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Application of Bayesian Method into a Mathematical Model for Airline Route Planning, Evaluation and profit maximization

The proposed mathematical model is based on the Bayes formula. The airline route planning takes into account the factors of commercial and customer preferences, safety and should allow a flexibility given the tremendous uncertainty about market conditions. The model allows optimizing the interaction of the different factors.

In establishing mathematical models to predict and forecast fleet planning, route evaluation and schedule development, large amounts of real time and historical data must be addressed, evaluated and inserted into appropriate models in order to create credible, usable information to initiate new profitable routes for an airline which includes fleet evaluation and schedule optimization.

The modelling results applied in network planning allow an airline management team to understand what is required, to provide an overview of the airline planning process, from the longest-range strategic decisions involving aircraft acquisition to medium-term decisions related to route planning and scheduling. The most important planning decisions faced by airline management can be categorized as follows:

- route planning establishes the geography of profitable flights, subject to fleet availability constraints;
- fleet planning determines the types, quantity of aircrafts to acquire, and the time of purchase them;
- schedule development is charged with operating frequency and time of the flights on each route, subject to operational and aircraft limitations.

Fleet Planning Methods mainly based on statistical data. Airline decisions related to fleet planning depend primarily on an evaluation of the expected impacts of new aircraft on the airline’s economic and financial performance:

- forecast of expected traffic;
- target average load factor;
- the number of aircraft required.

Fleet Planning Evaluation use two methods. A “top-down” or “macro” approach based on relatively high-level aggregate analysis, and a “bottom-up” or “micro” approach based on much more detailed analysis of data and forecasts of flights and routes.

The process of route planning and evaluation involves the selection by the airline of which commercially viable routes should be flown and therefore what fleet, which aircraft, should be chosen. The route selection decision is both strategic and tactical. It is an essential component of an integrated network strategy or “vision” for the airline, which must decide whether to focus on short-haul or longhaul services, domestic or international operations. At the same time, the characteristics of the selected routes will affect the types of “products” the airline offers to travellers. For example, an international route network will likely lead to a decision that business and first-class products should be offered in order to be competitive.

Given the airline’s choice of aircraft and a fleet plan that determines the availability of aircraft with different capacity and range characteristics, the next step in the airline planning process is to determine the specific routes to be flown. In some cases, the sequence of these decisions is reversed, in that the identification of a profitable route opportunity might require the acquisition of a new aircraft type not currently in the airline’s fleet. Economic considerations and expected profitability drive route evaluations for most airlines.

Schedule Development determines the factors, which affect the volume of Origin-Destination / Hub & Spoke, air travel Demand. There are so many variable factors, which can and do affect the volume and therefore correct mix of origin – destination demand. These factors will be addressed to understand what components need to be evaluated and utilized in the mathematical models, which will be used to forecast / predict future trends in airline route planning to increase profit maximization for airlines.

The more advanced airlines and Revenue Management Systems, (RM Systems), vendors have developed computerized RM systems that can perform forecasting and optimization by booking class for each flight leg departure, in addition to having the same database and booking monitoring capabilities of previous systems. Based on a variety of empirical studies and simulation experiments performed by airlines and academics alike, it is now commonly accepted that proper use of a RM system can lead to airline revenue increases of 4 to 6% [1].

Beyond the obvious incremental revenue benefits, the use of RM systems allows for better tactical matching of demand vs. supply by the airline. With RM capabilities, an airline can match or initiate almost any low fare that covers variable passenger carrying costs. Computerized RM systems manage the airline’s inventory of available seats by using mathematical models and computer databases to address three different problems:

- overbooking;
- fare class mix;
- Origin – Destination control.

Nowadays, the Bayesian methods [2] have become quite widespread and are actively used in various fields of activities. These methods have become really actual only with the development of information technology. When real data needs to be analyzed, it means some parameter θ of this data is interesting and must be calculated. Then the probabilistic value $P(\theta|Data)$ of the parameter can be obtained on the basis of the available data. Application of the Bayes formula leads to the following:

$$P(\theta|Data) = \frac{P(\theta)P(Data|\theta)}{P(Data)}$$

In fact, as a result of the analysis, the probability is the function of the parameter. Then this function can be maximized to find the most probable value of the parameter, calculate the variance and average value of the parameter, calculate the interval within which the parameter of interest lies with a probability of 95%, etc.

Probability $P(\theta|Data)$ is called a posteriori probability. In order to compute it the likelihood function $P(Data|\theta)$ and a priori probability $P(\theta)$ have to be known. The likelihood function is determined by the model. That is, a data collection model is created and it depends on the parameter of interest. The a priori probability includes information that is known before the analysis.

Perhaps the airline's economic indicator can be denoted as high, medium and low with the probabilities H1, H2, H3 respectively. A certain traffic index increases in accordance with the level of the airline's economic indicator and is equal to p1, when the economic indicator is high, p2, when it is average, and p3, when it is low. Suppose, at the moment, the traffic index has increased. Then the probability that the economy of the airline on the rise can be determined:

$$P(H1|A) = \frac{P(H1)P(A|H1)}{P(H1)P(A|H1) + P(H2)P(A|H2) + P(H3)P(A|H3)}$$

Conclusion: Worldwide Aviation Transport can be continuously optimized by applying appropriate mathematical models / algorithms to forecast and predict, to a high percentage probability, maximum profit margins, investment and expansion of airline companies with no compromise to safety and efficiency. Mathematical modeling with Bayes approach is a powerful tool, which allows prediction and optimization of commercial and traffic indices of airline companies.

References

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2. Judgment under Uncertainty: Heuristics and Biases / Daniel Kahneman, et al. — 21st. — Cambridge University Press, 2005. — 555 p. — ISBN 978-0-521-28414-1.