The Design of a Large Scale Airline Network

Many airlines have bankrupted in the past years, and today many of them are suffering from the economic downturn. Governments have had to help airlines to avoid bankruptcy. Governments have had to inject money to safe airlines. It is a measure that represents a big cost to the society in general. Governments should not use money to safe airline companies because this is money that could be invested for other purposes. It means that governments, investors, and airline managers need to design and operate sustainable networks, and study the feasibility or unfeasibility of new airline business models to assure a sustainable air passenger transportation industry.

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In other words, airlines have to know what routes represent good possibilities to subsist or succeed in a very competitive market. First, countries and states with high increments of gross domestic product (GDP) are more attractive to open airline services (i.e. China, Brazil). Second, the level of deregulation at different countries allows airlines to find new routes and new networks to invest in other carriers or open services (i.e. Copa and Continental Airlines). Third, low fares, offered by low cost carrier's (LCC's), appear to be the main cause of the increase passenger flow worldwide [Carmona Benitez, 2012]. Fourth, the evolutions of the LCC's have increased the possibilities of airports to increase their revenues and pax flow by opening more routes operated by LCC's. Finally, points one to four will occur in many countries after their Civil Aviation Authorities eliminate restrictions on routes and fares giving the opportunities for airlines, airports, federal governments, states and investors from other countries to find new opportunities by identifying the right networks to serve. These five points lead to with the main thesis question:

What passenger's airline networks represent business opportunities and are attractive for an airline to open new air services? (Main Question)

Besides the differentiation between full service carrier's (FSC's) and LCC's, airline business models can also be differentiated depending on the routes lengths. The long-haul business model has been studied by many researches and airline companies, and most of them determined the unfeasibility of the long-haul low cost business model. However, they did not assess the feasibility or unfeasibility of the long-haul business model using a mathematical calculation model technique that is made to design sustainable airline networks, as it has been done in Carmona Benitez [2012].

Therefore, another important sub question to solve is:

Photo 1. *Amsterdam Airport Schiphol is a major European gateway for Skyteam partner Delta. Photo by Hubert Croes*

Can the low-cost model be implemented to long-haul markets? (SQ4)

The main important for governments is to ensure air transportation systems that promote economic growth and enhance economic growth per capita for the population living in their cities and regions. Millions of people are related to the air transportation industry by different means. The passengers are the clients, workers make it operationally possible, and investors make it financially possible.

The air transport passenger (pax) growth is enhanced by certain variables that local economies might or might not have such as population, wealth, income, GDP, traveling culture, airport capacities and infrastructure, and communication facilities. Strong relationships exist between these parameters and the development of local economies [Macario et al, 2007].

Photo 2. *Empty gates at Amsterdam Airport Schiphol after an afternoon outbound wave. Photo by Hubert Croes*

Macario, Viegas and Reis [2007] divide the benefits of increasing airlines services on regional economies into three main classes: direct effects, indirect effects and catalytic effects. Burke [2004] estimated that for every million passengers through an airport, approximately 1,000 jobs are generated.

Project definition

To answer the main question above defined, it is important to investigate on the following sub questions:

SQ1. What are the main parameters that determine airline route fares, airline operational costs and airport charges between two airports/cities?
SQ2. What are the main parameters that determine the passenger demand per route between two airports/cities?
SQ3. What are the main consequences of the competition between different airline business models FSC vs. LCC?

These three sub questions allow understanding what are the parameters that play an important role and that have to be considered in a mathematical model that intents to simulate and optimize the behavior of an airline, and the consequences of the competition between airlines operating same routes. In Carmona Benitez [2012], these sub questions were solved, and different models were developed to analyze and generate enough data and make a good simulation of the behavior of the air passenger transport industry. The main characteristic of these mathematical models is the fact that they were developed using the less possible number of parameters with high correlation results with real data. The less possible number of parameters is expected to allow the application of the mathematical models developed in Carmona Benitez [2012] in different markets worldwide.

Methodology

The following steps are identified to provide answers to the research main questions and sub questions:

- Models and methodologies were developed to design airline networks by linking the demand of passengers with airline operating costs, route fares, and maximize the net present value (NPV) of the airline network constrained to airports capacities and infrastructures, aircrafts performance, and levels of services.
- On the basis of the passengers demand, a traveller demand model was developed. This model consists on different mathematical models that calculate airline route fares, and the induced demand per route. The calculations of these models are used as input parameters to design an airline network. A mathematical model to assess the competition between airlines serving same routes was developed. In the traveller demand model, the competitive average and range (min and max) fares are determined. The travel demand model also selects those routes that represent a new market opportunity to open air passenger transportation services.
- On the basis of the production, a production model was designed. This model consists on mathematical models that calculate airlines and aircrafts costs. The calculations of aircrafts costs are used as input parameters to design an airline network. The calculations of airline operating costs are used to understand the competition between airline business models.
- On the basis of the line service network, an optimization model to consider airports capacities and infrastructures, aircrafts performance, and levels of services was developed. The optimization maximizes the net present value (NPV) based on the minimization of the operating costs, and maximization of profits.
- A route generator algorithm was designed. The route generator algorithm re designs the airline network after each optimization iteration. The algorithm selects routes that are part of the network and eliminate routes that are not part of the network. Finally, the route generator algorithm stops when an optimum airline network is designed.

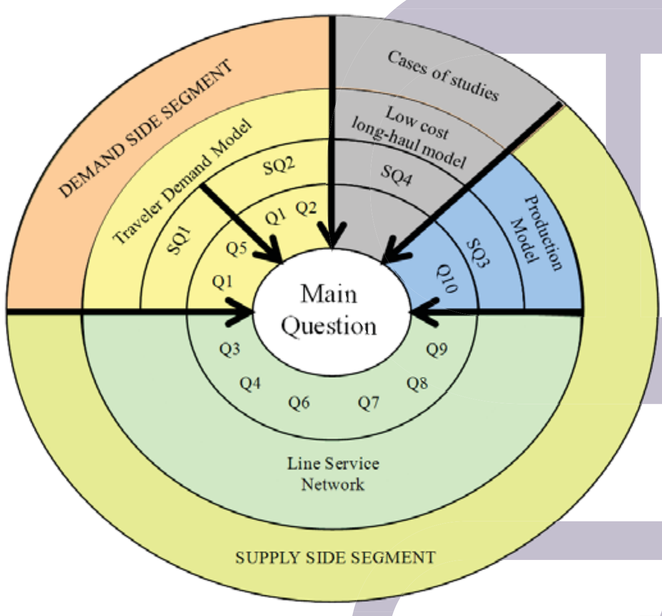

Figure 1. *Relation between the main research questions, the ten underlying questions (Q), the four sub questions (SQ), and the demand and supply sides*

Figure 1 shows a diagram that indicates the relation between business parameters (cost, services, and regulations) on the supply side, and the demand side segments with the research questions. The diagram also shows how the research questions interact to solve the main question and the relation between the four sub questions (SQ) and the ten underlying questions (Q).

Since no detail free information on European or Mexican aviation was available, this thesis focuses on the US aviation industry. Other empirical data was gathered from US Bureau of Economic Analysis, US Census Bureau, US Bureau of Transportation Statistics, Research and Innovative Technology Administration (RITA), and AviationDB database.

Figure 2 presents the logical steps and structure of the thesis. The approach is bottom-up from Figure 1.5. It shows the logical steps and structure of the thesis. The flow shows how the mathematical models work and relate each other to design an optimum network (NTW) per aircraft type. Figure 2 presents the mathematical models developed in Carmona Benitez [2012]: Competitive fare estimation model (CFEM), Pax induced demand model (PEM), Aircraft fuel consumption model (AGE), Aircraft operating cost model (POC), Route Generator Algorithm, and the NPV optimization model.

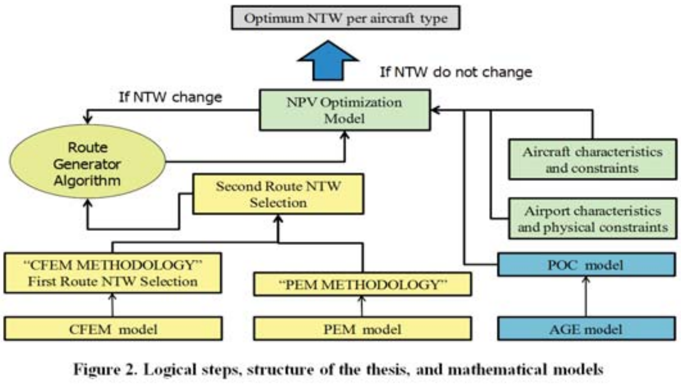

Figure 2. *Logical steps, structure of the thesis, and mathematical models*

Optimization model

The optimization model includes a bi-objective function, which is defined with based on multiple variables relations. The optimization model determines what routes to flight, what aircraft type and how many of them to buy, number of frequencies per route and number of passengers to attend when there are other airlines supplying service. This model aims to maximize the net present value and the network number of passenger, as a tool to design airlines networks. In this section, the summary of the optimization model is given taking into account the competition between airlines operating same links.

In order to consider the competition between airlines the relationship between market share and capacity share was added to the optimization model. The relationship between market share and capacity share may explain the reaction of passengers when an airline enters or increase the number of flights in a route link. The market share (MS) of an airline is determined as the ratio between the number of pax transported by the airline and the total number of pax transported on the link. In this thesis, the market share of an airline is calculated equation considering that each airline operating a link provides services to its optimum number of pax flow depending on their aircraft flight cost, airline optimum number of frequencies, an empirical constant value, and the desire of pax to travel a route.

Conclusions

Carmona Benitez [2012] designed an optimal airline network for short haul using data from the United States. This study case was used to validate the models and methodology. Then, the models and methodology were used to design a long haul low cost airline network as hypothetical study case. It can be concluded from the studies cases that the mathematical models and methodologies are able to determine those routes that represent an opportunity to open new services by designing an optimal airline network.

From the results of the simulation of the long-haul low-cost model, it can be concluded that the business model did not work. The results indicate that there are no so much differences with the long-haul FSC model, and this indicates that the development of a long-haul low-cost is very unlikely. In general, the long-haul low-cost study cases showed that carrying cargo is what allows long-haul airlines to earn more money, but this business is already operated by FSC's and cargo companies. Besides, the CFEM model developed [Carmona Benitez, 2012] calculate equal airline route fares between FSC's and LCC's as distance increases. It indicates that open services with low fares do not represent a competitive strategy.

Important contributions are the methodology and mathematical models developed in this thesis because they do not require many data to design an airline network. Their parameters are common for any geographical location, reason why these models and methodology are expected to be useful at different geographical locations. They have been proved to be reliable tools to develop an airline network, and they allow studying and assessing the feasibility of airlines networks. They can help airlines to visualize and plan future expansion, and they can help aircraft manufacturers to design aircrafts that are suitable with the future conditions of the air pax transport industry. Finally, the models can be used by airport companies, investors, and governments to make investment analyses, and maximization of airports capacities and infrastructures.

This thesis can serve as a base for future studies in airline network design, because it includes all variables in the system. The study contributes by joining all models, some taken from literature and the developed models, into one model.

Photo 3. *Lufthansa aircraft at Frankfurt, the main European hub of Star Alliance. Photo courtesy of Lufthansa Systems.*

About the author

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