Too early, too quickly:
Impact of short-term decisions in fleet renewal programs

Santiago Caicedo
Avianca S.A.
Contracts & Warranties dep't
Email: scaicedo@avianca.com

Fabio Andrés Díaz
Universidad de los Andes
School of Engineering
Email: fa-diaz@uniandes.edu.co

1. Abstract

In the air transport industry, decisions are made based on perceptions and predictions. Airlines order aircrafts when they believe the conditions to upgrade their fleet are appropriate in terms of profitability and market opportunities. However, the financial performance of an airline can be easily affected by several variables. Many types of delays are decisive in the income and expense structure of the organization. Fleet renewal, for instance, is a very lengthy process, since deliveries usually take five years from the date the order is placed. This paper uses System Dynamics to evaluate the performance of different strategies concerning fleet renewal in a commercial airline, taking into account the complex interdependence between variables and the delays involved in the process. The simulation model is absolutely based on real information retrieved from databases of aviation authorities and actual airlines in Colombia.

Keywords: Fleet renewal, Air Transportation industry, decision making, System Dynamics.

2. Introduction

Airlines are facing today a major challenge because the current financial crisis has affected not only their sales of tickets but also their plans of fleet renewal. Even though the cost of capital is the biggest concern when an airline decides to upgrade its fleet, its cash flow is also threatened by many other costs related to operating a new type of aircraft: training, initial provisioning, maintenance and support. The reduction of sales as well as the price of obtaining loan capital has put in danger the financial health of most of the commercial airlines in the entire world.

In recent years the commercial aviation industry has experienced an important boom of aircraft design and this, of course, has lead to a bigger demand of new aircraft. In March 2009, there are 878 orders of Boeing 787 aircraft and 483 orders of Airbus A350 aircraft, and remarkably neither the 787 nor the A350 has entered into service. Unfortunately for both manufacturers and airlines, Boeing will deliver the first 787 in the middle of the toughest financial crisis in decades.

The cyclic nature of the behavior of airline profit is widely accepted among Air Transportation experts. Thus, the purpose of this paper is to analyze the driving factor of this behavior and to assess the impact of fleet upgrade in the profitability of airlines.

System Dynamics is considered as a helpful tool to solve problems in public and private administration (Forrester, 1997). It is widely recognized as an efficient method to represent and analyze situations containing complex structures and it is often used as a decision-making aid in Strategy Planning (Warren, 2002). This methodology allows us to study the nature of the problem itself as well as its relation with variables than can determine its dynamics. This project aims at building a simulation model that analyzes the dynamics of fleet renewal in mid-sized airlines in order to give recommendations to local airlines in respect of the way they should face their fleet upgrade programs.

3. Overview of the air transportation industry

On March 12, 2009 every leading newspaper in the world revealed that cancellations of aircraft orders had increased since the beginning of the year at both Airbus and Boeing.[1] According to the Airbus' order book, Turkish Airlines placed four (4) A321 orders on January 30 and Korean Air placed two (2) A380 orders on February 3. However, the manufacturer posted cancellations of three (3) A318, three (3) A319, four (4) A320 and four (4) A321, resulting in a net deficit of eight (8) airliners as of February 28, 2009.[2]

Apparently, things are not going better with Boeing. As of March 10, it had received thirty-two (32) 787 cancellations and only twenty-two new orders: nineteen (19) of 737 and three (3) of 777. [3]

Airlines have also followed the same trend. On March 11 Lufthansa and Air France – KLM announced capacity reductions for the summer season, facing the world financial crisis and Cathay Pacific reported its biggest annual loss in its entire history.[4]

Bad results shown by operators in 2008 are partly because of wrong decisions taken in relation to the uncertainty about the oil prices. Considering that fuel expenses ranges from 30 to 35 percent of their operating costs, airlines sometimes search for to reducing their risk by means of financial instruments (*hedging*); especially futures contracts. Based on the trend shown by oil prices during the first and second quarter of 2008[5], airlines bet high on futures but oil prices rapidly began to decrease and reached $34/barrel on February 2009.

High oil prices in 2009 also drove airlines to accelerate their fleet renewal process. Fuel-efficient airliners, such as Boeing 737 Next Generation and Airbus A320 series, are quickly displacing the

---

[1] Google News http://www.google.com/hostednews/afp/article/ALeqM5iQAENbAeWlXRCY71yyskVsghI0Xw retrieved on March 15, 2009

[2] Airbus for analysts http://www.airbus.com/en/airbusfor/analysts/ retrieved on March 15, 2009

[3] Boeing orders sheet http://active.boeing.com/commercial/orders/index.cfm retrieved on March 15, 2009

[4] Financial Times http://www.ft.com/cms/s/0/acace9ba-0e6e-11de-b099-0000779fd2ac.html retrieved on March 15, 2009

[5] Oil price broke through $110 on March 12, 2008, $125 on May 9, 2008, $130 on May 21, 2008, $140 on June 26, 2008 and $145 on July 3, 2008. On July 11, it reached a new record of $147.27.

McDonnell Douglas MD-80, older variants of the 737, and other aircraft with a high fuel-consumption. For instance, Avianca, the flagship carrier of Colombia, decided to replace all its MD-83 aircraft with A319's and A320's and its Boeing 767's with Airbus A330's and not-yet-operating Boeing 787's. Facing a dramatic increase in its operating costs during the second quarter of 2008, Avianca accelerated the phase-out of the MD-83 and negotiated with Airbus an increase in the rate of deliveries of A319/A320. This, of course, lead to huge expenses in pre-delivery payments (or PDP's) and in shop visits of components, in order to comply with redelivery conditions of the old leased aircraft.

Also as a consequence of high oil prices in 2008, airlines were inclined to voluntarily ground their aircraft. As of February 2009, a total of approximately 2,300 jet airliners were grounded, according to information from aerospace consultant Ascend[6] 1,167 of them were added to the list during 2008, making last year the worst since 2001 in cutbacks. More than 11 percent of the global aircraft fleet of 20,293 is now parked. Though the percentage reached 13% in late 2001, the global quantity of jet airliners was only 15,950. Certainly, the number of aircraft now in storage is the highest ever.

However, with oil-prices near $40, the quest for a fuel-efficient airline seems to be not very important. Instead, the cash consumed by a fleet renewal process threatens to erode the financial results of airlines.

The decrease in passenger demand also represents a major challenge for operators. Recently, the International Air Transportation Association (IATA) revealed that global demand fell by 5.6% in January 2009 compared to the same month in 2008. The slowdown is evident, taking into account that the demand in December 2008 was 4.6% lower than that in December 2007. January 2009 is the fifth consecutive month of contraction.[7] Latin America is the most stable region: its decline in demand was only 1.4% and its average load factor[8] is 74.9%

---

[6] Journal of Commerce http://www.joc.com/node/409439 retrieved on March 15, 2009

[7] IATA Pressroom http://www.iata.org/pressroom/pr/2009-02-26-01.htm retrieved on March 15, 2009

[8] Demand as a proportion of capacity.

The financial crisis of 2007 – 2009 has also affected airlines' fleet renewal programs. The relationship between the Air Transportation industry and the financial market is very tight. Since the Air Transportation business requires large amounts of money, airlines lean on financers when it comes to acquire aircraft and other major assets. Rather than purchasing aircraft, airlines often prefer to lease them from a financer. Thus, the airline operates the aircraft in spite of not being its owner. This gives flexibility to airlines but requires massive amounts of money for the financers. Therefore some airlines might consider executing the order by themselves: since the collapse of the banking system, the access to credit is more limited as the financers are overestimating the risk of most financial transactions. This can have as setbacks the reduction of the flexibility and exposition to the risk of high fuel prices and low load factors.

The boom of low-cost carriers is somehow a consequence of the issues explained above. Since the public is eager for low fares, low cost carriers implement a series of policies oriented to optimize the cost structure: operating a single type of aircraft, eliminating on-board services, flying to cheaper alternate airports, selling unreserved seating, focusing on direct sales, etc. This certainly makes enormous pressure on standard airlines that are forced to decrease their fares in order to keep their market share.

4. How delays can affect decisions

The reasons for placing aircraft orders are basically the following:

- Increasing capacity in order to make advantage of evident market opportunities (including expansion to new routes).
- Replacing poorly efficient aircraft (in terms of fuel and maintenance) with more recent ones.

This paper will discuss particularly the second reason in light of the evident and not-so-evident risks for airlines.

Manufacturers do not have a stock of aircraft. Instead, they receive orders and commit to deliver aircraft some time later. For example, Airbus has received 6,311 orders and has delivered 3,789 aircraft of the A320 series (A318, A319, A320, A321) as of February 2009. Since the manufacturer reports a monthly production rate of 34 aircraft (recently reduced from 36), the average lead-time is 6.18 years.

The difficulty of the decision-making process lies in these delays. An airline is forced to buy aircraft under the uncertainty of the next six years. Of course, it has to suppose what is going to happen in six years based on *what is happening right now*. In other industries this might not be a big deal, since companies somehow can build their future. Air Transportation industry; however, is much more fragile because the performance of an airline strongly depends on several external factors: oil prices, availability of credit, exchange rates (of the countries where the airline flies), leasing alternatives, passenger demand, etc.

Clearly, placing orders of new aircraft as a consequence of new market expectations is a very risky bet. As stated above, an airline may order some type of aircraft in order to operate a route with some demand exceeding the capacity. During the waiting time, several threats can make things harder for the airline: some other operators may start flying that route, the permission for operating the route may be removed by aviation authorities or the demand in that route may change from the initial estimate. If some of such threats actually happen, the initial analysis stops being valid and the decision of ordering aircraft should be reconsidered.

An airline may also decide to renew its fleet as a means to optimize maintenance and fuel costs. Even though this can be seen as an appropriate long-term decision, many risks arise from the economic cost of the renewal program itself. An example was presented in a previous section. An airline is undergoing a whole domestic and long haul renewal. The existing short haul fleet consisted of several MD-80s with Pratt & Whitney JT8D-219 engines. Of course, the fuel consumption of these aircraft is a major concern.

Two consecutive quarters of oil prices escalation forced the airline to negotiate with Airbus the accelerated delivery of several A319 and A320 aircraft equipped with the CFM56-5 engine, which is more efficient than the existing -219 engines. Prices of petroleum, however, began to decrease and the airline faced several pre-delivery payments for the new aircraft. Fuel consumption stops being the fundamental problem and now seems much more like a symptom.

Of course, if the fleet renewal decision is seen in the long run, huge savings are made by means of replacing non-efficient aircraft with more recent ones. However, the problem in this case is the rate of replacement. This leads to one of the major concerns of this paper: What should be the desired rate of fleet renewal on different scenarios?

Speculation with production slots is often a reason for placing aircraft orders. Since it is expected that firm orders become more expensive as the delivery date approaches, airlines may engage in these transactions on the opportunity of considerable profit. The risk however is high, since order prices absolutely depend on the current condition of the industry.

Airlines in bad situation when receiving new aircraft may use this concept to relieve economical tensions. It can be assumed that the market is large enough to have other operators interested in the airline's firm orders. If the condition of the industry is fine, the sell-price of those orders can be a relief for the airline's cash flow.

The absolute prerequisite to order aircraft is, anyway, a good economical condition. The reason is simple: the airline must be capable of affording the Buyer Furnished Equipment (BFE) Process[9], the Initial Provisioning[10], the pre-delivery payments, and training for pilots, flight

[9] The gross price of an aircraft does not include some components that the airline has to buy directly from the manufacturers. Among these materials it is common to find the avionics or the seating.

attendants and maintenance personnel. As stated in previous sections of this paper, the airline can only guess its future conditions based on their actual situation. Airlines in a good condition are more likely to order aircraft than other ones with a bad performance.

Air Transportation industry has been subject to constant change for decades. Globalization, deregulation of markets, privatization of airports, emerging new business models (including the revolution of low-cost carriers), airline alliances and achievements like the Open-Sky Agreement are global growth drivers. (Kleer et. al. 2008)

These growth drivers, as well as the external factors affecting the airline industry, makes strategy planning a huge challenge for all airlines. Non-linearity observed in most of the industry parameters often causes wide deviations from the forecasts.

However, forecast of future demand and performance are essential for many business decisions. For instance: how much capacity and other resources will be required and how much financing will be needed by the business. (Lyneis, 1998)

Several approaches have been made to forecast the performance of the air transportation industry. Jiang (2004) presents a study of the financial dynamics of the airline industry from the points of view of the fundamental cycles of the profits and of the driving factors of the financial behavior. In her paper, Jiang assumes the industry as an undamped 2nd order domain and tries to find the cycle's period and growth. Her conclusion is that capacity and cost appear to be driving factors of the system behavior, and that the parametric model shows a consistent period of eleven years. Although the fit is good until the date of publication, the paper forecasts a major boom of airline profit in 2008 to 2010, which is inconsistent with the current situation.

The thesis is simple: The industry has some complex structures with cyclic behavior but is affected by several random variables. An appropriate method should be used to incorporate uncertainty in the decision making process.

System Dynamics has been recognized as a powerful tool to represent theories (Sterman, 2000); in the context of business decisions its helpfulness lies not only in its capability to represent

---

[10] A minimum stock of components, materials and consumables that the manufacturers suggest to have at the moment of receiving an aircraft.

interconnected complex structures and simulating behaviors associated with them, but also in its strength to communicate counterintuitive and novel ideas. (Olaya et. al., 2007)

Certainly, the proper use of system dynamics simulation can add value to airlines. Lyneis cites four advantages of System Dynamics models, compared to Statistics and other common forecasting tools:

1. System dynamics models can provide more reliable forecasts of short- to mid-term trends than statistical models, and therefore lead to better decisions.
2. System dynamics models provide a means of detecting changes in industry structure, as part of an early warning system or on-going learning system.
3. System dynamics models provide a means to determine key sensitivities, and therefore to develop more carefully thought out and robust sensitivities and scenarios.
4. System dynamics models allow the determination of appropriate buffers and contingencies that balance risks against costs. (Lyneis, 1998)

According to Lyneis (1998), if a System Dynamics model is capable of providing accurate short to mid-term forecasts, then the model can be used to detect changes in the structure of the industry. When new information becomes available, it is compared to the model's forecast. If wide deviations are found, a well-calibrated model provides a means to determining the source of the divergence. Certainly, when it comes to forecasting the airline industry, the model must be updated on a regular basis, since the performance of the companies is sensitive to several external factors.

Of course, airlines have to make decisions under uncertainty, but should be capable of forecasting future conditions with appropriate tools. Unlike other industries in which real world testing is preferred rather than simulation, air transport has to make decisions based on models and forecasts. In next chapters a System Dynamics approach will be presented in order to check its performance as an aid for the decision making process.

5. A model of the buy/lend decision

System Dynamics has been considered a tool to understand and face problems and decisions in both public and private sectors (Forrester, 1997). Its major advantage is the capacity to represent and analyze situations containing complex structures. The proposed stocks and flows model aims at building a simulation model that analyzes the dynamics of fleet renewal in mid-sized airlines in order to give recommendations regarding the way they should face their fleet upgrade programs.

This article introduces a model oriented to simulate the decision to buy aircraft to renew its fleet under uncertainty regarding fuel prices and interest rates. The model presented here shows a very simple and at the same time counterintuitive idea in terms of how the available cash of an enterprise could depend and affect the decision to finance the purchase of new airplanes.

The model presented here focuses on the delays related to the purchase decision and on the moment when airplanes will start to arrive to the airline, which not necessarily will correspond to the moment where is most profitable for the enterprise to disburse the BFE cost and the pre-delivery payment cost. This is because decisions made in the Air Transportation industry are defined by perceptions, so purchasing decisions will be made under promising scenarios. In this case the payment structure will be determinant to affect the profitability of a decision.

Given these characteristics, the model has been mapped using the software iThink 9.0.2. It is divided in four major sectors (see Figures 1-4). The first sector deals with the new aircraft arrivals. The second one concentrates on the cash available in the airline and the decision to finance the purchase of aircraft. The third sector refers to the existing fleet. The last one focuses on the production chain of the aircraft manufacturers.

This model incorporates some elements required to assess the benefits of a low cost airline when renewing its fleet. One of the most important components introduced in this model is the operating cost of new aircraft compared to that of older airplanes (similar in size), and how this difference could affect the cash income in the enterprise. This refers not only to the problem of incomes and outcomes of the enterprise, but also to the time when orders and money flows must be executed (they depend on the conditions bargained on the purchase contract with the aircraft manufacturer)(see Figure 1). Equations and data of the model are in annex 1.

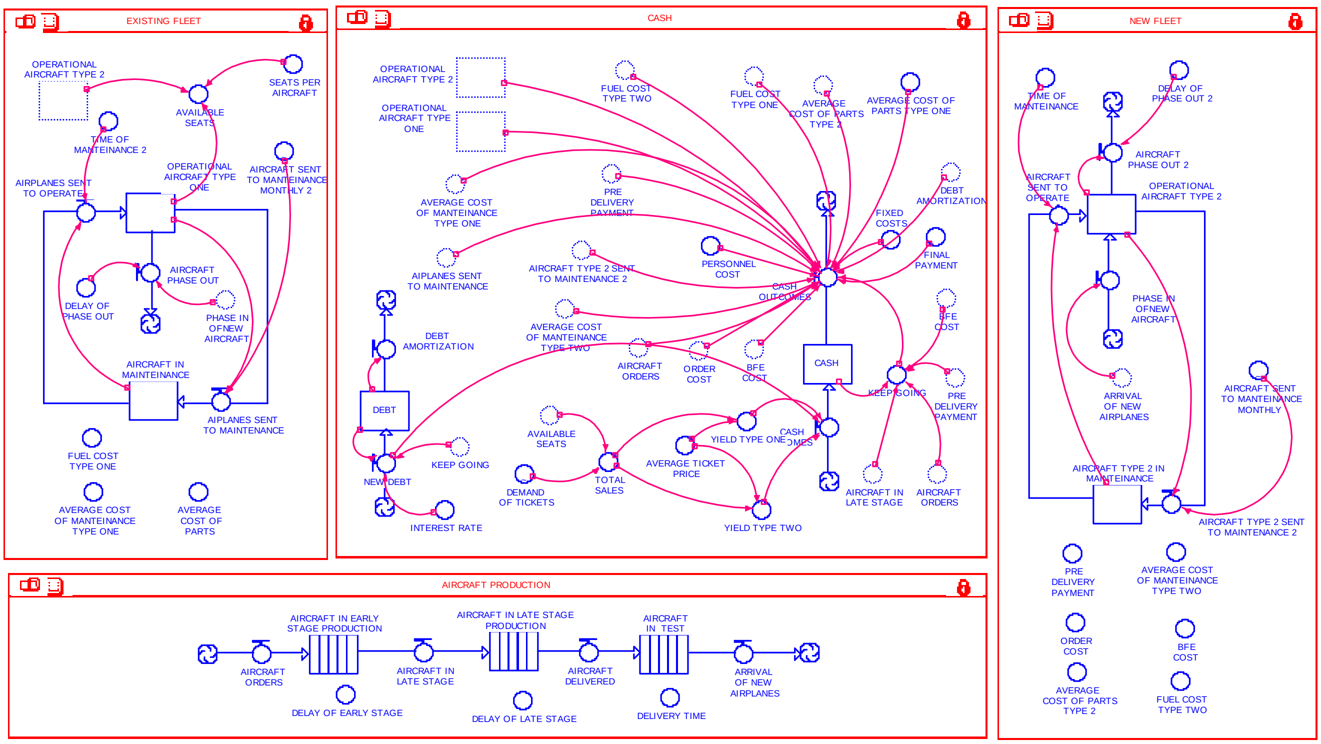

Figure 1. A stocks and flows diagram of the decision to buy/lend aircraft.

5.1. The new fleet sector

This sector will represent as a stock the amount of new aircraft currently operating (operational aircraft type two), as well as the aircraft that are currently in maintenance (aircraft in maintenance type two). In spite of the fact that for an airline there are four types of maintenances (with their respective delays), we assume, in order to simplify the model, that there is an average delay of aircraft on maintenance, and a fixed number of aircraft that are sent to maintenance monthly.

The stock of new aircraft will only increase when the manufacturer delivers airplanes. Of course, there is a flow representing a possible phase out.

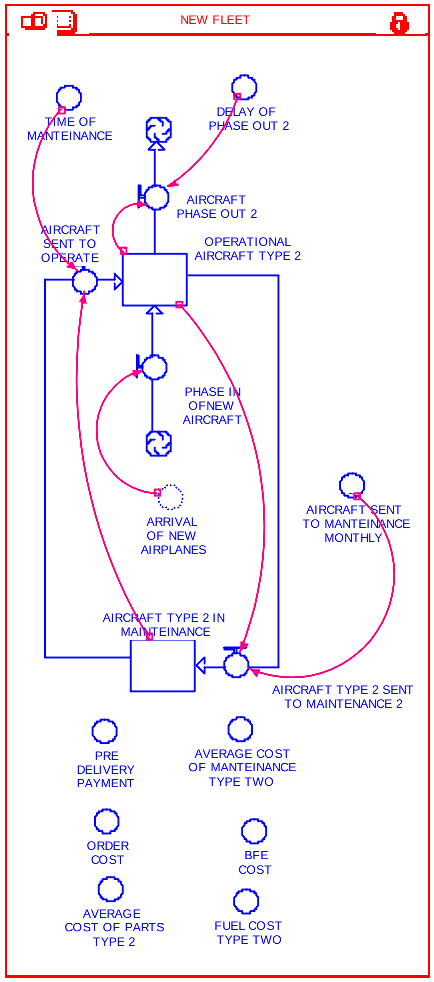

Figure 2. Sector of new fleet

Additionally, the sector includes some variables that are important to the cash flow of the enterprise, such as the average cost of maintenance (the average of A, B, C and D checks), the order cost (how much the manufacturer production slot will cost), the average cost of parts (how much will cost the monthly routine maintenance and the replacement of parts per aircraft), and the average cost of fuel (given a certain frequency of usage, how much will cost the fuel to fly this airplane).

5.2. The cash sector

This sector is the most important sector of the model, because it involves the decisions taken by the airline, the operational cost, the investment cost (related to the purchase of new aircraft), and the cost of financing the purchase of the aircraft through debt.

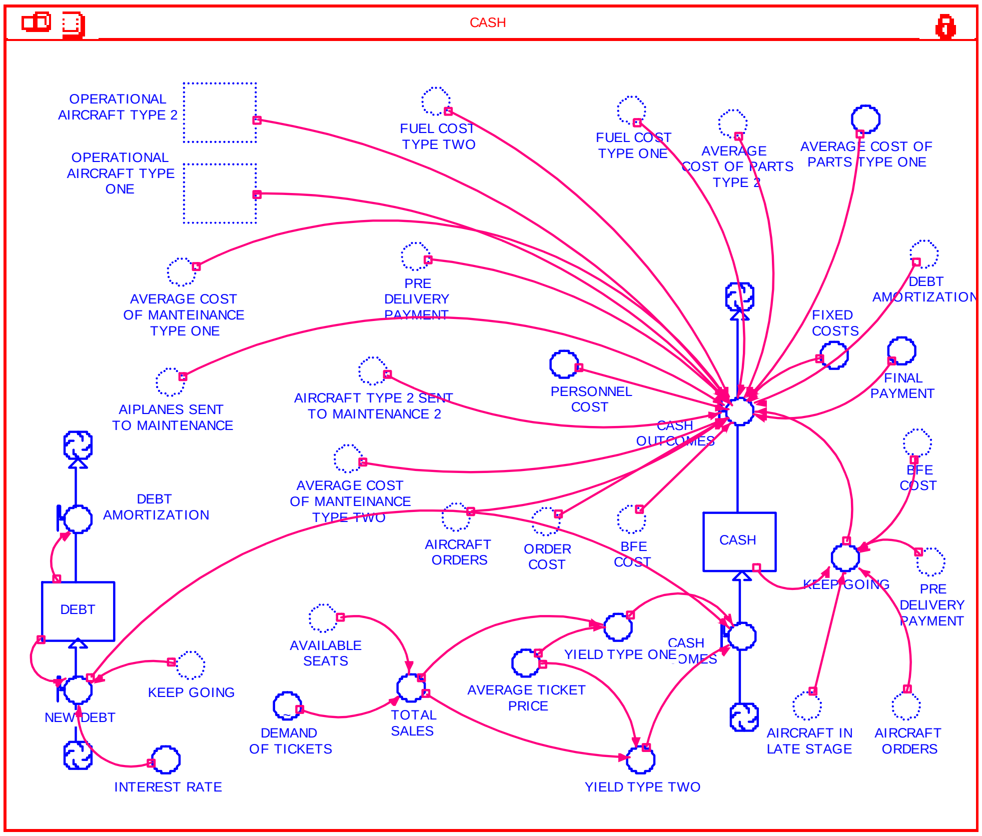

Figure 3. Sector of cash dynamics

The sector has two stocks (the cash and the debt) that depend on other stocks part of different sectors (operational aircraft of type one, and operational aircraft of type two) as well as on flows related to the manufacturer production. The cash inflow incorporates the operating incomes (total of tickets sold multiplied by the average price per ticket), and also incorporates cash flows related to contracted debt in order to finance the purchase process of the airplanes. Outflows consist of the maintenance cost (the average cost of maintenance per aircraft multiplied by the number of aircraft sent to maintenance), the operating cost (the number of operational aircraft of type one and type two multiplied by the average cost of operation per aircraft), the fixed costs (the cost of personnel and fixed operation costs –machinery, outsourcing-), the BFE cost (the cost of adequate an aircraft and the installation of seats, avionics and others –depending on the variant of the aircraft-), the debt amortization (the payments made to amortize acquired debt), the final payment (the amount of money to be paid at the end of the process for the purchase of the aircraft), the pre-delivery payment (the percentage of the total price of the aircraft that must be paid to the aircraft maker before the delivery), and the order cost (the cost to be paid for the right to purchase a plane).

Additionally, the other stock of this sector is the debt, that is the amount of money to be loaned in order to finance some stages of the purchase of the airplane. This model involves as inflows the amount of contracted debt and the interest caused by it, and as an outflow, the payments made in order to amortize the financial obligations. The decision to acquire a debt in this model is based on the amount of available cash in the moment of money flows related to the BFE, final payment and pre-delivery payment. When there is enough cash, the airline will use its existing money; when there is not, it will acquire money through debt.

5.3. The existing fleet

The existing fleet represents the older aircraft in the airline (to be replaced by the new fleet). This sector represents as a stock the amount of aircraft currently operating (operational aircraft type one), as well as the aircraft that are currently in maintenance (aircraft in maintenance type one). We assume, in order to simplify the model, that there is an average delay of aircraft on maintenance, and a fixed number of aircraft that are sent to maintenance monthly. In the model we expect the cost of maintenance of old aircraft to be higher than the cost of maintenance of new aircraft. The stock of old aircraft does not increase and decreases only when the manufacturer delivers new airplanes (this process is not immediate –it is a delayed process–, so it is possible to have old airplanes waiting to be phased out).

Additionally, the sector includes some variables that are important to the cash flow of the enterprise, such as the average cost of maintenance and the average cost of fuel (we expect that both costs are higher than those related to new aircraft).

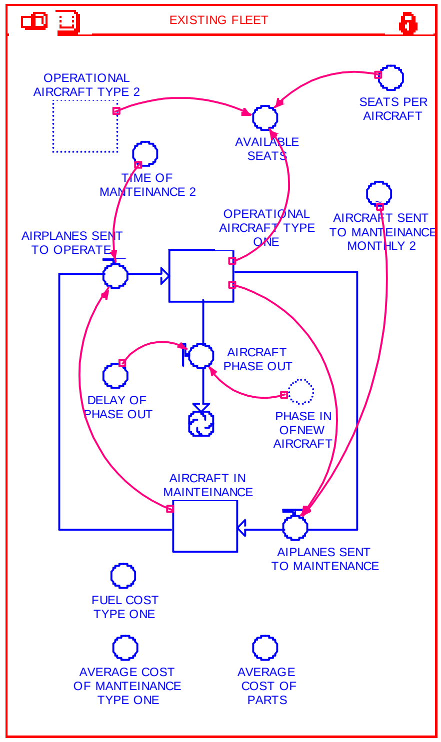

Figure 4. Existing fleet sector

5.4. The aircraft production sector

In this sector we model the production of aircraft by the manufacturer having three stages: early production, late production and aircraft in test. This part of the model considers that the orders are a fixed number (number of aircrafts to replace), and the rest of the chain will be another delayed chain accumulating the different stages of production of the aircraft during the 73 months period (approximately) required to produce and deliver an aircraft. The delays in all the stages are subject to negotiation between the airline and the aircraft manufacturer.

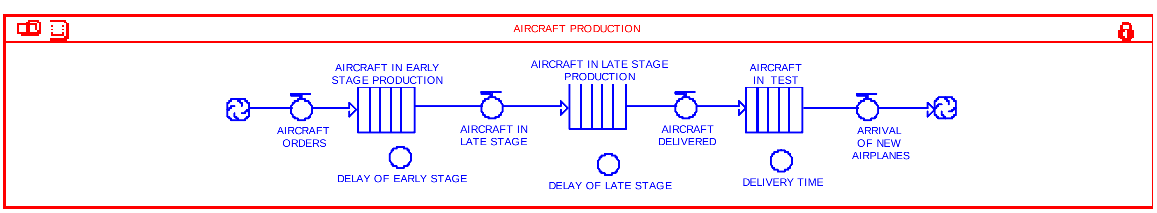

Figure 5. Aircraft production sector

6. Model validation and policy testing

The validation of the model must be performed in light of the assumptions used in its construction. Due to the complexity of an airline, the analysis of operating, indirect and overhead expenses was somehow limited. However, that constraint should not be a problem when explaining the behavior of the relevant variables, since it is plausible to think that the variables not included in the model would remain constant during a fleet renewal program. Or at least they will not depend strongly on the variables related to such program. Thus, we are trying to probe that the model is valid *ceteris paribus*.

6.1. Model assumptions

The assumptions that will receive more attention are those on which the spirit of the model depends. For instance, the model assumes an average operation for all the aircraft but that does not take into account the huge variance in the length of the routes of a mid-sized airline. An Airbus A319 can be suitable for a short domestic route such as Bogotá – Cali (200 miles approx) or an international route such as Bogotá – Toronto (2,800 miles approx). Of course, that simplification produces certain bias in the results because some costs do not depend proportionally on the distance between destinations.

In addition, the average one-way ticket price was assumed to be 170 USD, which is somehow expensive in light of the recent boom of the low cost carriers (even in third world countries).

The maintenance time was also used implicitly in the average fleet operation hours. The figures were acquired from the information that airlines report to the Colombian Aviation Authority (Aeronáutica Civil de Colombia).

The model also assumes an initial deficit of 540 million USD. The model is highly sensitive to this parameter because it determines whether or not the company gets a long-term credit to finance its operations.

Additionally, the dates and amounts of pre-delivery payments (PDP), order payments, BFE, and final payments are subject to the specific negotiation with the manufacturer. Most importantly, the possibility of wet or day lease or a sale and lease back (SLB) transaction was ignored in the model.

Maintenance costs are assumed to be constant. In a more detailed model these costs should be analyzed widely. For instance, the cost of parts and component repairs must rise when the fleet becomes old, particularly on new generation aircraft, because they have a “worst” old age and their maintenance is more expensive.

In the model, the phase out process is automatic and independent from the aircraft purchase structure. However, in real airlines the purchase decisions are made trying to keep constant the number of aircraft in operation during the entire replacement process.

All these constraints and limitations must be analyzed in a later version of the model.

6.2. Model results

When running the model, a time frame of 40 years was used because in this version, all the old aircraft are phased out after 20 years (240 months) or operation. The following results are observed.

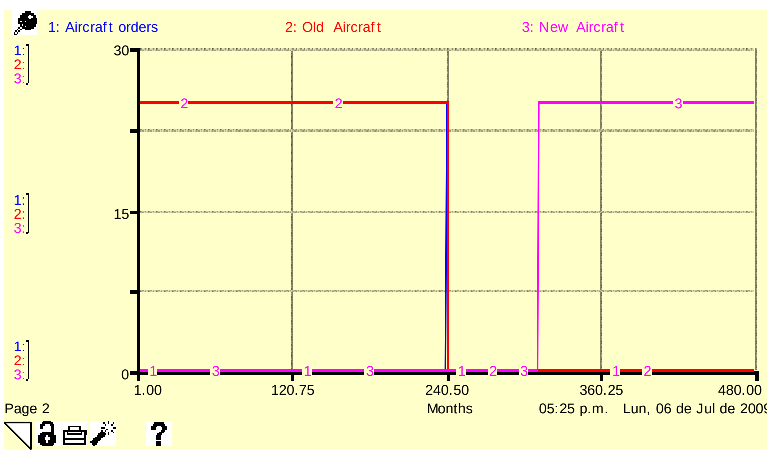

Figure 6. Old and new aircraft

The figure six appears to be consistent with the model, as it represents the fleet renewal process. A closer look to the graphic shows that at the moment of old aircraft phase out and the order of new aircraft, the model illustrates that the airline will be without aircrafts between months 240 and 308, this is a consequence of the delay between the order and the arrival of aircraft (68 months). As the order is made only at the moment of the phase out, it is expected to observe the lack of aircraft in the airline. Given this inconsistency, the model was enhanced modeling a renewal policy that allowed the preservation of the fleet size (see figure 7) making the orders of new aircraft each two months (from month 112), and starting phase outs from the month 180 (also each two months).

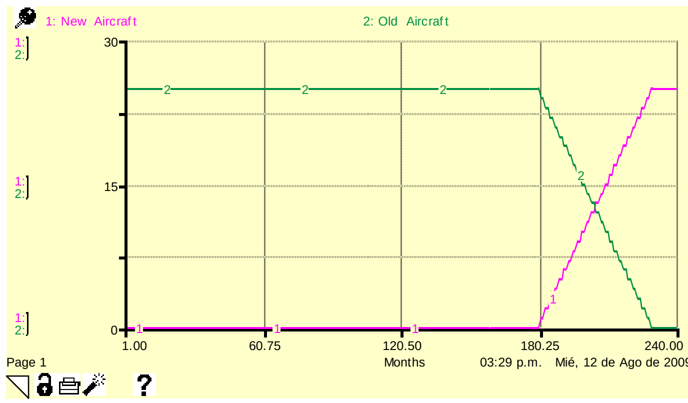

Figure 7. Old and new aircraft under the new model

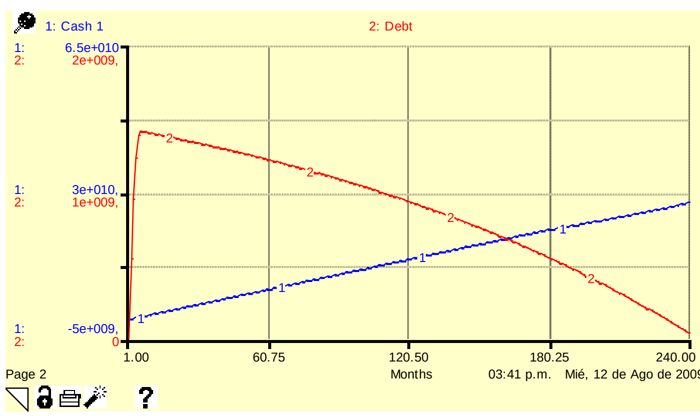

Figure 8. Cash and debt

With these changes we can observe on figure 8 the behavior of the cash and the debt. Because in this representation the fleet renewal process is started on the month 110, we see that the existing debt on the airline is covered by the incomes from ticket selling in the airline, therefore this explains the fall on the debt in the model, and the linear increase on the cash in the airline. In spite of these considerations, the debt size and the amortizations behave realistically.

6.3. Policy testing

The model was validated according to the procedures proposed by Sterman (2000). But due to the assumptions stated on section 6.1, we present in this section the evaluation of the model behavior under different scenarios which were validated with functionaries of an airline.

On the analysis we found that the model is sensible to the fuel price (as expected) so when oil price is higher to 100 dollars per barrel the decision to renew the fleet is completely justified. Additionally the load factor as well as the interest rate is determinant, because this conditions the cash flow of the airline.

During the years 2005 to 2007 the oil prices oscillated between 70 and 80 dollars per barrel (Figure 9), which correspond to the base scenario. Therefore this value corresponds to the cost of 2.685 dollars of fuel per flight hour (on a MD 83). In the case the fuel price reaches his maximum value, this would be a cost of 5.368 dollars per flight hour, that corresponds to the fuel price in the situation of an oil price of 147 dollars per barrel, as seen on July 11th of 2008[11]. The lower limit of the fuel price would be of 1.342 dollars per flight hour that is the fuel price that corresponds to the oil price on September of 2000.

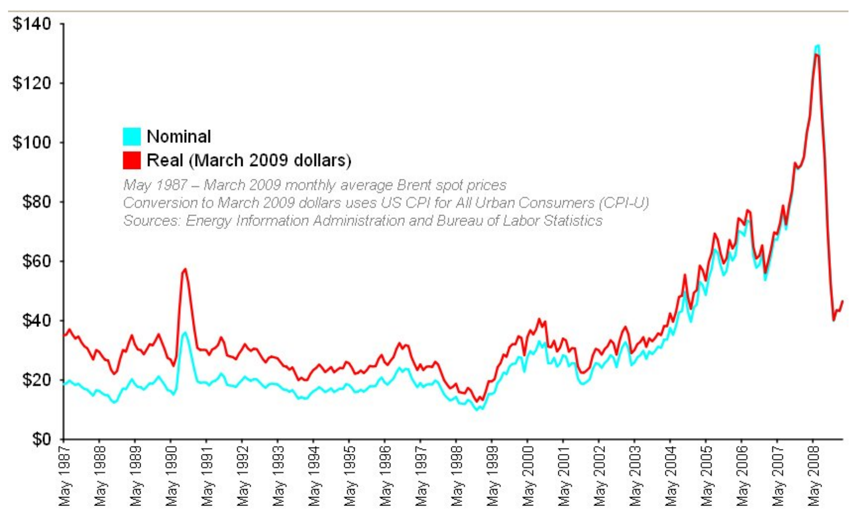

Figure 9. Oil price

---

[11] BBC news http://newsvote.bbc.co.uk/2/hi/business/7501939.stm retrieved on March 15, 2009

As a hypothesis we could affirm that as oil price rises, fuel prices would do the same, and then it would be a better option to renew the aircraft fleet. Under this test, we will assume that the renewal process is started on month one of the simulation and also that the fuel price is constant during the whole run, also the order is made before the old aircraft has been phased out.

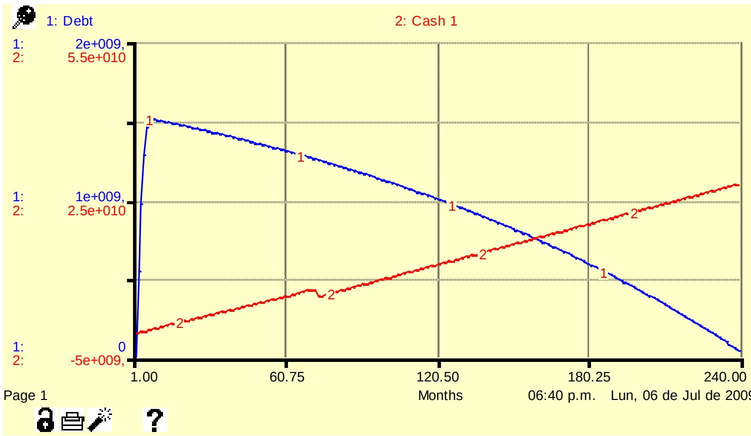

Figure 10. Base run

On figure 10 we can see that this decision increases the debt, but does not affect strongly the cash of the airline, which tends to improve from a high deficit to a linear improvement in the cash, due to the savings achieved to the replacement of the fleet.

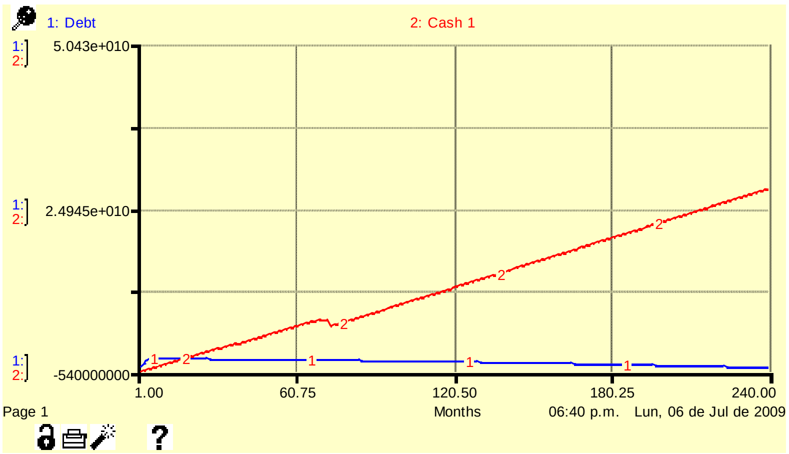

Figure 11. Lower oil price

When we evaluated the impact of a lower oil price we would expect that the decision of renewing the fleet might not be so good, but as seen on figure 11 the cash flow maintains the linear-growing tendency mentioned on figure 10. The debt is a little higher than the base case, and the cash has a slight decrease, this is a consequence of the debt and payments to banks and other cost as crew cost are (higher in A320´s); still with the new aircraft on the fleet there will be savings on fuel prices.

On the worst case scenario regarding the fuel price (a high fuel price), the renewal process of the fleet show an increase in debt size in the short term, but in the long time the cash improves given the lower expenses on fuel and maintenance (on the short term new aircraft requires a cheaper maintenance), allowing a greater capacity to redeem the debt (Figure 12).

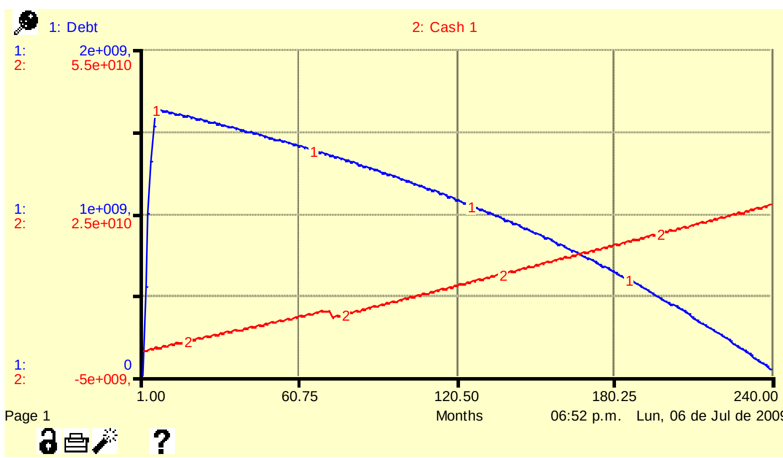

Figure 12. Higher oil price

Now evaluating the impact of the interest rates on the decision, we could expect that a higher interest rate would make less feasible the decision to renew the aircraft fleet, additionally higher interest rates reduce the interest of airlines to acquire debt. According to international interest rates, we will assume in the model an interest rate of 0.5% per month. As a possible scenario we could analyze what is the impact of a higher interest rate, let's say 1.5% per month; on this situation the debt increases from $ 23 USD millions to $ 53 USD millions, but the cash is not dramatically affected by this change, because as the debt is deferred, the impact on the cash is diminished.

On the other hand, when the load factor changes, this seems to affect dramatically the cash flow of the airline, but the decision of fleet renewal maintains its feasibility on the scenarios where the load factor is higher than the 46%. Because the current load factor for Latin America is 74,5% and the minimum load factor registered has been of 59%[12] , we can affirm that the decision of a fleet renewal process is highly recommended.

Now that we´ve seen that a fleet renewal process is higly reccomended, we should now analyze which renewal scheme woul be better for the airline in terms of their cash and debt. As can be seen on table 1 under the different purchase programs, the debt seem not to change dramatically. Avoiding the purchase of the aircraft would improve the cash on the airline, but should reduce competitiveness of the airline (older planes reduce the portafolio of possible on fligth services), the process of buying al the fleet at the begginnning causes a lower cash, but allows a faster phase out process. Delaying the process of fleet change (over a period of ten years or buying 3 airplanes each 68 months) would improve the cash but if oil prices rises, that also would imply higher costs. On the other side this would allow a easier transition to a new fleet and I a future a easier trancision to other aircraft (not all the planes would be on phase out at the same time).

POLICY/INDICATOR	CASH (MILLIONS OF USD)	DEBT (MILLIONS OF USD)
AVOID FLEET RENEWAL PROCESS	56000	23
FLEET RENEWAL PROCES UNDER A PERIOD OF TEN YEARS	35000	23
BUY BATCHES OF 3 AIRCRAFT EACH 68 MONTHS	45611	23,9
BUY ALL THE FLEET AT THE BEGINNING	23000	22

Table 1. Summary of results of different renewal schemes

[12] MIT *web.mit.edu/**airlines**/conferences/DC.../05-DC2002-Belobaba.pdf* retrieved on march 15 of 2009

7. Conclusions

Stock and flows diagrams used to map a real-world situation were helpful to understand the variables, parameters and structures relevant to it. In this case, the mapping process allowed the identification of key variables convenient to define possible dynamic hypothesis about fleet replacement programs.

The lack of sufficient data is a temporary constrain in terms of building a well-calibrated model. The model shown in this paper has several elements to consider; for instance, the variation of maintenance cost with the age of the aircraft, the impact of the flight hour/cycle ratio on the operating costs, the seasonality of passenger demand, the production line details and the contract provisions of aircraft orders, and how these parameters vary on each airline

In the short term, it can be inferred that replacing the existing fleet with a more recent one is not profitable in terms of the financial performance of the airline. Nevertheless, in the long run, the decision might be profitable and adequate, as the operating costs might be optimized. This does not neglect the sensibility of the decision to numerous external factors (e.g. oil prices, passenger demand, credit availability, interest rates or political factors).

The rate of renewal may be quite important, since in certain conditions the savings in operating costs are not capable of balancing the high expenses in pre delivery payments, in the BFE process and in the purchase of the initial provisioning. Of course, this is a tough planning problem that involves high dynamic complexity. Delays are the hardest factors to deal with. Airlines have to make decisions that will affect their financial and operational performance several years later. Being the air transportation industry so sensitive to external factors, this is quite a big deal.

It is strongly desirable to compare the model and its results against decisions made by actual commercial airlines.

8. References

Benkard, C.L. A Dynamic Analysis of the Market for Wide-Bodied Commercial Aircraft. Review of Economic Studies (2004) 71, 581-611

Braun, W. (2002). The System Archetypes. Available at: http://wwwu.uniklu.ac.at/gossimit/pap/sd/wb_sysarch.pdf Retrieved on: 22.03.07.Forrester, Jay W. Industrial Dynamics. Cambridge, MA, The M.I.T. Press, 1961.

Jiang, H., Hansman, J. Analysis of Profit Cycles in the Airline Industry. MIT Global Airline Industry Program. Industry Advisory Board Meeting. November 4th, 2004, Massachusetts Institute of Technology, International Center for Air Transportation.

Kleer, B., Cronrath, E., Zock., A. Market development of airline companies: A system dynamics view on strategic movements. Proceedings of the 26th International Conference of the System Dynamics Society. Athens, University of Patras - Panteion University Greece, 2008. ISBN: 978-1-935056-00-3.

Liebrand, W. (1998). Computer modeling and the analysis of complex human behavior: retrospect and prospect. In: Liebrand, W., Nowak, A. & Hegselmann, R. (eds.), *Computer Modeling of Social Processes*, London: Sage Publications, pp. 1-14.

Lyneis, J. System Dynamics In Business Forecasting: A Case Study of the Commercial Jet Aircraft Industry. May 1998. Proceedings of the 16th International Conference of the System Dynamics Society, Quebec, Canada, July 1998.

Olaya, C., Díaz, F., & Caicedo S. (2007). Towards a System Dynamics Model of De Soto's Theory on Informal Economy. Proceedings of the 25th International Conference of the System Dynamics Society. Massachusetts Institute of Technology – System Dynamics Group, Boston, MA, USA 2007. ISBN: 978-0-9745329-7-4.

Sterman, J. (2000). Business Dynamics. Systems Thinking and Modeling for a ComplexWorld. McGraw-Hill.

Wacker, J. (1998). A Definition of Theory: Research Guidelines for Different Theory- Building Research Methods in Operations Management. *Journal of Operations Management*,Vol. 16, No. 4, pp. 361- 385.

Annex 1. Equations of the model

AIRCRAFT PRODUCTION

Aircraft_in_late_production_stage(t) = Aircraft_in_late_production_stage(t - dt) + (Aircraft_to_late_production_stage - Aircraft___to_testing) * dt
INIT Aircraft_in_late_production_stage = 0
TRANSIT TIME = 33
INFLOW LIMIT = INF
CAPACITY = INF
INFLOWS:
Aircraft_to_late_production_stage = CONVEYOR OUTFLOW
OUTFLOWS:
Aircraft___to_testing = CONVEYOR OUTFLOW

Aircraft_in_testing(t) = Aircraft_in_testing(t - dt) + (Aircraft___to_testing - Delivery_of__new_aircraft) * dt
INIT Aircraft_in_testing = 0
TRANSIT TIME = 3
INFLOW LIMIT = INF
CAPACITY = INF
INFLOWS:
Aircraft___to_testing = CONVEYOR OUTFLOW
OUTFLOWS:
Delivery_of__new_aircraft = CONVEYOR OUTFLOW

Aircraft_on_early_production_stage(t) = Aircraft_on_early_production_stage(t - dt) + (Aircraft_orders - Aircraft_to_late_production_stage) * dt
INIT Aircraft_on_early_production_stage = 0
TRANSIT TIME = 35
INFLOW LIMIT = INF
CAPACITY = INF
INFLOWS:
Aircraft_orders = ORDERS
OUTFLOWS:
Aircraft_to_late_production_stage = CONVEYOR OUTFLOW

Delay_of_early_stage = 35

Delay_of_late_stage = 53

ORDERS = GRAPH(TIME)
(1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 0.00), (51.0, 0.00), (52.0, 0.00), (53.0, 0.00)...

CASH

Ammount_of__amortizations(t) = Ammount_of__amortizations(t - dt) + (New_amortizations - Paid_amortizations) * dt

INIT Ammount_of__amortizations = 0

TRANSIT TIME = 240

INFLOW LIMIT = INF

CAPACITY = INF

INFLOWS:

New_amortizations = Debt__payment

OUTFLOWS:

Paid_amortizations = CONVEYOR OUTFLOW

Cash_1(t) = Cash_1(t - dt) + (Operative__Incomes - Operative__outcomes) * dt

INIT Cash_1 = -540000000

INFLOWS:

Operative__Incomes = New_debt+Incomes*Flight_cycles__per_month-New_debt+DELAY((Aircraft_in_phase_out+Old_aircraft_phase_out)*Cost_of__selled_aircraft,2)

OUTFLOWS:

Operative__outcomes = BFE_Cost*Aircraft_to_late_production_stage+Aircraft___to_testing*Predelivery__payment+Final_payment*Delivery_of__new_aircraft+Aircraft_orders*Order_cost+Ammount_of__amortizations+Operative_cost__of_old_aircraft+COSTOS_OPERATIVOS_AERONAVES_NUEVAS

Debt(t) = Debt(t - dt) + (Interests + New_debt - Debt_amortization) * dt

INIT Debt = 0

INFLOWS:

Interests = Debt*Interest_rate

New_debt = Is_money_required?

OUTFLOWS:

Debt_amortization = Ammount_of__amortizations

Average__ticket_price = 250

Cost_of__selled_aircraft = 5000000

Debt__payment = (New_debt*Interest_rate*((1+Interest_rate)^240))/(((1+Interest_rate)^240)-1)

Final_payment = 45000000

Flight_cycles__per_month = 186

HORAS_DE_VUELO__AL_MES = 168

Incomes = Average__ticket_price*Seats__per_aircraft

Interest_rate = 0.005

Is_money_required? = if(Cash_1<0) then (-Cash_1) else(0)

Load_factor = 0.745

Operative_cost__of_old_aircraft = Old__Aircraft*(Manteinance_cost__of_old_aircraft+Fuel_cost_of_old_aircraft)*HORAS_DE_VUELO__AL_MES

Seats__per_aircraft = Load_factor*Available_seats

EXISTING FLEET

Old__Aircraft(t) = Old__Aircraft(t - dt) + (- Old_aircraft_phase_out) * dt
INIT Old__Aircraft = 25
OUTFLOWS:
Old_aircraft_phase_out = GRAPH(time)
(0.00, 0.00), (1.00, 0.00), (2.00, 0.00), (3.00, 0.00), (4.00, 0.00), (5.00, 0.00), (6.00, 0.00), (7.00, 0.00), (8.00, 0.00), (9.00, 0.00), (10.0, 0.00), (11.0, 0.00), (12.0, 0.00), (13.0, 0.00), (14.0, 0.00), (15.0, 0.00), (16.0, 0.00), (17.0, 0.00), (18.0, 0.00), (19.0, 0.00), (20.0, 0.00), (21.0, 0.00), (22.0, 0.00), (23.0, 0.00), (24.0, 0.00), (25.0, 0.00), (26.0, 0.00), (27.0, 0.00), (28.0, 0.00), (29.0, 0.00), (30.0, 0.00), (31.0, 0.00), (32.0, 0.00), (33.0, 0.00), (34.0, 0.00), (35.0, 0.00), (36.0, 0.00), (37.0, 0.00), (38.0, 0.00), (39.0, 0.00), (40.0, 0.00), (41.0, 0.00), (42.0, 0.00), (43.0, 0.00), (44.0, 0.00), (45.0, 0.00), (46.0, 0.00), (47.0, 0.00), (48.0, 0.00), (49.0, 0.00), (50.0, 0.00), (51.0, 0.00), (52.0, 0.00)...

Available_seats = (New__Aircraft+Old__Aircraft)*Seats_per_aircraft
Fuel_cost_of_old_aircraft = 2685
Manteinance_cost__of_old_aircraft = 1243
Seats_per_aircraft = 170

NEW FLEET

New__Aircraft(t) = New__Aircraft(t - dt) + (Delivery_of_the__new_aircraft - Aircraft_in_phase_out) * dt
INIT New__Aircraft = 0
INFLOWS:
Delivery_of_the__new_aircraft = Delivery_of__new_aircraft
OUTFLOWS:
Aircraft_in_phase_out = delay(Delivery_of_the__new_aircraft, 240)

BFE_Cost = 3660000
Fuel_cost_of__new_aircraft = 0.3877*Fuel_cost_of_old_aircraft
Manteinance__cost_of_new_aircraft = 682
Order_cost = 1000000
Predelivery__payment = 2000000
total_aircraft = New__Aircraft+Old__Aircraft

Not in a sector

COSTOS_OPERATIVOS_AERONAVES_NUEVAS = New__Aircraft*HORAS_DE_VUELO__AL_MES*(Manteinance__cost_of_new_aircraft+Fuel_cost_of__new_aircraft)