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PROJECTE O TESINA D'ESPECIALITAT

Títol

THE LOW-COST EFFECT IN A MULTI-AIRPORT REGION:

THE RYANAIR CASE STUDY

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RESUM

PARAULES CLAU: Ryanair, Low-cost, Aeroports, Aerolínies, Barcelona

Ens trobem en una era en què el transport aeri es troba en expansió i que a més constitueix una eina econòmica i estratègica. No per la indústria en si sinó pels interessos posteriors que aquesta genera : turisme, comunicacions, comerç, etc. Sense dubtes les companyies de baix cost nascudes arran de la liberalització de l'espai aeri s'han posicionat en aquest mercat forçant a les companyies tradicionals a reinventar-se. Ryanair n'és el màxim exponent europeu d'aquest fenomen i en els darrers anys s'ha convertit en la segona aerolínia en trànsit aeri de l'Estat. L'entrada de Ryanair a BCN-El Prat ha propiciat un entorn més competitiu entre els aeroports de Catalunya. Arran d'aquests fets el present estudi es concentra en determinar els mecanismes que regeixen la demanda atenent a les limitacions pròpies de les dades disponibles. Amb tot, s'han emprat xifres de passatgers, preus, freqüències i costos per calibrar un model de demanda en el que s'han obtingut les contribucions esperades en cadascun dels factors. A partir d'aquest, es construeix un arbre de decisió que permet identificar quines són les estratègies que poden adoptar cadascun dels actors implicats; per una banda les companyies aèries que competeixen directament amb Ryanair i, per l'altra l'operador aeroportuari en funció de regulador del sistema.

ABSTRACT

KEYWORDS: Ryanair, LCC, Low-cost, Airports, Airlines, Barcelona

In the present time air travel is expanding while it constitutes a strategic economic motor not by the industry itself but for further generated interests in form of tourism, communications, commerce, etc. With no doubt the low-cost carriers born as the result of deregulation of the airspace have strongly positioned in this market forcing traditional companies to reinvent themselves. In Europe, Ryanair is the best example of this phenomenon. In quite a few years it has become the second busiest carrier in Spain. The entry of Ryanair at Barcelona-El Prat Airport has led to a more competitive environment between airports in Catalonia. Because of these facts this study focuses on determining the mechanisms that govern the demand on the basis of limited available data. However, passenger numbers, fares, costs and frequencies have been used to calibrate a model of demand. By this, the contributions in each of the factors have been obtained as logically expected. From this, a decision tree is built that identifies the strategies that can be adopted by each of the actors involved, on one side carriers that compete directly with Ryanair, and secondly according to the airport operator regulatory function.

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List of Abbreviations

ANOVA	Analysis of Variance
ASK	Available Seat Kilometer
ASM	Available Seat Miles
BCN	Barcelona-El Prat Airport
CASK	Cost per Available Seat Kilometer
EU-15	European Union 15 Member States until April 2004
FREQ	Frequency
FSC	Full Service Carrier
GDP	Gross Domestic Product
GDS	Global Distribution System
GREG	Relative per capita income to the Spanish average.
GRO	Girona Airport (IATA CODE)
HHI	Hirschman-Herdindahl Index. Sum of squared MS of total competitors in the market.
IDESCAT	Institut d'Estadística de Catalunya
IIA	Independence from Irrelevant Alternatives
ILD	Lleida Airport
LCC	Low Cost Carrier
LF	Load Factor
MMNL	Mixed Multinomial Logit Model
MNL	Multinomial Logit Model
MS	Market Share
MS5%	Number of competitors with a Market Share greater than 5%
NL	Nested Logit model
OAG	Official Airline Guide
O-D	Origin-Destination
OLS	Ordinary Least Squares
OP	Oil Price
PAX	Passengers
PCA	Principal Component Analysis
P-P	Probability-Probability Plot
PRC	Relative prices in comparable currency
RASK	Revenue per available seat kilometer
REU	Reus Airport
RMSE	Root Mean Square Error
RPM	Revenue passengers miles
RYR	Ryanair
TMB	Transports Metropolitans de Barcelona
VY	Vueling

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1. INTRODUCTION

Low-cost concept since in 1971 was firstly introduced by South West Airlines has served as an inspiration to many other carriers in Europe and all over the world. Its business model is based on an intense use of aircrafts and crew by reducing turnaround times which enables to reduce unit costs. This recipe has been partially repeated not only by newborn carriers but also by existing full service carriers.

At that point of pursuit of costs cut does not surprise that in 1987, American Airlines announced that by eliminating one olive from each salad served in first class had saved $40,000. Indeed, Airline Business models have always been in the spotlight concerned with the fact that Airline Industry is framed in a very vulnerable reality. Carriers' net profit margins (maximum) are globally only around 4% (IATA), when positive, normally lower than almost any other businesses. Even so, minus returns are particularly usual because airlines have high fixed and variable costs such as aircrafts, maintenance and oil prices. Moreover, exogenous events can suddenly affect demand like political decisions, terrorism, natural disasters, economy recession, etc.

In Europe, after Aviation Deregulation took place many low-cost carriers have been founded. The most successful case of Low-cost carrier in Europe has become to be Ryanair. The carrier, with no doubt, has created a parallel network of European routes joining secondary airports. Named itself pretentiously Europe's ultralow-cost airline as well as Europe's favorite airline relies on a simplified business model characterized by:

- Point-to-point network: simplicity at the top.
- Secondary airports: less congested bases which allow less daily block hours of aircraft. Reduced airport fees.
- Single new aircraft fleet: Boeing 737-800NG with 189 single class seat configurations.
- No frills service: no food, no frequent flyer program, only carry-on luggage.
- Ancillary services: if you want something extra you will pay for it such as checked luggage, priority access, meals and even for boarding pass if you forgot to print it.
- No intermediaries: most of the tickets are sold via internet.

The important thing to note however in regard to the network of secondary airports is that lately, in the context of the worldwide economic recession air traffic had also experienced a significant drop in BCN-El Prat whilst Ryanair grew in passengers in Girona and Reus.

Therefore, the airport operator and authorities saw in the Irish airline the opportunity to attract back passengers in BCN. The following was that the most popular low-cost carrier started operating and carrying passengers from Barcelona. As a result of this new framework not only BCN-El Prat increased passenger numbers but also consequences extended to regional airports which began to have less seat supply and hence traffic decreased significantly.

1.1 OBJECTIVES

Given that nowadays interaction between mentioned airports in the region is a matter of concern due to socio-economic issues this research aims at capturing the dynamic of the multi-airport system which has been established in the recent times in the Catalan Region. This is made through an analysis of the evolution of air travel demand and services offered. At the same time, these changes in the market are adjusted to a demand model under a set of simplifying assumptions while reducing explicative variables.

After having validated the model within the observed values it will be used to predict possible scenarios that could take place in the multi-airport configuration. At the end, the main contribution is to recommend actions and measures to airport operators as well as airlines whose maneuver instruments: flight fare, taxes, frequencies, accessibility, etc. have been studied. To identify such strategies is to forecast changes in the projected predicted circumstances by answering the following addressed questions:

- What would happen if other carriers are able to cut on costs and therefore offer lower prices approaching Ryanair's ?
- In which context Girona and Reus would be forced to close operations?
- What would be the best strategy from the airport's operator point of view to protect vulnerable airports?
- Would it be Ryanair in market dominance if it keeps concentrating traffic in BCN-El Prat?

1.2 STRUCTURE

To achieve these objectives this document is structured in two main blocks. The first part focuses on coming through a reliable model that can imitate the reality of the market. This done starting in **Section 1.3** with the presentation of the current background in which actual position of carriers and airports along with a short-term historical perspective are explained.

Then an exhaustive literature review is made in **Section 2** in order to compare the study with similar references that might serve either as in form of arguments or of methodology to apply in this context. It should be noted that studies that combine demand analysis with new LCC market strategies rarely have been found.

In **Section 3** the instruments that might integrate the demand model are conceptually explained immediately followed by **Section 4** where the formulation is adjusted according to prior defined criteria. In turn, results are evaluated to verify the explanatory power of the study.

Secondly, assumed that demand performance is understood, in **Section 5** future predictions are made taking into account changes that are most likely to happen. The latter part of the chapter also provides an incursion in what could be framed into a game theory problem considering a multi-player strategy.

Finally, conclusions are drawn in **Section 6** of this dissertation. It is also in this part where the model is questioned in accordance with limitations that add constraints and which challenge future researches.

1.3 BACKGROUND: THE CATALAN AIRPORT SYSTEM

In the Catalan region there are nowadays four commercial airports one of which, Barcelona-El Prat, is considered an international airport or larger regional airport in the way that it does not serve the country's major city, Madrid. However, Barcelona- El Prat trends to attract larger airlines that may use it as a strategic hub for their networks. The three remaining Girona-Costa Brava, Reus and Lleida-Alguaire can be classified as regional or secondary airports in decreasing order of traffic respectively, meanly operated by low-cost carriers.

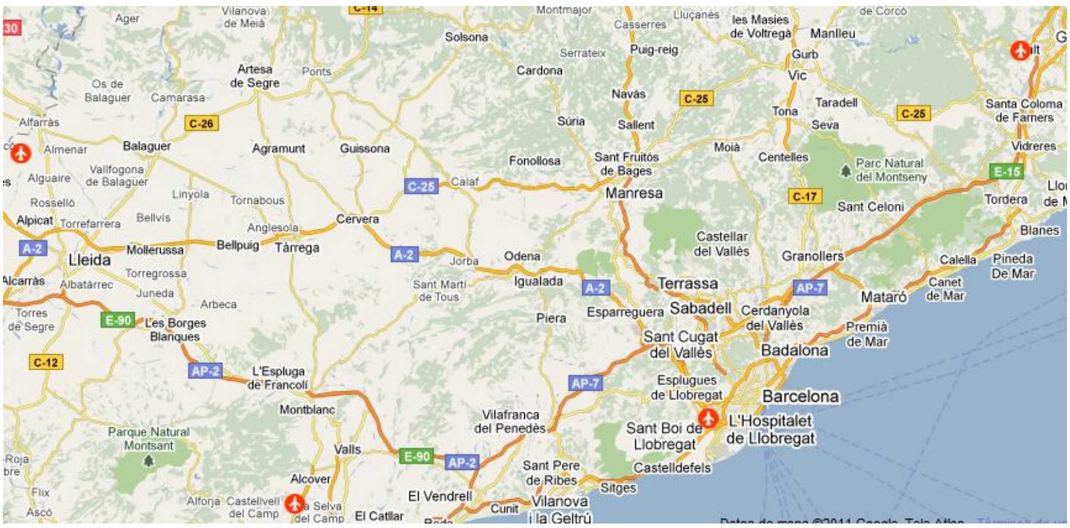

Figure 1 Airports in Catalonia

1.3.1 BARCELONA- EL PRAT AIRPORT (BCN)

Barcelona El Prat Airport is the second largest in Spain behind Madrid Barajas Airport and the largest in Catalonia. It is now a main base for Vueling as well as it was for Spanair before declaring bankruptcy in February 2012 and a focus city for Air Europa and Iberia. The airport mainly serves domestic, European and North African destinations, also having flights to South East Asia, Latin America and North America.

In 2011 over 34.3 million passengers set foot in Barcelona Airport, a 17.7% increase compared with 2010 and has become the 10th busiest airport in Europe.

Most of this passengers traveled in domestic and European flights, while despite the opening of the high speed train line, the busiest route remains to be the Air Shuttle[1] along with the other operators covering the same route (Spanair,Vueling and Air Europa), although frequency has been reduced.
The number of intercontinental connections at the moment is way below other European airports in the same traffic situation. However, there is a clear willingness to lead the airport to a higher level into the world air traffic, not just European.

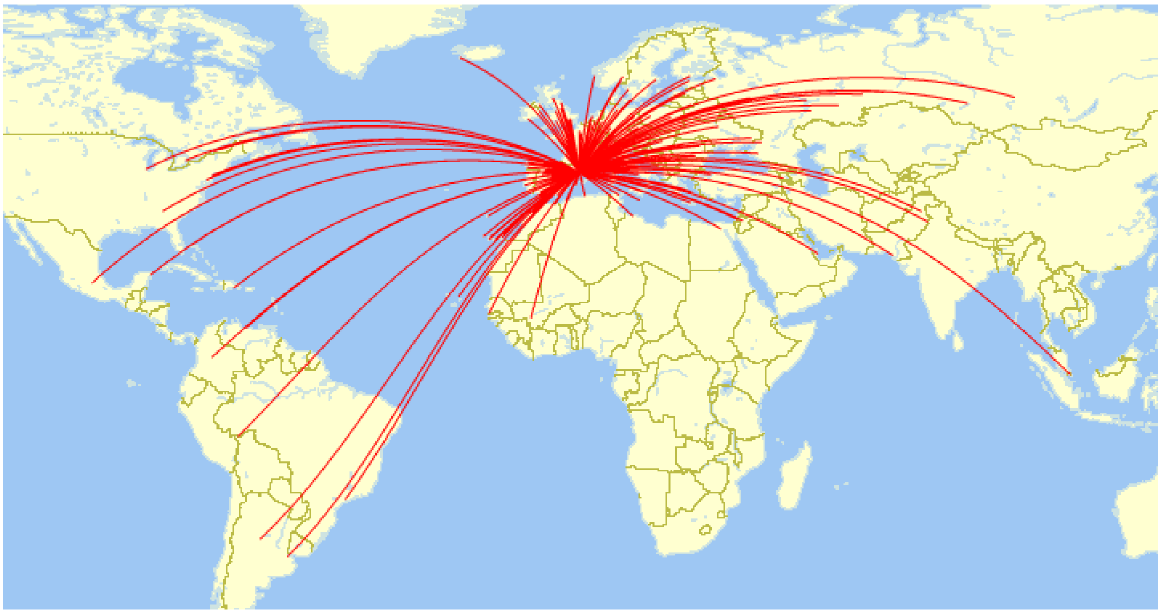

Figure 2 Routes from Barcelona Summer 2011

In the past recent years the traffic of low cost airlines has experienced a huge growth all over Europe due to the development of larger networks of airlines such as Ryanair and Easyjet.

[1]Air Shuttle : Iberia service between Madrid and Barcelona every 30-40min. The flight number is the departure time.

Barcelona El Prat was designated as the operational base for both Spanish LCC Vueling and Clickair that later merged. There are other low-cost airlines operating from the airport including easyJet, WizzAir and Ryanair who established a new base at the airport starting September 2010.

Since this last fact the controversy began about the possible future aspirations of the airport, especially motivated by the affected legacy and other low cost carriers in direct competition with Ryanair arguing it to be a step backwards for the airport.

Once the plan of expansion was completed with the new terminal building T1 the airport is capable to handle 55 million passengers annually. Moreover, a further expansion is planned with a new satellite terminal which will allow raising the capacity up to 70 million passengers annually.

1.3.2 GIRONA AIRPORT (GRO)

The Girona-Costa Brava Airport is an airport that underwent a spectacular growth in the early 2000 after Ryanair was based there. In 1993, Girona Airport dealt with only 275,000 passengers; but in the following six years from 2002 to 2008 passenger numbers increased by nearly ten times from just over 500,000 to more than 5.5 million. However, recently is experiencing some difficulties and traffic is decreasing because some routes have been transferred to Barcelona-El Prat and others have been cut.

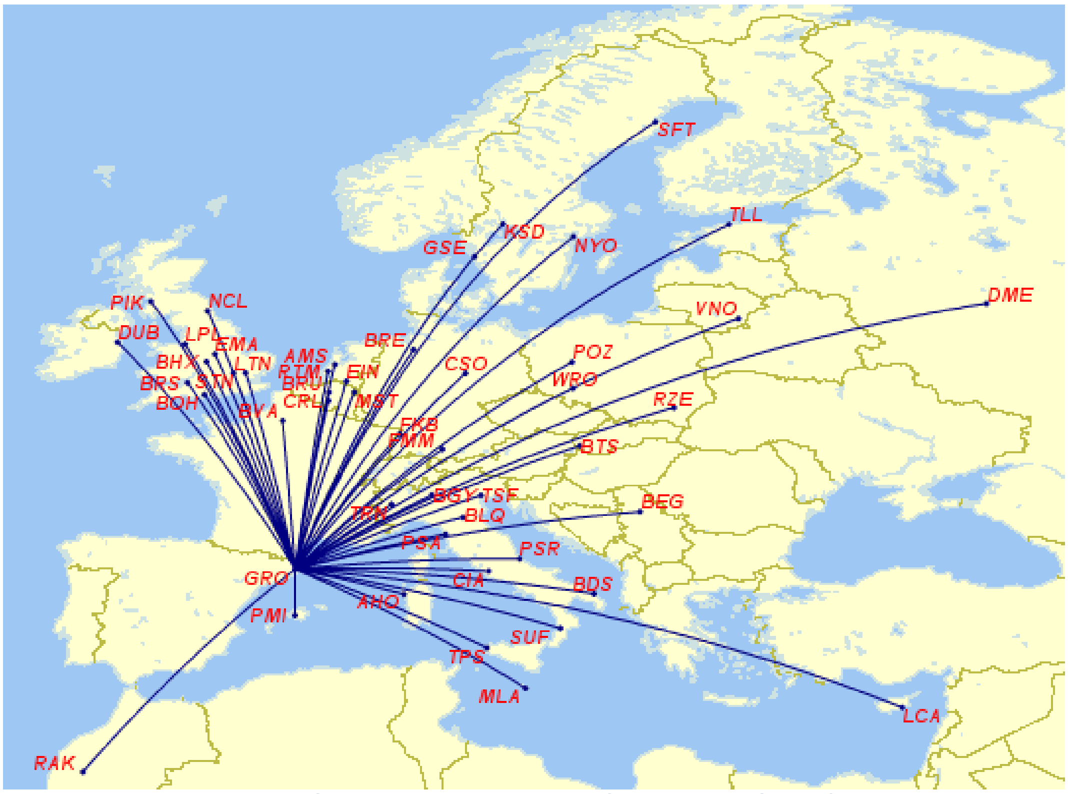

Figure 3 Girona Airport route map Summer '11 (Great Circle Mapper)

1.3.3 REUS AIRPORT (REU)

The Reus Airport used to be a seasonal airport for charter carriers but several years ago back in 2008 traffic experienced like in Girona a significant growth where the number of passengers more than doubled reaching 1.7 million in 2009.
At these days Reus Airport is also in danger as Ryanair already announced its base closure at least during winter season 2011 cutting 28 routes, and so such a reduction is expected in 2012.

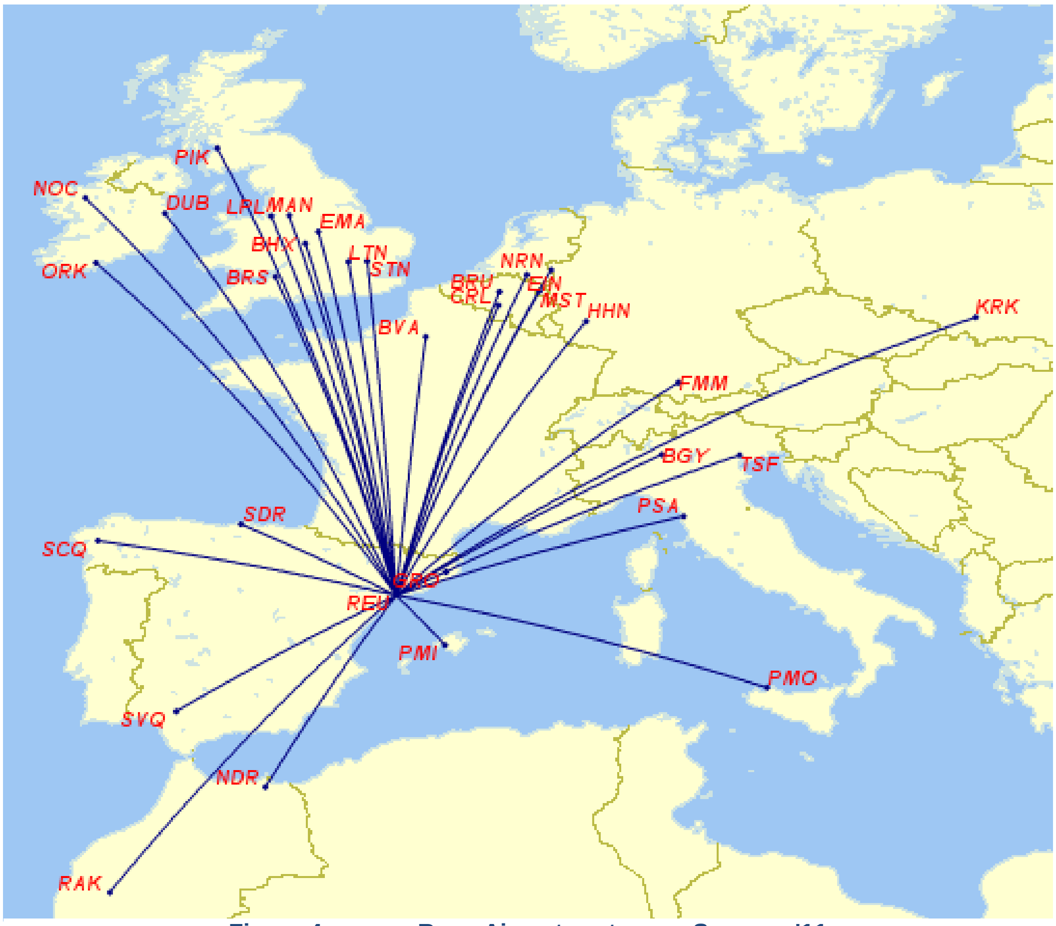

Figure 4 Reus Airport route map Summer '11

1.3.4 LLEIDA-ALGUAIRE AIRPORT (ILD)

Lleida-Alguaire Airport was designated as a regional airport to bring passengers to the Catalan Pyrenees. The operations began in January 2010 with 4 routes weekly and during the first 12 months of operation over 50,000 passengers were carried. Although this first period was considered successful, the serving carriers, Vueling and Ryanair, positioned against carrying on their contribution to the traffic growth.

The only remaining route is Palma de Mallorca and a seasonal service to Menorca and Eivissa and it is looking forward to receiving skiers during winter season (Pyrenair and UK Charters).

1.3.5 THE MULTI-AIRPORT SYSTEM

The allocation of the airports presented above must be framed in a multi-airport system as they mostly serve the same metropolitan region, Barcelona. Both Reus and Girona have been very attractive for low-cost carriers, especially for Ryanair which made them one (two) of its niches. The mono-airline reality threatens now the future of these airports.

Barcelona airport for its part, in 2009 experienced a great enlargement with the new air terminal. By this extension is to provide the proper infrastructure to accommodate new airlines and to host passengers in transit.

Although this pretensions, the changing market has forced the airport to open to low-cost carriers as they have clear increasing market shares. The old terminal was designated to companies that were not part of an international alliance and the low-cost carriers (except for Vueling). Moreover, with the facing strong economic crisis the entrance of Ryanair in Barcelona-El Prat was taken into consideration. Along with Barcelona El Prat, Ryanair operates now from 25 Spanish airports, including 11 bases. At any rate, the Ryanair dominance in Spain covers the two major airports in the country breaking at the time the secondary airport strategy which has characterized the airline ever since. Thus, it has consolidated as the second carrier in the Spanish air travel market.

Note that Barcelona-El Prat is about 100km far from both Reus and Girona airports and does not surprise that Ryanair might pursue a strategy of concentration in the region to the extent it is operationally and economically achievable. However, this involves a significant depopulation of the secondary airports situated in its radius and the opportunity cost that Barcelona-El Prat would assume with the slot allocation to LCC in spite of major carriers. This issue is discussed in the next section through the different authors who have written about concentration.

Barcelona-El Prat has Catalonia's largest catchment area. Barcelona is the 2^{nd} biggest city of the country and its metropolitan area has 3.2 M inhabitants. Considering 90 minute drive distance at least 5 million inhabitants are reached, the 70% of the total population. On the hand of foreign tourists coming to Catalonia, half of whom have Barcelona as destination while Costa Brava (Girona) and Costa Daurada (Reus) stand in second and third position respectively. Therefore, both touristic demarcations reaffirm to have demand attraction.

Table 1 Visitors distribution in regions during 2010 (IDESCAT)

Region	%	Region	%
Barcelona	46.5	Costa del Garraf	6.0
Costa Brava	25	Central Region	2.3
Costa Daurada	11.6	Pyrinees	1.6
Costa Maresme	6.3	Terres de Lleida	0.6

Regional competition between airports which is one of the main objectives of the research can be firstly analyzed from global passenger numbers which are presented in the figures below:

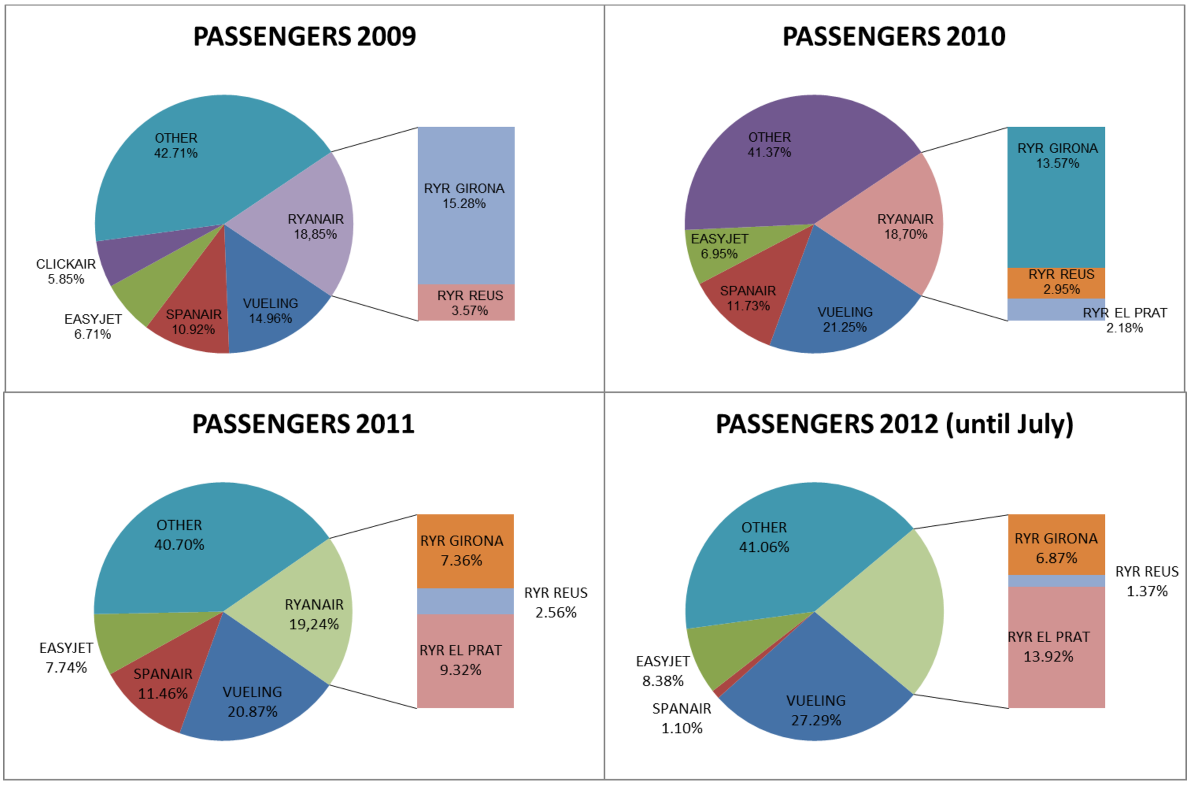

Figure 5 Market share evolution of the main short-haul competitors.

According to the graphics above a clear dominance of LCC can be seen from 2009 onwards where around 20% of the 2009 annual traffic was carried to and from regional airports by Ryanair. In fact, around a total of 50% of passengers did travel on low-cost airlines. When comparing at the time traffic increases as well as decreases at the airports of study (Figure 7) to the most important Ryanair's commitments to the region (Figure 6) can be seen in that trend inflection points match up with route broadenings or cuts.

Not only that, but over the past years readjustments in traffic distribution in the region have happened, in which it becomes evident that competition between airports constitutes a dynamic reality.

It can be noted that while part of the airports experience traffic growth others reduce its passenger numbers or its growth ratio moderates. For example, in 2007 Girona carried 40% more passengers and globally there was the largest traffic increase whereas Reus became the loser (-8%) in this case despite having had positive growth during the previous periods. However, Reus airport began a great expansion in 2008 which culminated with its consolidation as one of the Ryanair's bases. That traduced in an astonishing traffic increase of 90% by 2009. At this time the system seemed to have reached an equilibrium but at the cost of several years of traffic drop in Barcelona airport.

Therefore, it was in 2010 when authorities were forced to introduce Ryanair at Barcelona and as a matter of fact, the company has reorganized its fleet in the region in order to distribute efficiently operations. By these means by the end of 2010 Girona experienced a drastic decrease while Barcelona started moving on from negative ratios.

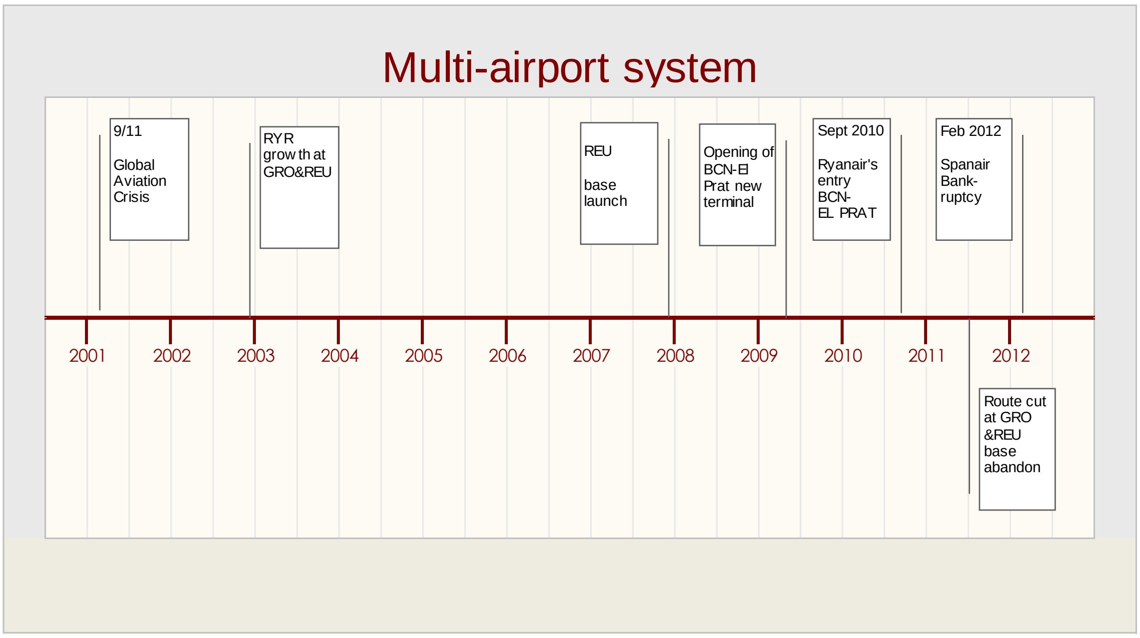

Figure 6 **Main facts occurred since 2001**

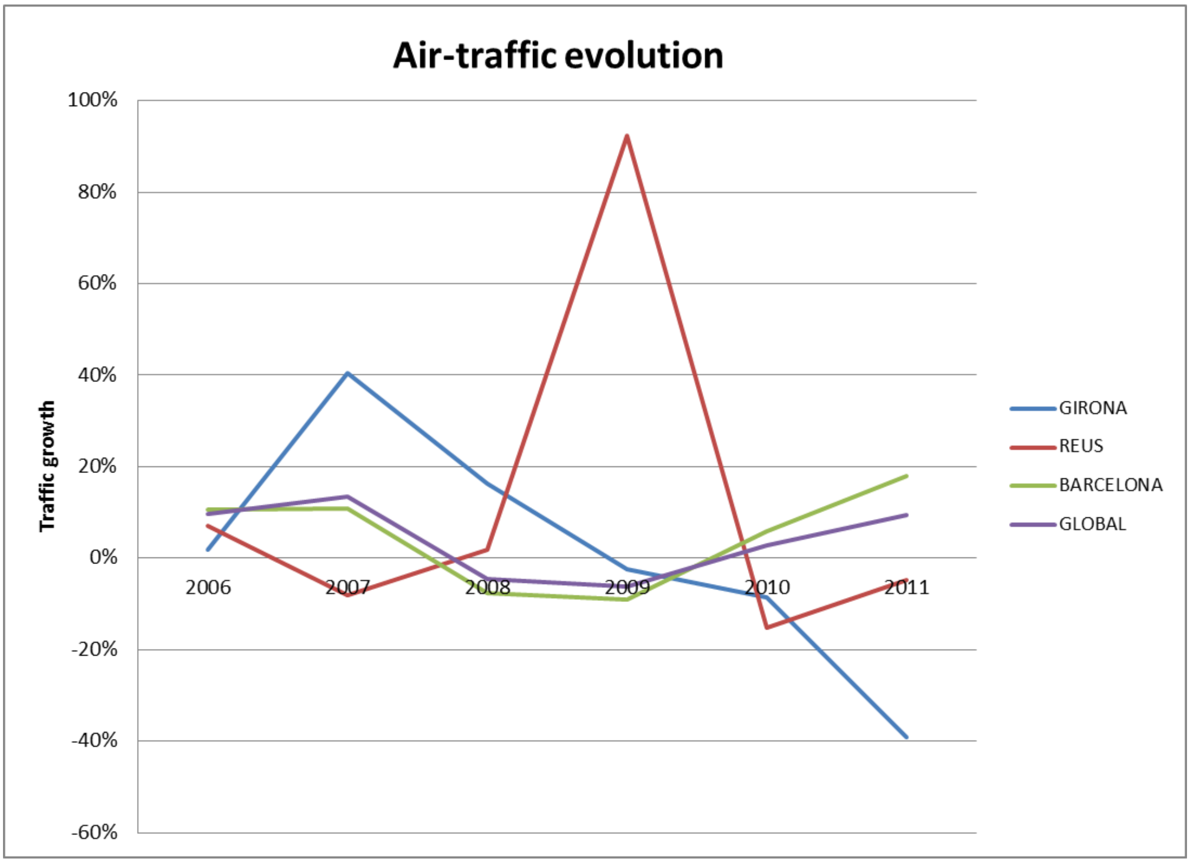

Figure 7 Traffic growth evolutions

It is worth pointing out that these are impressions that emerge from a back-analysis without any tool to identify these behaviors, although it is expected that with the design of the model in the present research is to understand the functioning of this system. Nonetheless, some mechanisms in relationship with supply and demand may remain unknown because of governmental strategies that are difficult to predict.

2. STATE OF THE ART

While at this time many papers and studies have been published about air travel demand and airport choice topics, they have become in few years quite apart from the new scenario in air travel such as the expansion of major low-cost carriers' networks. The revolution of this market due to this new entry and its model success have led academics to study their business strategies very closely to find out how air travel processes can be optimized and reinvented from less productive traditional operations. Thus, since the low-cost model emerged in 1970s the discussion about the competition between legacy carriers and LCC has also been reviewed.

Given that this study aims to predict impacts of LCC on demand it is necessary to refer to two main fields of literature, the analysis of the low-cost model along with a note on airline business strategies and the air travel demand models involving also airport choice models.

2.1 ANALYSIS OF THE LOW-COST MODEL

The concept of low-cost carrier was originated in the United States with Southwest Airlines and was later copied in 1991 in Europe by Ryanair, the main LCC in Europe nowadays. The astonishing success of the new generation airlines has clearly appeared to be a result of a simple point-to-point operation model to and from high-density markets. On the contrary, legacy carriers used to have a cost-penalized model due to their complexity such as hub connections, alliances and highly sophisticated information systems and infrastructures.

At the beginning the differences between those both models reflected into a significant structural cost gap. It can be seen in Table 2 from Doganis (2001) that overall, the LCC model can operate at 49% of the FSC and in particular the 37% out of a total of 51% of costs difference can be attributed to explicit network and airport choice. Another 9% of the LCC cost advantage comes from direct booking in spite of GDS's (Amadeus, Galileo,…) and the commercial agreements and the remaining 13% is in-flight service related. This table particularly is made on a per seat basis and it is assumed a similar load factor in both cases. In Franke (2004) both models are compared and discussed. The document notes that in fact, the contribution of the LCC to the airline market does not represent a retreat but an increased pressure to the network carriers to implement successful business innovation. Thereby, it is expected to reach equilibrium with a wider range of business models, operating at a higher level of efficiency.

Actually, new types of airlines are founded with a low-cost carrier cost structure but providing some of the characteristic services of legacy carriers.

Table 2 Cost advantages of low-cost carriers on short-haul routes

	Cost reduction	Cost per seat
Full-service carrier		100%
Low-cost carrier		
Operating advantages		
Higher seating density	−16	84
Higher aircraft utilization	−2	82
Lower flight and cabin crew costs	−3	79
Use cheaper secondary airports	−4	75
Outsourcing maintenance/single aircraft type	−2	73
Product/service features		
Minimal station costs and outsourced handling	−7	66
No free in-flight catering, fewer passenger services	−5	61
Differences in distribution		
No agents or GDS commissions	−6	55
Reduced sales/reservation costs	−3	52
Other advantages		
Smaller administration and fewer staff/offices	−3	49
Low-cost carrier compared with a full-service carrier		49%

The traditional airlines have had to remove schedule constraints in hubs, simplify the user interface and market segmentation even offering a no-frills service to a range of their demand.

It is also worth mentioning the analysis made in Dobruszkes (2006) in which after a great description of the main characteristics of the LCC strategy, all the European LCC networks are submitted to a Principal Component Classification. The PCA uses in this case logASK (Annual available seats kilometers), logFlights, logSeats corresponding to volume variables and finally network characterization variables such as the proportion of flights making the most of 5th to 9th freedoms on the air[2], % flights imitating charter, % exclusive airports, % international flights, connexity, destinations and routes.

In this document two graphics are obtained (see Figure 8); in one hand, the factor loadings which correspond to the linear correlation between the original variables and each of the principal components.

[2] 5th: fly between two foreign countries during flights while the flight originates or ends in one's own country
6th: fly from a foreign country to another one while stopping in one's own country for non-technical reasons
7th: fly between two foreign countries while not offering flights to one's own country
8th: fly between two or more airports in a foreign country while continuing service to one's own country
9th: fly inside a foreign country without continuing service to one's own country
(Source: Wikipedia)

These enable to identify their meaning to allow the positioning of the carriers. In the second graphic, the carriers are represented whether operating with a supply above the average or not as well as if they are more charter-orientated than the average.

The classification reveals that there is a limited use of the air freedoms except for Ryanair and Easyjet which have broad networks with much exclusivity or imitating charters and they continue to boost the point-to-point configuration. Consequently almost the 50% of the growth of the air supply between 1995 and 2004 is caused by the development of LCCs. In Figure 8 can be observed that mostly West-European towns benefit from this new routes mainly secondary or regional airports that are exclusively linked to LCCs, for example Girona and Reus. Nevertheless, in 2004 only a 13% of city-pair routes were offered by more than two carriers.

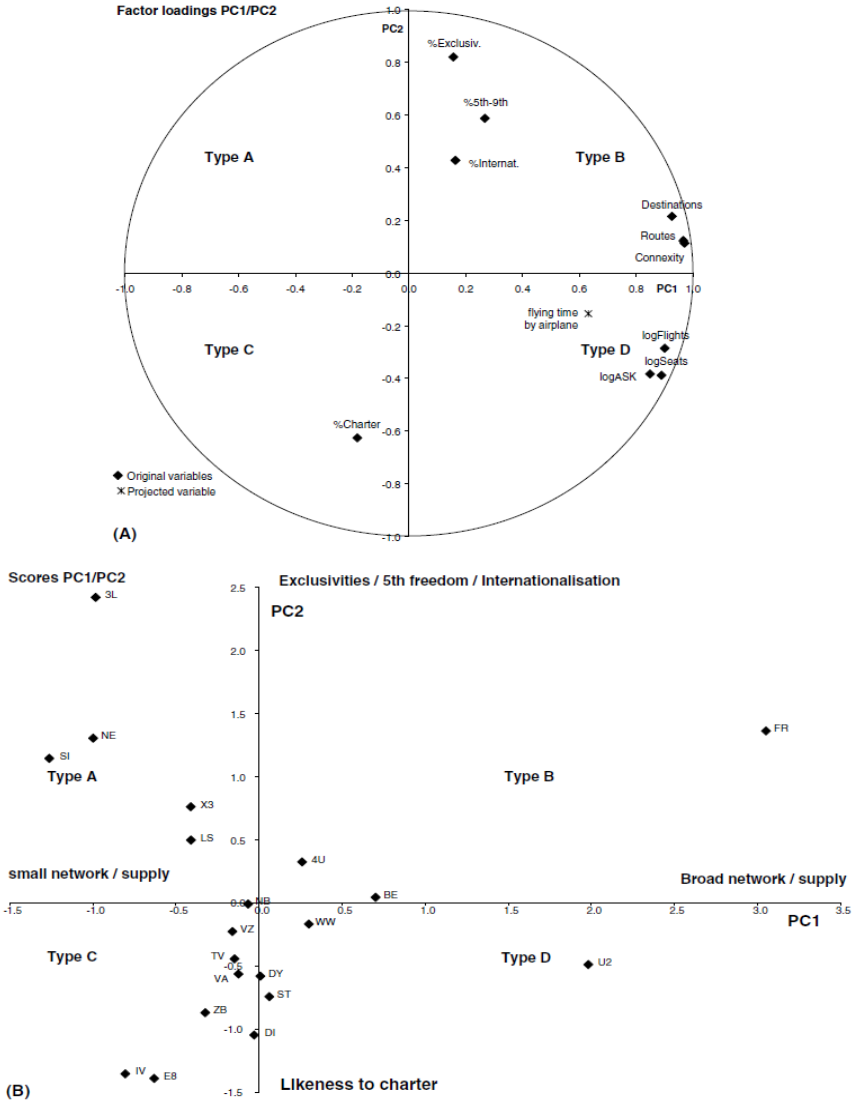

Figure 8 **Types of low-cost carriers. Dobruszkes (2006)**

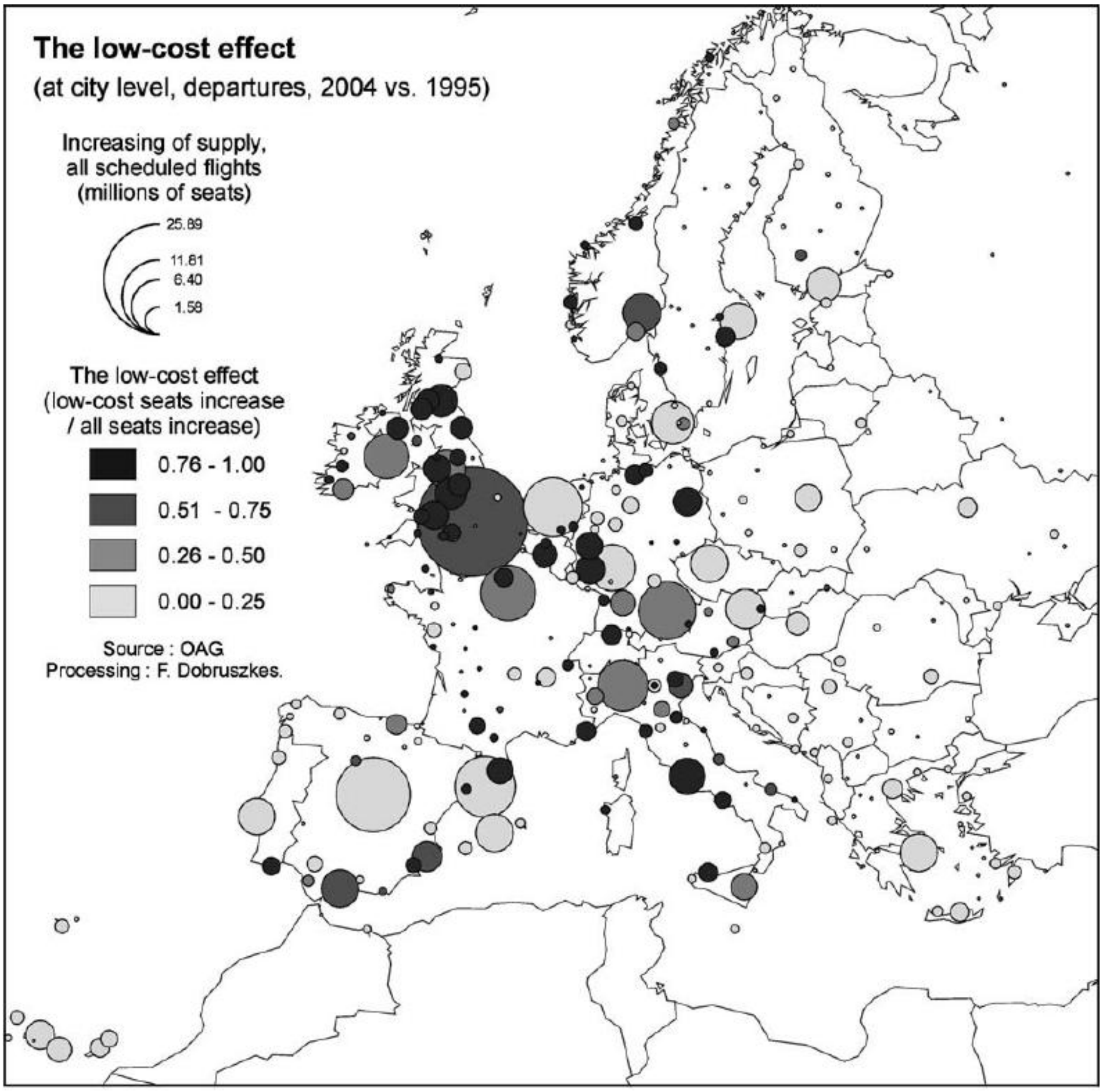

Figure 9 **The low-cost effect. Dobruszkes (2006)**

Regarding the situation of LCCs in Spain, Aguiló, Rey and Rosselló (2007) identify the evolution of the low-cost carriers in Spain as a clear cause of the increase in seat supply and also in tourism growth as well as an economic advantage for the involving regions especially for those airports located in small cities.

Rey, Myro, and Galera (2011) create a methodology to estimate the low-cost effect in tourism in Spain. This paper could be also mentioned in the assignment models because an estimation demand of tours between a set of six Spanish regions originating from ten[3] EU-15 is implemented.

[3] AUSTRIA,BELGIUM,DENMARK,FRANCE,FINLAND,GERMANY,IRELAND,ITALY, the NETHERLANDS, UK

The final form also introduces a LCC variable which measures the proportion of low-cost travelers:

$$\begin{aligned} lnTOUR_{ij,t} = a &+ \beta_1 lnGDP_{ij,t} + \beta_2 lnPRC_{ij,t} + \beta_3 lnOP_t \\ &+ \beta_4 lnLCC_{ij,t} + \beta_5 lnI_{j,t} + \beta_6 lnD \\ &+ \beta_7 lnGREG_{j,t} + \beta_8 lnd_{2001} + \beta_9 lnd_{2002} \\ &+ \mu_{ij} + \epsilon_{ij,t} \end{aligned} \quad (3.1)$$

where sub-indexes refer to the originating country i and the host region j, the explanatory variables are: OP, oil price, LCC; low cost travelers; I, infrastructures in destination; D, distance (km); GDP, per capita GDP origin; PRC, relative prices in comparable currency; GREG, relative per capita income of each hosting region to the Spanish average; d2001 and d2002 are dummies referring to the air travel downturn[4] occurred in this period. In this study, the estimation is carried out as dynamic-type estimation; this means that the dependent variable is also introduced among the explanatory ones as the value of the preceding year to avoid overestimates. In this case they use several estimates to find the best fit of the model. All of them show a positive effect of LCCs on the demand for tourism in Spain. Finally, the paper concludes that a 10% growth of the number of visitors travelling by LCCs could increase the average per capita tourists by 0.2%.

De Neufville (2005) reckons a set of secondary airports that were built prematurely and did not reach the success they were designed for. However, they are currently experiencing traffic growth due to the low-cost carriers which are operating parallel secondary airports networks. That is the case for Ryanair but not for Easyjet, this latter one is more charter orientated and operates from major airports. According to the document Easyjet is to have a better business model over long term because margin benefit is more advantageous at higher market shares, thus concentration in major airports. Ryanair and its homonymous benefit from taxes discounts to operate in many airports of their network.

The airport-airline interaction is discussed in detail in Graham and Dennis (2003) with the analysis of two cases; one secondary airport in the shadow of a major hub which offered up to 14% discount in the cost per flight to attract the low-cost carrier and focused in non-aeronautical revenue and retail; on the contrary, the second case only increased passenger numbers but no revenue because some regional airports only benefit from air side revenue.

[4] The crisis was initially a revenue crisis, followed by the cost impact of growing overcapacity. Moreover, the terrorist attacks of 9/11 in 2001 worsened the downward trend in air travel demand.

2.2 AN INTRODUCTION TO THE AIRLINE INDUSTRY MANAGEMENT.

From an economic perspective, the airline industry in which a reduced number of sellers offer similar products it can be likened to an oligopolistic market. Like many other oligopolistic industries it has high obstacles to entry as it requires of a significant amount of capital. Added features are economies of scale, mutual dependences, price rigidity and growth through mergers. Roughly one might say that airlines pursue economies of scale to obtain lower unit costs by intensive utilization of its resources. This explains that sometimes a path of success can be found in mergers so that purchase power and market shares increase. Moreover any initiative in the competition framework has to take into consideration rival's actions up to a limit. Price competition with the presence of low-cost carriers can result in a significant drop in operating margin. Thus, some traditional carriers place in various forms of non-price competition such as added-value products. Other specific characteristics are the extreme exposure to changes in outside variables such as economy and overall air travel perception, higher labor and fuel expenses. The latter factor determines how cost advantageous to compete with lower prices airlines are which it also involves working with thin profit margins.

Airline profitability indicators that determine operating profit for an airline are:

- CASK. Cost per available seat kilometer, operating cost to fly one seat one kilometer.
- Yield (Revenue per RPK), average revenue for carrying one passenger one kilometer.
- Load factor, total Revenue Passenger Kilometers divided by total available seats kilometers.

Airlines seek to increase yields, decreasing seat costs while having high occupancy rates. If either pricing or network planning strategies cause that one of the mentioned indicators moves in the wrong direction, then profit already very thigh will suffer.

As far as costs are concerned two possible classifications can be taken; on one side that linked to direct or indirect operational costs and non-operating costs. Besides, there is the traditional distinction between fixed and variable costs. In Figure 10 a real income statement is shown. Fixed costs are those that for a specific short-term schedule plan do not vary with the number of seats operated. Generally are referred to staff, maintenance and fleet minimum requirements every airline must take in its slot allocation and scheduling decisions. Variable costs are dependent on airline's seat supply or number of flights such as fuel, crew expenses, airport and navigation taxes, maintenance, advertisement and passenger service costs.

Cost group	Item	Type
Variable Costs	Fuel	Directly operational
	Handling	Indirectly operational
	Airport taxes	Directly operational
	Navigation taxes	Directly operational
	Crew staff	Directly operational
	Maintenance	Directly operational
	Commercial and marketing	Indirectly operational
	Other expenses	Indirectly operational
	Total variable costs	
	Contribution margin	
Fixed / Semi-fixed Costs	Crew staff semi-fixed expenses	Directly operational
	Maintenance semi-fixed expenses	Directly operational
	Fleet insurance	Directly operational
	Fleet rentals	Directly operational
	Other production costs	Indirectly operational
	Total semi-fixed costs	

Figure 10 **Cost structure differentiation in Vueling's Income Statement**

Airline costs in the short-run for a fixed capacity engagement, usually meet the law of diminishing returns. This is when at some point despite of efficiently increasing resources available output increases at a decreasing rate and so do subsequently marginal costs. Something similar appears in maximizing revenue strategies, although passengers might be sensitive to price reductions beyond some point additional traffic is hardly generated. Seen in the present context traditional carriers involved a in strong competition with low-cost carriers, traditional carriers beyond a certain price cut the total numbers of passengers do not balance reduction of total revenues. As represented in Figure 11 airlines can find an optimal seat supply that generates a number of stimulated passengers to a certain yield so that profit maximizes. However, while traditional carriers can have service-based pricing whereas low-cost cost carriers, as originally conceived, should follow cost-based pricing.

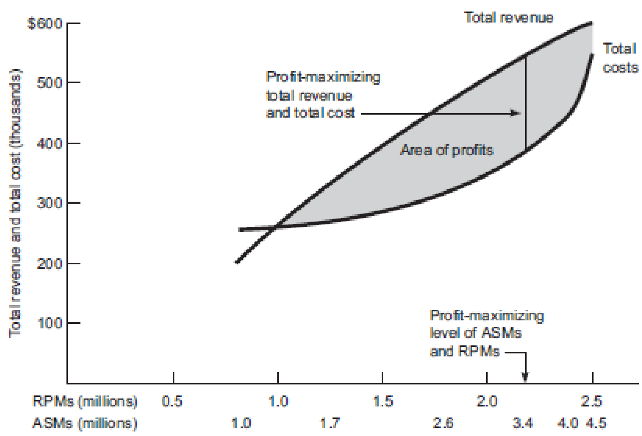

Figure 11 **Total revenue and total costs for an indivudual airline in the short-run. Wensveen J. (2011)**

2.3 AIR TRAVEL DEMAND MODELS

Forecasting travel demand has become not only a key factor for an airline success but also to predict airport future constraints and potentials. A large number of demand models have been developed for all types of transportation as a part of its planning but as mentioned above, they still not consider the fact of having this new generation type of carriers in the market.

First of all, it is necessary to distinct between two ways of modeling demand, which include:

- Demand forecasting models
- Travel choice models.

Demand forecasting models or demand generating models usually depend on aggregated variables as price, travel distance, GDP, income,....This kind of models normally are used to predict higher level activities and therefore, do not concern with individual choices. In the table below models that can be used at different levels of aggregation are represented, obtained from Hsiao and Hansen (2008).

Table 3 Models characterizations

		AGGREGATION LEVEL					
		System	City/Metropolitan	Airport	City-pair	Airport-pair	Route
Model type	Demand Generation						
	Demand assignment						

2.3.1 DEMAND FORECASTING

Aggregated demand models or first generation models are based on observed relationships for groups. They have been the most widely used in the majority of transport projects, at least until the beginning of the 1980s.

A very common model specification is the constant elasticities or Cobb-Douglas production function:

$$D = \beta_o X_1^{\beta_1} X_2^{\beta_2} \dots X_n^{\beta_n} \qquad (3.2)$$

where $\beta_o \dots \beta_n$ stand for the demand D elasticities of variables X_i .

Price elasticity of demand measures the percentage change in quantity demanded caused by a percent change in price and it has the same meaning for any other explanatory variable that could be included in the demand expression. After taking logarithms of the equation 3.2, it results in a lineal model in coefficients, namely elasticities, therefore the adjustment is to be more simple.

$$logD = log\beta_o + \beta_1 logX_1 + \cdots + \beta_n logX_n \quad (3.3)$$

The X_i represent the explanatory variables of the model and they are in general related to socioeconomic and geographic characteristics as well as to the transport mode specifics. Income, price, frequency, access time, intermodality are variables used to perform demand generation models.

In Kanafani and Fan(1974) a total air demand generation model is proposed and after that is implemented in a choice model. The document itself admits that having a cross-sectional input data at one point in time, and not time series; makes it difficult to capture system changes over time. However, it can reveal some views into the possible expected trends.

The set of variables as mentioned above are mainly: on one hand population, income and employment; on the other hand travel time (including access time), frequency of service and total trip cost. Actually, the so called level of service was used to involve all of the three transportation variables: trip cost, travel time and frequency of service. It is also to be noted that three different forms were specified separately for each trip purpose. This separation could be a starting point from the model of the present research as it is to capture heterogeneous passengers including those who might be very price sensitive.

Later, Wei and Hansen (2006) introduced an aggregated demand forecasting model with the form of equation (3.4) in a hub-and-spoke network, at a route-carrier level using cross-sectional data. The log-linear demand model takes into consideration demographic, socioeconomic condition in spoke areas and also airline variables such as frequency, aircraft size, ticket price, flight distance, number of spokes.
It also takes into account by the characteristics of the network studied, the hub capacity and indeed the model reveals its elasticity 0.35 that means that a 1% increase of airport acceptance rate can bring about 0.35% more connecting passengers. Interestingly, the model concludes to be applied in valuation of airport capacity expansion benefits, which are sometimes dismissed by airlines. Note that the authors point to the fact that advances should be done in the accuracy of the model and in the study of interdependences among the factors.

These models are the so called gravity models which establish a relationship between the transportation demand on an origin-destination and the exploratory variables of the origin X_i, and the destination Y_i and specific variables of the pair T_i.

The form of the model with constant elasticities could be as follows:

$$D = \beta_o X_1^{\beta_1} X_2^{\beta_2} \dots X_n^{\beta_n} Y_1^{\gamma_1} Y_2^{\gamma_2} Y_n^{\gamma_n} \dots T_1^{\delta_1} T_2^{\delta_2} \dots T_n^{\delta_n} \tag{3.4}$$

Authors that made a significant approach to this model were Grosche, Rothlauf and Heinzl (2007). In the document two gravity models are developed, one deals with multi-airport regions and the other not.

In this case only geo-economic variables are used because the long term estimation allows dismissing much of the airline service-related factors. The parameters are calibrated using ordinary least squares from booking data.

The problem accounting multi-airport regions should be studied in detail as our background has three or four airports that would aim to compete. Therefore, the models should include also supply characteristics and competitive effects. Most of the papers considered only postulate aggregate values representing the competitiveness of the airports.

Obtained from Kanafani and Fan (1974) most of the demand models follow sequence below:

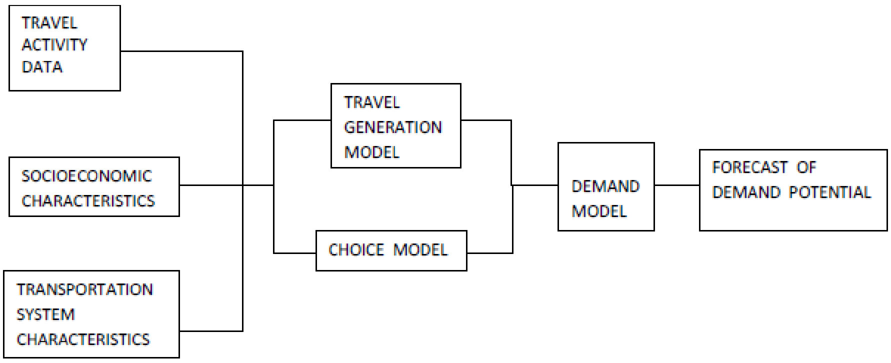

Figure 12 Model Framework sequence

Probably for the problem explained above discrete choice models were formulated in order to depict demand distribution among alternatives. Although demand generation models are quite simple at higher levels of aggregation when being implemented for route-levels or city-pairs are less realistic.

2.3.2 DEMAND ASSINGMENT

Disaggregated models or discrete choice models are based on individual decisions made by travelers and provide market shares of routes serving same airports or cities. The first application of the discrete choice model was made by McFadden in 1972 who used a multinomial logit model to forecast demand to a new BART line. Since the deregulation of airline industry demand forecast studies became every time more essential in the network planning for airlines, especially those which could perform competition and predict market shares of future routes and regions.

These ever-increasing pressures seeking the higher revenue has come into a new scenario with two models facing: the conventional carriers and the low-cost carriers; which has dramatically changed the point of view of air travel.

The main idea of these models is the random utility theory. The most frequently use models in the practice are the Multinomial logit (MNL), the nested logit (NL) and more lately the mixed multinomial logit (MMNL). According to Garrow (2010) MNL formulates the probability one individual selects an alternative from all in the choice set. Although the MNL is simple and widely used, for example in Coldren et al., (2003) the independence of irrelevant alternatives (IIA) can result in unrealistic substitution patterns. Due to this property, the ratio of choice probabilities between two alternatives is independent of the other alternatives if attributes do not change. Therefore, any changes in the attributes of any alternative causes an equal proportional effect on all other alternatives. However, IIA property is very useful when introducing new alternatives but this limitation led to the new models with relaxed assumptions on the error terms by grouping alternatives into M nests for the case of NL.

Further advances are reflected in the Mixed Multinomial Logit, MMNL, which provides more flexibility concerned with the alternatives and error terms but contrasts with its computational costs. In fact, allows random taste considerations as well different sensitivities along the variables such as fare, access time, frequency and can provide its distribution (Hess and Polak, 2005). In between, there is then the Nested Logit where errors terms are independent for different nests whereas in the same nest share a common error term which means correlation. That makes more sense in alternatives that have similar attributes and therefore they have higher competitiveness.

The standard logit model's taste coefficients are fixed, this means equal for everyone. Mixed logit has different coefficients for each decision maker. In the MNL the utility that individual n obtains from alternative is given as $U_{ni} = \beta_n \cdot x_{ni} + \varepsilon_{ni}$, however for the mixed logit model the set of β's are random realizations from the density function $f(\beta|\theta)$ where θ is a vector of parameter estimates associated with the density function such as mean and variance.

The unconditional choice probability is the integral of the logit formula conditioned to β over the density.

$$P_{ni} = \int \frac{\exp(Vni)}{\sum \exp(\mathrm{Vni})} f(\beta|\theta) d\beta \quad (3.5)$$

Kanafani and Fan (1974) adopt a special probabilistic form that also takes into account random individual taste through weight parameters which is a form of the MMNL. Along with the demand generation model explained in the previous section. Scheduled frequency here was found to have the strongest effect on travel choice rather that cost or total travel time. Nonetheless, since the deregulation of air travel and several years after this study air travel patterns have changed due to the growth of leisure travel. Therefore in that conjecture travel cost might have not been determinant but as of recently new passengers profiles have emerged the elasticities now probably would have different weights.

Hsiao and Hansen (2008) formulate a city-pair passenger demand model and combines both demand generation and assignment at the time with socioeconomic, geographic and supply variables. The paper approaches the route demand as the product of the market saturated demand and the route market share. The factors considered are route-specific socioeconomic and geographic characteristics, air fare, scheduled flight time, flight frequency, on-time performance, market distance, routing type, and fixed effects for the route supply. Among all the discrete choice models the aggregate nested logit (NL) is chosen along with the MNL for comparison.

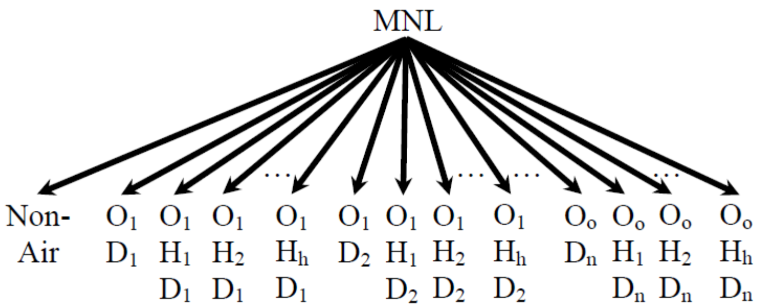

Figure 13 Nesting scheme Hsiao and Hansen (2008)

In this research five nesting structures are studied including the simplest MNL (one level) up to four levels including in the first step the "outside good": no air travel either no travel or travel by other means. The levels of distinction are then non-air or air travel, airport-pair and routing type (connecting or not).

One of the causal factors is the price of the ticket but it may be endogenous because normally in air travel dynamic pricing is one of the principal instruments of revenue management so the interaction between fare-demand-supply can even change at a daily basis. To solve this endogeneity problem the model applies instrumental variables in the estimation such as cost. Indeed, fare coefficients with the instrumental estimation are larger (in absolute value) which evidence to be more reasonable when considering inferred values of travel time. Finally, the preferred model is the three level nested considering correlation between same O-D airports regardless if they are connecting or not.

Despite assuming an arbitrary number of flights for population unit concerning with the demand generation, after performing sensitive analysis results show that the estimated coefficients change very little and therefore are insensitive.

Different findings can be named from this dissertation. For example, it suggests that there is a concave relationship between market distance and demand; when involving connecting routes minimum frequency is more critical and passengers avoid hubs where delays are expected.

The model however has not a direct application on multi-airport regions because different airports are in different nests. Further researches focusing on airport demand or competition have also been developed in the literature. As well as for demand assignment, discrete choice models based in random utility are the most widely used.

Lian and Rønnevik (2011) deal with a problematic that happens nowadays in Norway where many regional airports are losing market shares because of the presence of few carriers serving them and therefore usually air fares must be more expensive than nearby main airports. Note that from regional airports all the flights are connecting at a higher fare so travelers, especially leisure, do prefer to expend several hours on the road for a cheaper and direct flight. The factors considered to estimate the probability of choosing the main airport are fares, route type (direct or indirect) and the difference in access time to regional and main airports, afterwards a logistic regression is applied to model airport shares.

In Hess and Polak (2005) MMNL is used to model random taste across the decision makers. The only variables influencing considered are fare, frequency and access-journey time. The market is segmented into three dimensions: purpose, residency status and income. A significant effect of fare was only identified for the low-income group whereas frequency for high-income segment. On the contrary the results for the access time were more random probably due to the lack of data, so advances might be possible to model that factor. An important remark is that although in origin many airports may compete for market shares the decision can be influenced when in destination there are also several airports to choose, for these reason two destination airports are included in the sample.

Belobaba and Van Acker (1994) concern the airline concentration after the market deregulation and submit the top 100 O-D to a concentration analysis through HHI and effective competitors (MS5%) between 1979 and 1991. Results show that there has been an increase in competition in all those markets analyzed but not all at the same scale. For example, hub networks experienced greater concentration since several mergers took place from 1985 in contrast non-hub markets experienced a slightly increase over time. Changes in market concentration can bring to differences in market competition and of course in airfares, nonetheless airports can be a limited good as long as they have congestion and capacity constraints that must be scoped out from airlines strategy.

The model of the present research is intended to provide a useful tool to analyze air traffic distribution in the territory from the view of the most interested operators: airlines and airports. Moreover a global view here is also required as the airports are managed by a single airport operator (AENA).

Once the system working is decoded the most interesting part of it is to play the role of the different actors involved. On the one hand like the airline managing price and frequency to capture more market share and on the other like the airport improving accessibility, allocating slots or managing airport charges in order to keep a sustainable passenger numbers.

2.3.3 OVERVIEW

Table 4 Literature overview

Study	Model	Aggregation level	Variables	Estimation Method. Model	Limitations
Kanafani and Fan (1974)	Demand generation and assignment	City-pair	Population, income, employment, travel time, frequency, cost.	Three model forms depending on travel purpose	
Grosche et al.(2007)	Demand generation	City-pair	Population, catchment, buying power index, GDP, distance, travel time.	Gravity model Ordinary least squares	No service-related factors
Wei and Hansen (2007)	Demand generation	City-pair	Frequency, aircraft, hub frequency, flight distance, number of spokes, number of flights between hubs and spokes, local passengers , ticket price, socio-economic, demographic conditions.	Gravity Model Ordinary least squares	Correlations between variables
Coldren et al. (2003)	Demand assignment	City-pair-day of the week	Level-of-service, connection quality variables, carrier, carrier market presence, fares, aircraft size and type , time of day, code share.	MNL maximum likehood techniques.	
Hsiao and Hansen (2008)	Demand generation and assignment	City-pair	Income, price, scheduled flight time, frequency, on-time performance, routing type, market distance, dummy variables, population,	Instrumental variables method. Nested logit. Ordinary least squares	Specification models
Hess and Polak (2005)	Airport choice	City-pair	Fare, frequency, access time, trade -offs	MMNL	
Neufville (2005)	-	-	Analysis of multi-airport system worldwide	-	-
Belobaba et al. (1994)	Analysis of carrier concentration	City-pair	Market shares, number of competitors	HHI MS5%	
Lian and Rønnevik (2011)	Airport Competition	Airports	Distance, travel purpose, air fare	Logistic Regression	Income, airport choice variables

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3. DEMAND MODEL FORMULATION FOR A MULTI-AIRPORT REGION

3.1 CONCEPTUAL FRAMEWORK

The present research deals with the modeling of air passenger demand in airport-destination city pairs at the route carrier level.

In the studied territory potential travelers may have many choices regarding available routes at different departure airports, described as discrete choice. Based on the random utility theory discrete choice models are used to predict the probability one individual will choose one alternative representing its attractiveness by using the concept of utility.

Utility is a scalar index of value related to the socio-economic characteristics and attractiveness of both individual and alternatives. It represents the value an individual places on different attributes and the tool throughout the decision. Thereby, it is assumed that individuals select the alternative that maximizes their utility. The utility function applied in this model describes the generalized cost of choosing each of the alternatives.

3.2 FUNDAMENTALS OF THE DISCRETE CHOICE MODEL

Following the framework exposed in Garrow (2010) the choice process is based on four pillars: a decision-maker, the alternatives available to the decision-maker, attributes of these alternatives and a decision rule.

3.2.1 DECISION-MAKER

A decision maker can be an individual or represented by a company which chooses for its corporate travelers. For this model, corporate travelers are modeled as business travelers whose perception of utility may not be influenced by loyalties or membership programs and thus disaggregating all selections to the individual. Moreover, in this case the decision maker is someone who already has decided to book an itinerary although this fact introduces a loss of exhaustiveness in the model.

3.2.2 AVAILABLE ALTERNATIVES

Usually when a passenger decides or needs to fly to a destination, namely a city chooses among a finite number of alternatives according to the trip which are mutually exclusive. However, sometimes at least in leisure travel, the process is all the way round selecting the destination depending on the route price, departure time, availability, etc.
This discussion about where to travel is not part of this research. Thus, *willingness to travel no matter where as long as it fits my holiday and price expectations* will not be implemented. Thereby, the set of alternatives for a destination neither include other cities nor as said above no-travel possibility.

Once the destination is clear, the passenger is faced with the decision of the most convenient route considering the departure airport and even arrival airport. Like in the Catalan region many European cities can connect from up to 5 different airports, e.g. London (Heathrow, Gatwick, Stansted, Luton and London City). While major airports are used to being associated with some metropolis, regional airports can also be part of the urban core only that they receive less traffic or might be placed quite apart from it. Extremely, secondary airports can even serve an important city from another country.

In Europe several examples exist for this situation, having Ryanair taking advantage of them, advertising the most popular destination although the airport is located 100km faraway next to another town. Having a quick look at Ryanair's website anyone who wants to purchase a flight to Barcelona can now choose between Barcelona Reus, Barcelona Girona or Barcelona El Prat; the same happens to Vienna, London and many others. Furthermore, there exist some routes that locals know they lead to the final destination after 100s km drive or a large ride in the public transportation chain even though tickets are not sold as they could be. In the table below are to find some examples:

Table 5 Deceptive advertisement.

AIRPORT	ADVERTISED AS	CONNECTING TO	DISTANCE
MALMÖ	MALMO	COPENHAGUEN	43km
MAGDEBURG	MAGDEBURG	BERLIN	193km.
VAUTRY	PARIS VAUTRY DISNEYLAND	DISNEYLAND PARIS	150km
EINDHOVEN	EINDHOVEN	AMSTERDAM	135km
BRATISLAVA	BRATISLAVA VIENNA	VIENNA	87km
ST.ETIENNE	ST.ETIENNE LYON	LYON	75km
BEAUVAIS	PARIS BEAUVAIS	PARIS	90km
HAHN	FRANKFURT-HAHN	FRANKFURT	130km
BERGAMO	MILAN BERGAMO	MILAN	60km
NIEDERRHEIN (WEEZE)	DÜSSELDORF	DUSSELDORF	90km
LUBECK	HAMBURG LÜBECK	HAMBURG	80km

It is very important to delimit a representative choice set for each of the destinations involved in the model. This research will focus on routes between any of Barcelona's serving area airports and cities which are Ryanair's but non-exclusive.
Notice that the model is referred to cities (except for the territory studied) and not to airports in an attempt to simplify the demand distribution especially for foreign countries where socio-economic and transportation data is more difficult to acquire. By this, the model truncates at city level which means that the last leg of the transportation is omitted.

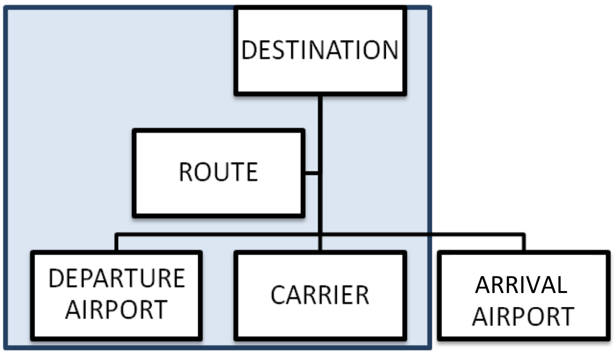

Figure 14 Model definition

Regarding the consideration of deceptive advertisement as well as other routes which implicitly include other airports and therefore they are susceptible of being part of the selection set only ones promoted by the carrier are recognized. It is assumed that passengers associate the alternatives as they are sold by the airline, further knowledge is then not considered.

Each set of alternatives that belong to a destination k ,A^k , will have two categorizing variables which are: Barcelona's connecting airport i and carrier j and will be denoted as $A_{i,j}^k \in A^k(t)$,where $A^k(t)$ represents the group of alternatives considered for traveler t; but, from this point onwards it is assumed that the choice set available may be equal to any individual.

A^k is defined as a binary matrix 3·m where $a_{i,j}$ elements take 1 or 0 values depending on the availability or not , for the season studied, of the route from airports i = 1...3 and airline j= 1…m.

$$A^k = \begin{pmatrix} \{0|1\} & \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \{0|1\} \\ \{0|1\} & \ddots & \{0|1\} \\ \{0|1\} & \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots & \{0|1\} \end{pmatrix} \quad (3.1)$$

The subset of matrices containing different connections {A} form the space of events scope of this research which is marked below:

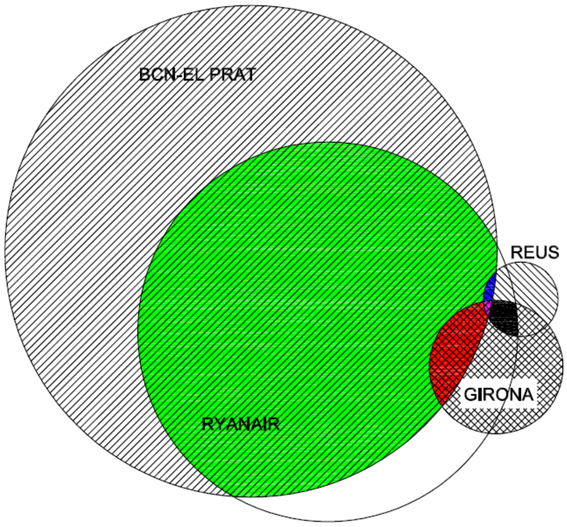

Figure 15 Alternatives to study (non-scaled)

3.2.3 ATRIBUTES OF THE ALTERNATIVES

Attributes are characteristics of the alternatives that individuals consider during the choice process. The third part of the model tries to identify the factors which influence travelers to select one route out of the set. *Why is an alternative more attractive than others?* Immediately fare comes up to this question while considering a highly price-sensitive market. But that is not true; heterogeneity in willingness to pay is present and drives airlines to invest in the so called yield management, selling a ticket to the right individual at the right rate and at the right time to maximize revenue. In turn, business travelers are rather frequency-sensitive than price sensitive.

Trade-offs made by individuals will be step-wise implemented. Firstly three groups of service's attributes are placed, related to the airport, the airline or to the route itself. Note that here individual's relative attributes are already omitted.

The vector of measurable attributives to each alternative is$\{X^k, X^{1k}_{i,j}, X^{2k}_{i,j}, X^i\}$, relative to the route consists in the value of travel time X^k for the flight offered by the airline j with a frequency opportunity cost $X^{1k}_{i,j}$ at $X^{2k}_{i,j}$ price from/to the airport reached at an average cost X^i.

Furthermore, it is possible to add non-measurable items to the model that could include taste and preferences like perception of airport's convenience, airline's reliability, etc; denoted as error terms ε_i and ε_j. Also stochastic terms can be represented for the case for on-time performance.

3.2.3.1 Travel access cost.

Whether a passenger should choose one secondary airport depends on the ticket price as well as the distance or access time. Although most of the travelers visit Barcelona competitive fares are offered in both Reus and Girona airports.
There should be a clear relationship between willingness to pay for the airfare and the cost or access time because price-sensitive travelers would be more likely to travel via secondary airports as long as they get a cheaper ticket. However, given that access cost is not paid at the time of purchase when considering different alternatives it might be mistaken as an ancillary cost like luggage checked, priority boarding, insurance, etc. Even so, distance to airport is taken into account in terms of schedule and comfort, thus can be traduced into cost.

Travel access cost has been modeled as an airport's characteristic so that for each alternative a unitary average cost is implemented based on the following adjusted summatory:

$$X^i = \sum_{m=1}^{3} \sum_{l=1}^{8} {w_{m,l}}^i \, {w_l}^i \cdot p_{l,m}^i \qquad (3.2)$$

Where,
X^i average access cost to airport *i*.
$p_{l,m}^i$ price for travelling from zone l to airport i, by *m* mean (taxi, public transportation, or vehicle)
${w_l}^i$ proportion of travelers to airport i from zone l
${w_{m,l}}^i$ proportion of travelers who travel to airport i from zone *l* by *m* mean.

The Catalan area has been divided into 8 regions according to touristic demarcations (Table 1). Each of them is represented by a centroid which concentrates the population. The main idea is to estimate the market share of REU, BCN and GRO from every centroid.

Given that it constitutes a demand generation problem the so called gravity model becomes useful in this case.

Attracted trips to any of the airports are modeled making use of geo-economic variables such as population, distance to airport and the gross domestic product per inhabitant on the one hand and number of airport's operations on the other.

$$T_{li} = \alpha \frac{GDP_l^{\mu} \cdot OP_i^{\beta} \cdot P_l^{\gamma}}{{d_{li}}^{\delta}} \tag{3.3}$$

where,

GDP_l^{μ} is the gross domestic product per inhabitant in region l .
OP_i^{β} number of operations in airport i.
P_l^{γ} is the population in region l.
${d_{li}}^{\delta}$ is the distance between airport I and region.
μ, δ, β, γ are exponents that have been submitted to a sensitivity analysis to obtain the best fit.

As an estimate of the mode choice probability Figure 16 has been used which distributes transportation along with the distance between airports and the centroids. Although the model incorporates the number of operations at each airport no data is available to become a doubly constrained method, if that was the case then it could be implemented to obtain a result with a higher level of calibration.

Values obtained correspond to an homogeneous criterion of evaluation of travel access cost and do not reflect that in fact these airports have different accessibilities and public services provided which results in a slightly difference in price per Km.

Table 6 Public services to airports and costs

Airport	Bus	Train + Bus	Train	Freq/flight
BCN	TMB 2€ Aerobus 5.75€	RENFE 3.6 € TMB: 1€	RENFE 3.6€	3:4
GRO	From Bcn Sagalés 15€ From GIRONA Sagalés 2.65€	Renfe + Sagalés 11.3€	∄	5:7
REU	From Bcn Hispano Igualadina 12.5€ From Reus : 2.40€	10.8€	∄	5:6

Values computed for accessibility ratios indicate that Reus Airport should be the highest accessible, however calculating only services originating in Barcelona ratio downs to 1:5.

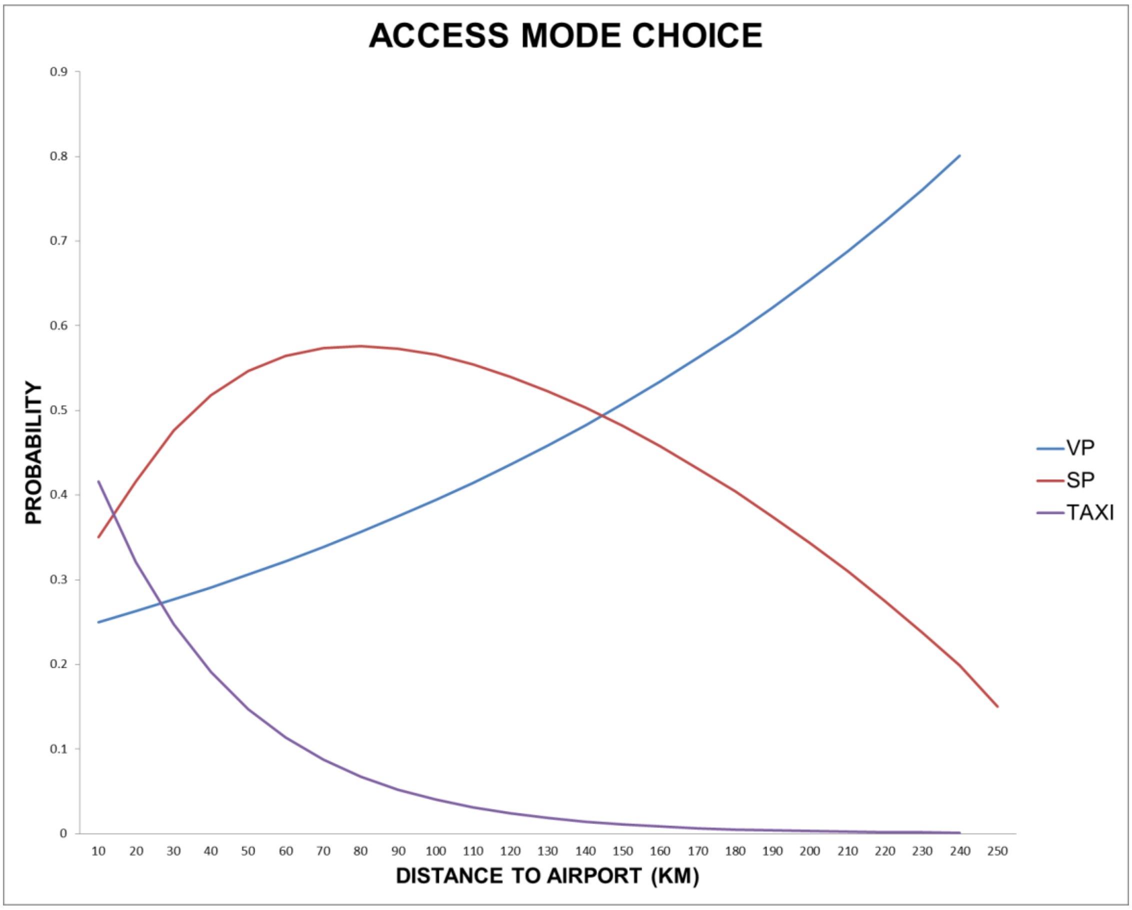

Figure 16 **Access mode choice (VP= Private vehicle; SP= Public service)**

Final results for the travel access cost per ride are:

Table 7 Access costs

GIRONA-COSTA BRAVA	12.34 €
BARCELONA-EL PRAT	11.58 €
REUS	13.91 €

3.2.3.2 Value of travel time.

By establishing a connection between the in-flight time and utility of the alternatives it probably will not make a difference because flight time is approximately the same through all of them.

Nonetheless, it helps to find out if there exist different behavior patterns whether flight is short or mid-haul. That is for example if, when increasing flight distance price elasticities would tend to become steeper.

Regardless of which is the airport of origin or destination (as long as it is the same destination) flight times for the same route will be taken the same along the choice set. This data will implement the official flight times according to OAG MAX database. Travel time will be expressed as a cost for the traveler through values obtained from literature references (0.3€/min).

3.2.3.3 Average airfare.

Generally flight price has a great influence in decision-makers. However not only demand heterogeneity exists but also on the hand of supply different rates are applied for the same route or even for the same flight. That means that a flight can be found at different price categories according to cabin classes and ticket flexibility to changes and refunds.
On top of that, web vendors also sale the same product with price differences due to own taxes and services fees.

Flight selling prices are usually modified as a function of load factor and departure date. Busiest routes may start at a higher rate whereas other flights ensure a reasonable load factor creating demand by offering lower fares to earlier bookers. Flight tickets get more expensive prior to departure unless the carrier includes the last-minute fare in its pricing strategy.

Price will be modeled through different search engines such as kayak.es, trabber.com that gather most of the web sales. Although booking time until date of departure it is not a matter for this study several flights are requested to estimate an average fare.

3.2.3.4 Frequency cost.

Frequency opportunity cost stands for the chances a traveler loses of managing the time. That means the cost for a passenger to travel to a destination choosing a carrier with a lower frequency than others offer which probably will led to the fact that the passenger will not be able to depart at the desired time in order to optimize his daily routine or time. On the other hand if carrier offers a wide range of frequencies it is likely to find a schedule that perfectly fits working time, vacation issues, etc.

3.2.4 DECISION RULE

Individuals who make decisions among the choice set are assumed to have all the information needed and act rationally so that the selected alternative is the one which has the maximum utility (minimum generalized cost).

3.3 METHODOLOGY

In this chapter the general formulation of the demand assignment model is presented. This research is focused on choice processes involving LCC carriers in Barcelona area and aims to investigate and model choice behavior in a multi-airport region with a wide offer of low-cost supplementary and complementary routes at different departing airports in the region.
The analysis proposed in this research makes use of discrete choice models based on Random Utility Theory models.
The Multinomial Logit model (MNL) is the simplest random utility model and also the most common therefore it will be used to adjust demand assignment.

3.3.1 CHOICE OF DATA SOURCES

One of the most important problems or barriers faced in this study is the availability of reliable passenger booking data or even passenger carried data at route-carrier level. The fact is that only passengers at a route level are available, however on the hand of supply, wider data can be used like OAG database.

Nonetheless OAG database has some dark points because some airports are not in the database especially for low-cost destinations. In the case of low-cost or Ryanair exclusive airports, data is available at route-carrier level from AENA, whereas for multiple carrier routes AENA public data only provides passengers aggregated at a route-level.

To solve this lack of disaggregation the relationship between frequency share and market share can be taken into account. It is logic to use as a law of the thump that airline market shares would be approximately equal to their frequency share without considering any changes in the market; however for a more accurate study this consideration becomes quite poor. In fact, the differences between market share and market frequency share are attributed to quality, price, time, and were represented in a S-Curve (Baseler, 2002).

Although several authors have criticized the S-Curve performance especially for those markets with leisure segments and low-carriers in this research constitutes the unique form of disaggregation. Therefore it will be cautiously implemented.

The S-curve relationship between frequency and market share helps to explain the use by airlines of flight frequency as an important competitive tool. The more frequency offered by an airline, it will capture a superproportional higher market share.

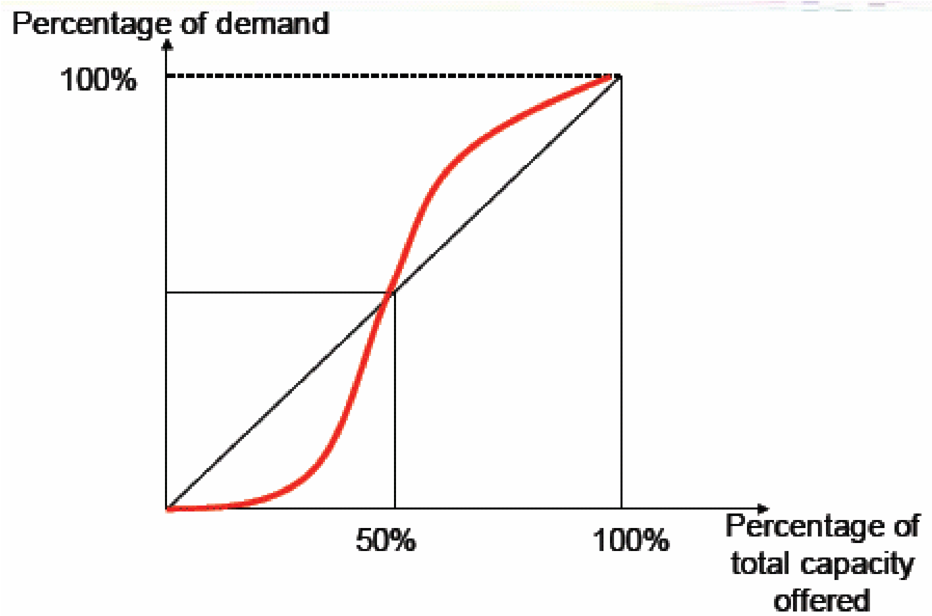

Figure 17 Market Share vs. Frequency Share "S-Curve" Model (Lenoir, 2007)

Therefore the following mathematical relationship will be implemented:

$$MS(A) = \frac{FS(A)^a}{FS(A)^a + FS(B)^a + FS(C)^a} \qquad (3.4)$$

Where :
MS(i) = market share of the airline i
FS(i)= non-stop frequency share of airline i.
a=exponent greater than 1.0 and generally between 1.3 and 1.7.

In the model the value of the exponent a determines how far the S-curve bends away from the linear diagonal model and thus greater is the market share return for an airline that offers more frequencies than its competitor. This factor is determined by how sensitive the market is to frequency changes.

When facing with the problem of distributing air traffic amongst carriers an arbitrary value for exponent a will be taken as it follows:

- For domestic and business destinations which are more frequency sensitive: 1.5.
- For major leisure destinations: 1.3.

Despite the fact of having two different data sources only monthly aggregate on departing /arriving passengers has been gathered from them. Unfortunately origin and destination data for individual passengers is not available. Therefore, this model is not able deal with individual decisions due to the lack of survey information. As exposed in equation 3.4 the probability of an individual q choosing a destination k from airport i with airline j is usually expressed as a function of attributes relative to the alternatives and the decision maker:

$$P_{i,j,q}^{k} = f(X^{k}, X_{i,j,}^{k} X_{q}^{k}) \qquad (3.5)$$

However our information is related to a population Q which is the group of monthly passengers of the space of events considered. For this Q the population share of alternative $A_{i,j}^{k}$ is the expected value of the individual probabilities:

$$P_{i,j,Q}^{k} = \frac{1}{Q}\sum_{q} f(X^{k}, X_{i,j,}^{k} X_{q}^{k}) = \frac{1}{Q}\sum_{q} f(X^{k}, X_{i,j,}^{k} \not{X_{q}^{k}}) = \frac{1}{Q} f\left(X^{k}, X_{i,j,}^{k}\right) \cdot Q = f\left(X^{k}, X_{i,j,}^{k}\right). \qquad (3.6)$$

As data available is the monthly share of a route the choice sets are modeled as the set of all itineraries between city-pair per month. For example all July itineraries between Barcelona (either BCN, REU or GRO) and Milan constitute an alternative set.

Besides, further data needed to adjust the model, the characteristics or attributes of the alternatives also have to be collected in a reliable form. That is the case for average airfare, frequency, travel time and travel access cost which all have been exposed in prior sections.

3.3.2 MULTINOMIAL LOGIT MODEL

The multinomial logit model (MNL) is the simplest discrete choice model and is used to describe how an individual chooses among a set of alternatives. This model estimates probabilities assuming that error terms are Gumbel IID distributed with the following expression:

$$P_q(i,j|k) = P_{i,j}^{k} = \frac{e^{V_{i,j}^{k}}}{\sum_j \sum_{i=1}^{3} e^{V_{i,j}^{k}}} \qquad (3.7)$$

$P_{i,j}^{k}$= Probability of an individual q (Group of individuals Q) travelling to a destination k will take route offered by airline j from airport i.

$V_{i,j}^{k}$ Corresponds to the observed utility function, in this case the generalized cost of the alternative which is given as:

$$U_{i,j}^{k} = V_{i,j}^{k} + \varepsilon_{i,j}^{k} \tag{3.8}$$

In fact $V_{i,j}^{k}$ is known as representative utility related to all observable elements of the choice, whereas $\varepsilon_{i,j}^{k}$ is attributed to error terms associated with non-observable or unknown factors of the utility functions such as taste variations across the studied population.

The generalized cost (systematic utility) function is usually expressed as an algebraic linear in the coefficients of the attributes form. Note that this does not imply that all the attributes considered must have linear relationships but can take different functional forms using useful parametric functional transformations such as Box-Cox.

$$V_{i,j}^{k} = \theta \cdot X^{k} + \beta_1 X_{i,j}^{1k} + \beta_2 X_{i,j}^{2k} + \gamma \cdot X^{i} \tag{3.9}$$

X^{k}: Value of in-flight time to destination k.
$X_{i,j}^{1k}$: Airfare offered by airline j from airport i to destination k.
$X_{i,j}^{2k}$ Frequency opportunity cost associated to route offered by airline j from airport i to destination k.
X^{i} Average travel access cost to airport i.
θ, β_1, β_2, γ: unknown coefficients.

However using non-linear expressions the formulation is:

$$V_{i,j}^{k} = \theta \cdot f(X^{k}) + \beta_1 f(X_{i,j}^{1k}) + \beta_2 f(X_{i,j}^{2k}) + \gamma \cdot f(X_i) \tag{3.10}$$

At this point Box-Cox transformation can be applied to let the functional form of the model come out during the analysis.

$$\text{f(X)} = \begin{cases} (X^{\tau} - 1)/\tau, & if\ \tau \neq 0 \\ logX, & if\ \tau = 0 \end{cases} \tag{3.11}$$

On the other hand, $\varepsilon_{i,j}^{k}$, namely random deviations between modeled and observed utilities are assumed to be independently and identically distributed over the population according to a Gumbel distribution of zero mean and scale one (variance $\pi^2/6$).

This already aforementioned assumption leads to the so called IIA property, independence of irrelevant alternatives in which the ratio of choice probabilities between any two alternatives is independent of the availability of other alternatives.

If the model is completely specified and in the absence of heterogeneity, the average probabilities obtained from applying the model to individual choices will approximate to the sample shares.

Thus, it can be assumed that the share of passengers assigned to each itinerary or alternative between a city-pair for a given month is:

$$S_{i,j}^{k} = P_{i,j}^{k} = \frac{e^{V_{i,j}^{k}}}{\sum_j \sum_{i=1}^{3} e^{V_{i,j}^{k}}} \tag{3.12}$$

One of the implications of the IIA property can be noted when cross-elasticities among alternatives. Elasticities provide the sensitivity of choice probabilities to a unit change in either one of the attributes from the alternative or from any other.
Thus, the sensitivity of the probabilities can refer to a direct effect or cross effect respectively. For example, direct elasticity is the variation of alternative $A_{i,j}^{k}$ market share relative to a unit change in one of its explicative variables$X_{i,j}^{k}$.

$$E_{P_{i,j}^{k},X_{i,j}^{k}} = \frac{\partial P_{i,j}^{k}}{\partial X_{i,j}^{k}} \cdot \frac{X_{i,j}^{k}}{P_{i,j}^{k}} = \left(1 - P_{i,j}^{k}\right) \cdot \beta_{i,j} \cdot X_{i,j}^{k} \tag{3.13}$$

While cross-elasticity of $P_{m,n}^{k}$, for m,n ≠ i,j :

$$E_{P_{m,n}^{k},X_{i,j}^{k}} = \frac{\partial P_{m,n}^{k}}{\partial X_{i,j}^{k}} \cdot \frac{X_{i,j}^{k}}{P_{m,n}^{k}} = -\beta_{i,j} \cdot \left(P_{i,j}^{k}\right) \cdot X_{i,j}^{k} \tag{3.14}$$

In equation 3.14 can be noted that cross-elasticities are independent of the alternative $P_{m,n}^{k}$ considered and therefore the cross-elasticity relative to changes in attribute $X_{i,j}^{k}$ is the same for all routes.

3.3.3 ESTIMATION METHODS

The goal of this section is to set a methodology to estimate the parameters of the choice models. Having observations associated with individual choices the most commonly used is the maximum likelihood method. This method solves the set of parameters for which maximizes the probability of the observed responses.

The maximum likelihood function is derived from the product of the probabilities of a group of individual choosing the alternative selected.

Nonetheless, given that in this model only aggregate data is provided becomes useful to transform probability functions (market share) in the way that can be estimated by linear regression. This form of the model can be achieved with the Odds ratio which is defined as the log of the ratio of probabilities of two alternatives from the same set.

$$\ln\left(\frac{P_{i,j}^{k}}{P_{m,n}^{k}}\right) = \ln\left(\frac{S_{i,j}^{k}}{S_{m,n}^{k}}\right) = \ln\left(e^{V_{i,j}^{k}-V_{m,n}^{k}}\right) =$$

$$\beta_1(X_{i,j}^{1k} - X_{m,n}^{1k}) + \beta_2(X_{i,j}^{2k} - X_{m,n}^{2k}) + \gamma \cdot (X^{i} - X^{m}) \quad (3.15)$$

The adjustment of the utility function through multiple linear regression, is based on the ordinary least squares method which produces a line that minimizes the sum of the squared vertical distances from the line to the observed data points.

Note that from this formulation the influence of travel time, which is the same for each alternative set, cannot be determined.
To solve this problem, an instrumental variable is implemented. The cost of travel time will be expressed as the quotient between the cost of flying time and the access cost to the chosen airport to travel, defined as:

$$X_i^k = \frac{X^k}{X_i} \quad (3.16)$$

OLS is based on several assumptions which imply that if provided the regression estimators (coefficients/parameters) are:

- Unbiased: expected value of the estimator is equal to the true value of the parameter.
- Efficient: the estimator has smaller variance than any other.
- Consistent: bias and variance of the estimator approach zero as the sample size approaches infinity.

The basic assumptions for the regression model which have to be checked on the error terms are:

1) Homoscedasticity and centrality: The expected value of the residuals is zero and the variance of the residuals is constant. This assumption is checked in residuals analysis with scatterplots of the residuals against predicted values.
   If the form of the plot is shapeless then this assumption is provided.

$$E(\varepsilon_i) = 0 \qquad\qquad Var(\varepsilon_i) = \sigma^2 \quad (3.17)$$

2) Normality: the error term is normally distributed. This assumption is checked by Kolmogorov-Smirnov test. This statistic compares between the empirical distribution on the residuals and the cumulative normal distribution function under the null hypothesis. If the distance between both values is large enough the null hypothesis that both samples come from the same distribution is rejected.

3) Non-autoregression: The residuals are random or uncorrelated which means that residuals should be independent of any other residual.

   The Durbin-Watson statistic tests autocorrelation of residuals. The Durbin Watson statistic tests the null hypothesis of no first-order autocorrelation which is written as:

$$\hat{e}_i = \rho \hat{e}_{i-1} + \delta \quad (3.18)$$

   Where,

   $\hat{e}_i$ is the estimated error term at i.
   $\hat{e}_{i-1}$ is the estimated error term at i-1.
   δ is a random error.
   ρ is the first-order autocorrelation coefficient of the residuals.

   If the test is for positive autocorrelation of residuals, the hypotheses for the D-W test can be written:

$$H_0: \rho = 0$$

$$H_1: \rho > 0$$

   The Durbin-Watson statistic is given by the estimated the error terms as follows:

$$d = \frac{\sum_{i=1}^{n}(\hat{e}_i - \hat{e}_{i-1})}{\sum_{i=1}^{n}\hat{e}_i^{\,2}} \quad (3.19)$$

Durbin and Watson established upper (d_U) and lower (d_L) limits for the significance levels of a computed *d.* For this study a significance level of 95% is chosen. For positive autocorrelation, the decision rule depends on d_L and d_U :

a) If $d < d_L$ reject H_0
b) If $d > d_U$ do not reject H_0
c) If $d_L < d < d_U$ inconclusive

4) Linearity: The relationship between the independent variable and the prediction variables is linear. If the predictand Y is linear to the predictor $x_{i,k}$ the coefficient of the kth predictor should be different from 0.

Linearity is checked by obtaining the confidence interval of 100(1-α)% for the coefficient b_k. If $b_k \neq 0$ then the relationship is linear.

If the regression assumptions on the residuals are satisfied, then it can be assumed that the term $\frac{b_k - \hat{b}_k}{S(b_k)}$ draws from a t distribution with n-2 degrees of freedom.

Alternatively linearity assumptions can be gathered from variance analyses. By these means the regression equation is estimated such that the total sum-of-squares can be partitioned into two components due to regression, non-random, and residuals:

$$SST = SSR + SSE \quad (3.20)$$

Sum of squares, total

$$SST = \sum_{i=1}^{n} (Y_i - \bar{Y})^2 \quad (3.21)$$

Sum of squares, residuals

$$SSE = \sum_{i=1}^{n} (Y_i - \hat{Y}_i)^2 \quad (3.22)$$

Sum of squares, regression

$$SSR = \sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2 \quad (3.23)$$

Where, $\hat{Y}_i$ is the predicted value for Y_i for the model and $\bar{Y}$ is the mean value for Y.

If all the observed values are located on the estimated line residuals are 0 and therefore, SSE= 0. It can be noted that the higher is the value of SSE the greater is its contribution to variation of observation values.

On the other hand, SSR stands for the non-random error term due to linearization. Therefore SSR/SST is the part of the variation that can be explained by the regression, by this the explanatory power of the regression is summarized by the R^2 , determination coefficient, computed from SSR, SSE or SST.

$$R^2 = \frac{SSR}{SST} = 1 - \frac{SSE}{SST} \tag{3.24}$$

The relative sizes of the sums of errors terms indicate the quality of the regression in terms of fitting the calibration data. If R=1 the adjustment is perfect. However this value does not provide if the adjustment is correct enough. Hence, a statistical hypothesis test is required which is written as:

$$H_0: b_k = 0$$

$$H_1: b_k \neq 0$$

The statistic used in this case is Fisher's F:

$$\frac{\frac{SSR/\sigma^2}{3}}{\frac{SSE/\sigma^2}{n-3}} \tag{3.25}$$

It is important to remark that F ratio incorporates sample size and number of predictors in an assessment of significance of the relationship. The significance of the F-ratio is obtained by referring to a table of the F distribution using 3 (4) degree of freedom for the regression and n-3 (n-4) for the residual mean square. For this study the rejection region is defined as follows:

1) Good adjustment. H_0 is not rejected for a significance of 0.01.
2) Correct adjustment. H_0 is not rejected for a significance of 0.05 although rejected for 0.01.
3) Acceptable adjustment. H_0 is not rejected for a significance of 0.1 although rejected for 0.01 and 0.5. .

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4. ANALYSIS

4.1 META-MODELS

The first step of the analysis basically consists in categorize different response patterns of the multi-airport system due to changes in the key variables such as flight frequency and flight fare. This is done by implementing the formulation from prior sections without empirical data but normalized to ratios referred to Ryanair's routes attributes and by this means identify any type of behavior. Through this a very simplified model would be able to adjust to the actual database. Moreover, the results will we discussed in order to correct the model or even emphasize it before the whole set of numerical data is submitted to prediction scenarios in the following chapters.

As the model aims to find out the influence of Ryanair, will take into account the different changes occurred in the region (see Chap.1.3) to estimate possible evolutions as a result of the introduction of new Ryanair's routes overlapping existing routes. For this reason periods from Table 8 are considered across the analysis made. Utility function parameters will be obtained for each of the periods studied to verify if they persist.

To achieve an overview of the system a MATLAB code has been written. This code is able to read data from each alternative sets from Table 9 and evaluate the MNL model for different values of the frequency and price ratios expressed as:

$$\tau_P = \frac{\overline{Price}_{RYR}}{\overline{Price}_{Other}} \qquad \tau_F = \frac{\overline{Freq}_{RYR}}{\overline{Freq}_{other}} \tag{4.1}$$

These ratios are set to vary from 0.2 to 1 to capture the sensibility of the model to these attributes although their average values were around 0.48 for the price and 0.36 for the frequency in July 2010. The output generates curves of trends and so bivariate surfaces which allow having an overview of the main attributes involved.

The form of the utility function follows the notation already explained in the formulation chapter but on the ratio basis from equation 4.1.

Here a great simplification is made by reducing values to only pairs that depending on how much differ from the mean value will better represent demand choices. The reason for this to be taken is to materialize a macroscopic perspective while having to modify a reduced number of values.

For Ryanair flights,

$$V_{i,j}^{k} = \theta \cdot X_i^k + \beta_1 \cdot 1 + \beta_2 \cdot 1 + \gamma \cdot X^i \quad (4.2)$$

For non-Ryanair flights,

$$V_{i,j}^{k} = \theta \cdot X_i^k + \beta_1 \cdot 1/\tau_P + \beta_2 \cdot 1/\tau_F + \gamma \cdot X^i \quad (4.3)$$

Where

X_i^k: Value of in-flight time to destination k. Cost of flying time divided by access cost to airport i.
τ_P: Ryanair's fare by others fare.
τ_F : Ryanair's frequency by others frequency
X^i : Average travel access cost to airport i.
$\theta, \beta_1, \beta_2, \gamma$: unknown factors

The difficulty lies in giving adequate values to the coefficients which determine the weight of each of the attributes. As an approach one set of data is submitted to the regression (see Chap.3.3.3) by the ordinary least squares method explained above.

Every period considered has a set of variables that fulfill the requirements exposed. The routes considered are listed in the table below. Note that the number in brackets indicates the number of carriers that serve the route. After that, a summary table is filled by the total amount of routes taken from each of the airports. This selection has been made consolidating the data from the OAG MAX database and further checked with AENA Passenger data.

Table 8 Ryanair non-exclusive routes (number of alternatives for each destination)

JULY 2010	NOVEMBER 2010	MARCH 2011	JULY 2011	NOVEMBER 2011	JULY 2012
					ALACANT (2)
					ASTURIAS (2)
					BILBAO (2)
			BIRMINGHAM (2)		BIRMINGHAM (4)
BOLOGNA (2)	BOLOGNA (2)	BOLOGNA (2)	BOLOGNA (2)	BOLOGNA (2)	BOLOGNA (2)
	BRISTOL (2)	BRISTOL (2)			BRISTOL (3)

JULY 2010	NOVEMBER 2010	MARCH 2011	JULY 2011	NOVEMBER 2011	JULY 2012
BRUSSELS (4)	BRUSSELS (5)	BRUSSELS (5)	BRUSSELS (5)	BRUSSELS (3)	BRUSSELS (5)
					BUDAPEST (2)
					COLOGNE (2)
CORK (2)					CORK (3)
DUBLIN (2)	DUBLIN (3)	DUBLIN (4)	DUBLIN (4)	DUBLIN (2)	DUBLIN (4)
DUSSELDORF (4)	DUSSELDORF (5)	DUSSELDORF (5)	DUSSELDORF (4)	DUSSELDORF (3)	DUSSELDORF (4)
EAST MIDLANDS (2)	EAST MIDLANDS (2)				
EDIMBURG (2)					EDIMBURG (2)
	EINDHOVEN (2)	EINDHOVEN (2)	EINDHOVEN (3)	EINDHOVEN (2)	EINDHOVEN (3)
EIVISSA (4)	EIVISSA (4)	EIVISSA (4)	EIVISSA (4)	EIVISSA (4)	EIVISSA (4)
FRANKFURT (3)	FRANKFURT (2)	FRANKFURT (2)	FRANKFURT (3)	FRANKFURT (2)	FRANKFURT (3)
	FUERTEVENTURA (2)	FUERTEVENTURA (2)	FUERTEVENTURA (3)		FUERTEVENTURA (2)
GDANSK (2)					GDANSK (2)
		GLASGOW (2)			GLASGOW (4)
GOTEBORG (2)	GOTEBORG (2)	GOTEBORG (2)			GOTEBORG (2)
GRAN CANARIA (4)	GRAN CANARIA (4)	GRAN CANARIA (4)	GRAN CANARIA (4)	GRAN CANARIA (4)	GRAN CANARIA (2)
HAMBURG (2)					HAMBURG (3)
LANZAROTE (3)	LANZAROTE (4)	LANZAROTE (4)	LANZAROTE (3)	LANZAROTE (2)	LANZAROTE (2)
LEEDS (2)	LEEDS (2)	LEEDS (2)	LEEDS (2)	LEEDS (2)	LEEDS (3)
LIVERPOOL (2)	LIVERPOOL (2)	LIVERPOOL (2)	LIVERPOOL (2)		LIVERPOOL (3)
LONDON (4)	LONDON (3)	LONDON (4)	LONDON (4)	LONDON (2)	LONDON (6)
			MAASTRICHT (2)		
MADRID (5)	MADRID (5)	MADRID (5)			MADRID (4)
MALAGA (3)	MALAGA (3)	MALAGA (4)	MALAGA (3)	MALAGA (3)	MALAGA (2)
MALLORCA (6)	MALLORCA (7)	MALLORCA (7)	MALLORCA (7)	MALLORCA (6)	MALLORCA (7)
MALTA (2)			MALTA (3)		MALTA (2)
					MANCHESTER (5)
MARRAKESH (4)	MARRAKESH (4)	MARRAKESH (4)	MARRAKESH (3)	MARRAKESH (2)	MARRAKESH (2)
					MENORCA (3)
MILAN (8)	MILAN (9)	MILAN (9)	MILAN (9)	MILAN (7)	MILAN (5)
MUNCHEN (4)	MUNCHEN (3)	MUNCHEN (3)	MUNCHEN (4)	MUNCHEN (3)	MUNCHEN (3)
					NEWCASTLE (3)
			NOTTINGHAM (3)		NOTTINGHAM (3)
OPORTO (2)	OPORTO (2)	OPORTO (2)	OPORTO (2)	OPORTO (2)	OPORTO (2)
OSLO (3)	OSLO (4)	OSLO (4)	OSLO (3)	OSLO (3)	OSLO (3)
		PALERMO (2)	PALERMO (2)		
PARIS (5)	PARIS (6)	PARIS (6)	PARIS (6)	PARIS (5)	PARIS (5)
PISA (3)	PISA (2)	PISA (3)	PISA (3)	PISA (2)	PISA (2)
					POZNAN (2)
ROMA (3)	ROMA (4)	ROMA (4)	ROMA (3)	ROMA (3)	ROMA (3)
SANTANDER (2)		SANTANDER (3)	SANTANDER (3)	SANTANDER (2)	SANTANDER (2)
SANTIAGO (3)	SANTIAGO (3)	SANTIAGO (4)	SANTIAGO (4)	SANTIAGO (3)	SANTIAGO (2)

JULY 2010	NOVEMBER 2010	MARCH 2011	JULY 2011	NOVEMBER 2011	JULY 2012
SEVILLA (4)	SEVILLA (4)	SEVILLA (5)	SEVILLA (4)	SEVILLA (3)	SEVILLA (2)
STOCKHOLM (3)	STOCKHOLM (3)	STOCKHOLM (3)	STOCKHOLM (3)	STOCKHOLM (2)	STOCKHOLM (5)
TENERIFE (4)	TENERIFE (4)	TENERIFE (5)	TENERIFE (4)	TENERIFE (4)	TENERIFE (3)
TORINO (2)	TORINO (2)	TORINO (3)	TORINO (2)		
	VALENCIA (3)	VALENCIA (3)			
					VALLADOLID (2)
VENEZIA (4)	VENEZIA (4)	VENEZIA (4)	VENEZIA (5)	VENEZIA (4)	VENEZIA (4)
VIENA (4)		VIENA (4)	VIENA (4)		VIENA (3)

Table 9 Routes considered in the model

ROUTES AIRPORT/ PERIOD	JULY 2010	NOVEMBER 2010	MARCH 2011	JULY 2011	NOVEMBER 2011	JULY 2012
REUS	16	8	14	20	0	17
GIRONA	35	26	28	21	10	26
BARCELONA	72	84	93	85	72	112

4.2 REGRESSION RESULTS

Focusing on July 2010, for only leisure passengers, the regression is carried out by using the IBM SPSS STATISTICS 19 software. This software constitutes a global data analyzer. Performing a multinomial regression not only tables of results are obtained but also distribution plots and descriptive statistics. To all this, by inserting de data object of adjustment the software is able to realize the linear regression giving the necessary parameters to evaluate it : ANOVA table, R^2, residuals plot, normal distribution plot, etc.

Through this method the estimates for the factors are:

$$\beta_1\ (frequency) = 0.984$$
$$\beta_2(fare) = -1.341$$
$$\gamma(acces\ cost) = -0.259$$
$$\theta(travel\ time) = 1.576$$

The model must be checked on the residual assumptions presented in Chapter 3.3.3. According to the results assumptions 1, 2, 3 are satisfied and the Fisher test can conclude that the model has a good adjustment, together with a R^2 of 87.1%. Moreover the confidence intervals for all factors do not include 0. Therefore, an acceptable significance by t-Student test is achieved.

As the focus was only on leisure passengers, definitely business travelers are to have different expectations of both flight and airport service and have been accordingly estimated separately. The distribution of type of passengers has been estimated by 45% Business in Barcelona and only 8% in both Girona and Reus. Even though business travelers' percentages have been uniformly set passengers may not distribute at the same ratios across the routes studied especially for those only offering low-cost services. Once more is evident that the data constraint is substantial.

For this reason and due to non-logical results, for example Price factor >0, finally the model has been simplified to only to one type of passengers without distinction of travel purposes.

Carrying out again the adjustment to the whole set of passengers assumptions on the residuals are also met. Both P-P Normal probability plot and residuals scatterplot show normality, homoscedasticity and centrality. Non-auto regression is associated with the value of the Durbin-Watson statistic, 2.094 which is close to 2.

In terms of linearity the determination coefficient R^2 indicates that 88.3% of the variation can be explained by this approach, moreover, F test in the ANOVA table with a level of significance within the established limits reflects that the adjustment of the model is correct enough.

Because of these results the time variable set as instrumental variable with the access cost remains as an explicative variable. From the factors obtained it can be seen that the instrumental variable has a positive effect on utility. However, by excluding this variable from the utility function the adjustment is still acceptable, therefore this attribute has been removed to simplify the model. By modeling the relationship between the data and the 3 remaining attributes the following outputs are obtained from the software used:

Table 10 Model summary

Model	R	R^2	R^2corrected	Error estimation	Durbin-Watson
1	0.936[a]	0.877	0.872	0.30446	2.044

Table 11 Coefficients

Model	Coefficients non standardized		Coefficients typified	t	Sig.	Confidence interval 95,0% for B	
	B	Error typ.	Beta			Lower limit	Upper limit
FREQ	0.970	0.054	0.907	18.135	0.000	0.864	1.077
PRICE	-0.760	0.069	-0.655	-11.066	0.000	-0.896	-0.623
ACCESS	-0.516	0.046	-0.599	-11.217	0.000	-0.608	-0.425

4.3 MODEL EVALUATION

Although route specific frequencies are applied price is half to any other airline in all the periods studied. In addition to that condition coefficients of the model are maintained in order to find out if despite all these simplifications the model can perform at a desirable goodness of fit.

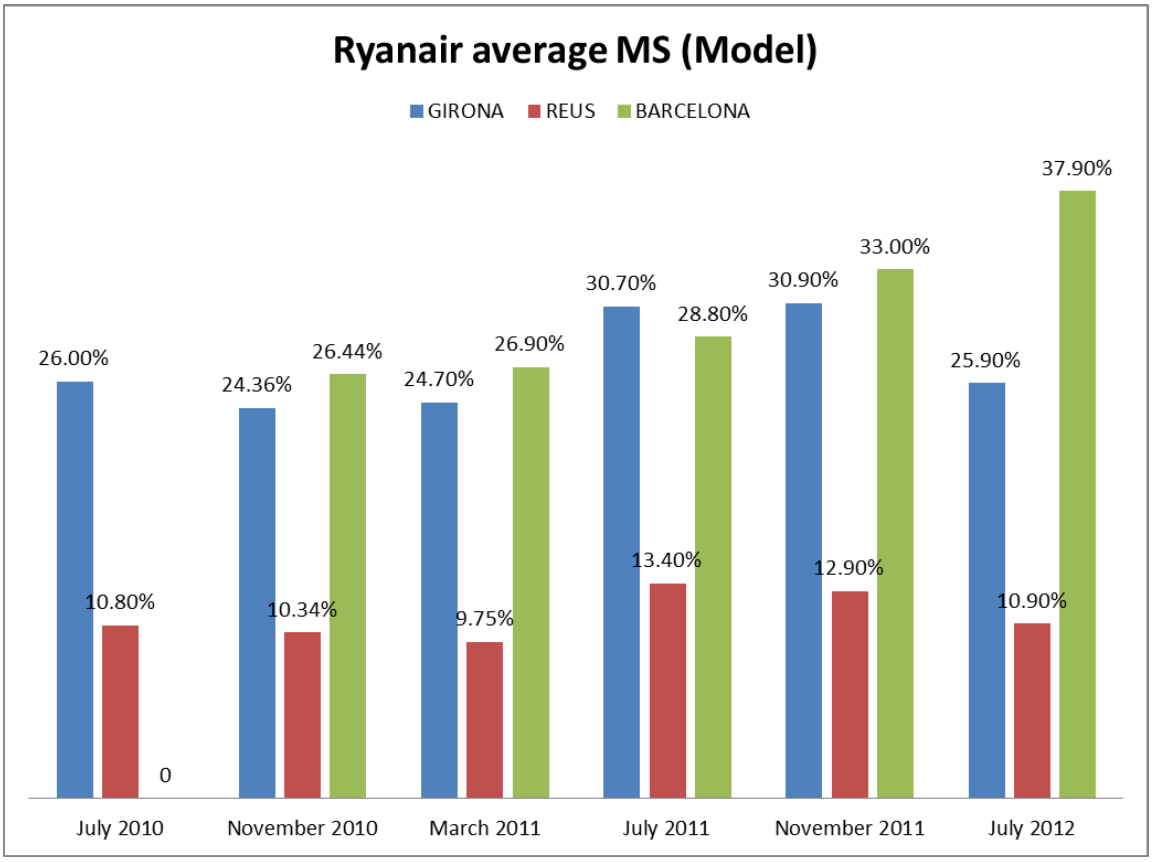

Figure 18 **Average Ryanair Market Share vs Others Market Share**

It must be noted that these values correspond to averaged values of market shares which are completely dependent on the number of values averaged and the number of alternatives of the choice set. For example, in November 2011 Reus airport experienced growth with an average market share of 12.90 % according to the model, however, Reus airport is only included in one choice set, destination Dublin, shared with Barcelona's Ryanair and Air Lingus. The most significant events from Figure 6 are here not noticeable, for example Ryanair's start of operations from Barcelona which can only be slightly seen above in how Ryanair Girona and Ryanair Reus MS decreased after that in 2010. In July 2010 the average market share in the routes served by Ryanair Girona was 32.6% while the same value with the MNL is 26.0%.

For the case of Reus a 10.8% of MS is predicted, having 14.1% from the AENA database. Further predicted results are shown in the table below:

Table 12 Average Ryanair Market Share Comparison Model-Aena Statistics

Month	Airport	Aena Statistics[5]	Simplified MNL model	Relative error
July 2010	Barcelona		0	
	Girona	32.70%	26.00%	-20.49%
	Reus	14.10%	10.80%	-23.40%
November 2010	Barcelona	30.70%	26.44%	-13.88%
	Girona	28.34%	24.36%	-14.04%
	Reus	10.40%	10.34%	-0.58%
March 2011	Barcelona	28.50%	26.90%	-5.61%
	Girona	27.50%	24.70%	-10.18%
	Reus	7.90%	9.75%	23.42%
July 2011	Barcelona	25.40%	28.80%	13.39%
	Girona	32.00%	30.70%	-4.06%
	Reus	18.00%	13.40%	-25.56%
November 2011	Barcelona	29.50%	33.00%	11.86%
	Girona	30.50%	30.90%	1.31%
	Reus	3.80%	12.90%	239.47%
July 2012	Barcelona	35.00%	37.90%	8.29%
	Girona	26.90%	25.90%	-3.72%
	Reus	17.40%	10.90%	-37.36%

In November 2011 Reus-Airport will accordingly not be considered as a single route fails to be representative enough. From the table above modeled results although following the same pattern from the coefficients obtained for July 2010 it can be seen that at most a 25% of error is displayed. Regardless of the results obtained it must be noted that disaggregated synthetic data from Aena Statistics can contain overestimations of passengers as a consequence of the bias towards frequency introduced to ascribe passengers from airport level to a route-carrier level. Even so in many cases Ryanair passengers have already been collected at this level due to the fact that routes are served either exclusively, from secondary airports or both.

One of the most important contributions in this chapter is to evaluate the utility function in the form of equations 4.2 and 4.3.

[5]When necessary disaggregated data has been estimated through the criteria exposed in Chap. 3.3.1 FREQUENCY S-CURVE

After the procurement of the first parameters it appears to not have the required fit. Share values and total passengers numbers do not correspond when the model is evaluated on single values.

This means that assuming only bivariate values for frequency and price an acceptable goodness of fit is not achieved with the uniformity considered. However, if the evaluation is made through normalized values but particularized for each route the performance is ensured. Results in Figure 19 show this disconformity put into comparison with the real values of market share despite considering different factors for each period.

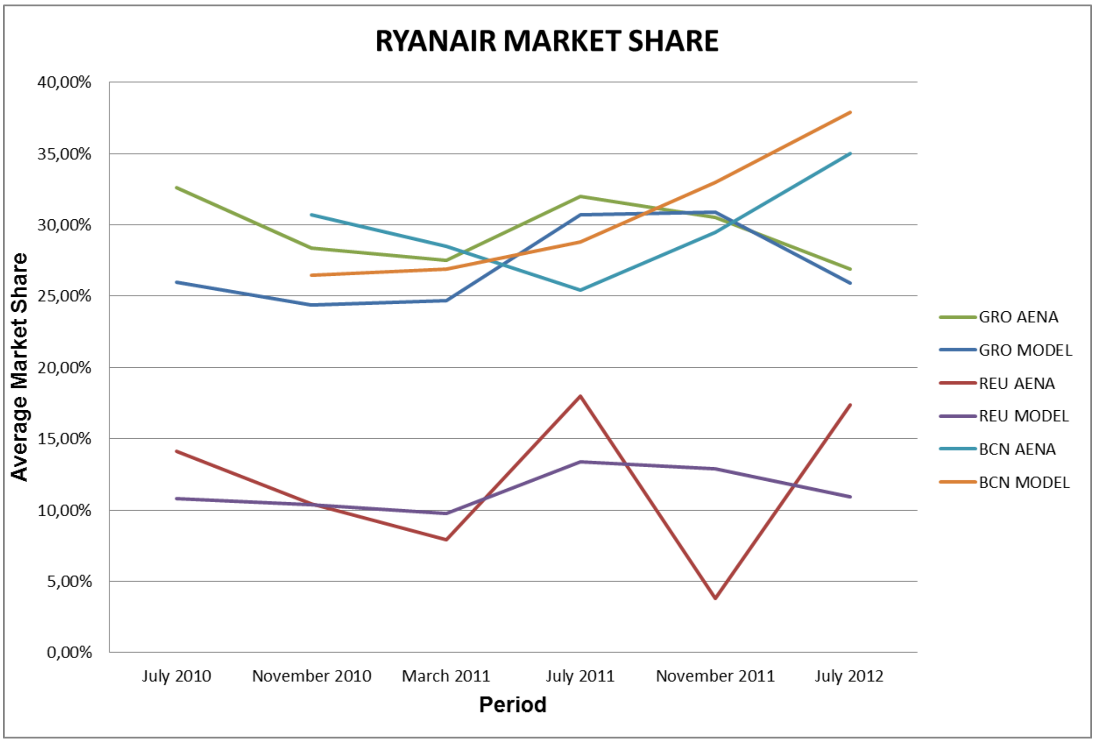

Figure 19 Model comparison

When regression is made for all the periods considered coefficients do not preserve. The main reasons to experience this effect is the market change with the entrance of Ryanair in Barcelona and the seasonality of the air travel. Particularly July is a month at the top of the yearly passengers' profile. The coefficients obtained in further calculations are:

Table 13 Regression results across periods studied

	Regression factors			Elasticities		
	Price	Frequency	Access	Price	Frequency	Access
JULY 2010	-0.760	0.970	-0.516	-0.79	1.28	-3.72

	Regression factors			Elasticities		
NOVEMBER 2010	-0.554	1.070	-0.398	-0.58	1.46	-3.65
MARCH 2011	-0.534	1.131	-0.534	-0.57	1.52	-4.55
JULY 2011	-0.547	1.187	-0.311	-0.57	1.46	-2.33
NOVEMBER 2011	-0.144	1.063	-0.653	-0.14	1.19	-4.25
JULY 2012	-0.492	1.110	-0.263	-0.418	1.21	-1.81

Some variability of the coefficients is evident in Table 13. Whereas frequency is the most stable value and also the strongest; price and access price suffer fluctuations. This indicates that the configuration of demand has changed over the time.

Despite having analyzed the performance of the model comparing the results of case-detailed market shares it is important to put emphasis on the total number of passengers. To conclude the estimation with a better fit of the model it is necessary to refer essentially to the final purpose of the formulation. Although regressions have a correct adjustment it would be highly valuable if despite the simplification of delimiting variances of key factors on the ratio basis goodness of fit is still acceptable. Thereby, a macroscopic significance is endorsed. The so called dummy variables are introduced. Such a variable indicates de absence or presence of some categorical effect by assigning the values 0 or 1.

This is done either to penalize or favor alternatives that due to the simplicity of the model its contributions have been absorbed. Differences in estimated terms are attributed to the loss of specification in the type of alternatives considered. After looking carefully at the results, it has been decided to contemplate mostly the demand of full service carriers and the low-cost carriers in BCN El-Prat which are neither Ryanair nor Vueling. To choose the right value for the dummy variable the root mean square error (RMSE) has been minimized to represent monthly passengers.

$$RMSE = \sqrt{\frac{\sum(MS_{i,j}^{k} - \widehat{MS}_{i,j}^{k})^2}{n}} \qquad (4.4)$$

In addition with both dummies above it is believed to be necessary to incorporate a dummy involving Girona Airport and Reus Airport because of the variance of frequency in which by fixing an average number the model tends to overestimate the number of passengers carried.

Table 14 Readjustment of regression process

	Regression factors			Dummies			
	Price	Frequency	Access	FSC	LCC	GRO	REU
JULY 2010	-0.760	0.970	-0.516	-0.4	-0.1	-0.15	-0.3
NOVEMBER 2010	-0.554	1.070	-0,398	-0.4	-0.1	-0.2	-0.1
MARCH 2011	-0.534	1.131	-0.534	-0.4	-0.2	-0.15	-0.1
JULY 2011	-0.547	1.187	-0.311	-0.2	-0.1	-0.25	-0.25
NOVEMBER 2011	-0.144	1.063	-0.653	-0.5	-0,2	-0.1	-0.2
JULY 2012	-0.492	1.110	-0.263	-0.5	-0.2	-0.35	-0.2

When implementing the Matlab code for the MNL using the final factors for each of the periods calculated above the following graphics are obtained for the situation observed and calibrated from July 2010 until July 2012.

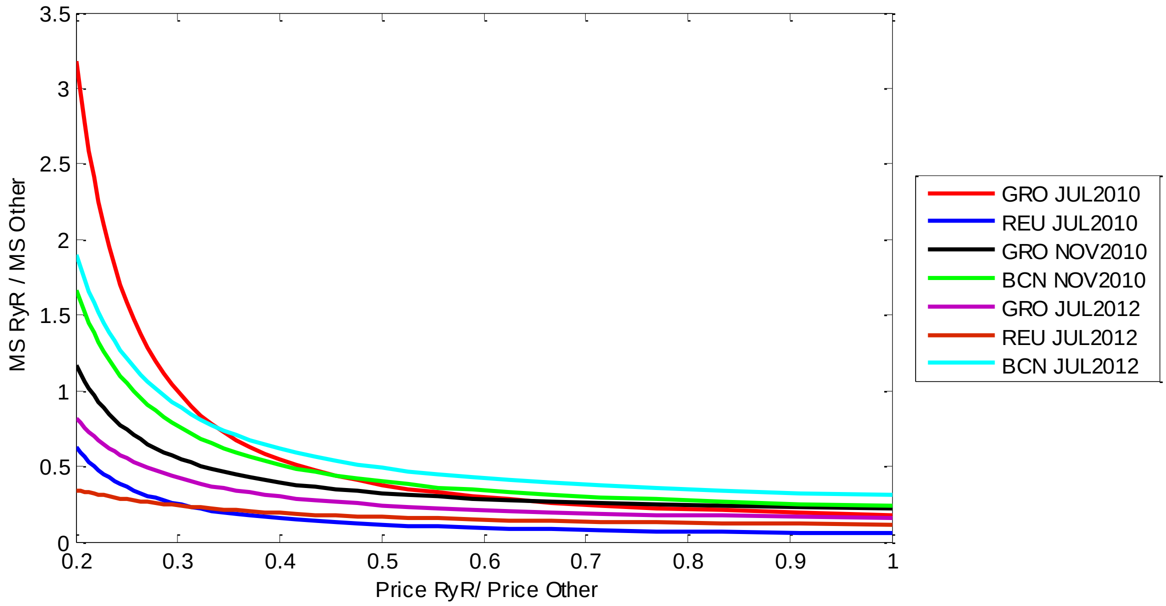

Figure 20 Ryanair average Market Share for a τ_F=0,38

Figure 20 shows clearly two areas of tendency, Reus appearing at the lower part of the graph while Girona and Barcelona take greater values. Concerning Reus airport it can be noted that the lower the price ratio is, the cheaper Ryanair fares are, as of 0.4 times others' the more concave the curves draw.

Above this value demand becomes more inelastic. In July 2012, demand remains practically constant to price for the frequency ratio considered. Further curves are represented in APPENDIX 3.

The curves displayed also indicate that having moved operations to BCN Airport maintaining average price ratios for every period the average Ryanair market share in Girona appears to be relieved by passengers in Barcelona.

The variability of the curve is evident between last period and July 2010. Without taking into account November 2011 (not drawn) and most recent period July 2012 in BCN all the curves draw around Girona July 2010. During July 2012 it makes sense to predict a great increase on demand shares because of Spanair's end of operations. That fact traduced into a configuration of a low-cost carrier duopoly with Vueling.

In consonance with Ryanair's presence strengthening in the Catalan region, average frequencies between Ryanair and other carriers have gone closer. Regarding that passengers have been merged in one single category, frequency also plays an important role in demand and so is noted by its corresponding demand elasticity. To show this effect in the figure below MS ratio is represented for an average price ratio of 0.50.

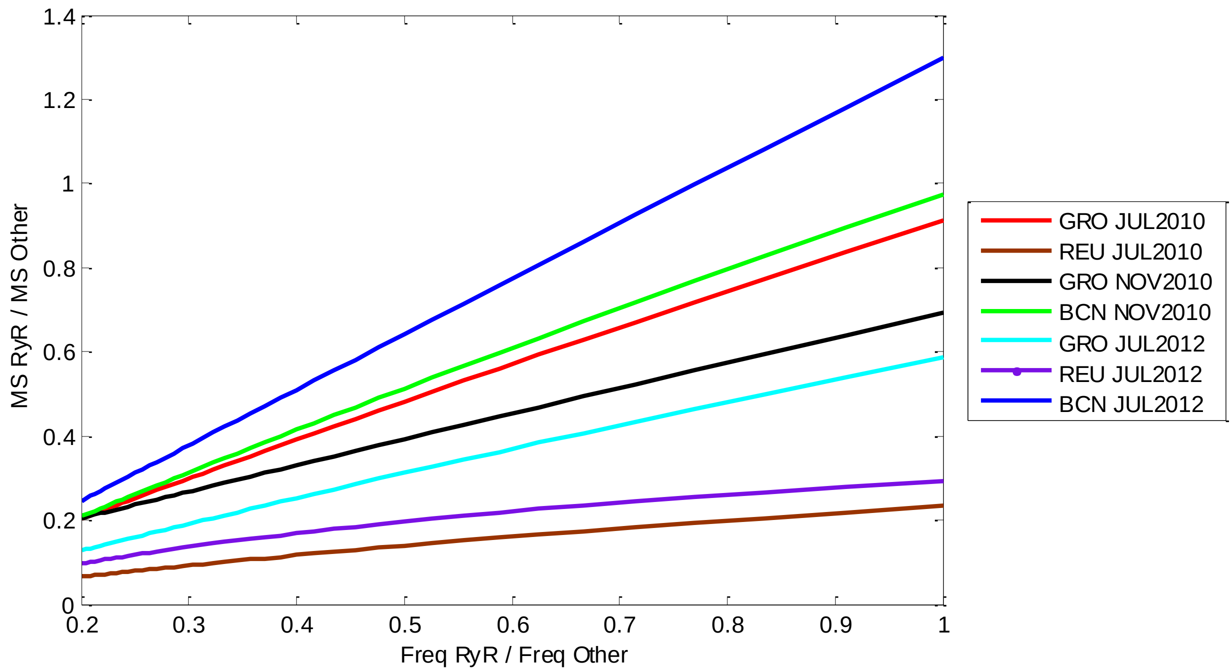

Figure 21 **Ryanair average market share for a τ_P=0.50**

In keeping with the model results while Reus Airport curves draw more flat, BCN Airport (July 2012) draws steeper. One important observation would be that if Ryanair was intended to increase frequencies positioning into a 0.75 ratio in average would tend to capture even more traffic than other carriers: MS RyR / MS Other > 1.
It is interesting to point out that, as mentioned before, that the curves represented do not cross each other in the same time span. Then at no point traffic interdependences between airports are recognized for this fixed route configuration.

Noticeable is in both Figure 20 and Figure 21 that the MS curve after Ryanair's start of operations in Barcelona in November 2010 it seems to be picking up the reins of Girona Airport. The Utility function defined in 4.1 has been submitted to a sensitivity analysis for both variables frequency and price simultaneously. The resulting plot is an intrinsic relative surface that points the growth direction as well as the scale at which airports move. In Figure 22 essentially the surfaces corresponding to July 2010 and two years later are represented.

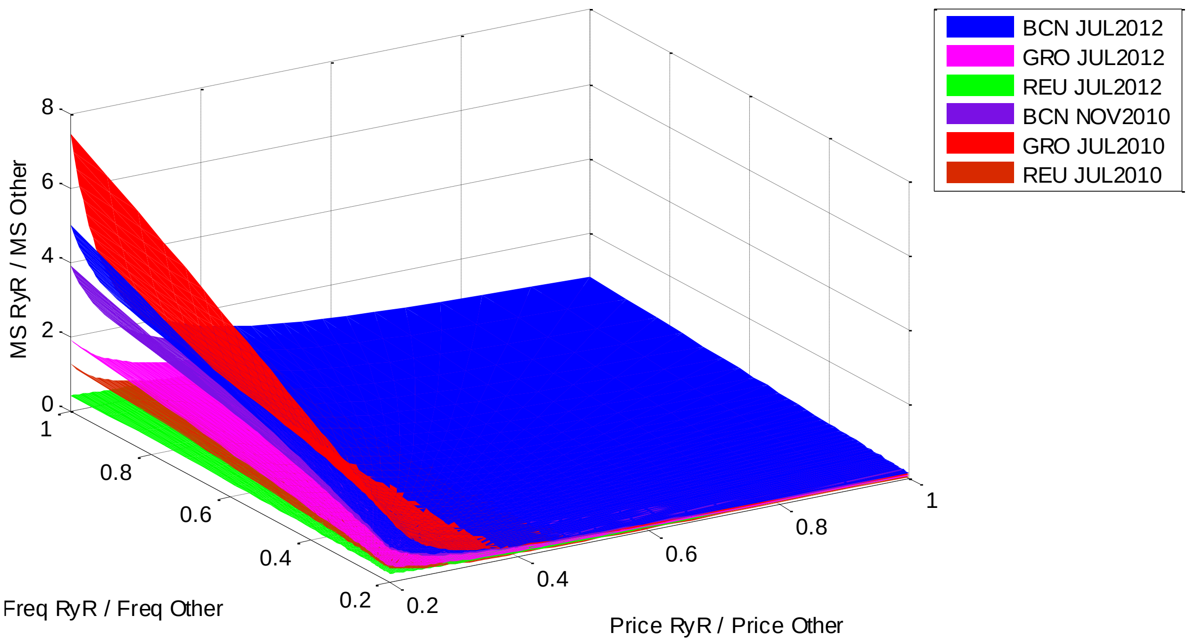

Figure 22 Ryanair MS vs Others MS depending on τ_F and τ_P

Its route configuration, frequencies offered and higher access costs contribute to leave Reus airport out of the league. Figure 20, Figure 21 and Figure 22 evidence that Reus market share tendencies have maintained through different periods. But this is not the case for BCN and GRO which in relative terms have gone together according to Figure 19.

The main assumptions in which circumstances could have led to these numbers can be listed below:

a) Demand generation.
b) Profitable routes operation. Decreasing offer at routes already served and promoting routes with a lower competition capturing higher market shares.
c) Other carriers to the effect of Ryanair might have been forced to reduce suppply.

In order to get an insight into the organization of Ryanair's operations in the region of study it is now useful to characterize whether passengers are carried in routes offered by more than one carrier/airport or only Ryanair.

The new route map scenario can be taken from Table 8 as choice sets have increased ever since in Barcelona El Prat. The indicator is the percentage of travelers carried out of the routes considered in the model, which means how exclusive the routes served at GRO, REU, BCN trend to be.

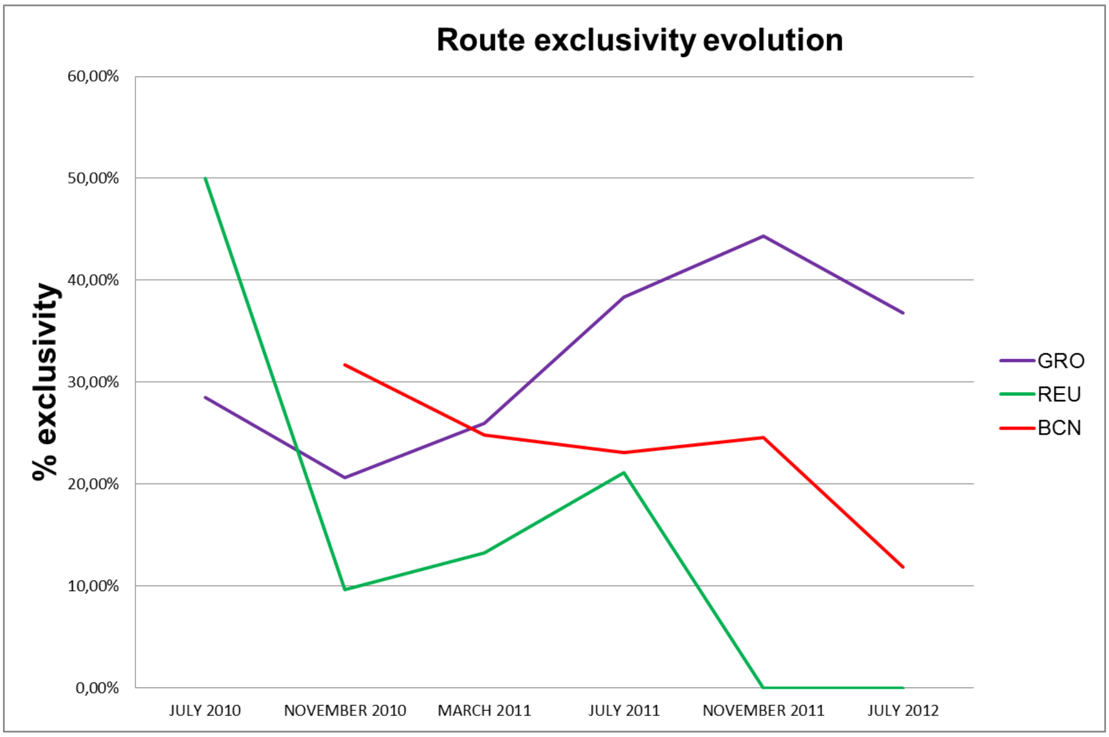

Figure 23 Ryanair's routes exclusivity trends

Ryanair entered BCN-El Prat Airport very aggressive starting its services in consolidated routes (68%) either in BCN or GRO. In fact it has kept apparently increasing mobilization of demand having by the end of the study almost the 90% of its passengers carried in shared routes.

The same has happened to Reus airport, while originally it was a seasonal charter orientated airport it remains to have seasonal services but routes are now also offered in any other airport in the region. On the other hand, Girona Airport having a greater competition pole, Barcelona, only at 100 km faraway has turned to focus on a parallel market keeping around 40% of the routes in exclusivity. Actually, Ryanair has lately developed to seek demand in Baltic Countries consistently moving domestic operations to BCN-El Prat. Route configuration in this airport system far from being a result of carrier's strategy in some cases is the corollary of the negotiation with the Catalan Government who aims to promote certain traffic through subsidiaries offered to the company. Therefore, in the present research the effects can only be evaluated from the point of view of the consequences , the cause may be intuited but always the question of whether a third party is involved or not.

4.4 MODEL VALIDATION

Taking now into a brief summary the situations and the states seen in previous sections the scope is to take a zoom out to strictly analyze the validation of the utility function in absolute figures. This constitutes the preceding step before projecting the system to future hypothetic scenarios. Then, at this point is to lay the dynamic out on the line to focus on possible upcoming events. In the graphics below are to find monthly Ryanair's passengers per airport for the carrier's, Ryanair's, non-exclusive routes. Beyond the merely statistical interpretation must be given place to a conceptual positioning of the traffic evolution. Besides, main events occurred at these airports as well as changes in route configuration must also be taken into consideration.

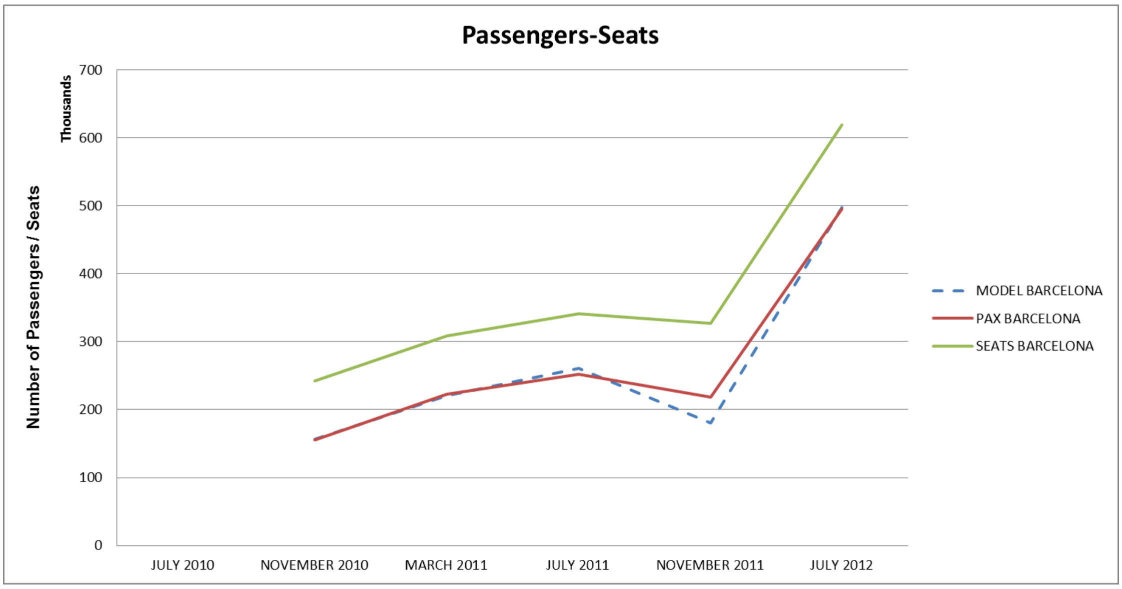

Figure 24 Ryanair BCN Airport Model Results Comparison

At first glance what mainly emerges in the model display in Figure 24 is that absolute numbers of passengers are well estimated with exception of November 2011. Also, as observed in the following Figure 25 passengers are slightly overestimated. Regardless of this anomaly the estimation performs predominantly smoothly along both seats and passengers (from database) lines. Modeled results departures from the trends might be attributed to outside goods or even price ratios variations in the absence of additional data. It should be emphasized that the model started from a very complex variable driven by highly heterogeneous behaviors with the avoidance of non-observed variables. Other examples of influencing factors in the individuals that in this study remain unobservable could be listed as:

- Airlines loyalty programs.
- Passenger's preferences.
- Quality perception of both airport access as well as the services offered by the airline: on time performance, flight time departure, availability, accessibility, comfort, etc.

However, through the assumptions made during the process it has been able to set a methodology reducing complexity to only 3 attributes. At the same time these explanatory variables have been simplified to the maximum. On the one hand by normalizing frequency and price and on the other hand with the assumption that access cost is only likened to the departure airport rather than also to traveler's journey origin.

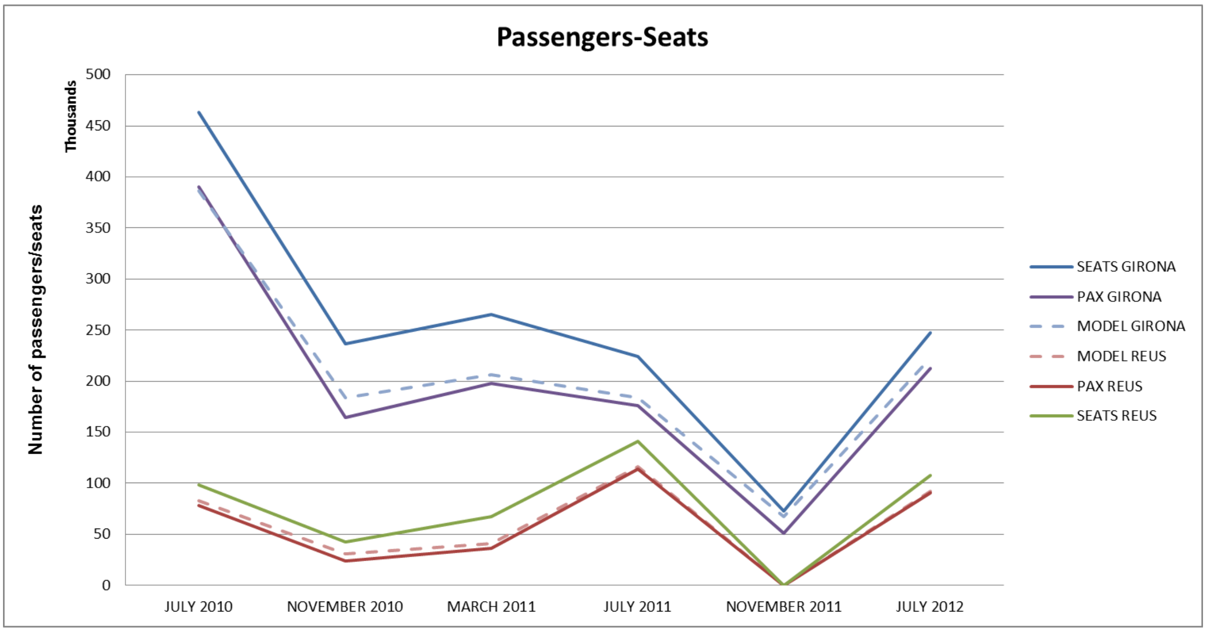

Figure 25 **GRO and REU Airport Model Results Comparison**

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5. MODELLING RESULTS

5.1 INTRODUCTION

Provided the tool designed in previous analysis chapters it is now time to figure out how disruptions to the stability of the system will affect to businesses (qualitatively) of both airlines and airports. The model which has been calibrated will be used as the base to predict what would have happened if different scenarios had taken place in the Catalan Airport system. To achieve this goal, these inputs will be applied to the last calibrated period namely the most recent: July 2012. The principal reason that led to this selection is that by this month Ryanair's route network has reached its plenitude in route configuration with a great presence in BCN-El Prat while keeping a moderate but adequate traffic at its regional niches, Reus and Girona.

Through this latter part of the research the sensibility of the demand will be tested and will allow establishing a new demand assignment by forcing hypothetical situations. The new synthetic market situations have been devised based on the interest that may arise from these combinations from the point of view of airport's management and airlines.

From the airport's perspective vulnerability affects regional airports which seek to have a sustainable number of passengers to ensure its subsistence. The answer to the question if Ryanair happens to undertake a strategy of concentrating routes at the main airport, which is now very reasonable, is quite clear: it will represent the dramatic closure of Girona and Reus because both are mostly depending on passengers Ryanair provides.
To this threat the airport operator can use its position to increase airport charges by establishing preferential rates to the airports in danger. Nevertheless this would imply an overturn of a decision enforced to take a couple of years ago.

Another concern that may come from this event is the loss of market share of competing companies established in BCN. The questions to this regard are related to the company's competitors. Linked to this fact competitors already in its own battle to beat prices by lowering cost would anticipate to this situation yet making an effort to approach Ryanair's prices while keeping with the added value offer (frequent flyer advantage programs, business traveler facilities, etc).

5.2 SCENARIO 1: PRICES

It is widely known Ryanair can operate at lower costs and thus is able to offer the most competitive prices. A commonly used measure of unit cost in the airline industry is CASK, cost per available seat kilometer. This number is expressed in Euro cents c€ to operate each seat each kilometer flown. CASK is obtained by dividing total expenses by available seats kilometer. This indicator is frequently used to compare costs across different carriers or for even the same carrier between different periods. Actually, this number is a well published number in the accounting results under the search for investors.

In the documents consulted corresponding to the relationship with investors of airlines the following can be found:

Table 15 Most recently publicated CASK

	Ryanair	Vueling	Easyjet	Iberia
Cost per ASK	3.2c€	6.00 c€	6.4c€	7.66 c€(2010)
Cost per ASK ex-fuel	1.9c€	4.07 c€	4.4c€	6.10 c€(2010)

As shown above Ryanair is able to operate at a cost per ASK less than a half that of any other carrier. Therefore ostensibly is to think that for Ryanair is easier to offer lower fares.
Another indicator is the yield (revenue) per revenue passenger kilometer (RPK). RPK stands for Revenue Passengers Kilometer and is obtained by multiplying the number of paying passengers by the kilometers flown (average passenger haul). Normally low costs allow having more net profit margin. However, in absolute terms is sometimes lower than other carriers that have higher costs and accordingly higher revenues. Yet this value based on an average can have significant variations when comparing various flights with different characteristics. For instance, on a flight to Berlin (1512km haul) reporting a 75% of load factor at an average price per journey of 80€ computed yield per RPK is 5.3c€ while the same for a flight to Rome (850 km haul) having passengers paid an average of 60€ then yield per RPK is 7.1c€.

In order to measure the cost structure of an airline the so called break-even load factor can be calculated. This type of LF defines the number of revenue units needed to recover costs. In the airline industry is expressed as:

$$LF_{B\text{-}E}\,(100\%) = 100 \cdot \frac{RRPK}{CASK} \tag{5.1}$$

By this, if the actual load factor is greater than the break even factor then the carrier is losing money to cover its costs. However, it must be noted that the real load factor considered slightly differs from its original meaning: Passengers carried divided by Seats offered; on top of that it also takes into account the part of no-show passengers and thus instead of the number of passengers carried is the number of paying passengers used.

Here are to find the examples also published from the carriers above:

Table 16 Revenue per RPK

	Ryanair	Vueling	Easyjet	Iberia
Revenue per RPK	3.7c€	8.28 c€	6.87c€	6.54 c€(2010)
Load factor break even	70%(86%)	72.5%	94.1%	117%

Despite the difference other carriers such as Vueling could after all achieve a reduction of costs. Note that there is only 2.5% differences from Ryanair to recoup double that of Vueling's costs. It is important to highlight that the Ryanair's break-even load factor does not correspond to the strictly cost / revenue quotient. This may be due to the subsidies received that can reduce the cost to 2.6 c€ almost a 20% off. As in AirScoop analysis is remarked: "Being paid from flying nowhere to nowhere "subsidies are a key to understand Ryanair's business model, in fact without this component the break-even would be higher than Vueling. AirScoop's report provides a close analysis of the strategy followed by the Irish airline and fixes its subsidies as a 20% of the total revenues.

For that, the possibility of a cost cut to take place that could translate into price reduction has been considered. This model works with two price types, one for Ryanair and one for Other Carriers. The ratio for July 2012 has been set as 0.55 through collected current data. By this time Ryanair operates already the 48.7 % of the routes included in the model while a 16% is attributed to Vueling.

Table 17 Average prices

July 2012	Vueling	Ryanair	Non-Ryanair
Average price	69.6€	49.5€	89.2€
Price ratio	0.71	1	0.55

The situation in matter of prices reveals that Ryanair offers prices close to the half of other carriers but only a 71% of Vueling prices since Ryanair's average has gone up from an average of 35 € lately due to fuel prices and other surcharges.

With this distribution in supply in the market if Vueling could decrease its prices to 1:1 with Ryanair the overall ratio would be τ_P=0.6. To model this possible variations the market share distribution on the total amount of passengers of Ryanair's routes has been plotted to the price ratios.

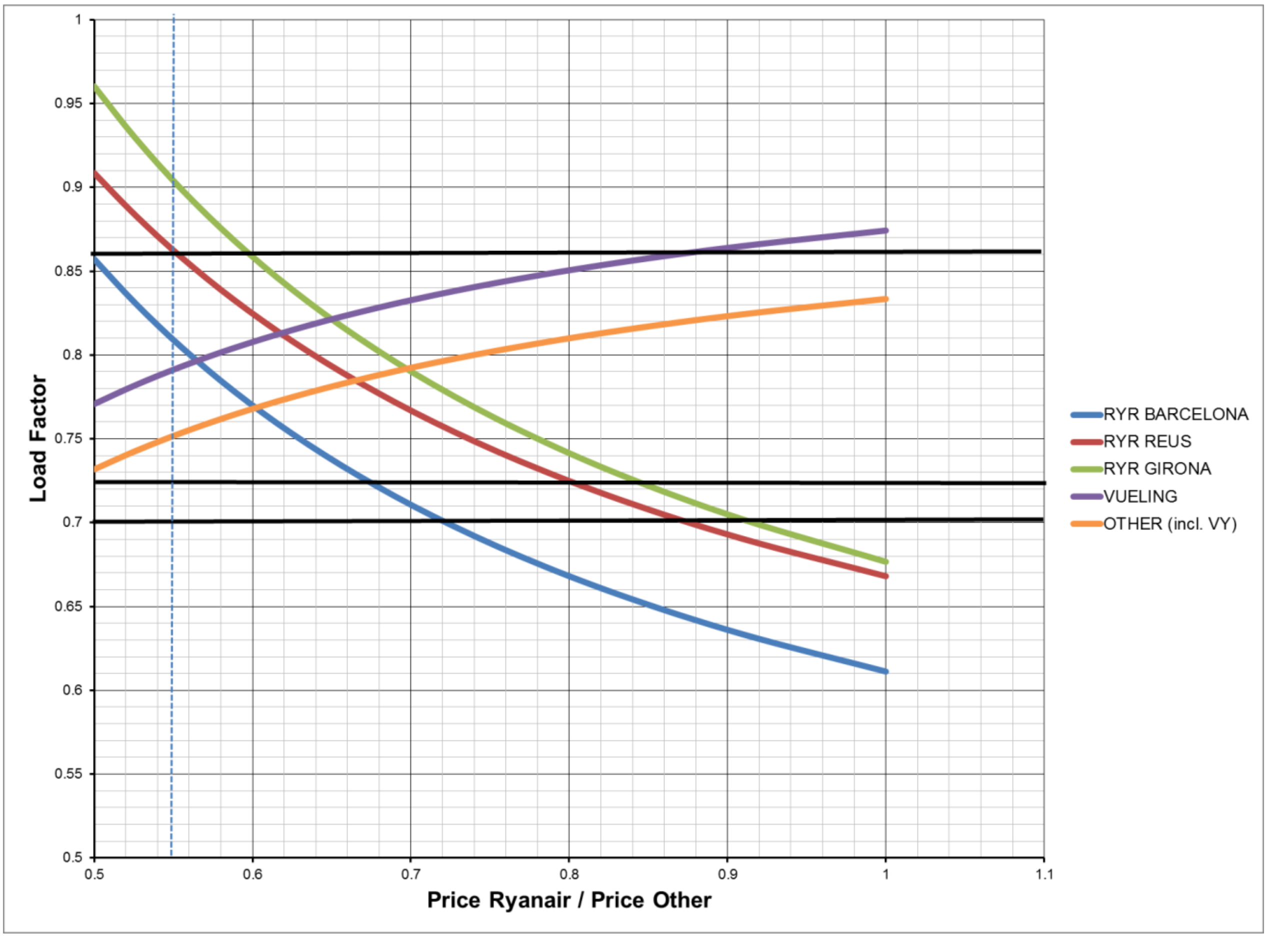

Figure 26 Load Factor for July 2012 price dependence. Scenario 1

In this figure Vueling's traffic is also shown as it is present in many of the routes studied.
It is observed that the rate of loss in the number of Ryanair passengers is greater than the growth rate experienced Vueling passengers with lower prices. Three horizontal lines which represent the operating thresholds, break-even factors, are also marked in the graphics: Ryanair's operational 86% LF while actually is 70% due to subsidies and the 72% stands for Vueling's breakeven.

Considering that Vueling could offer prices at an average price of 55€ , 20% cheaper, the price ratio would down to be 0.58 and the share for this situation would not be very different but from this ratio upwards Vueling Load Factor becomes higher than Ryanair's.

Moreover, as it is inferred from the graphic in Figure 26 Vueling may be attributed to certain perception of added value or service preferences as long as average price is only 1.11 times Ryanair's.

Table 18 Passenger variation for scenario 1

		ACTUAL PASSENGERS	PREDICTED AFTER VARIATION PASSENGERS	PRICE DECREASE	PASSENGER VARIATION
RYANAIR	BARCELONA	497,666	484,861	0%	-2.57%
	GIRONA	222,608	216,654	0%	-2.33%
	REUS	92,093	89,949	0%	-2.67%
	TOTAL	812,367	791,464	0%	-2.57%
OTHER	VUELING	799,626	808,449	-20.98%	1.10%
	TOTAL OTHER	1,843,157	1,864,065	0%	1.13%

By this analysis is evident that Ryanair is highly dependent on Government subsidies. In case of not being paid prices should be kept lower than the half of other carriers to have positive returns. But still, in keeping with this advantage price difference between its competitors is high enough.

5.3 SCENARIO 2: RYANAIR CONCENTRATION.

The second situation considered in order to be evaluated is the most criticized which is that Ryanair decided to concentrate all of its routes in BCN-El Prat Airport. If Ryanair would be predisposed to remove operations from Girona and Reus and simply reduce to the center of gravity which is Barcelona would indeed take airlines to struggle as to maintain demand and passengers.

Avoiding the always controversial discussion of allocating slots to low-cost carriers in BCN Airport the focus is to predict if this market supply widening would cause any effect on other carriers.

To reproduce this scenario provided that demand is kept constant all routes and frequencies originally offered in Reus and Girona during July 2012 are then represented in BCN. With this the frequency ratio is set to be now 0.6 (0.4 before) caused by the number of flights increase in routes originally served simultaneously.

Passenger numbers predicted by the model are:

Table 19 Predicted passengers for scenario 2

	RYANAIR BARCELONA	VUELING	OTHER (incl. Vueling)
% Seat variation	0%	0%	0%
Passengers (Model)	944,692	720,078	1,710,834
Load Factor	0.97	0.72	--
Earnings /Loses Passengers	132,325	-29,572	-132,323
% Variation	16.29%	-9.95%	-7.18%

To remark is that the traffic growth experienced is calculated together with Girona and Reus. This means that Ryanair's concentration process does not only capture passengers from regional airports but also from other carriers, but at a lesser extent from Vueling's.

This situation would put pressure to other carriers which would have to reorganize costs and revenues to capture more passengers. For sure any wrong movement can only worsen the situation; however the solution might lie among the following possibilities:

- Cut on operational costs.
- Offer lower prices.
- Enhancement of yield management.
- Raise prices to increase revenue.
- Reduce seat supply.
- Ryanair's way: ask for an especial treat and be paid to preserve traffic.

These options considered can most of them have bilateral effects. For example, it is true that offering flights at lower prices might capture more demand but at the time the revenue for those passengers would be consequently lower.
The same happens if prices are so high that revenue is higher but it is possible that demand decreases unless most of the portion of the most sensitive passengers to prices is already flying Ryanair. Besides, another tap is then the seats supply. With this is evidenced how this scenario would put up against the ropes other carriers and would take Network planners and Revenue analysts into a very interesting Game Theory Problem which is later developed in chapter 5.5.

5.4 SCENARIO 3. AIRPORT OPERATOR STRATEGIES.

Ryanair's strategy based on an intense negotiation process with Airports is a key factor of its cost structure. Ryanair has turned the tables completely converting expenses or costs into revenues.

On the other hand the airport operator which is in common in the region could play the role of a regulator in other to avoid situations such as the market concentration, the market segmentation or even airport closures. A total 20% advantgatge of the revenues cannot at all be considered as marginal and thus Ryanair despite greater distances would go for the airport that was cheaper because at the end the final destination would be on the passengers' pockets. But not content with this, the bargaining and marketing expands up to this last leg of the transportation chain with bus operators, car rentals and partnerships part of the ancillary revenue.

The increase of Airport taxes is not far from being a hypothetic reality since it has already been implemented an asymmetrical distribution of airport charges. Considering increments the new price differences have been obtained following the ratio basis:

Table 20 Taxes rise after June 2012

AIRPORT	SURCHARGE	RATIO(Ryanair)
RYR BARCELONA	+8.95€	0.92
RYR GIRONA	+0.42€	1.08
RYR REUS	+1.72€	1.05
OTHER BARCELONA	+8.95€	0.54

In the assumption that current charges are only affect prices which means that they are taken on by passengers favor regional airports Reus and Girona. The ratios in Table 20 have been used in the model from July 2012 to obtain passenger variations rates.

Table 21 Passenger variations due to changes in Airport taxes

		ACTUAL PASSENGERS	PASSENGERS AFTER	PRICE INCREASE	PASSENGER VARIATION
RYANAIR	BARCELONA	497,666	482,388	18.11%	-3.07%
	GIRONA	222,608	230,669	0.85%	3.62%
	REUS	92,093	94,027	3.48%	2.10%
	TOTAL	812,367	807,084	9.09%	-0.65%
OTHER	VUELING	799,626	804,502	12.82%	0.61%
	TOTAL OTHER (incl Vueling)	1,843,157	1,848,442	9.72%	0.29%

The results from new circumstances modeled end up to some observations. Due to the increment in prices it was expected that Ryanair would lose passengers in BCN. However, the results indicate that not all of these passengers would select as an alternative to fly via Girona or Reus with Ryanair as well.

Actually, some of the travelers would be willing to travel from Barcelona with other carriers such as Vueling which offer more expensive flights. Despite growth in Girona and Reus total Ryanair's; a part of Ryanair's total share happens to be captured by other existent carriers in BCN.

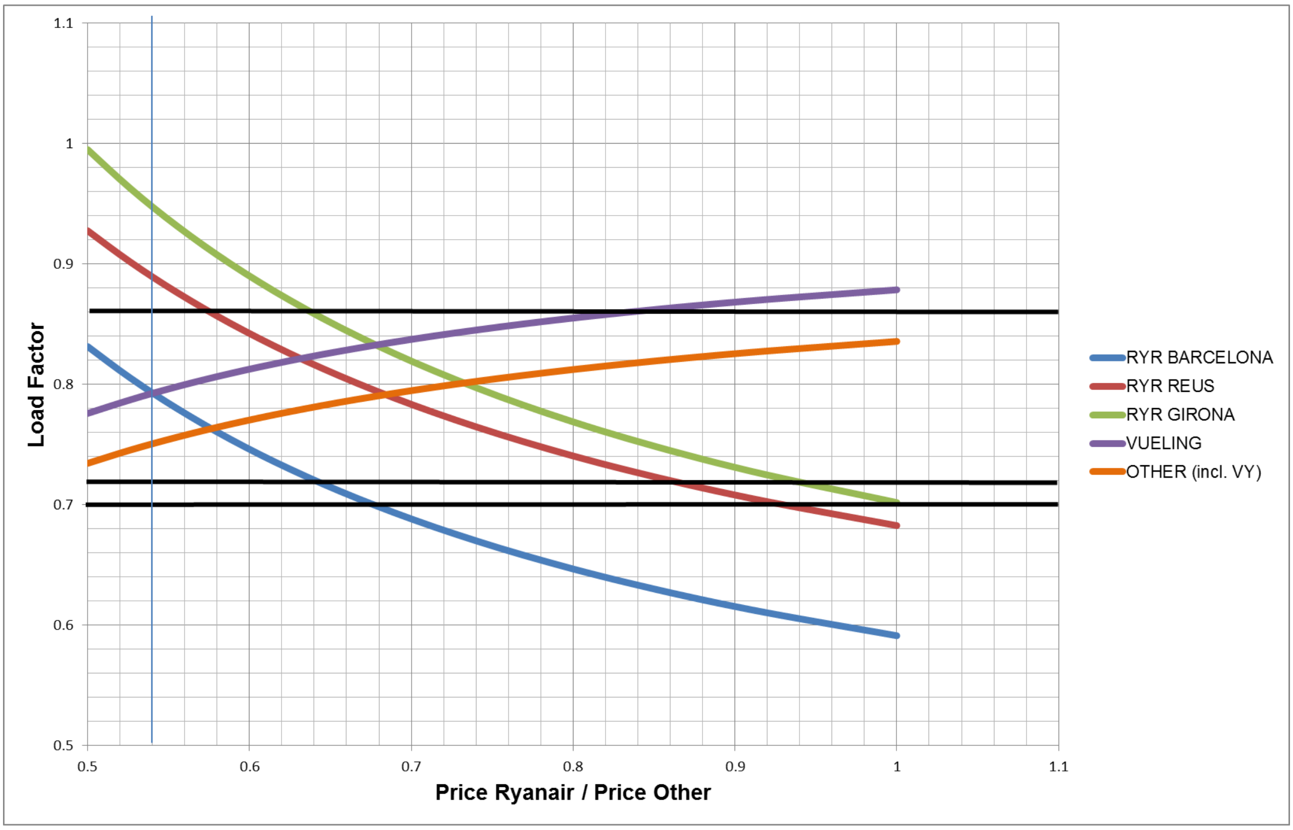

Figure 27 Load Factor for July 2012 price dependence. Scenario 3

Causes for this behavior might lie in the fact the price increase is in relative terms lower than Ryanair's as shown in Table 21; 18 % for Ryanair and 12% for Vueling. In Figure 27 plot is represented that in the enforced conditions Ryanair would have to keep prices below that of other carriers in the absence of subsidies.

In case it was decided to remove back aids that Ryanair receives only in Barcelona to prevent its expansion at the major airport the pattern or trend observed before emerges even more clearly. Other carriers, particularly Vueling would benefit from rising prices in BCN while in Girona and Reus stay the same.

Table 22 Passengers after Ryanair loses airport subsidies in Barcelona.

		ACTUAL PASSENGERS	PASSENGERS WITHOUT AID	PASSENGER VARIATION
RYANAIR	BARCELONA	497,666	450,334	-9.51%
	GIRONA	222,608	230,027	3.33%
	REUS	92,093	93,273	1.28%
	TOTAL	812,367	773,634	-4.77%
OTHER	VUELING	799,626	821,245	2.70%
	TOTAL OTHER (incl. Vueling)	1,843,157	1,881,886	2.10%

To this situation of share loss that Ryanair would experience in BCN-El Prat it would probably move operations again back to the regional airports as long it was more cost advantageous due to lower airport charges. If this happens, then is to find out what would be the trend in passengers in accordance with this framework: whether they keep traveling from Barcelona or from Girona or Reus.

If the airport operator should distribute subsidies among for example all low-cost carriers in Barcelona preserving the advantages in Girona and Reus the results obtained are:

Table 23 Effects on an equitable distribution of subsidies in BCN.

		ACTUAL PASSENGERS	PASSENGERS AFTER	PASSENGER VARIATION
RYANAIR	BARCELONA	497,666	450,582	-9.46%
	GIRONA	222,608	224,417	0.81%
	REUS	92,093	91,174	-1.00%
	TOTAL	812,367	766,173	-5.69%
OTHER	VUELING	799,626	823,288	2.96%
	TOTAL OTHER (incl. Vueling)	1,843,157	1,889,348	2.51%

The amount of discount has been set in 4€ per passenger per single flight and it has been applied to all low-cost carriers in BCN. A remark on this measure according to these results is that Ryanair experiences a greater loss of passengers. Some passengers who had previously traveled from Girona or Reus (Table 23) they now choose other airlines from Barcelona. This can be seen in a more moderate growth in Girona and Reus loss of share.

5.5 SCENARIO 4: AIRPORT CLOSURE

In connection to prior sections the multinomial problem can be summarized in analyzing how would it be possible to experience a traffic decrease that became clearly unsustainable for Ryanair in Girona or Reus. For this reason, Ryanair would abandon Girona or Reus Airports. Thereby, the airport would have to close as its passengers mostly are provided from this carrier. The situation of study accounts on route configuration features: price, frequency and access costs. A study carried out by Deutsche Bank quoted in Airscoop (2001) estimates the breakeven number of passengers (yearly) for an airport to be profitable is between 0.5 and 2 million passengers.

This scenario will be projected in the near future rather than focus on a seasonal level.
The objective of this last step of the model is to find the moment or the circumstances that may cause that Girona could remain with a non-profitable number of passengers. While dealing with annual traffic the implicit seasonality of passengers is laminated.

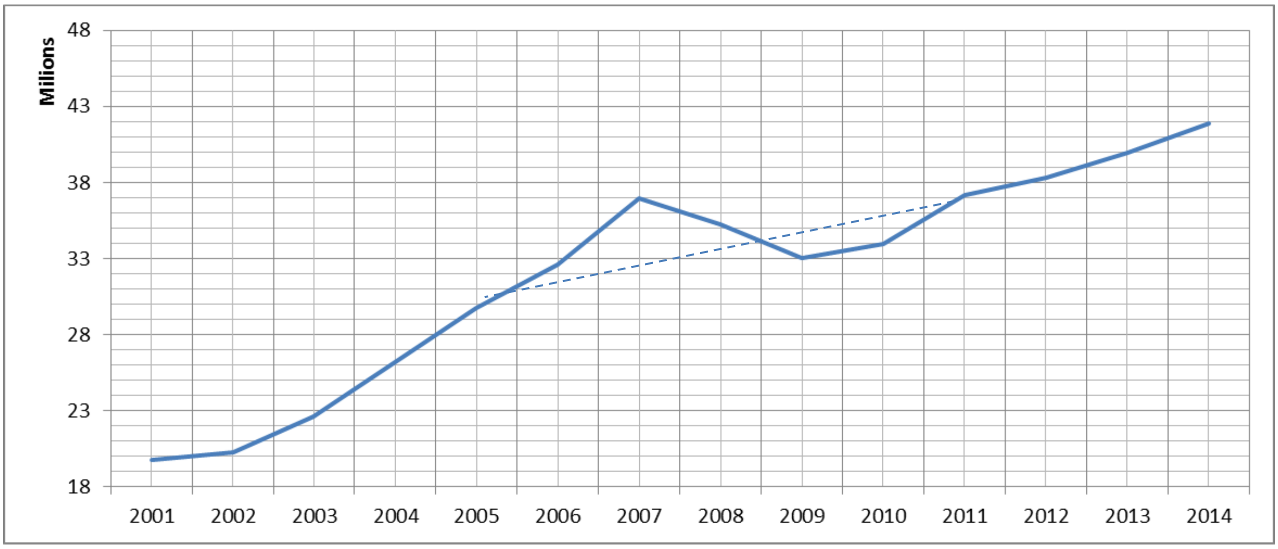

Figure 28 Air travel demand

Traffic evolution in the Catalan region is presented in Figure 28 from 2001 providing a mid-term forecast. The projection is made based on ICAO reports on traffic growth which state an average percentage growth around 4.6% until 2014. It also can be seen that traffic growth rate would draw approximately linear if not for the events between 2007 and 2010 corresponding to the economic boom and subsequent economic recession.

Aforementioned seasonality is now worth being analyzed because it follows similar patterns across every period. To prove this statement, as a matter of fact, the contribution of monthly passengers with respect to the annual traffic is represented in Figure 29.

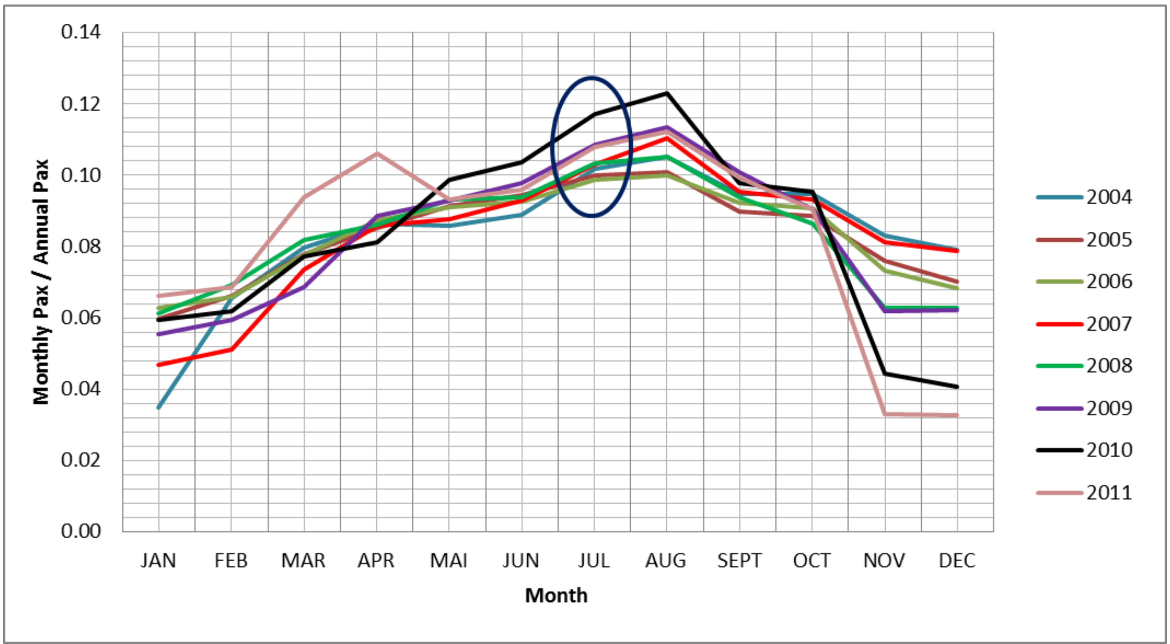

Figure 29 **Contribution of monthly passengers to total traffic in Girona**

As seen, ratios stay similar with some exceptions. This is because in 2010 and 2011 airport's seasonality is more pronounced which means that passengers as well as supply of seats in off-peak period is well lower in comparison with other periods. In Figure 29 the circle highlights the month of July in which traffic usually represents to be between 10 and 12 % of annual passengers. Since it is the period that has less variability among ones calibrated and available in the model is used to estimate traffic figures in Girona. In order to begin with, a validation is carried out by applying the prior principle to a known year for example 2010 or 2011. Although the model is based on non-exclusive routes the total number obtained could represent a lower bound.

Table 24 Performance appraisal of passenger estimation

Period	Ratio	Monthly Passengers	Annual Passengers	Corrected Exclusivity Passengers	Actual annual Passengers
JULY 2010	0.117	386,246	3,301,248	4,522,258	4,694,982
JULY 2011	0.108	183,847	1,702,287	2,745,624	2,859,629
JULY 2012	0.10-0.12	222,608	1,855,067	2,935,232	?

In July 2010 the model predicts 386,246 passengers and correspondingly 3,218,717 passengers during the whole year while the actual number of passengers was 4,694,982.

Offsets derived from the configuration of exclusivity allow shuffling different possibilities considering the trends from Figure 23.
Referred to the contribution of July to the rest of the passengers as well as the exclusivity a range of percentages is taken into account. This means that different possibilities are calculated.

With regard to the seasonality trends it refers to the passenger profile of the airport and it is applied as the part of passengers that traveled within the peak months. For its part, exclusivities ensure given a potential demand to operate flights at an acceptable load factor because of the absence of competitive alternatives. The already studied situation for July 2012 is summarized in:

Table 25 Annual passengers for year 2012 in GRO

		% Annual Passengers				
		10	11	12	13	14
Non- % Exclusivity	40	5,565,200	5,059,273	4,637,667	4,280,923	3,975,143
	50	4,452,160	4,047,418	3,710,133	3,424,738	3,180,114
	60	3,710,133	**3,372,848**	**3,091,778**	2,853,949	2,650,095
	70	3,180,114	**2,891,013**	**2,650,095**	2,446,242	2,271,510
	80	2,782,600	2,529,636	2,318,833	2,140,462	1,987,571
	90	2,473,422	2,248,566	2,061,185	1,902,632	1,766,730

It seems that during 2012 the interval of the total number of passengers will be comprised between 2.6 and 3.4 million passengers. This range of results can be expected since the committed number of passengers with the Government is of 3 million in Girona.
Yet having proven the sustainability of Girona airport during 2012 with a slight growth compared to year 2011 the turn is for the year 2013.
Supposing a slight growth of traffic applied to the model calibrated in July 2012 distributed uniformly enables to estimate the future passengers. Along with this an assumption of a possible action that could take place has been made. The selection of alternatives considered consists of several routes that although they compete with routes in Barcelona they are served from Reus and Girona :

- Bologna
- Birmingham
- Bristol
- Cologne
- Cork
- Eindhoven
- Frankfurt
- Gdansk
- Madrid
- Malta
- Manchester
- Newcastle
- Pisa
- Viena

With this, it emerges the possibility that Ryanair should keep some routes at regional airports because of incentives while those routes mentioned above could be transferred to BCN as to be more competitive.

Table 26 Annual passengers for year 2013 in GRO

		- --------------------------------Seasonality --------------------------------→+				
		% Annual Passengers				
		10	11	12	13	14
% Non-Exclusivity	40	3,154,825	2,868,023	2,629,021	2,426,788	2,253,446
	50	2,523,860	**2,294,418**	2,103,217	1,941,431	1,802,757
	60	2,103,217	**1,912,015**	1,752,681	1,617,859	1,502,298
	70	1,802,757	1,638,870	1,502,298	1,386,736	1,287,684
	80	1,577,413	1,434,011	1,314,510	1,213,394	1,126,723
	90	1,402,144	1,274,677	1,168,454	1,078,573	1,001,532

In case this happened in light of these results in Table 26 it is quite clear that exclusivity and asymmetric distribution of passengers would be greater. For this reason the range of bound values for the foreseen traffic are between **1.9** and **2.3** million passengers. These findings are certainly alarming in the way that since 2004 the number of passengers carried from Girona has been above 2 million. If the same is done for 2014 projecting a 4.8 % of traffic growth the results are:

Table 27 Annual passengers for year 2014 in GRO

		- ------------------------------------Seasonality -------------------------------→+				
		% Annual Passengers				
		10	11	12	13	14
% Non-exclusivity	40	3,299,800	2,999,818	2,749,833	2,538,308	2,357,000
	50	2,639,840	**2,399,855**	2,199,867	2,030,646	1,885,600
	60	2,199,867	**1,999,879**	1,833,222	1,692,205	1,571,333
	70	1,885,600	1,714,182	1,571,333	1,450,462	1,346,857
	80	1,649,900	1,499,909	1,374,917	1,269,154	1,178,500
	90	1,466,578	1,333,253	1,222,148	1,128,137	1,047,556

In 2014 although traffic grows due to the overall increment of demand in the same conditions as in 2013 in terms of route configuration the number of passengers remains very moderate between **1.9** and **2.4** million. Additionally other tools can be used for the problem considered for example price and frequency to play the most unfavorable conjecture which is done in the next section.

Apparently how an airport would carry less than 500,000 is to figure out: let it estimate that Ryanair bases in Girona 2 aircrafts that in average can operate 4 flights per day each. Having daily frequencies so not to have resources grounded already 450,000 passengers during a year are carried. Whatsoever would take Ryanair to the decision whether to base an aircraft in Girona, Reus or Barcelona would be where with the same number of enplanements it could capture more share and the most important: more revenue.

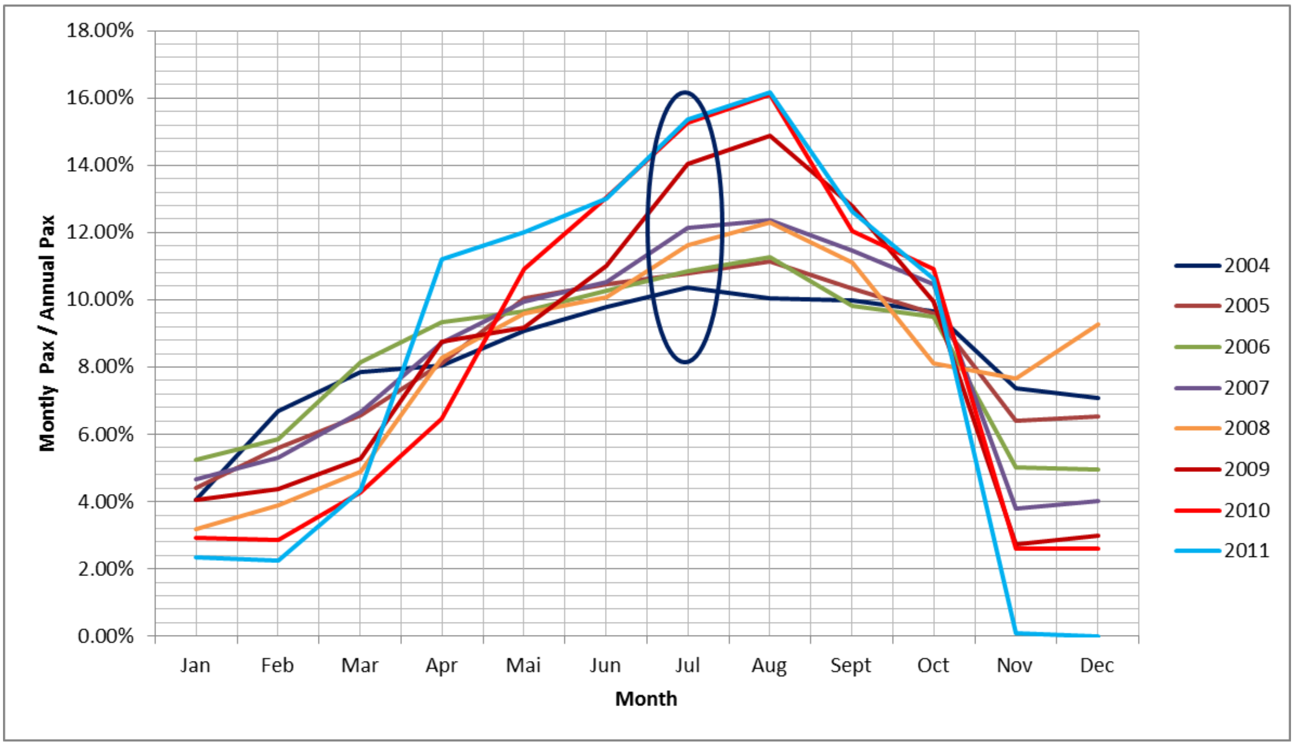

Figure 30 Contribution of monthly passengers to total traffic in Reus.

In the same order reasoning Reus airport is led to desertion. Far from being a new situation already by the end of 2011 traffic practically disappeared. A seasonal service character has mostly prevailed in Reus as it can be seen in Figure 30. This role seems to have aggravated in the recent 2011, 2010 and even back in 2009. On the contrary the routes are less exclusive taken from Figure 23. Modeled results are found in the tables below:

Table 28 Annual passengers for year 2012 in REU

		- --------------------------------Seasonality --------------------------------→+					
		% Annual Passengers					
		11	12	13	14	15	16
% Non-Exclusivity	50	1,674,418	1,534,883	1,416,815	1,315,614	1,227,907	1,151,163
	60	1,395,348	1,279,069	1,180,679	1,096,345	1,023,256	959,302
	70	1,196,013	1,096,345	1,012,011	939,724	877,076	822,259
	80	1,046,511	959,302	885,510	822,259	767,442	719,477
	90	930,232	852,713	787,120	730,897	**682,170**	**639,535**
	100	837,209	767,442	708,408	657,807	**613,953**	**575,581**

With the same argument traffic in 2012 stands between **0.5** and **0.7** million passengers in Reus like back to 2006. Once some of the routes are operated in Barcelona yet in 2013 then passenger's numbers drop to below 500,000.

Table 29 Annual passengers for year 2013 in REU

		- ---Seasonality --------------------------------→+					
		% Annual Passengers					
		11	12	13	14	15	16
% Non-Exclusivity	50	1,075,000	985,417	909,615	844,643	788,333	739,063
	60	895,833	821,181	758,013	703,869	656,944	615,885
	70	767,857	703,869	649,725	603,316	563,095	527,902
	80	671,875	615,885	568,510	527,902	492,708	461,914
	90	597,222	547,454	505,342	**469,246**	**437,963**	**410,590**
	100	537,500	492,708	454,808	**422,321**	**394,167**	**369,531**

Still after traffic grows in 2014, the total number of passengers remains under 500,000.

Table 30 Annual passengers for year 2014 in REU

		- --------------------------------Seasonality --------------------------------→+					
		% Annual Passengers					
		11	12	13	14	15	16
% Non-Exclusivity	50	1,124,418	1,030,717	951,431	883,471	824,573	773,038
	60	937,015	858,931	792,859	736,226	687,144	644,198
	70	803,156	736,226	679,593	631,051	588,981	552,170
	80	702,761	644,198	594,644	552,170	515,358	483,148
	90	624,677	572,620	528,573	**490,817**	**458,096**	**429,465**
	100	562,209	515,358	475,715	**441,736**	**412,287**	**386,519**

Finally, conservatively setting the most likely described conditions in seasonality and in exclusivity depending on prices and on frequency will also serve to predict annual passengers.

Table 31 Fixed useful forecasting seasonality and exclusivity factors

JULY 2012 (current)	% annual passengers	% non-exclusivity
Girona	0.11	0.60
Reus	0.15	0.90

5.6 OVERVIEW: AN APPLICATION OF GAME THEORY

Notwithstanding actions designed in the model prediction framework represent critical affairs, some of them become interdependent in the way that after an action a reaction must be expected. The latter constitutes one of the statements of the science of strategic thinking which is called game theory. Game theory is based on a set of players each of whom has its strategy set in order to maximize an objective (payoff) function whose final value not only depends on its own actions but each of the players' actions involved in the game. While crafting prior scenarios into a game, players defined are the airport operator and airlines considering Ryanair individually and Vueling and others on the other hand. Additionally a player from outside the model which comes from non-observable goods such as public opinion is considered. This player cannot be understood through its actions because they are difficult to formulate but reactions from affected players may represent consequences to the causes.

Regarding the so called payoff function as mentioned in Hansen (1989), whereas players in the model may have multiple objectives here only profit-maximization is assumed to be sought for both carriers and airports. This is directly related to the number of passengers flown and set feet on airports .Besides, it must be taken into account at what fare as well as spending per passenger at the airport.

With all of these situations, scenarios 1, 2, 3 and 4 represent only one part of the decision sequence shown in Figure 31 where different points of decision corresponding to each of the players are collected and developed progressively. The context now is not simple because the game can start with any of the players in turns (sequential game) like chess and checkers or alternatively several at once simultaneously when for example every carrier has to take action to compensate rising fuel prices or taxes. Ideally to deal with the map of decisions between the players which seek profit-maximization several assumptions must be done to craft a simplification of reality.

Due to the assumption of constant demand the game functions as a zero-sum game. In zero sum-games players can neither increase nor decrease the available resources, in this case total number of passenger carried during a certain period of time. In terms of passengers, one player may win exactly the passengers lost by another carrier but not necessarily benefits if revenue per passenger is lower. A strategic market orientation combined with an efficient cost structure can provide higher returns rather than an aggressive low-cost pricing strategy. As seen in Figure 31 the number of games can lead to an intractable dimension of the problem, however because of an important information limitation only some decision sequences are planned.

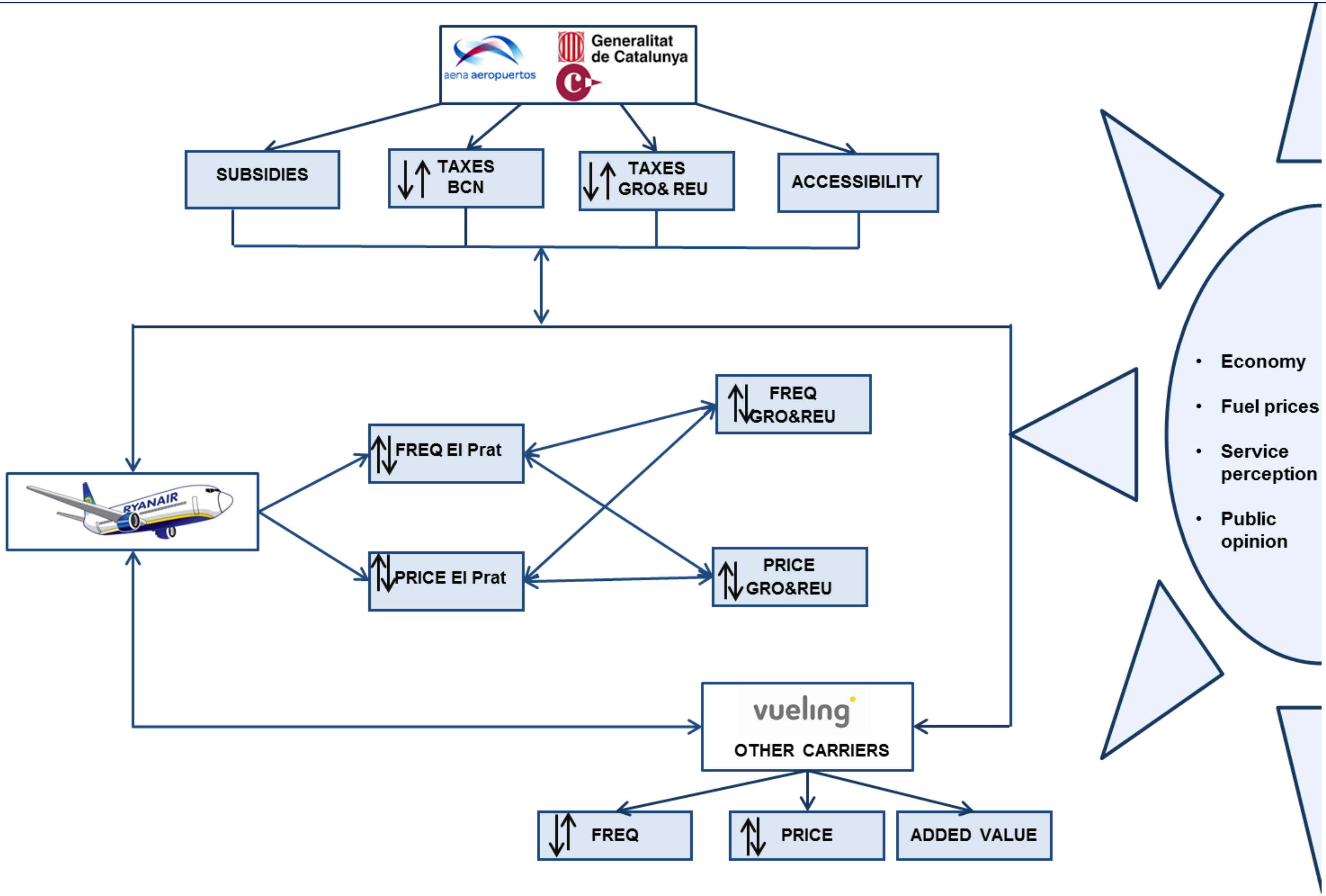

Figure 31 Game theory decision tree

Games are planned according to events considered in prior sections but combined with other players' actions.

The first event in which it is referred is scenario 1. In this context Vueling is predicted to pursue a price reduction strategy expecting that the increase in passengers will trade off the tightening of margin per passenger. In the face of revenue maximization it can be remarked that with every other factor constant to maintain original profit levels the number of passengers must inversely increase the price reduction ratio. Although price variations may not incur in the same way, to can give an order of magnitude is useful to consider it . For example, if a 5% of the fare is discounted a 5.26% of traffic increase would be needed to recover costs and maintain the same results.

$$\frac{Pax_{\ new}}{Pax_0} = \frac{1}{\frac{Price_{new}}{Price_0}} \tag{5.2}$$

Nonetheless, it is clear that an airline would not take only this type of action to maximize its profit unless along with a cost reduction or a frequency and service enhancement. Also, in order to anticipate other carrier's reactions this combination of movements could lead to the success in this game. *Look forward but argue backwards* (Dixit and Nalebuff,1993) is rule 1 for strategic thinking.

Table 32 Game 1 sequence for July 2012. Part 1

		Origin	↓ Vueling price		↑ Ryanair frequency	
		Passengers $_0$	Passengers $_1$	Δ_1	Passengers $_2$	Δ_2
RYANAIR	BARCELONA	497,666	484,861	-2.57%	672,786	38.76%
	GIRONA	222,608	216,654	-2.33%	124,513	-42.53%
	REUS	92,093	89,949	-2.67%	60,297	-32.97%
	TOTAL	812,367	791,464	-2.57%	857,596	8.36%
OTHER	VUELING	799,626	808,449	1.10%	780,594	-3.45%
	TOTAL OTHER (incl. Vueling)	1,843,157	1,864,065	1.13%	1,797,931	-3.55%

In this case price decrease has been followed by a strengthening of Ryanair in BCN through a route expansion. Routes subject to be transferred are those considered in 5.5, those based in Girona or Reus which compete with other carriers in BCN. The results after all show that if this reaction of Ryanair might be expected then plainly Vueling should not take the initiative to cheapen prices.

However, if the airport operator reckons that having such a concentration in El Prat represents an abandonment of regional airports and then decides to raise airport charges as stated above in Table 20 or even remove any type of aid given to Ryanair in El Prat then:

Table 33 Game 1 sequence for July 2012. Part 2

		↑ Airport charges (BCN)		Elimination of subsidies in BCN		
		Passengers $_3$	Δ_3	Passengers $_4$	Δ_4	$\Delta_{(origin)}$
RYANAIR	BARCELONA	649,849	-3.41%	600,811	-7.55%	23.91%
	GIRONA	132,988	6.81%	130,562	-1.82%	-39.74%
	REUS	59,155	-1.89%	58,864	-0.49%	-34.56%
	TOTAL	841,992	-1.82%	790,237	-6.15%	-0.16%
OTHER	VUELING	788,432	1.00%	811,526	2.93%	0.38%
	TOTAL OTHER (incl.Vueling)	1,813,533	0.87%	1,865,288	2.85%	0.07%

This can be an example of what a strategic market orientation combined with an efficient cost structure can provide higher returns rather than an aggressive low-cost pricing strategy.

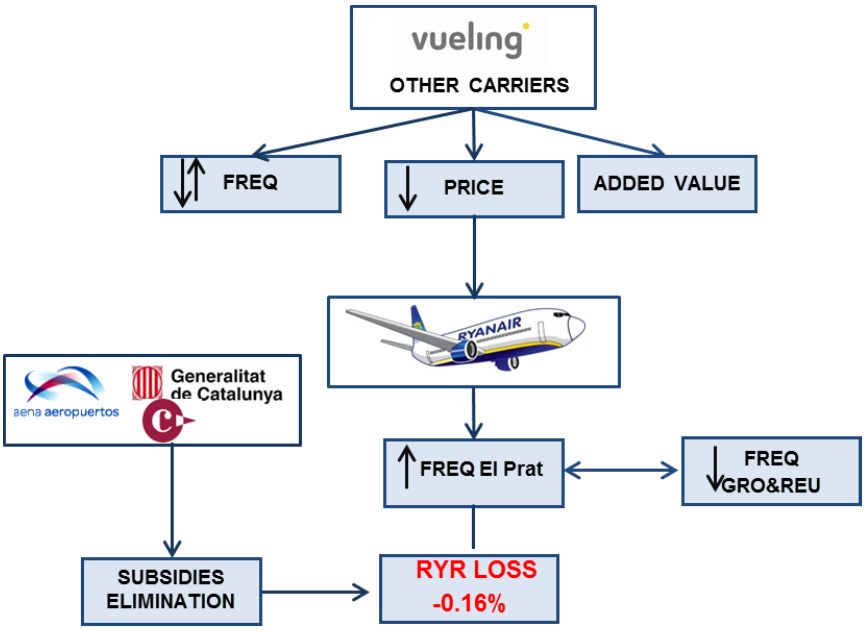

Figure 32 Game 1 Results Scheme

Under this situation according to Table 31 yearly passengers in GRO would have been 2 million while 0.4 in REU.

If now starting with a tax growth coming from the airport operator Ryanair decides to *push back* and focus again on Girona and Reus. There, due to reduced taxes prices can be lower and the question addresses to what is going to happen in the market in these new conditions.

Table 34 Game 2 Sequence for July 2012. Part 1

		Origin	↑ Airport charges (BCN)		↑ Ryanair Reus&Gro	
		Passengers $_0$	Passengers $_1$	Δ_1	Passengers $_2$	Δ_2
RYANAIR	BARCELONA	497,666	482,388	-3.,07%	0	-100.00%
	GIRONA	222,608	230,669	3.62%	514,244	122.94%
	REUS	92,093	94,027	2.10%	114,384	21.65%
	TOTAL	812,367	807,084	-0.65%	628,628	-22.11%
OTHER	VUELING	799,626	804,502	0.61%	887,731	10.35%
	TOTAL OTHER (incl. Vueling)	1,843,157	1,848,442	0.29%	2,026,894	9.65%

But as long as operating from secondary airports has lower costs due to reduced taxes and subsidies; should Ryanair lower airfares a 25% it can be seen that it manages to recover part of the losses.

Table 35 Game 2 Sequence for July 2012. Part 2

		↓ Ryanair Fares		
		Passengers $_1$	Δ_1	Δ_{ORIGIN}
RYANAIR	BARCELONA	0	0.00%	-100.00%
	GIRONA	634,680	23.42%	185.11%
	REUS	136,798	19.60%	48.54%
	TOTAL	771,478	22.72%	-5.03%
OTHER	VUELING	828,525	-6.67%	3.61%
	TOTAL OTHER (incl. Vueling)	1,884,051	-7. 05%	2.22%

In this game the demand is relatively responsive to price changes which give rise to more passengers in Girona and Reus. The form of the tendency surface allows identifying possible strategies to counteract Ryanair's market share.

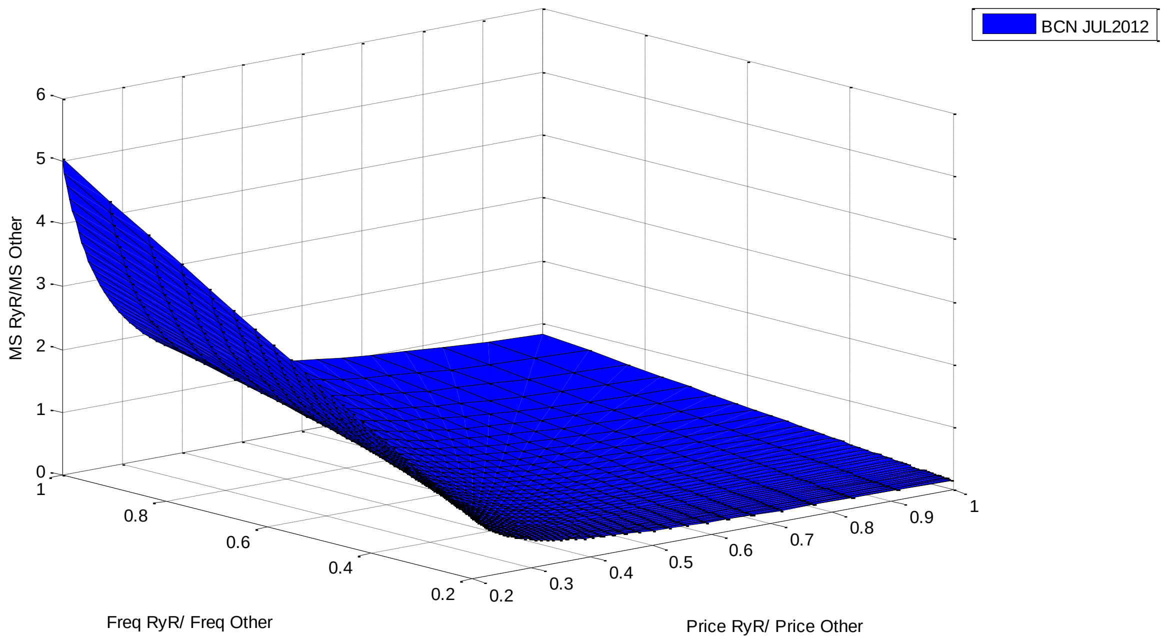

Figure 33 **Ryanair MS vs Others MS depending on τ_F and τ_P in BCN July 2012**

Price strategies become advantageous since other carriers offer minimum 1.6 that of Ryanair's fares because, as shown, the surface is approximately flat and constant below this value (τ_P=0.6) therefore changes in price do not correspond to the same increase in passengers. Meanwhile frequency influences more uniformly to the share at the point that operating at half of the price and at a similar frequency passenger carried in Ryanair's routes exceed those of any other.

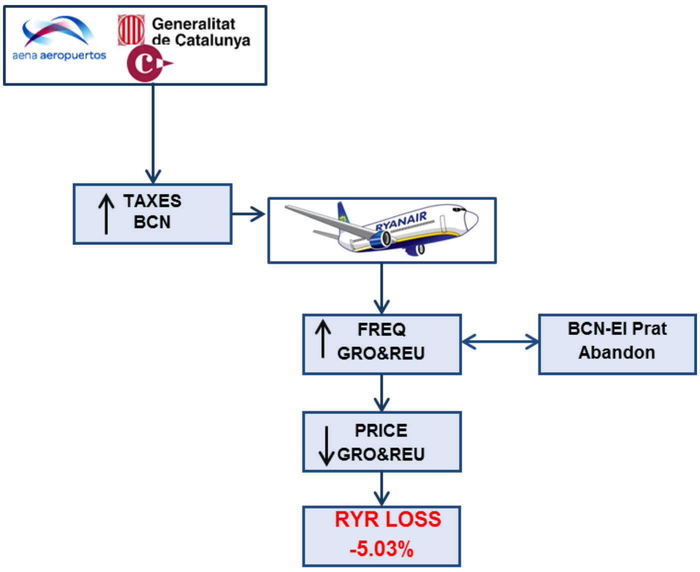

Figure 34 **Game 2 Results scheme**

Another game is set with the opening of other carriers' new routes or increased frequencies for example, in the event of Vueling of expanding its network with the following destinations: London, Dublin, Pisa and Marrakech.

Table 36 Game 3. Sequence for July 2012

		Origin	↑ Vueling expansion		↓ Price Ryanair		
		Passengers $_0$	Passengers $_1$	Δ_1	Passengers $_2$	Δ_2	Δ_{ORIGIN}
RYANAIR	BARCELONA	497,666	482,629	-3.02%	548,561	13.66%	10.23%
	GIRONA	222,608	213,932	-3.90%	244,842	14.45%	9.99%
	REUS	92,093	85,422	-7.24%	96,152	12.56%	4.41%
	TOTAL	812,367	781,983	-3.74%	781,983	13.76%	9.50%
OTHER	VUELING	799,626	873,385	9.22%	822,930	-5.78%	2.91%
	TOTAL OTHER (incl Vueling)	1,843,157	1,873,540	1.65%	1,765,973	-5.74%	-4.19%

Significantly Vueling would boost passengers with this action capturing Ryanair's losses maintaining a 79% of Load Factor. However after Ryanair's fares fall, the corresponding quantity demanded rises which moderates Vueling expansion.

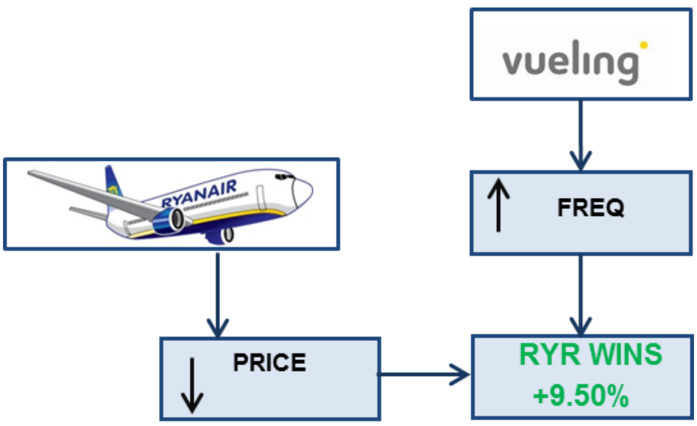

Figure 35 Game 3 Results scheme

As to conclude at some point the strategies combination, is evident that multiple initiatives can be taken by the involved parties. Each of which destabilizes the balance in favor of the interests of one or other. At any rate though, it is clear that the calibrated utility function along with single-player and sequential scenarios satisfies the analytical purposes of this research.

6. CONCLUSIONS AND DISCUSSION

6.1 SUMMARY

A model of a multi-airport competition market dominated by Low-cost carrier services or, by Low-cost strategies has been formulated, adjusted and applied to a set of routes previously selected. Even prior to designing the model, certain links between passenger's figures and some market inputs could be intuited from the demand evolution curve. It seems reasonably clear that traffic patterns have changed in the recent years.

The formulated model of demand is based on utility functions derived from expressions representing generalized cost. It deals with aggregated monthly data while normally this type of formulation is applied to individual decisions known as discrete choice models. The limited data available and the willingness to simplify the problem in order to obtain a macroscopic view of the system have led to this development. To the same, variables considered include only fare, frequency and access cost to the airports which aim to explain demand assignment at a route (origin airport- destination city) – carrier level. The proposed model's constraints beyond the lack of booking passenger data are that neither does it consider demand generation nor the possibility that travelers would choose other destination cities or even not to travel. Average prices have been collected at the beginning of the period of study as well as at the end: July 2010 and July 2012. Observed values reveal that price ratios between Ryanair's and other carriers decreased apparently due to efforts made by other carriers whereas Ryanair's average prices climbed. The same happens with frequencies at least in BCN where average monthly frequency is 67.8 per route in July 2012 after an average of 58 in July 2010. Remaining attributes considered are related to airports in the form of access costs inferred using a gravity model to establish a method to quantify the access mode choice. However, actual airport mode choice distribution data is not available to balance and check amounts obtained.

Once the adjustment is made by the OLS method the model is able to correlate passenger demand with both airlines' and airports' services variables. As shown in the results, elasticities of each of the attributes correspond to the expected plus/minus sign: negative correlation with price and access cost while positive with frequency. In addition, values stay generally similar across the periods studied.

Exceptions can be cited, at first July 2010 when there is the greatest sensitivity to price (-0.79) due to the fact that Girona did capture a significant passenger share which has been attributed to willingness to pay despite higher access costs and less. The second case is November 2011 which is not worth taking into account because by that time seat supply in Girona was reduced to the minimum and to null in Reus, thus results are not satisfactory.

In general from regressions carried out emerges a good explanatory power with R^2 around 0.80 and assumptions made on the residuals inherent in the method are satisfied. Yet subsequent predicted values on a simplified ratio basis appear to be overestimated at some points. Therefore, a set of dummies have been introduced in Girona, Reus and certain carriers. By this observation predicted passenger figures display an improved fit.

From the model validation it emerges that the proposed methodology consolidates as a first effort to set a useful decision making tool. The most important findings in this research are the quantitative relationships established between the main demand determinants which characterize a competitive air traffic market in the Catalan Region. Actually, it allows having anticipated key results to planned strategies in order to adopt foreseen responds into a market-driven corporate positioning.

The next step following the analysis of the variables that can affect the problem has been operating with the various decision tools held by the actors/players involved in the system. Whilst the first part of the research develops a form of data processing, in the second this methodology is incorporated as to propitiate specific situations. These have been spotted from a rational and strategic perspective so that questions posed at the very beginning have been answered. The questions set refer to airport and airline competition.

Firstly individual player's decisions have been studied to later combine them into a game theory problem in grouped sequences. Given the need to distinguish between airside and landside interests, airlines and airports, appraisal of results obtained is divided into separate points of view.

6.1.1 IMPLICATIONS FOR AIRLINES.

- In the event of a price fall from Ryanair's competitors having the same cost structure and route configuration the loss in revenue caused by the lower price (-21%) per unit is higher than the gain in revenue caused by the larger ticket sale (1.10%). Therefore, a price war should not be taken unless accompanied with an efficient cost cut. Alternatively, segmentation towards a target market with differential product features could be a strategy.

- Price strategies become advantageous since other carriers offer minimum the double that of Ryanair's fares because, as shown, above this value Ryanair shares grow at an increasing rate, while beyond, Ryanair's average share draws more flat (constant frequency). If the price decrease ranges between 0.2 and 0.6 then market share loss is greater than an effort to drop prices in the higher ratios interval. Meanwhile frequency influences more uniformly.

- The model does identify that Ryanair has potentially dominating strategies as long as it is able to concentrate more routes in BCN. A total number of 132,325 passengers (16.29%) are captured by Ryanair when operating all routes from BCN-El Prat. However this dominance is also vulnerable to price changes caused by recent taxes increase which would force to climb prices.

- The proposed Game 1 after a Vueling price reduction forces a partial expansion of Ryanair in BCN. In this event, followed by higher airport charges then advantage is taken from other carriers. Passenger figures obtained show that while carriers such as Vueling have relatively lower fare increase rates, part of Ryanair's demand (61,398 passengers, a 1.82%) decides to purchase competitor's tickets.

- As shown in Game 3. Other carriers such as Vueling could benefit from route expansions in the destinations considered maintaining its load factor.

6.1.2 IMPLICATIONS FOR AIRPORTS.

- The final part of Game 1 aggravates Ryanair's traffic loss since the Government would decide to remove subsidies for noncompliance of the 3-million agreement. In these circumstances it would mount up a 6.15% of traffic loss. This derived, nonetheless, under the assumption at constant demand. Actually, this might not be met because of Ryanair's capability of generating demand. Thus, some price sensitive travelers would not plan any journey and with this, demand progressively would stand back.

- For the situation above, it is not unreasonable to think that Ryanair could go back and focus again on regional airports. If Ryanair takes this decision in this circumstances would lose 178,456 passengers that still would be likely to travel from BCN with other carriers even so after taxes and subsequently prices had risen. This may be due to the fact that allocation carries a lower acceptance price threshold in both Girona and Reus.

- If Ryanair would be intended to move more routes from Girona and Reus, such ones to capture greater market share from BCN, passengers would fall to be around the same values like back in 2006 or 2004.

- To highlight is that Ryanair has no commitment with the region and whenever wherever circumstances make it not possible to handle a profitable market it will have no big deal in moving to any other place in the same region or not as long as it is cost advantageous and hence leave the competition. Then airport operators have a regulatory power for this system. The actual tax per passenger in BCN-El Prat around 20€ is already a lot for Ryanair's pricing strategies given that at the cost of 2.6c€ seat kilometer for an average of 1,233 km length of passenger haul the estimate for the total cost is 52€.

6.2 FUTURE RESEARCH

Regarding the proposed study, the considered mechanisms of decision include only strategies set on price, either carrier directly and frequency. Other toosl such as access cost already present in the model does not vary. Changes in this parameter are difficult to achieve and to predict in the short-run; hence it has prevailed through the study. The lack of adequate data has forced to adjust a basic instrument using available resources. Therefore, a future research perspective on this field is to analyze other properties of the alternatives that individuals may value in the choice process. Further parameters need a more detailed disaggregation of data at an individual decision level. This additional information can be collected by carrying out an ad-hoc survey campaign known as *stated preferences* survey. Stated preferences questionnaires not only collect real individual choices but also hypothetical situations can be suggested to the user. Through answers obtained, an improved estimation process considering real non-observable variables and passenger taste preferences could be obtained. By this, having passenger heterogeneity better represented the demand assignment model could sophisticate in a nest structure (Nested Logit Model) or allowing that coefficients of the attributes evolve (Mixed Logit Model) in a unique utility function able to work with panel data.

In addition, complementary contributions to the dynamic of the model lie in the demand forecast in the region. Air traffic can be boosted or inhibited subject to some conditions. With the presence of low-cost carriers the gap between price and purchasing power can be overcome. Conversely a decrease in low-cost seat supply can traduce in a significant loss of travelers. This task will be based on finding demand generation qualities in flight's supply itself, in addition to socio-economic and demographic variables

At the end, alternative approaches may deploy wider data into a more complex problem to get a more realistic representation of the system. On top of that, a third progress in this direction is related to a rigorous formulation of the decision tree in the Game Theory strategies.

Instead of studying situations already designed, an algorithm can be written that uses different decision tools of the players so that equilibrium states are found. Also known as Nash equilibrium, in which no player has anything to gain by changing only his own strategy unilaterally.

Although further researches will add accuracy to the model it is important to highlight that its simple configuration manages to obtain useful figures that allow understanding the flow of demand for the studied periods in the Catalan region .

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