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AIRLINES MAINTENANCE COST ANALYSIS USING SYSTEM DYNAMICS MODELING

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Abstract

Maintenance costs in airlines change as time passes. As airplane ages, it needs more often and more expensive checks. Due to these growing expenses, airlines are getting more interested in cost analysis. Under financial pressure, they avoid buying new airplanes and try to maintain the old ones, but sometimes try to cut the maintenance costs by ignoring or delaying some checks. In other words, they are more disposed to spend small amount of money frequently through time, than to spend a great deal on a new airplane with low maintenance costs. Therefore, in such situations, the following questions raise that what solution is more efficient as we look dynamically to the system?

For answering this question, this paper will present a System Dynamics (SD) model of the influence of aging aircrafts and their growing costs in an airline. This goes further by presenting an overall maturity factor based on Boeing's maturity curve [1] which is a function of aircraft age. The result will be variation in costs, revenue and margin through time.

1 Introduction

Cost reduction can increase profit. So, cost reduction in the Airline industry is a very important way of being competitive. Cost of Ownership, Maintenance and Fuel are major parts of airline costs and vary regarding aircraft's age and type. These three main components of cost account for more than half of an airline's operation expenses.

According to increasing cost of airlines, an important decision for Airline managers is when to buy aircrafts and when one should do life extension. Aircraft life extension is a contemporary method in which aircrafts can be used in a longer time by implementing an excessive unscheduled maintenance program.

System Dynamics is a methodology for modeling complex systems over time and this approach provides a feedback loop diagram between causes, effects, and influences in the system [2], and, this method is widely used for cost estimation. It is therefore proposed to use SD as a methodology to analyze the problem of deciding between buying an aircraft to answer demands or committing life extension. SD method helped us to model and simulates the maintenance part and estimate the effect of implementation of different policies to an airline costs.

2 Literature Review

Applying System Dynamics methodology is a recent approach to study and manage transportation. In 1994, Abbas and Bell evaluated modeling approach that applying SD in transportation and mentioned its benefits. Whereas transportation systems are consists of variety of elements and members, they mentioned it helps to understanding relationship between transportation systems' elements and its surrounding environment [3].

Also Rassafi and et al, studied traffic problems in major cities using SD approach. They developed a comprehensive model which includes social, economic, and environmental variables. They are used the situation of Mashhad transportation as a case study and analyzed the effect of two policies. First, increasing average car occupancy and second increasing salvage rate of vehicles. Finally, they

found increase salvage rate of vehicles can reduce urban traffic and fuel consumption [4].
In another study Prasad Iyer studied the impact of maintenance policies on maintenance costs and Life Cycle Cost (LCC) using SD modeling. Learning, aging, and technology improvements are considered as changers of costs and cost of preventive maintenance in aircrafts is evaluated. [5].

Leandro Salazar Rosales and et al, worked on relationship of scheduled and unscheduled maintenance and their impact on delays and disruption during aircraft heavy maintenance. They developed a SD model to understand effect of routine and non-routine tasks on delays and disruption. In addition, the model has been presented in this work can be applied to similar problems [6].

Also, Shepherd at 2014, listed many papers in which applied system dynamics models by area of application that includes the fuel vehicles, Supply chain management of transportation, highway maintenance, and strategic policies. That paper also has a part about airline and airport infrastructure business which includes description of some papers about airline industry. He mentioned, these papers modeled airlines alliances, investment in airport runway and impact of GDP on both runway and terminal capacity, and Global aviation industry dynamics which includes passengers, airlines, and manufacturers as a three sectors of business [7].

Finally, despite the influence of aging of an aircraft on maintenance and fuel costs is reported by oliver wyman[8] none of studies analyzed the dynamic effects of these parameters on total cost, average fleet age, and number of active aircrafts in an airline. So, this paper concentrates on study and analysis of impact of these parameters on an airline's life cycle cost.

3 Modeling and Simulation

SD modeling and simulation works in three main stages: causal relationships and important loops, stock and flow model, and finally application of different policies to make the optimized decision. In order to visualization and simulation of this model, VENSIM PLE software Copyright ©Ventana Systems, Inc. (Academic Use Only) is used in different stages. In the following subtitles each stage is described thoroughly.

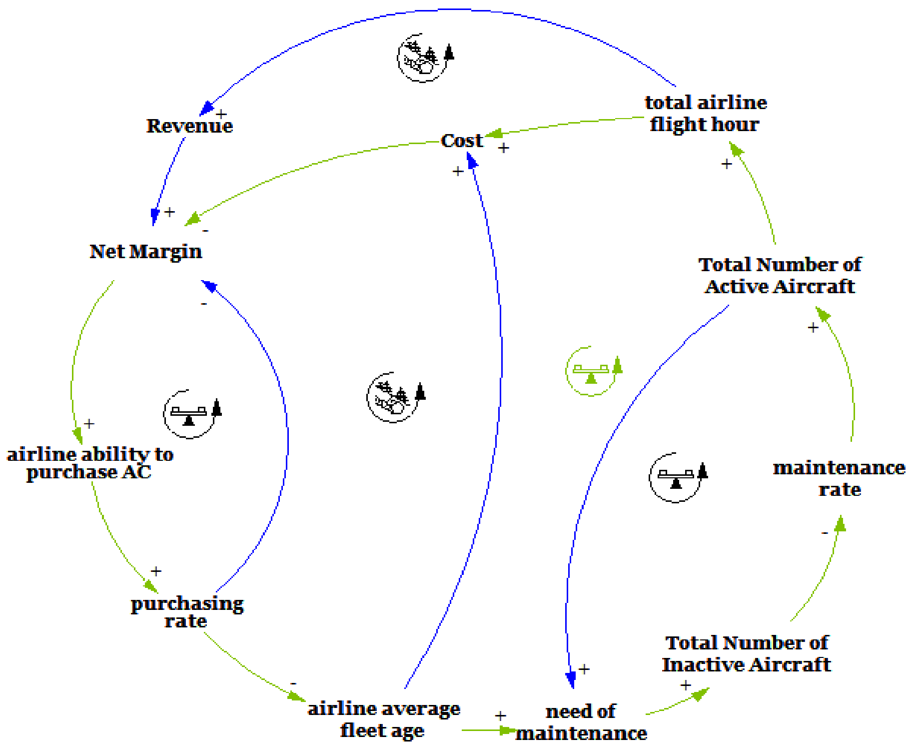

Fig. 1 Casual Loop of airline's cost analysis

3.1 Causal Loop

There are cause and effect relations between elements of transportation systems; in the Fig. 1 causal loop of objective system proposed. Average Fleet Age has a huge impact on revenue in different ways. As fleet ages, due to its aero dynamical and structural changes, its fuel consumption increases noticeably. Hence, the total costs raises up and net margin reduced. Maintenance schedule and the heavy maintenances increases as well and has a similar impact on airline costs. Furthermore, it has an effect on availability time of aircrafts due to an increase in need of maintenance. By a reduction in availability, work force and facilities for maintenance experience a large number of out of service aircrafts, so number of active ones decreases and influences of a decline in need of maintenance and a decrease on total airline flight hour which diminished both costs and revenue of ticket selling. Purchasing and retirement are the main determinant of airline average fleet age but aircraft purchase costs a lot and airline ability to purchase new aircrafts depend on its budget. In fact, the more net margin, the more purchase ability of airline and average fleet age decrease as a result.

3.2 Stock and flow model

The final model is displayed in Fig.2. In this model, aircrafts are categorized in four groups by their age: 0-6 years old aircrafts are known as “new aircrafts”, 6-12 years olds as “Mid-life aircrafts”, 12-18 years olds as “Old Aircrafts”, and finally, aircrafts over 18 years old have choice to be in life extension program (18-30 years old aircraft) or get retired (18-23 years old aircrafts).

Three major categories of costs are considered extensively: Maintenance costs, Fuel costs and Purchase costs. All mentioned costs are related to aircraft flying operation, so known as flight Direct Operation Costs (DOC). Due to the Belobaba’s presentation in Massachusetts Institute of Technology (MIT) [9] DOC approximately cover 50% of the whole costs; So in this paper twice the DOC cost is used as approximation of total cost.

To estimate the maintenance costs, Boeing maturity factor based on Boeing’s Maturity curve is used [1]. This curve provides the normalized average cost of airframe maintenance for one hour flight as a function of aircraft age, which is normalized by airframe maintenance costs of a 6 years old aircraft. So, in the model total maintenance cost is calculated using maturity factor from the curve.

For calculating the fuel cost of airlines, average fleet age is used because according to document published by Hazel and et al [8] fuel efficiency has correlation with aircraft age. So, the number of fuel gallons which is used per seat per hour flight in different ranges of ages has been considered. Then cost of each gallon [8], average number of seats and airline flight hours are used to determine the total fuel costs.

As it is mentioned at causal loop section, maintenance rate and availability have a strong correlation. It also has influence on demand fulfillment. Active aircrafts have different flight hours per day. The more flight hours, the more aircraft needs maintenance. Hence aircrafts in a fleet flies roughly more than 8 hours a day, it could cause considerable increase in grounding time and forcefully reduction of total airline flight hours. In this situation, revenue of ticket selling and finally profit margin will be diminished.

It is worth to mention some of the assumptions considered to simplify this model. The main consideration is the total cost can be calculated as a function of age of aircraft and its flight hours and it is assumed that other parameters have not significant effects. The other one is boundary of system of interest which did not include change of airline’s demand, so it is assumed as a constant variable.

Also, it is important to indicate, in addition to the revenue of ticket selling, retirement or selling of an aging aircraft makes revenue that has been assumed to be about five percent of new aircraft’s price. Finally, purchasing cost is calculated regarding purchase policy and purchase cost per aircraft (all the policies will be explained at policies subtitle).

3.3 policies

As Michael Porter stated there is two basic strategies for creating value and improving a firm's profitability [10]. The first one is low cost strategy and the other differentiation. In former, an airline should have same rate for purchasing and retirement, therefore, the number of total aircrafts remain constant. In the latter strategy an airline should make higher value for customers by maintaining average fleet age and their safety ratings. Furthermore, according to the airline's strategies, different policies are proposed for making a decision about purchasing and retirement schedule. Here, 6 different policies for aircraft purchase are introduced using *budget* and *life extension program* as constraints. The applied policies listed as below:

1. Constant fleet size with limited budget and aircraft life extension program
2. Constant fleet size with unlimited budget and aircraft life extension program
3. Constant fleet size with limited budget
4. Constant fleet size with unlimited budget
5. Constant average age with limited budget
6. Constant average age with unlimited budget

The results will be discussed in next section.

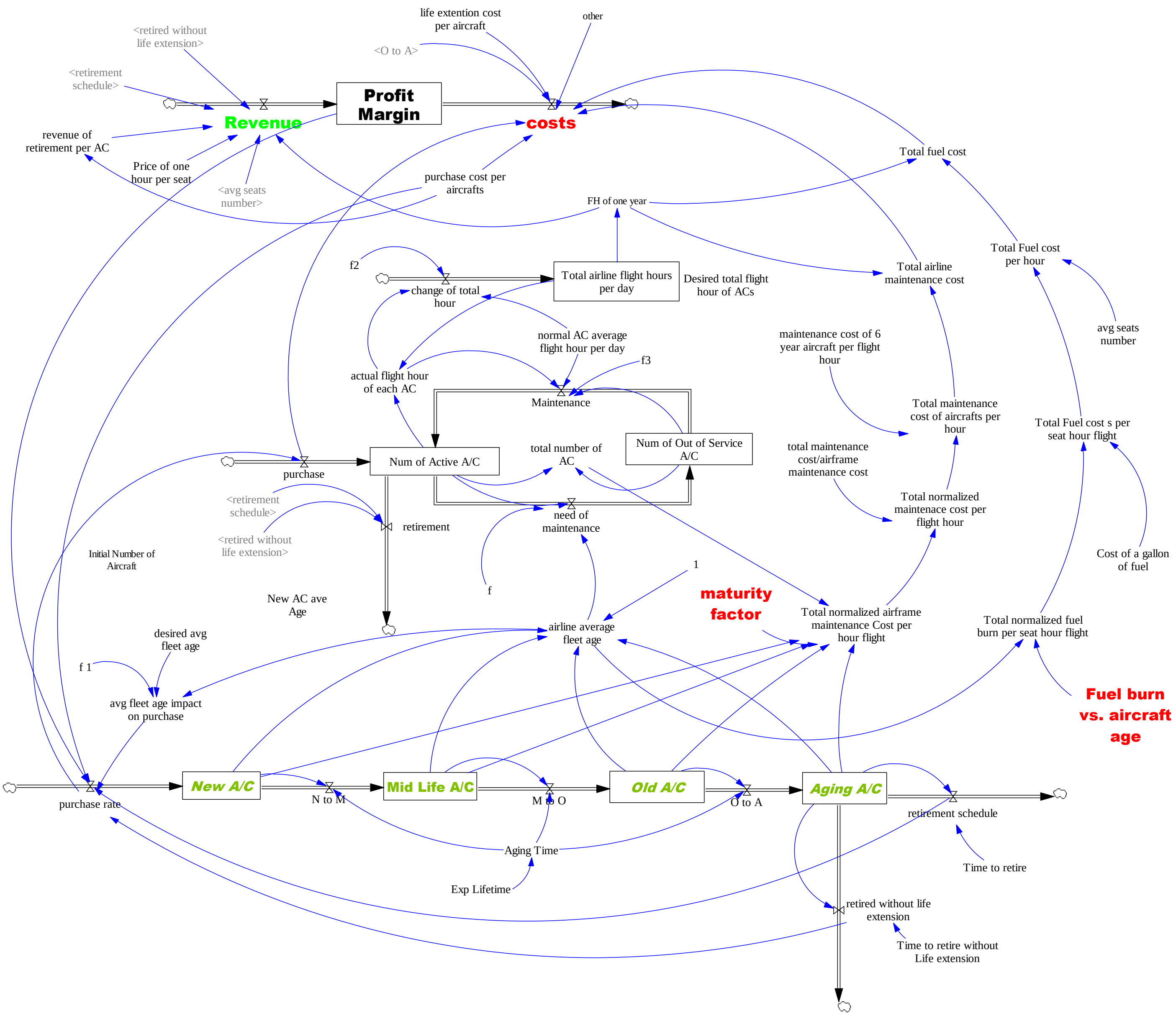

Fig. 2 Stock and flow model of airline cost analysis

4 Results

The purpose of the model is to investigate cost of an airline and make a decision to buy an airplane or extend its life. By simulating this condition Fig.3 represent annual costs of the airline. First, as the airline ages, the cost of airline increases because of aging's effect on airplane's costs. But, after 15 years cost of each aircraft gets minimized, costs of the airline which took low cost strategy remains constant but other strategies lead to decrease in costs. It is worthwhile to mention that cost decrease in differentiation strategy is due to decrease in number of aircrafts and revenue drops (Fig.4).

Fig.5 shows that all policies have the same profit for first 5 years, and the best policy to achieve maximum profit is to maintain constant fleet size with a limited budget and life extension. The reason behind this is limiting airlines expenditure on new aircrafts.

Furthermore, Fig.6 shows that airlines which

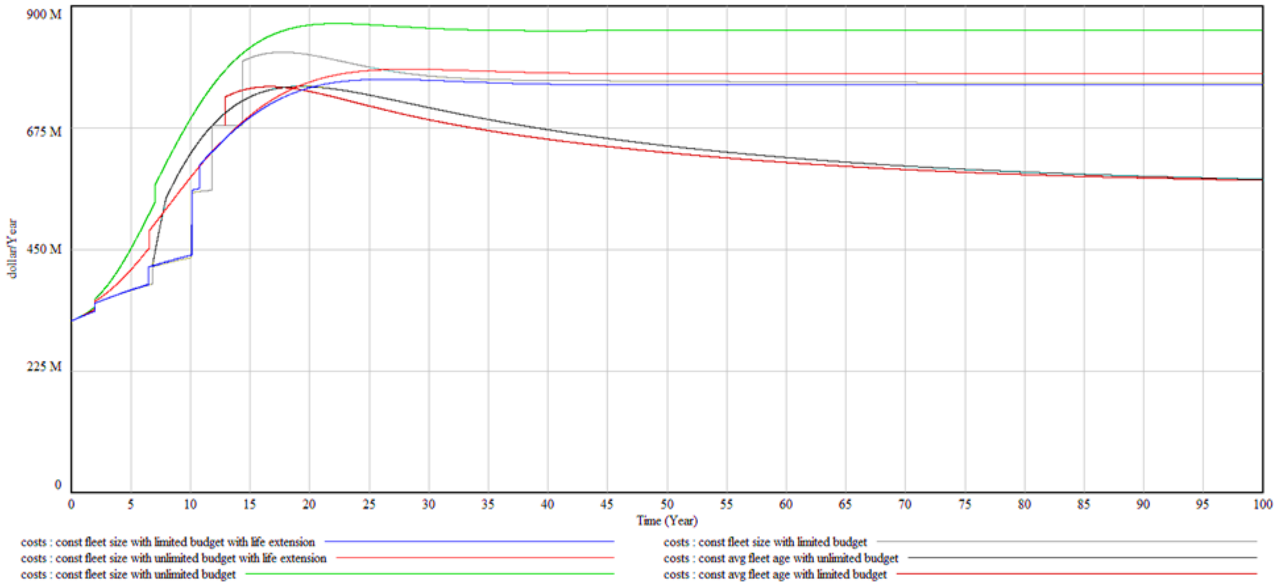

Fig. 3 Costs

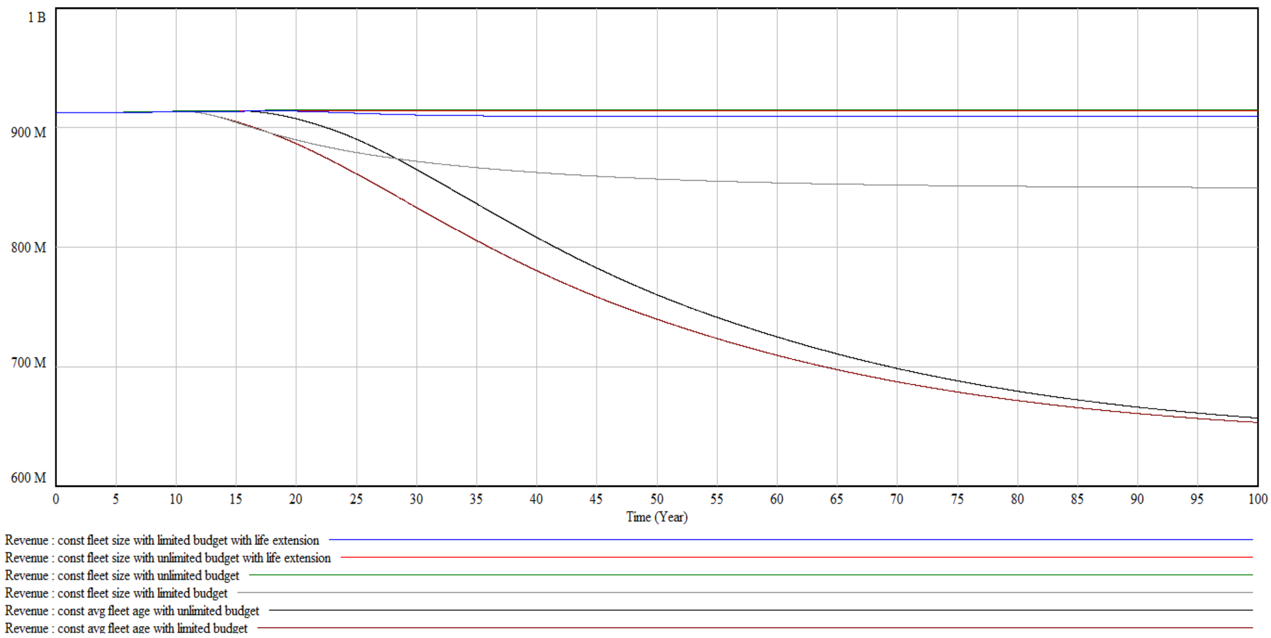

Fig. 4 Revenue

maintain the constant fleet age should reduce total size of their fleet and as result reduction in total flights which lead to decrease in annual revenue (see Fig. 4).
Fig. 7 shows the impact of different policies on airline average fleet age. The policy of constant fleet size with life extension (both with limited and unlimited budget) lead to having oldest average fleet age, compared to other policies. Life extension causes a delay in the retirement of old aircrafts and also reduction of annual purchase rate of new aircrafts. Having the old average fleet age causes increase in total maintenance costs of airlines. However, this policy boosts revenue considerably and in conclusion these policies cause the most annual profit margin.

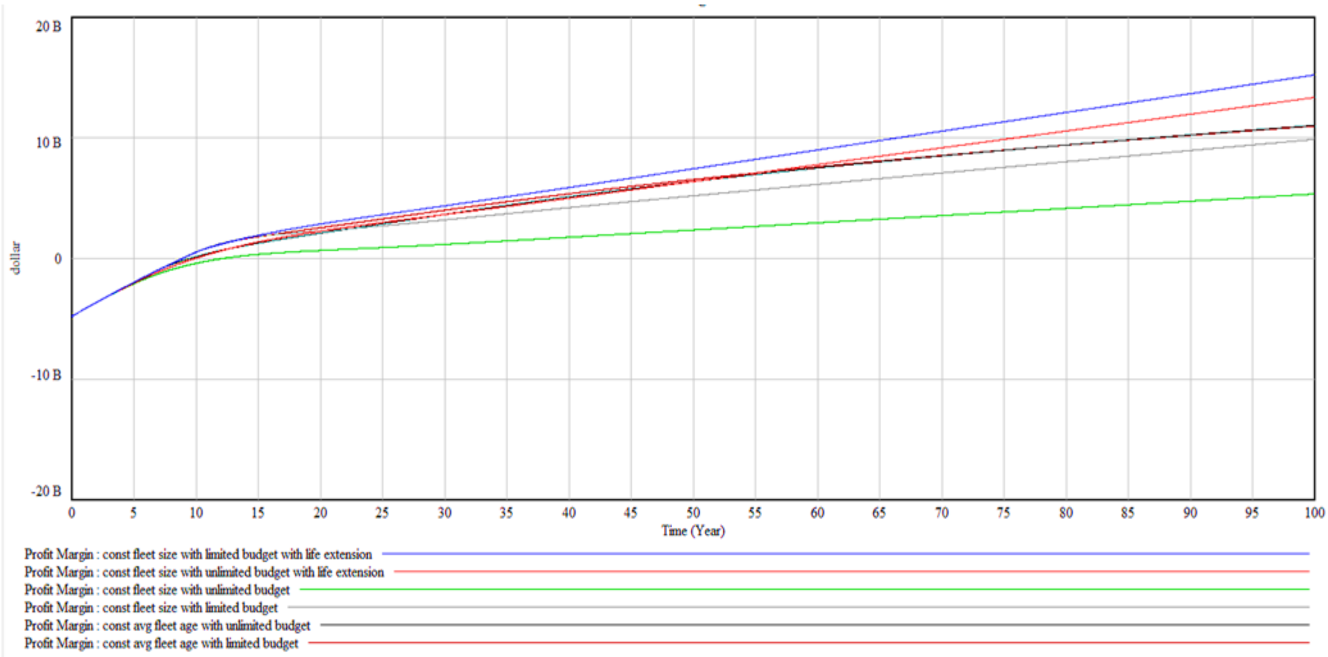

Fig. 6 Profit Margin

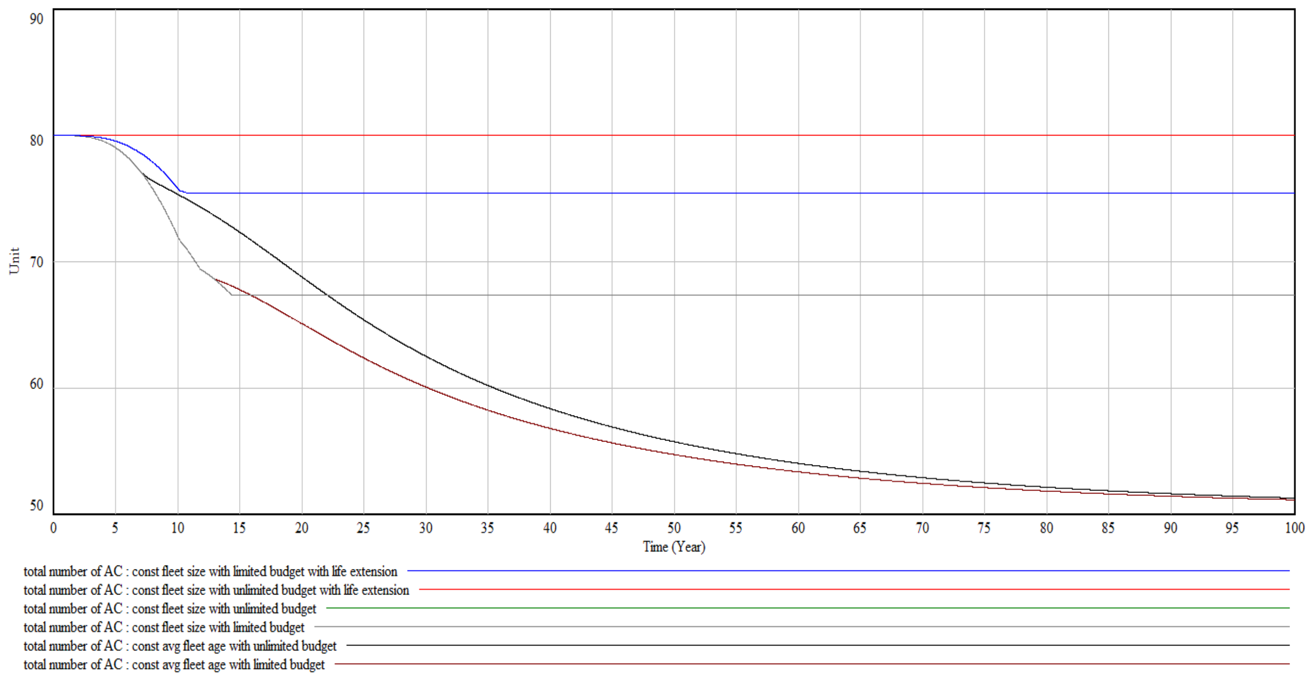

Fig. 5 Total number of aircrafts

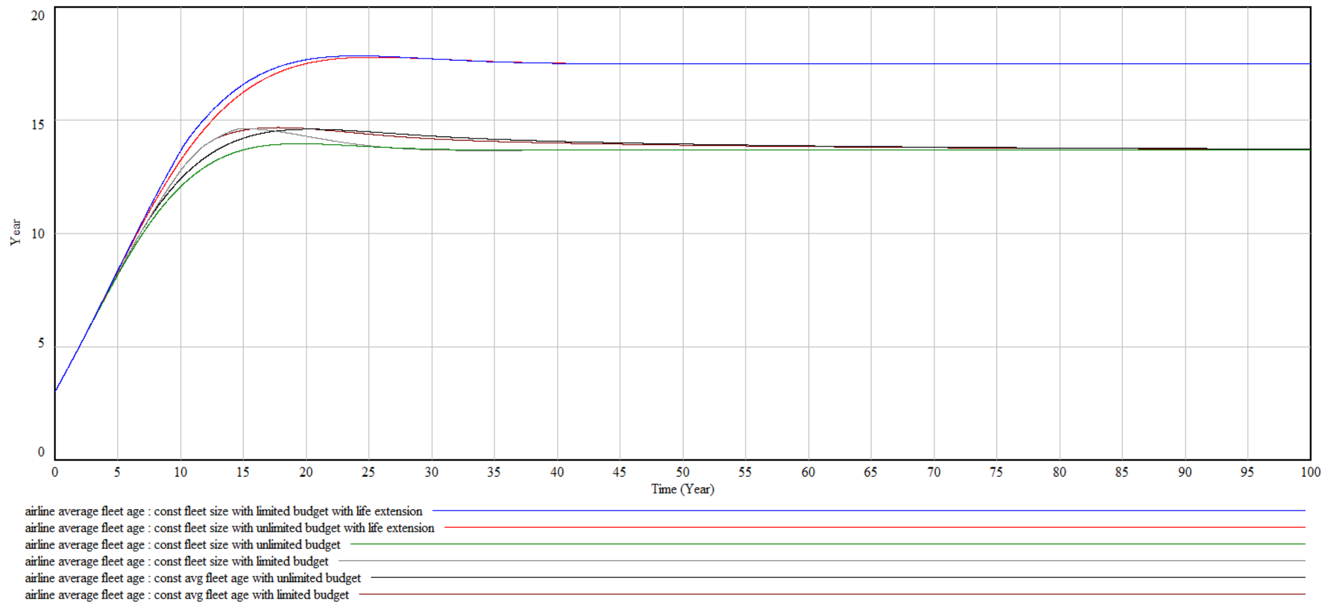

Fig. 7 Airline average fleet age

5 Conclusions

In this paper, System Dynamics method is proposed for analyzing effects of age, maintenance availability, and flight hours on airline's costs, as a methodology to study complex systems. Therefore for understanding the interactions between these variables, the casual loop diagram was introduced. In order to simulate dynamic behavior and examine how different policies effect costs, the stock and flow model was built. Final result of this simulation is that the best technical strategy for an airline is differentiation. With this explanation that airline can achieve higher profit margin through decease in costs.

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