + \alpha(1-\alpha)S_{t-1} + \alpha(1-\alpha)^2 S_{t-2} + \dots + \alpha(1-\alpha)^{t-n+1}\; S_{t-n+1} \tag{9}$$

or

$$P_{t+1} = \alpha S_t + (1-\alpha)[\alpha S_{t-1} + \alpha(1-\alpha)S_{t-2} + \dots + \alpha(1-\alpha)^{t-n+2}\; S_{t-n+1}] \tag{10}$$

It is also possible to apply the Holt method in exponential smoothing, if the demand for air transport achieves a certain value level and trend element. This method however does not have any element of seasonality. It is the case of double exponential smoothing [3].

The algorithm of the computation is as follows:

1. equalization of the series of known values from the third period
2. the first value for the second period is $P'_{2,1} = S_2$
3. the first difference will be $d'_1 = S_2 - S_1$
4. the equalized value for the third period then equals:

$$P'_{3,2} = (1-\alpha)(P'_{2,1} + d'_1) + \alpha S_3 \tag{11}$$

$$d'_2 = (1-\beta)d_1 + \beta(P'_{3,2} - P'_{2,1}) \tag{12}$$

To adjust the series with seasonal fluctuations in air transport Holt-Winters method can be used, however it has to be sufficiently long to catch the seasonality. Moreover, this method also uses time indexes, which are computed as follows:

$$I_t = \frac{S_r}{\sum_{i-1}^{s} S_i / S} \tag{13}$$

where *s* is the length of the seasonal series. The time series can be further equalized including differences and time indexes according to the following formulas:

$$P'_{T+1,T} = (1-\alpha)(P'_{T,T-1} + d'_{T-1}) + \alpha\frac{S_t}{I_{T-s}} \tag{14}$$

$$d' = (1 - \beta)\, d'_{T-1} + \beta\,(P'_{T+1,T} - P'_{T-1,T}) \qquad (15)$$

$$I_{T+1} = \gamma \frac{S_T}{P'_{T+1,T}} + (1 - \gamma) I_{T-s} \qquad (16)$$

5. Prediction for the k-th period is then:

$$P_{T+i} = (P'_{T-1,T-2} + i d'_{T-1}) I_{T-s} \qquad (17)$$

The methodology of the computation is as follows:

a) computation of seasonal indexes in every seasonal series
b) computation of means of seasonal indexes for every period in a seasonal series,
c) estimation of the first difference as a subtract of average needs for the last two seasons divided by the seasons' length,
d) estimation of the equalized centered moving average for the last period of the last season as an average of the last season plus the multiple of the estimated mean difference,
e) computation of the equalized moving averages and the computation of prediction for the next season.

One of the applicable methods in prognostic planning of demand in air transportation can also be the Brown exponential equalization, which includes automatic weighting of all previous data, where the weights are decreasing exponentially over time. This method can set a prediction for one period ahead. The method is suitable only for time series with a constant trend

6 DECOMPOSITION MODELS OF TIME SERIES

These models have an important place among the prognostic models. Except the equalization according the means, analysis is used to estimate trends or seasonal fluctuations.

These models distinguish three elements of time series:

1. trends,
2. seasonal elements,
3. stochastic elements.

The task in decomposition of time series is to quantify their trend and seasonal elements. The process of quantification of these elements is called decomposition of time series

The models of decomposition are divided into the following categories:

1. additive models
2. multiplicative models.

Additive decomposition can be defined as:

$$D = T + S + E \qquad (18)$$

The multiplicative decomposition can be defined as:

$$D = T \,.\, S \,.\, E \qquad (19)$$

where

D = time series of historical data,
T = the trend element,
S = the seasonal element,
E = the stochastic element.

The additive model can be applied where the course of the trend of demand is quite stable. If the trend shows some considerable growth or decline it is more suitable to use the multiplicative model. The information gathered by the decomposition can be used in evaluation of the present development of demand and its future behavior. If the trend is to be quantified, it is necessary to use moving averages for setting the trend and further use the knowledge to set the seasonal factors [5].

Decomposition of time series consists of the following algorithmic steps:

1. Search of the trend, which represents the main tendency of the relatively long period of the analyzed demand described by the methodology known as centering the trend (mean of two moving averages), ,
2. finding of the seasonal element by the afore mentioned formula for additive decomposition where the stochastic element is neglected: $S = D - T$,
3. creation of the cleaned time series from seasonal influences. The result is represented by trend elements including only random elements. This means that $D - S = T + E$, where the left side represents the seasonally cleaned series.

The task can be considered as finished only when we see that the seasonal element is not changing, this means that the forecast is done by the trend. If it is not the case, causal models can be used. One of the models can be represented by a simple linear regression, which represents a relation between two parameters in a general shape as y = f(x), where *y* is the dependent variable and *x* is the independent variable

The precision of the regressive analysis is largely dependant on selection of the correct data that will be used in regressive analysis. In case where several variables exists, multiple level regression has to be applied [3].

7 EVALUATION OF THE FORECAST

In order to evaluate precision of the forecast the methodology of computation of mean absolute deviation or mean absolute error can be used. The mean absolute error is a basic tool to evaluate error created by the forecasting model in relation to historic data of the time series

The formula for computation can be expressed by the relation:

$$\boldsymbol{MAD} = \frac{\sum_{t=1}^{n} |D_t - F_t|}{n}, \qquad (20)$$

where,

D_t = the real demand in a time period t,

F_t = forecast of the demand in a time t,

n = number of the used time periods.

The absolute value is needed to ignore the direction of the deviation. This characteristics is used when we want to express the error of the forecasting in the same units as the previous statistical series.

7.1 Mean Square Error

Mean square error uses the same variables as MAD for computation. This characteristics penalizes large deviations in the forecast because the error is squared. Based on the square error, we prefer the model, which shows only slight values of error in front of a model which shows only very small values of errors and one extreme forecast error [5].

Mean square error can be computed as:

$$\boldsymbol{MSE} = \frac{\sum_{t=1}^{n} |D_t - F_t|^2}{n} \qquad [21]$$

7.2 Mean Forecast Error

It happens only seldom that the forecasted value and the real demand are the same. However, the difference between the mean forecast value (scope of several time intervals) and the average value of the real demand should be the smallest possible [5]. To evaluate this demand, the following computation of the average error of the prognosis can be done:

$$\boldsymbol{MFE} = \frac{\sum_{t=1}^{n} |D_t - F_t|}{n} \qquad (22)$$

7.3 Mean Absolute Percentage Error

The last important characteristics is an addition to improve the understandability in evaluation of forecasts. Even though this characteristics is named as absolute it denotes relative error. The formula to calculate this error can be expressed as follows:

$$\boldsymbol{MAPE} = \frac{100}{n} \sum_{t=1}^{n} \left| \frac{D_t - F_t}{D_t} \right| \qquad (23)$$

Conclusion

The forecasting of demand and supply in air transport belongs to important analytic studies in creation of future flight plans, logistic planning, financial, organizational, operational and personal elements. Forecasting of air transport is generally a combination of analysis of historic data, intuition, experiences of analytics and prognostics of air and airport companies.

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