

The European Small Aircraft's Total Operating Cost and Accessibility Evolution: a probabilistic prediction for 2020

Dániel Rohács, PhD student
Budapest University of Technology and Economics

Abstract

The goal of this paper is to provide a European Small Aircraft prediction model in order to establish the background for further investigations in decision making and risk analysis related to Small Aircraft. It also revises the possible model structures and finally presents an analogical approach based on Monte Carlo Simulation. This enables to address the uncertainties in Small Aircraft development and to provide the results with a probability distribution. Finally, the simulation result shows that the developed model could be used in the preliminary prediction of the European small aircraft activity, and for further investigations, such as the analyze of the impact of Small Aircraft on ATC/ATM.

I. Introduction

From our definition, SA is a Small Aircraft for up to 4 or 6 passengers, that is powered by a single or multi piston engine, due to the relatively short flight distance, as it comes from initial investigations in this domain, a European small aircraft air traffic analysis [1]. To fly these aircraft, in 2006, there are approximately [2] 300 000 private pilots in Europe that use more than 60 000 small aircraft. On the other hand, as the technology is already available [2] to establish a safe, economical and environment friendly new air transportation system based on personal air transportation purposes (similarly to the philosophy SATS [3], UK JETPOD [4], PATS [2] and SkyCar [5]), the SA accessibility or affordability might change [3],[4],[5]. In the face of this increase, the current ATC/ATM is already reaching its limits [3], thus it might not be able to meet that tomorrow's capacity. Therefore, the European SA activity has to be analyzed, in order to understand, what the impact of SA on ATC/ATM is. However, since such European SA is limited in 2006, the available information that might be rely on is inadequate to accomplish such analyze. Consequently, firstly relevant data calls for a SA prediction model for the European context. The importance of the study is to facilitate further investigations and to establish the background related to the European SA.

As for the related works, in the literature several demand models are available [6], however none of them focuses on the European market. This led us to discover the demand models, applied generally in air transportation. As a result, the most often used techniques [6] are the linear, log-linear, logit (or linear logit) and translog demand models. Between these, the most popular is the log-linear [6] because the coefficients themselves are the respective elasticities. However, the application of these techniques to SA purposes, could no be carried out due to their biggest drawbacks namely the need of sufficient statistical data on the European SA activity, and the constant elasticities.

II. Methodology

Due to the limitations of the generally used demand models applied in air transportations, in this paper, an analogical approach has been used: the prediction of accessibility of personal cars. To carry this investigation out, one potential technique instead of a linear or log-linear approach, is some sort of an S-curve [7], which provides detailed information on the adoption

of a new technology [7], due to the division of the market into several segments. Investigations showed [7], that it could also be applied to determinate car ownerships, since on the long-run, good could also mean transportation systems. Additionally, its advantage is that provides non-linear elasticities, since it is a non-linear approach. Other advanced technique is the idea of the Traveling Money Budgets (TMB), first observed by [8], as a fix proportion of income devoted for traveling. It has been clarified [8] that it rises with the GDP or income growth, therefore knowing the total operating cost of traveling by personal cars and using GDP, we can estimate the budgetary constraints of the population, associated to traveling. However, for SA purposes a more advanced approach lies in the idea of having instead of one TMB for the whole population, several curves, associated to different social classes. This is also more realistic, since the population ratio with higher income is less sensitive to GDP increase or to small aircraft cost decrease, however they only represent a small proportion of the population. Since generally the population is also price sensitive, finally form our analogical approach, the SA accessibility is determined by the budgetary constraints (or the TMB) and the small aircraft total operating cost evolution, that is also in line with basic economic theories of the demand.

III. Proposed prediction model

In our model, once again, an analogical approach is proposed, therefore we assumed, that SA becomes accessible, once its TOC meets the budgetary constraints, estimated from the TOC of cars, from different market segments. This approach is advantageous, since SA might become similar to today's personal cars, and the data on cars is widely available, which is also country specific [9]. Consequently, the model first estimates the TOC of both SA and cars, by the sum of each cost elements [9] as mentioned in the followings. Afterward, the model computes the total car ownership using an S-curve [7] - Gompertz function - as given with the equation (1):

$$C_i = \gamma * e^{\alpha * e^{\beta * GDP_i}} \quad (1)$$

(where C_i is the total car ownership at i ; α , β , γ are country specific Gompertz curve coefficients; and GDP_i is the GDP at i). Using equation (1) and knowing the market shares - associated to the budgetary constraints around the TOC of SA – the market of SA is provided by a regression such as follows:

$$S_i = S_{i/l} + \left(\frac{TOC_i^{SA} - TOC_{i/l}^{car}}{TOC_{i/u}^{car} - TOC_{i/l}^{car}} \right) * (S_{i/u} - S_{i/l}) \quad (2)$$

(where S_i is the market share; TOC_i is the total operating costs at i ; and the index i/l and i/u (at TOC and S) stands for the lower and upper market segment around the one of SA at i). Finally, with equations (1) and (2) the SA accessibility, or the population ratio whom SA is affordable in terms of costs, takes the following form (3):

$$A_i = \left[S_{i/l} + \left(\frac{TOC_i^{SA} - TOC_{i/l}^{car}}{TOC_{i/u}^{car} - TOC_{i/l}^{car}} \right) * (S_{i/u} - S_{i/l}) \right] * [\gamma * e^{\alpha * e^{\beta * GDP_i}}] \quad (3)$$

where A_i stands for the accessibility of SA at i .

IV. Estimation of model elements

To compute the TOC of SA and cars, the following elements have been considered for SA [10]: (i) the ownership; (ii) the air navigation charges (including en-route and terminal) [11]; (iii) the airport costs (such as parking, landing, and others); (iv) the fuel cost (estimated for different flight phases) [12]; (v) the pilot costs (or pilot hire cost); (vi) the maintenance cost (including parts, labor and overhaul) [13]; (vii) and finally the insurance (with liability and hull). In case of personal cars [9];[10]: (i) the ownership cost; (ii) the maintenance cost; (iii) the fuel cost; (iv) the parking and highway cost; and (v) the insurance cost. Note, that the estimation of these parameters is given in [10].

V. Simulation

To estimate the base TOC (or the TOC at the beginning of the simulation horizon) of both SA and cars of different market segments, the mean value of several relevant SA and cars have been used, as in 2006. However to carry out future estimations, uncertainty was faced, due to the unclear evolution of the cost elements. To deal with them, a Monte Carlo Simulation (MCS) has been applied, since it is a probabilistic approach that can quantitatively address the uncertainties by defining the inputs with probability distributions. In this paper, several distributions have been applied during the MCS. First of all a uniform, when no information was available which potential value is more probable to happen as a future evolution for one particular variable. Generally, these are the ones of SA, due to the limited data and the wide range in its development. For instance, SA could be a professionally or personally operated easy to fly small aircraft [2], which would not oblige any user to pay/hire a pilot, or to have a today's PPL (private pilot license) similarly to experience of the PATS [2] and SkyCar [5] projects. These flights could also happen in controlled airspaces, or in FIRs under VFR, which following the current experience of en-route charge payment [11], could make the en-route costs irrelevant. As for airport charges, SA would have the choice to use major airports (taking the benefits of better connectivity) or small airports to bring into play lower costs. Finally, SA could be defined to follow the past evolution of ownership and maintenance costs, or to be closer to today's luxury cars as it comes from the investigations of the SATS [3] and SkyCar [5] projects using more reliable materials and the newest technological achievements [2]. As for other variables, such as the SA fuel consumption, car ownership [9], car fuel consumption [9], car maintenance [9] and car other costs, a normal distribution has been used, since only a point estimate was available to estimate their future evolution. In respect to the fuel price and GDP per capita evolution, a triangular distribution has been applied, which is the practice, when all minimal, maximal and a most likely value as a future evolution is known.

VI. Results

The SA's TOC and accessibility estimations resulted in the figure 5.1. and figure 5.2., given by a three dimensional probability distribution. As the figure 5.1. shows,

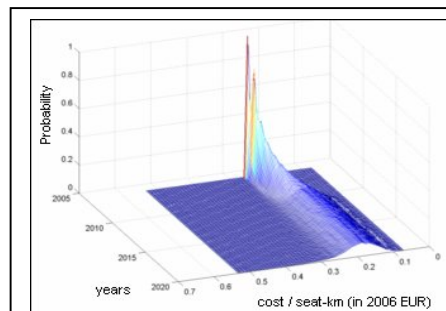


Figure 5.1. The probabilistic evolution SA's TOC by the MCS.

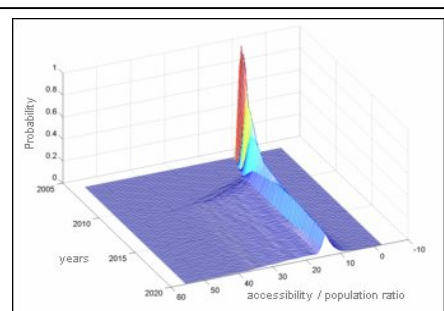


Figure 5.2. The probabilistic evolution of SA accessibility by the MCS.

we calculated that in 2020, 60 % of the results are in the range of 0.15 - 0.2 and the most probable result is 0.18 EUR / seat-km. Otherwise since only one percent of the results are more than 0.25 EUR / seat-km (that is the mean value of 2006), generally a decrease in the TOC can be observed. As for the SA accessibility (see figure 5.2.), the simulation gave the most probable value of 14.4 % in 2020, meaning that for 14.4 percent of the population SA becomes accessible, in terms of costs. That is a 74 % of growth relative to the 2006 value. On the other hand, probabilities of a higher accessibility / population are low, since only 8.06 % of our results gave this ratio more than 30 %.

VII. Conclusion

The generally used solutions for predicting the air traffic demand could not provide a suitable result, since it called for relevant knowledge on the European SA activity. Therefore, an analogical approach has been used, and the developed model was based on the total operating cost evolution of both small aircraft and cars from different market segments. This approach is advantageous, since (i) SA might become similar to today's personal cars, (ii) the data on cars is widely available and (iii) also country specific. To address uncertainties in the total operating cost and accessibility estimation, a Monte Carlo Simulation has been used, since it is a probabilistic approach that is powerful in dealing with variables having an unclear evolution. Finally, the result of the simulation showed that the TOC of SA might decrease to the most probable value of 0.18 EUR / seat-km in 2020. This shift had an impact on SA accessibility, since it increased by 74 % relative to the 2006 value, to reach its most probable value of 14.4 % in 2020. Otherwise, the probability of a higher accessibility (like more than 30 %) was only 0.08.

VIII. Future works

In the future, further investigations should focus on the validation of the proposed model, that could be carried out by running a simulation on known past data from the CFMU database. Otherwise, results could also be compared with a multi-regression model on SA's popularity and several independent variables such as the total costs of traveling, aircraft performance, manufacturing year, and others.

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