SYSTEM DYNAMICS BASED SIMULATION FOR AIRPORT REVENUE ANALYSIS

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ABSTRACT

Under increasing competition and pressure for financial self-sufficiency, airports have adopted various strategies. This paper presents a System Dynamics simulation model exploring relationships between airport, airline, and passengers through fares and fees. The case study is a small to medium size international airport (Perth, WA), fully private and light-hand regulated and the model investigates two scenarios of airport charges for two routes where five airlines operate. The changes in airport fees affect differently the airlines and the cumulated aeronautical and non-aeronautical revenues confirm the two-sided view of airport operation.

1. INTRODUCTION

With the growing trend of commercialisation and privatisation, airports have been under increasing pressure to become more financially self-sufficient and less reliant on government support (Graham, 2009; Gillen, 2011; Fu et al., 2011; Fuerst et al., 2011). In this situation, the airports are increasingly being operated like businesses. These changes have not only required airports to increase their revenue and reduce costs, but have also encouraged airport managers to explore new business strategies.

An airport derives its revenue from two types of business: (1) the traditional, aeronautical operations; and (2) the non-aeronautical (commercial) operations (Ivaldi et al., 2011). The former refers to aviation activities associated with runways, aircraft parking, ground handling, and terminals' check-in, security, passport control, gates operations, etc. (e.g. aircraft landing fees, aircraft parking and taxiway charges, passenger terminal and facility charges), whereas the latter refers to non-aeronautical activities occurring within terminals and on airport land, including terminal concessions (duty-free shops, restaurants, entertainment facilities, etc.), ground transport, property rental and other income from activities on airport territory.

Aeronautical charges are usually regulated. Airports rely on commercial and other non-aeronautical services to bring in an increasing portion of their total revenues. For example, the Air Transport Research Society' global airport performance benchmarking project (ATRS, 2006) reports that most of the major airports around the world generate anywhere between 45% and 80% of their total revenues from non-aeronautical services, mainly coming from concession revenue. Traditionally, non-aeronautical revenue is associated with the passenger volume of the airport. So, there is an incentive to restrain aeronautical charges to increase the non-aeronautical revenue (Zhang and Zhang, 1997; Gillen and Morrison, 2004; Kratzsch and Sieg, 2011). But under a certain value, the aeronautical charge may create congestion problems; hence it is important for airports to understand the balance between the two revenue streams.

Since an airport's operation and derivation of revenue involves different agents – the airport, the airlines, the government, and the passengers - its revenue is affected by many interrelated factors. This study will explore the interrelationships among these factors through developing a simulation model to identify the determinants of the airport revenue.

2. LITERATURE REVIEW

A variety of methodologies have been used to explore the structure of revenues and attempt to identify drivers for increasing the airport's profits or performance. Zhang and Zhang (1997 and 2003) applied optimisation models, Starkie (2002 and 2008) economic/econometric models, Basso (2008) numerical analysis, whereas Oum et al. (2004) and Gillen and Morrison (2004) relied on descriptive and qualitative analyses or Fuerst et al. (2011) used macro level regression models. Their findings are consistent: increased airside movements impact on passenger volumes and non-airside revenues have a strong effect on air pricing incentives. Lower aeronautical charges are intensifying the variety of services supplied by airlines and hence stimulating demand. Kratzsch and Sieg (2011) analysed a non-congested private airport with market power in providing aeronautical services. They found the profit-maximising landing fee decrease in the degree of complementarity of aeronautical and non-aeronautical activities. Furthermore, their model implied airports will not take advantage of their market power if non-aeronautical revenue exceeds a critical threshold. This finding extended the previous research by Basso (2008), who showed that unregulated private airports would overcharge for the congestion externality, but the resulting airport pricing strategy would lead to a downstream airline alliance.

The situation of the airport in the market dictates to a large extent the type of relationships it establishes with the airlines and consequently its price structure and revenue (Starkie, 2008). Fu et al. (2006) analysed the differential competitive effects of changing airport user charges on airlines. They found that an identical increase in airport charge will affect the airlines to different degrees, and that airlines cannot fully pass on such an external price increase to consumers. As a result, the increase in airport user charges would harm competition in the downstream airline markets to and from the airport. Using data on 55 large US airports, Van Dendar (2007) examined the dependence of aeronautical and concession changes on the market structure and found that aeronautical charges are lower at airports with significant local competition and they increase with the airline concentration. In addition, airports with large proportions of international traffic, with slot-constraints, and long flight distances record, non-surprisingly, higher charges. More recently, many scholars pay attentions to the vertical relationships between airport and airlines. Barbot (2009a and 2009b) applied a two or three-stage game framework to explore the effects of vertical contracts on airport pricing. Game models were further employed by Tiziana and Alberto (2010) and Zhang et al. (2010) to assess aeronautical pricing and revenue sharing. Fu et al. (2011) reviewed and summarised the forms and effects of vertical relationships and concluded that the positive externality of the airport's aeronautical activities on the commercial services can provide incentives for both airport and airlines to strike exclusive deals.

The total airport revenue problem is unique for each airport and pricing is decided by the interrelationships among numerous elements. Both aeronautical and commercial revenues need to be included in the system. A step forward in the direction of approaching the airport revenue as a complex system was made by Ivaldi et al. (2011). They modelled the airport as a two-sided platform (Gillen et al., 2011), where airlines and passengers interact, and the airport internalises the network externalities arising from both types of demand. Their nested logit model, applied to secondary data collected on US airports and airlines, showed that increases in both ticket fares and/or parking fees diminished the passenger demand, and that passengers prefer frequent departures but they do not like congestion at the airport. These results support the two-sided view and incorporate feedbacks from one side to another. Moreover, the pricing schemes showed that airports can cross-subsidise between the two sides with respect to their elasticities.

This study views airports as platforms where airlines, passengers and companies interact and hence the network of relationships is what affects the total revenue of the airports. We explore here the interactions governing the airport operation to identify how the airport can optimise its revenue under specific ownership, airport-airline relationships, and different regulatory schemes. After a brief presentation of the methodology, the paper describes the structure of the model and presents the simulation results. The summary of findings and recommendations for further research conclude the paper.

3. METHODOLOGY

System Dynamics (SD) is the study of information – feedback characteristics of industrial activity to show how organisation structure, amplification (in policies), and time delays (in decisions and actions) interact to influence the success of enterprise (Forrester, 1958 and 1961).

Several scholars have used SD to research airports management. Miller and Clarke (2007) developed a SD model to explore the relationship among airport investment, capacity and congestion. Suryani et al. (2010 and 2012) established a SD model to forecast air cargo demand related to terminal capacity expansion. These models forecast demand based on the macro economy (e.g. GDP growth) and only evaluated the impact of demand change on airport capacity.

Manataki and Zografos (2009) applied a SD model for aggregate airport terminal performance analysis with respect to a variety of performance metrics. Their model was based on the operation processes and their interconnection. It only showed the time dimension and did not use the SD's main characteristic, i.e. the system's behaviour being decided by the dominant structures.

Minato and Morimoto (2011 and 2012) designed a SD model to analyse an unprofitable regional airport as an ecosystem. This model simulated different strategies (e.g. airport charge reductions, subsidies for the airline tickets) and evaluated their impact on the airport, the airline and the local government in terms of the financial state. However, this research is limit in the unprofitable regional airport. It forecast the passenger demand based on the local economy. Although the ticket price elasticity was considered in this model, only the impact of government subsidies was included while the airport charge reduction was excluded.

In summary, the suitability of SD to the airport revenue problem specifications is confirmed through the following underlying characteristics of the method:

1. SD consists of interacting feedback loops (e.g. sharing of non-aeronautical revenue between airport and airline do not decrease the airport's revenue, on the contrary, by encouraging and allowing airlines to reduce their airfares, it increases non-aeronautical revenue derived from increasing passenger volume);

2. Behaviour of the system is decided by its structure;

3. SD uses a system of coupled, non-linear, first-order integral equations. The fundamental variables are rates (flow) and levels (accumulations of the rates), which vary in time. In the airport system, the total revenue (level) is a function of the landing and terminal fees (rates) through time;

4. Time delays could change the behaviour of system in SD, and they need a careful treatment (e.g. time lags between the airfare change and passenger volume).

4. MODEL

In this study, our aim is to develop a system dynamics model to explore the relationship between the airport revenues and passenger volumes and then forecast the airport revenues using various scenarios.

4.1 Model structure

Since more than one agents interact in the airport platform, the airport revenue system involves many sides: the airport, the airline, passengers and the government. Such relationship could be clarified in Figure 1. Figure 1 presents the high-level causal loop diagram of the model, while Figures 2-5 the stock and flow diagrams for the modules. They are further described in Sections 4.1.

The total airport revenue is the main output we focus on. In our model, we only consider revenues related to the traffic volume of the airport, i.e. aeronautical revenues from landing and terminal charges, as well as the non-aeronautical revenues from ground transport and trading/concession. Other revenues like rental are excluded in this model.

At this stage, a preliminary model was built with some revenue components being simplified (e.g. trading revenue without specific structures). In the further study, the model will extend to integrate more detailed information (e.g. passenger shopping behaviours).

4.1.1 Causal loop diagram

As indicated, Figure 1 represents the Causal loop diagram (CLD) of the airport revenue system in our SD model. It explains the relationships among airport traffic volume, airport charge, airline passenger demand and airfare, airport revenue.

Figure 1 shows that the total airport revenue is calculated as the sum of the aeronautical revenue paid by airlines and the non-aeronautical revenue obtained mainly from passengers in the terminal. The landing and terminal fees are core components of the aeronautical revenue, while the trading revenue and the ground transport revenue account for the majority of the non-aeronautical revenue. The airport charges airlines an aeronautical fee based on traffic volume: flights and passengers. Therefore, it is clear that the passenger volume affects both aeronautical and non-aeronautical revenues.

In general, because of price elasticity, lower airfare will lead to higher passenger volume. The airfare is affected by not only the airline policy (e.g. airline competition) but also the airline operation cost (e.g. the airport aeronautical charges). On the other hand the traffic volume is also influenced by market power of the airport. For example, in some airport with low market power, the airport should face the competition with other airport and other transport mode like high speed rail. In this case, the airports and the airline both prefer to an agreement sharing benefits. The airport provides lower aeronautical fees to attract more airlines and passengers. This will then have a positive effect on retailer and ground transport demand in the airports, with non-aeronautical revenues growing.

From the Figure 1, it is also showed that the aeronautical charge is not only decided by the airport, also monitored by the government. In terms of the airport, the basic charge rate is set depending on the single-till and dual-till regime. The main difference resides on the types of revenues and costs that are considered. For the single-till, both aeronautical and commercial revenues and costs are considered in determining the level of aeronautical charges. For the dual-till, only aeronautical revenues and costs are considered. Besides, the airport would adjust the charge rate based on the market power and the agreement with the airline. It is not uncommon that the airport charges different rate for different airlines and routes, although the price discrimination is not allowed in the government documents. On the government side, there are two regulation regime considered in our model: price-capped and light-handed. The light-handed regime is implemented in Australia and New Zealand only. *“The regulators use a trigger or "grim strategy" regulation where a light-handed form of regulation is used until the subject firm sets prices at unacceptable levels or earns profits deemed excessive or reduces quality beyond some point and thus, triggers a long-term commitment to intruding regulation.”* (Gillen, 2011: 7). Therefore, the aeronautical charge has different impact on the airport revenue under the different regulations.

The airport cost is relative fixed compared with the revenue, so it is excluded in this model. Instead, we employ other indicators like rate of return, revenue per pax, etc. in the aeronautical charge decision-made process.

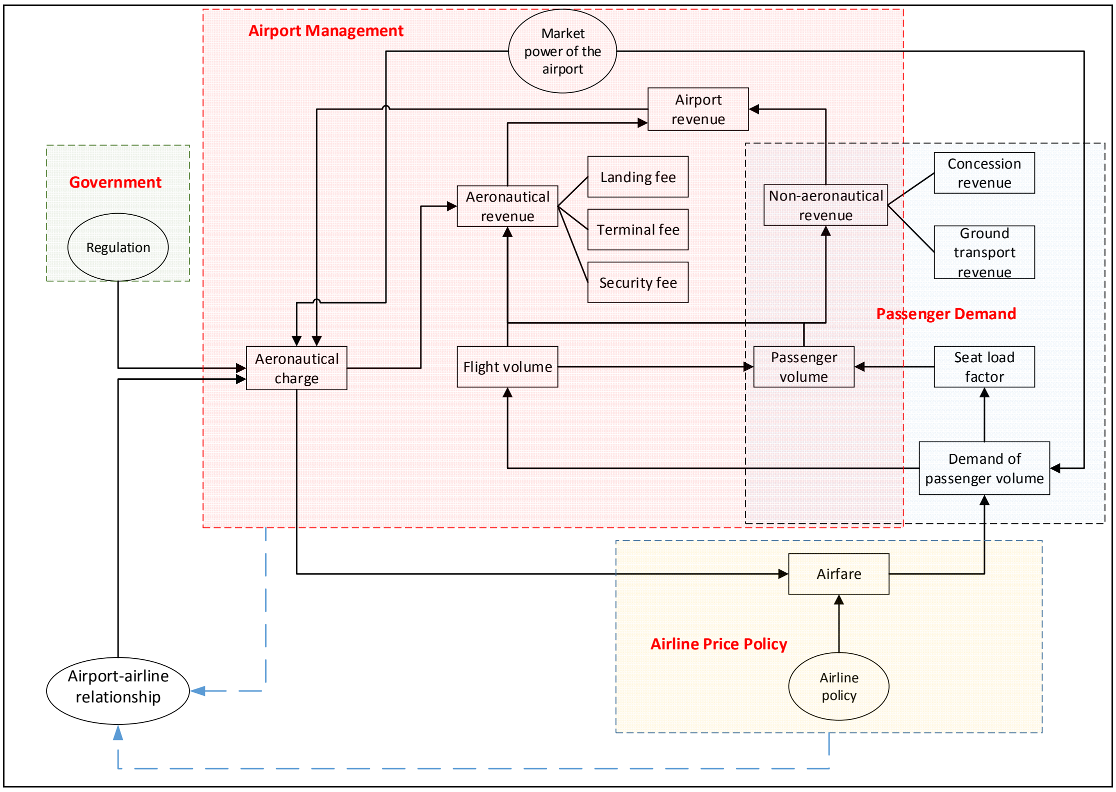

Figure 1 – Causal loop diagram for the airport revenue system

The main output of this model is the airport total revenue. All the main inputs are explained in table 1. The final objective of our study is to explore how the airport revenue changes under different value of these inputs. Because there are many airlines and routes in one airport, we use a two-dimension array to describe all the variables relating to the traffic, e.g. frequency (airline, route), airfare (airline, route).

Table 1 – Main inputs in the top model

	Inputs	Description
Endogenous	Airport aeronautical fee	Including landing fee, terminal fee and security fee.
	Flight frequency	How many flights per day for all airlines and routes. Two dimension array- frequency (airline, route).
	Airfare	Average economy airfare for all airlines and routes, depending on the type of the airline (low cost or full service).
Exogenous	Regulation	Two regime could be chosen via switch variable: price-cap and light-handed.
	Market power of the airport	Different value of demand elasticity applied to the different power of the airport: high, medium and low.
	Airport-airline relationship	This could be represented by discount of the aeronautical fee charged to airlines.
	Airlines policy	1. The impact of airline competition on the airfare. 2. How much the airline pass the change of aeronautical charge to the passengers (see Section)
	Passenger behaviour	1. Average spending on shopping. 2. Market share of different mode on ground transport (see Section

The SD model is comprised of the following four key modules: traffic volume, demand elasticity, the airport aeronautical revenue, and non-aeronautical revenue. These modules allow us to investigate various components of the airport activity and aggregate its revenue.

4.1.2 Airport traffic volume module

Figure 2 represents the stock and flow diagram of the airport traffic volume module.

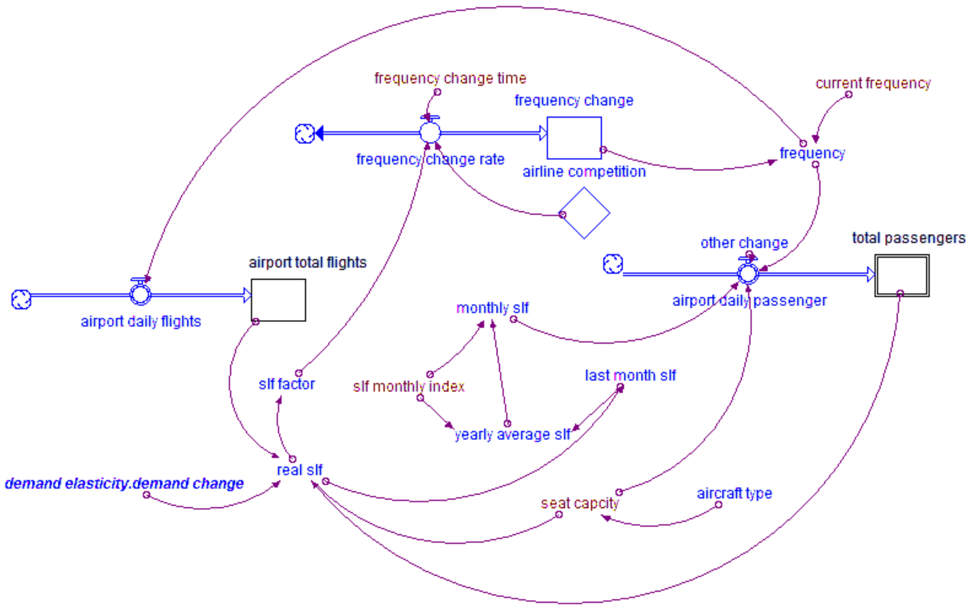

Figure 2 - Stock and flow diagram of traffic volume module

In this module, the output is the passenger volume at the airport. The number of daily passengers is affected by the airline frequency; aircraft seat capacity and monthly seat load factor (SLF), which is calculated in equation (1). The total passenger volume is cumulated daily, monthly, and annually.

$$\text{Airport Daily Passengers} = \text{Frequency} * \text{Seat Capacity} * \text{Monthly SLF} \tag{1}$$

$$\textbf{Monthly SLF} = \textbf{Yearly Average SLF} * \textbf{Monthly Index} \tag{2}$$

In this model, we estimate the monthly SLF with the current year average SLF, which is then adjusted by the real SLF (see Figure 2). The real SLF is influenced by the shift in demand change resulted from the change of the airfare, which will be explained in Section 4.1.4. Airlines' frequency is changed by the demand fluctuation and airlines competition.

The module inputs are described in Table 2.

Table 2 - Inputs of the traffic volume module

Inputs	Description
Demand change	The output of the demand elasticity module, affected by the change of the airfare and price elasticity (see Section 4.1.4).
Current flight frequency	Airline daily regular flights
Seat capacity	Aircraft maximum number of seats
Monthly SLF index	The season factor of monthly SLF, computed from the airport's monthly traffic statistics
Airlines competition and change time	Used in frequency policy-making for airline competition situations

4.1.3 Airport aeronautical revenue module

Airport aeronautical revenues include landing, terminal and security revenues. Figure 3 displays the stock and flow diagram of the landing revenue module. The other two have the similar structure, thus we do not state them here.

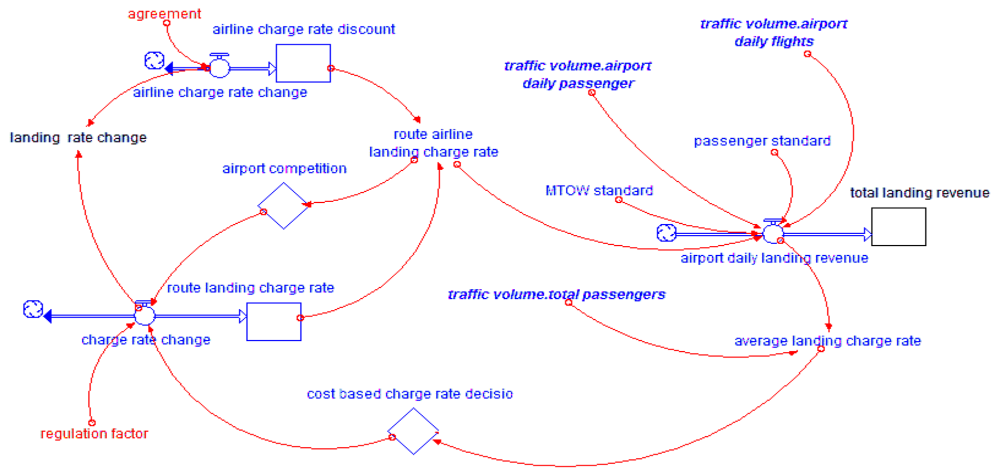

Figure 3 - Stock and flow diagram of landing revenue module

One output of this module is the landing revenue, decided by the landing charge rate and the airport traffic volume from the traffic volume module (see Section 4.1.2). In general, airports charge airline landing fees in two different ways: 1) on a per passenger basis; 2) based on maximum taking off weight (MTOW) of the aircraft. To account for these two methods, two switch variables with values of 1 or 0 were incorporated to match different airports' strategies. In Figure 3, these two variables are passenger standard and MTOW standard. The daily landing revenue is calculated using equation (3).

$$\begin{aligned}\textbf{Daily landing revenue} = \; & \textbf{route airline landing chargerate} \; * \qquad \textbf{(3)} \\ & (\textbf{passengerstandard} * \textbf{daily passenge} \\ & + \textbf{MTOWstandard} * \textbf{daily flights} \;)\end{aligned}$$

Since the landing charge rate could be different for different routes and different airlines, we denote it as route airline landing charge rate, which is computed in equation (4). Using array, we can get the landing fee for every route operated by different airlines.

$$\begin{aligned}\textbf{Routeairline landing charge rate} = \; & \textbf{route landing charge rate} \\ & * \; \textbf{airline charge rate discount} \qquad \textbf{(4)}\end{aligned}$$

The initial value of the route landing charge rate is the standard charge rate of the airport. Airline charge rate discount stands for the percentage decrease or increase based on the basic rate. This percentage is decided in agreement between airlines and the airport (see the Figure 3) and compounds onto the route landing charge rate. The landing charge rate will also lead to the change of the airfare. This is described in Section 4.1.4.

All the inputs of this module are listed in Table 3.

Table 3 - Inputs in the landing revenue module

Inputs	Description
The volumes of daily passengers and daily flights	The output of the traffic volume module (see Section 4.1.2).
Agreement	Airline – airport relationship (contracts between airport and airlines, e.g. landing fee discount, terminal rent)
Regulation factor	The impact of regulation on the charge rate

The charge rate is affected by the different regulation regime: price-cap and light-handed and depends on the single-till and dual-till method as well.

Another decision process could be applied in the airport competition, especially considering competition with other transport modes (e.g. high speed train). In this situation, the airport must compare the airfares with train ticket prices for similar routes and act accordingly in order to increase the market share of the air transport.

4.1.4 Demand elasticity module

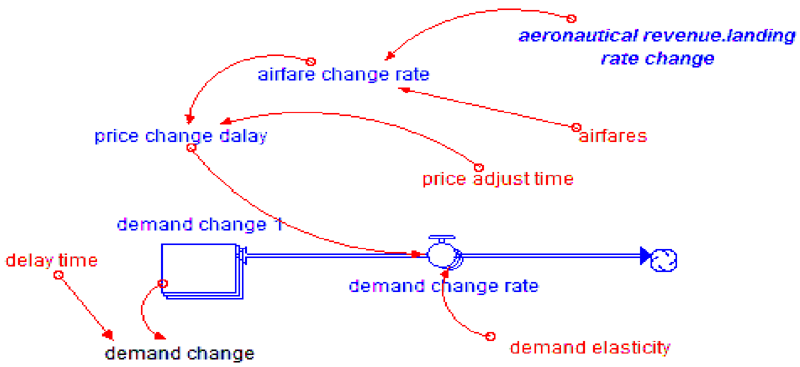

Figure 4 - Stock and flow diagram of the demand elasticity module

Figure 4 illustrates how the airport charges affect the passenger demand through the price elasticity. The output of this module is the change in passenger demand, which will influence the airline traffic volume. The key point of this module is the value of demand elasticity, which depends on the different routes (international/domestic, long/short haul, domain/rival airline).

All the inputs are given in Table 4.

Table 4 - Inputs in demand elasticity module

Inputs	Description
Change of the airport charge rate	The output of the aeronautical revenue module (see Section 4.1.3).
Airfares	They are decided by the airlines.
Price-demand elasticity	Base on previous research, e.g. a point estimate of -1.33 is considered

	for international routes (IATA, 2007) in following case study.

4.1.5 Airport non-aeronautical revenue module

Airport non-aeronautical revenues include the ground transport and trading revenues. In this preliminary version of the model, the structure of trading revenue is not to be explored. It is only computed by passenger volume and spending per pax (see Figure 1). We will investigate the relationship between passenger type and their shopping preference in terminal in the next stage.
Figure 5 shows the stock and flow diagram of the ground transport revenue module.

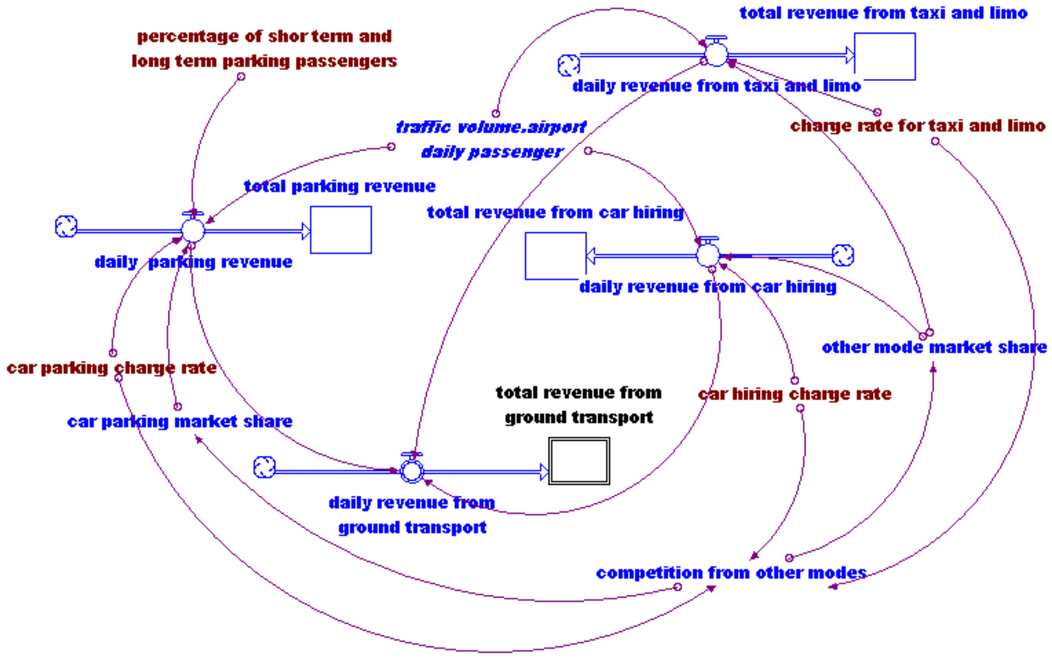

Figure 5 - Stock and flow diagram of ground transport revenue module

The output of this module, the ground transport revenue, is determined as the sum of the revenues from parking, car hiring, taxi and limousines. The calculation of each revenue component is described in equations (5), (6) and (7).

$$\begin{aligned}\text{daily parking revenue} &= \text{daily passengers} * \text{car parking market share} \\ &\quad * (\text{short - term parking charge rate} * \text{percentage of short - parking passengers} \\ &\quad + \text{long - term parking charge rate} * \text{percentage of long - term parking passengers})\end{aligned} \tag{5}$$

$$\begin{aligned}\text{daily revenue from car hiring} &= \text{daily passenger} * \text{car hiring market share} \\ &\quad * \text{car hiring charge rate}\end{aligned} \tag{6}$$

$$\begin{aligned}\text{daily revenue from taxi and limo} &= \text{daily passenger} * \text{taxi and limo market share} \\ &\quad * \text{charge rate for taxi and limo}\end{aligned} \tag{7}$$

In equation (5), the parking charge rate is considered to follow a normal distribution around the average passenger spending on parking. There is some competition among these three modes, depending on their charge rates, accounted for in the current model via market share. Normally, the airport charges the parking passengers on time while charges the companies of car hiring and taxi and limo the rate of their revenue.
The model inputs are presented in Table 5.

Table 5 - Inputs for the ground transport revenue module

Inputs	Description
The volumes of daily passengers	The output of the traffic volume module (see Section 4.1.2).
Market share of each mode	The competition among all modes of ground transport.
Charge rate of each mode	Influence revenue and competition.
Percentage of short-term parking and long-term parking passenger	Decided by parking facilities and passengers' behaviour, excluded in this model.

4. 2 Case study data

Our model aim is to find out how the revenues change with the change of passenger volume and with different policy measures (e.g., special agreements with airlines, parking policies, etc.). Although such analysis may differ from one airport to another, we keep the proposed model as generic as possible. In this study, we use this base model to simulate the revenue in Perth (Western Australia) International Airport. The main characteristics of Perth International Airport are summarised in Table 6.

Table 6 – Features of the Case Study Airport

	Regulation	Ownership	Market Environment
Perth International Airport	Light-hand regulation (price monitoring)	Fully private for –profit via trade sale with share ownership tightly held	High market power because of fewer substitutes and limited competition. 25-30% of revenues come from aeronautical services (2006-2011).

The simulation timing was set for one year, from 1st July 2010 to 30th June 2011 (based on the Australian fiscal year), based on the historical data we had. The simulation time unit is 1 day and for simplicity there are 360 days in one year (12 months with 30 days each month). We simulate the aggregated revenues based on two international routes: Perth – Singapore and Perth – Hong Kong.
The airfares for the two routes are given in Table 7. These prices are based on the statistics of the economic tickets and compared across five airlines. It is also important to note that no disaggregated data was available for the two routes; hence the simulation results were compared with the total airport activity.

Table 7 - Airfares (one-way) in the two routes

Route / Airline	Qantas	Singapore	Cathay Pacific	Jetstar	Tiger
Perth-Singapore	$ 400	$ 400	No flight	$ 200	$ 200
Perth–Hong Kong	$ 400	No flight	$ 400	No flight	No flight

Table 8 provides the flight frequencies and aircraft types on the two routes for the 2010-2011 financial year.

Table 8 - Airline frequency for the two routes (flights/day)

Route / Airline	Qantas	Singapore	Cathay Pacific	Jetstar	Tiger
Perth-Singapore	2 (A333)	3 (B772)	No flight	1 (A320)	1 (A320)
Perth–Hong Kong	1 every other day (A333)	No flight	Daily + 1 on every Wed., Fri, Sun (A333)	No flight	No flight

4.3 Simulation and scenarios setting

4.3.1 Base model run results

Figure 6 presents the simulation results for the number of daily passengers from Perth in these two routes over the 2011-2011 year. The x axis represents the time in days, with 1 being July 1st 2010. We notice that the simulation results for daily passenger volumes reflect the dependency with the frequency of flights, in its turn affected by seasonality. It is clear that December and January are busy-travel months in Australia, while outside these two months the travel diminishes, with February and August being normally off-season. The simulation shows that the daily average number of passenger for these two routes is 1,750. The maximum number of passengers is 2,360 in January, while the minimum is 1,399 in February. Figure 6 also highlights daily variability within a week.

For validation purposes, we compare the pattern of monthly total passengers of the two-route obtained in the simulation with the total international passenger statistics for the Perth Airport during the same period (Figures 7a and 7b). The simulation results match the pattern shown in real situation, which is further confirmed by the strong Pearson correlation of 0.997 between the two series.

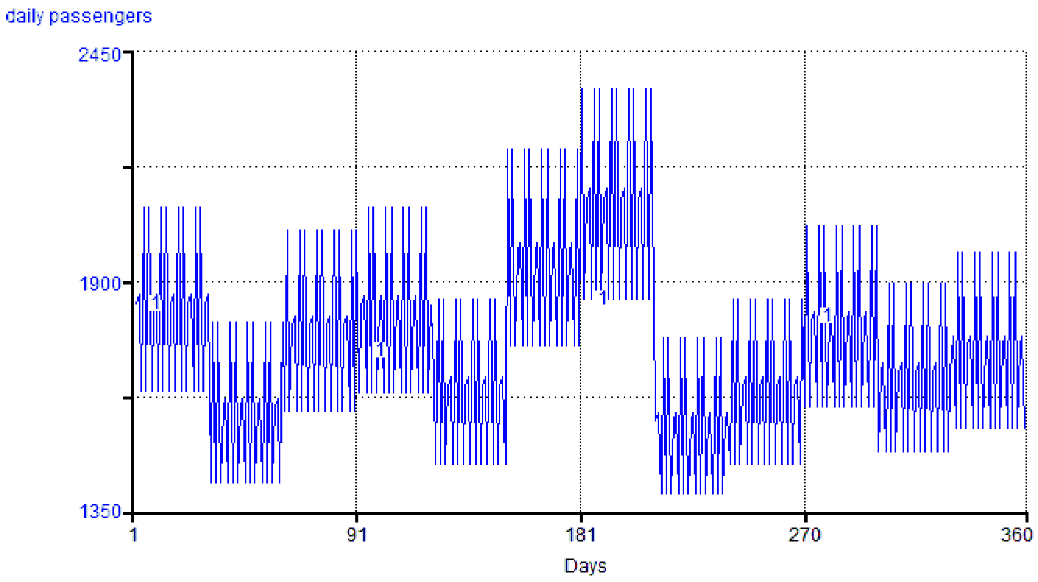

Figure 6 - Simulation result for daily passengers (from July 2010-June 2011)

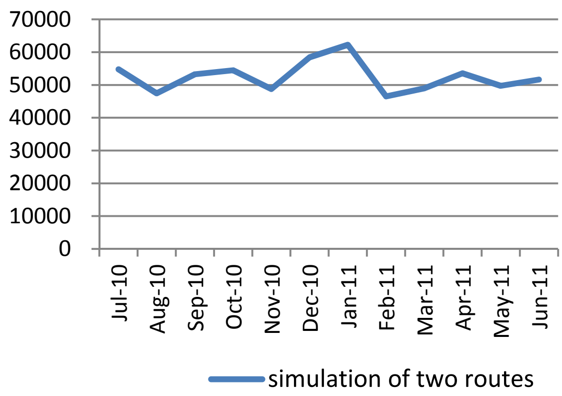

Figure 7a Simulation results - monthly average passengers in two routes

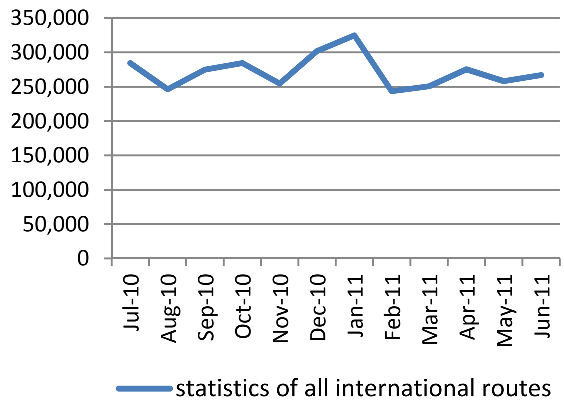

Figure 7b Perth Airport 2010-2011 monthly international passenger statistics (source: http://www.perthairport.com.au/AboutUs/CorporateInformation/AirportStatistics.aspx)

Table 9 lists the simulation result of total landing revenue and total passengers for each route (absolute and relative measures). The average landing charge rate was $4.28/passenger in 2010-2011 (Perth International Airport: www.perthairport.com.au). In the base model simulation, we assumed the airport charges all the airlines the same charge rate. Given the higher number of passengers travelling between Perth and Singapore, the landing revenue for that route is proportionally higher, representing 78% of the landing revenue in the model.

Table 9 – Total landing revenue for each route and the percentage of the total landing revenue

Routes	Annual landing revenue (AUD)	% of total landing revenue	Annual passengers	% of total passengers
Perth-Singapore	2,098,503	78%	490,304	78%
Perth–Hong Kong	590,750	22%	138,026	22%
Total landing revenue	2,689,253		628,330	

Figure 8 presents the daily parking revenue, also strongly related to the daily number of passengers. The total simulated parking revenue from the two routes is $2,454,760 ($188,499 from taxi and limo and $565497 from car hiring, respectively) Short-term parking represents 65% (with $1,581,220) and the long-term accounts for 35% ($856,005).

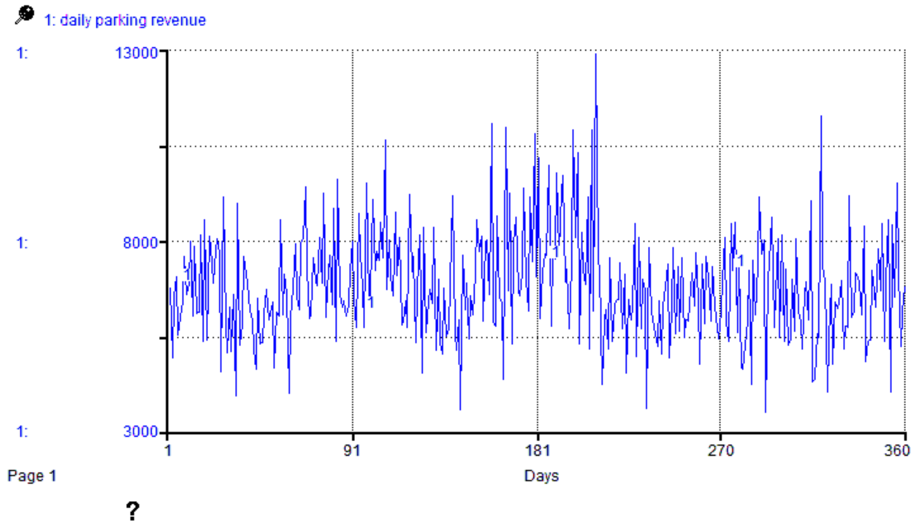

Figure 8 - Daily parking revenue

Acknowledging the importance of validating the model with real data, we compared aeronautical and non-aeronautical revenues for Perth International Airport. Figure 9 shows the monthly ratio of the landing revenue to the ground transport revenue. During 2010-2011, the simulated total revenues from landing and ground transport were $2,689,253 and $ 3,223,802, with an average ratio is 84%. From the statistics in the annual report of Perth Airport 2010-2011, we obtained the annual landing revenue and the ground transport revenue of $47,023,176 and $55,600,000, leading to a ratio of 85%. Hence, the simulation error rate measured in relative terms is acceptable (0.01).

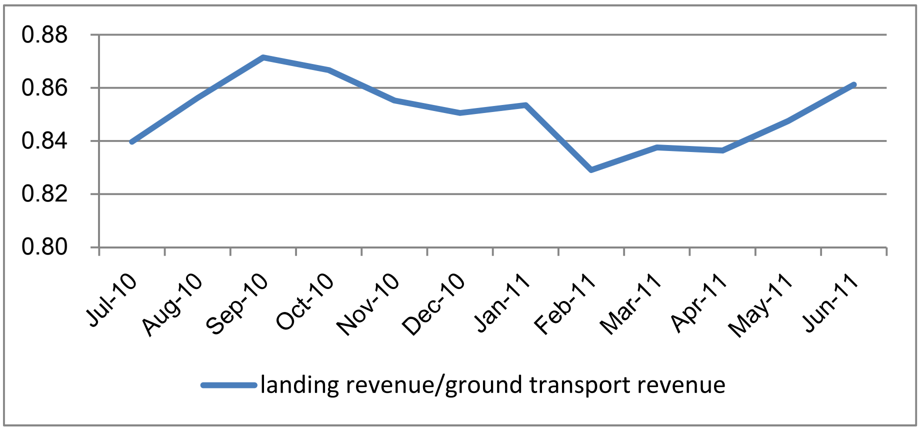

Figure 9 - Monthly ratio of landing revenue to ground transport revenue

These results give us confidence that the model is likely to be valid when fully applied to the Perth International Airport.

4.3.2 Scenario simulation

Scenario is an approach to develop a "set of stories" that might happen in the future. Several alternative scenarios can be obtained from a valid model by adding or changing some structures or parameters. The scenarios show how the impact to input variables into the model results. In this preliminary study, we present two parameter scenarios, with more robust sensitivity analysis following the full development of the model.

(1) Influence of the airport charge (the sum of the landing, terminal passenger and security fees)

Currently, the total airport charge is $20.28 per passenger (landing fee $4.28, passenger fee $10 and the security fee $6). If the airport decreases the airport fees by $10 (from $20.28 to $10.28), then we likely responses of the airlines and the passengers would be: 1) the airfares would not be changed, that means the airlines keep the additional profit; 2) airfares would decrease by $10, that means the airlines fully pass this reduction to the passengers; 3) airfares decrease by $10, but the average spending on shopping increases by $5 ($8.72 per pax) because passengers save $10 in the tickets, part of which could be spent at the airport. Figures 10a and b compare the results of the airport total revenues and airline revenues after airport fees with the baseline.

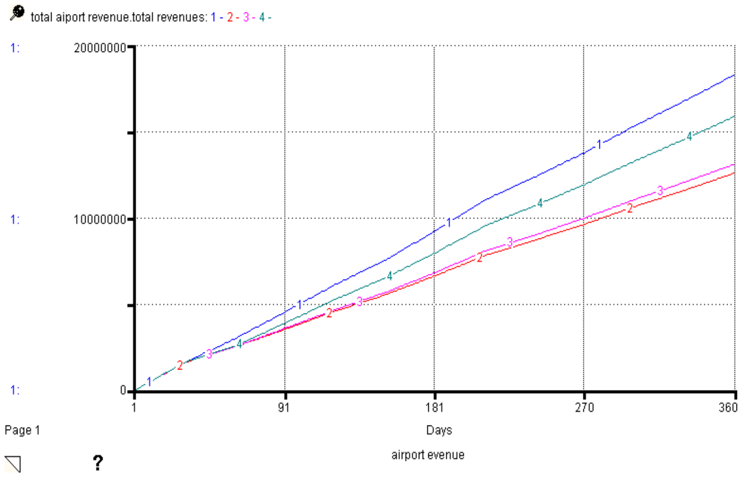

Figure 10a - Impact of reduced airport fees on the airport revenue

1-baseline: the airport charge is $20.28 per pax

2- the airport charge is decreased to $10.28 per pax, the airfares is not changed

3- the airport charge is $10.28 and the airfares are decreased by $10

4- the airport charge is $10.28, the airfares are decreased by $10 and the average passenger spending on shopping is increased by $5 to $8.72 per pax

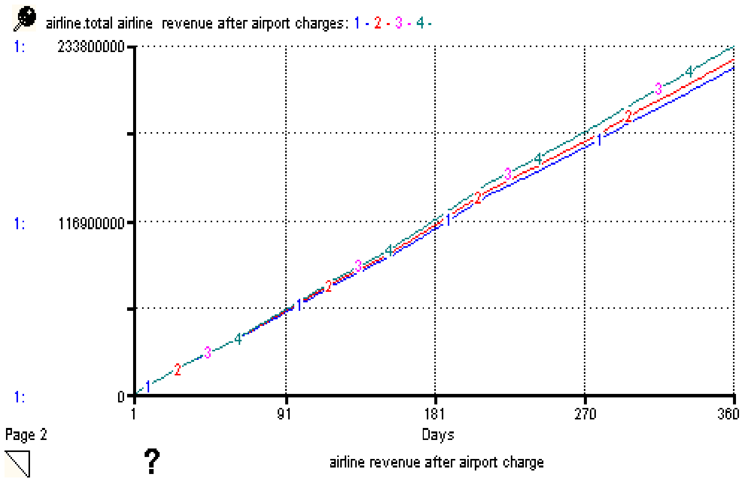

Figure 10b - Impact of reduced airport fees on airline revenues

Figure 10b indicates that the best way for airlines to increase their revenues is to pass the full amount of fee reduction to the passenger. At the same time, the decrease of the airport fee is translated in decreased airport revenues. However, it is worth noting that the passenger may be willing to use some of the amount saved on the airfare to spend more on shopping while at the airport. In such situation, the loss of the airport aeronautical revenue could be substantially compensated by higher non-aeronautical revenues (line 4 in Figure 10a). We also find that airfares' decrease will improve the airport revenue (line 2 and 3 in Figure 10a). This is cause by the impact of price elasticity on the passenger volume.

If, on the other hand, the airport increases the airport fees by $10 to $30.28, several potential responses were investigated: 1) the airfares are not changed; 2) airfares increase by $10; 3) airfares decrease by $10, and the average spending on shopping decreases by $2 ($1.72 per pax). Figures 11a and b compare these results.

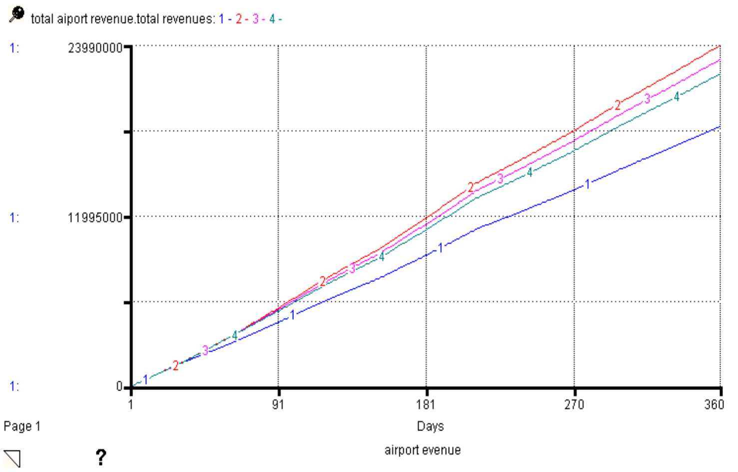

Figure 11a - Impact of increased airport fee on the airport revenue

1-baseline: the airport charge is $20.28 per pax

2- the airport charge is increased to $30.28 per pax, the airfares is not changed

3- the airport charge is $30.28 and the airfares are increased by $10

4- the airport charge is $30.28, the airfares are increased by $10 and the average passenger spending on shopping drops $2 to $1.72 per pax

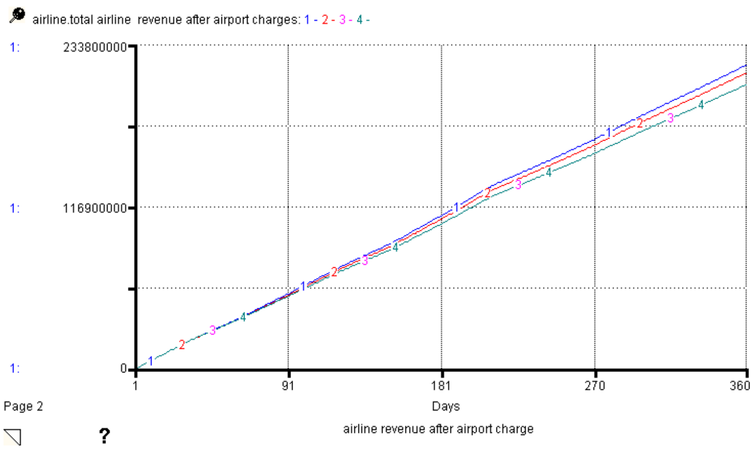

Figure 11b - Impact of the increased airport fee on the airline revenue

As shown in Figure11, the airport revenue will increase when the airport charge raises, but this increase will be diminished when the airlines also increase their airfares (lines 2 and 3 in Figure 11a). Moreover, if considering the decrease of the passenger spending on shopping, the increase of aeronautical revenue will be further eroded by the loss of the non-aeronautical revenue (line 4 in Figure 11a). In both cases, when airlines pass or not the full increase in airport fee to the passenger, their profit will be reduced, but more strongly when the airfares increase by $10 (line 3 in Figure 11b). This finding is consistent with the previous research (Fu, 2006). But, since our study ignored the airlines' competition in this stage, this conclusion is only made on the aggregate level. Further development should consider individual responses based on airline competition.

(2) Effect on the airport revenue of an identical change in the airport charge (under various airfare values)

Next, we applied different airfares for the two routes under consideration, assuming that the airlines will increase their airfare when the airport charge rises. Figure 12 illustrates the impact on the total airport revenue. The impact on the total airport revenue changes depending on the airfare value. Specifically, when the relative increase in airfare is large (e.g., $10 increase for $100 and $200 tickets), the airport revenue is likely to decrease. However, when the relative change is minute (e.g., a $10 increase in airfares of $800 or more is likely to be "absorbed" more easily than in a $200 airfare), the airport will see a more substantial increase in its aeronautical revenues. This implies that an identical increase of the airport charge is not an optimal solution, as it will influence differently airlines and hence the revenue derived from different route and carriers. In fact, such price discrimination is not uncommon for the airports, especially with the increase of low cost carrier (LCC) market share. The same increase of airport charge in the same route would lead to two contrary results for full service airline (FSA) and LCC according to Figure 12. The airport is willing to provide lower charge to the LCC mainly because of increase in the passenger volumes which will bring more non-aeronautical revenues. The only way to stay financially sustainable for airports is to compensate their loss from aeronautical activities with non-aeronautical ones. Furthermore, we believe that the impact on spending patterns and preferences of LCC passengers on the concession revenue is non-negligible. This is however beyond the scope of this study.

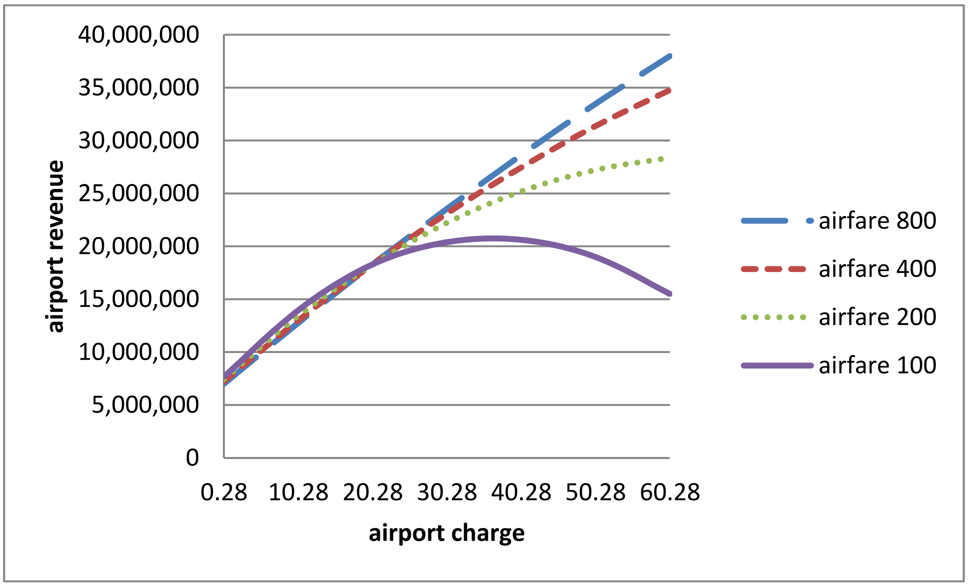

Figure 12 - Impact of the identical increase in airport fee on the airport revenue under different airfares

5. CONCLUSION

This paper provides a system Dynamics model for airport revenue, illustrating relationships between airport, airlines, and passengers via responses to fees and charges. Although preliminary, the modular structure demonstrates its viability for expansion and the model results are in sync with the aggregate statistics available for the case study. The possibility to explore various scenarios is particularly appealing: the model can be viewed as an “experimental laboratory”, useful for testing and forecasting multiple combinations of possible real conditions.

The main findings so far support the view that the airport is a two-sided platform and the feedback relationships are incorporated as demand elasticities in the simulation model. Another important finding is the magnitude of impact of airport fees on both aeronautical revenues, but also concessionary fees. Finally, airlines will be affected to different degrees by the airport fees and LCC would need to find alternative strategies for survival and profitability if the airports are not nuanced enough in their policies.

However, the model is only demonstrated based on one airport and two routes in the first stage. In the further study, we will apply the model into other airports with different regulation and market situations. Additionally, more structures related to decision-making will be developed, such as airport and airline competition and airport-airline relationships.

REFERENCES

Albers, S. Koch, B. & Ruff, C. (2005). Strategic alliances between airlines and airports theoretical assessment and practical evidence. *Journal of Air Transport Management* 11, 49-58.

Amos, P. (2004). The World Bank Group Transport Paper: Public and Private Sector Roles in the *Supply of Transport Infrastructure and Services*, available at <http://siteresources.worldbank.org/INTTRANSPORT/214578-1099319223335/20273720/tp-1_pproles.pdf>, [accessed Aug 22, 2011].

ATRS (Air Transport Research Society). (2006). *The ATRS Airport Performance Benchmarking Report: Global Standards for Airport Excellence*, 3-Volume report, published by the Centre for Transportation Studies, University of British Columbia, Vancouver, British Columbia. July 2006, available at <www.atrsworld.org>, [accessed Jun 10, 2011].

Auerbach, S. & Koch, B. (2007). Cooperative approaches to managing air traffic efficiently – the airline perspective. *Journal of Air Transport Management* 13 (1), 37–44.

Barbot, C. (2009a). Airport and airline competition: Incentives for vertical collusion. *Transportation Research B* 43 (10), 952–965.

Barbot, C. (2009b). *Vertical contracts between airports and airlines: is there a trade-off between welfare and competitiveness?* Manuscript, CETE, Faculty of Economics of Porto, Porto, Portugal, available at < http://www.fep.up.pt/investigacao/cete/papers/DP0901.pdf>, [accessed May 10, 2011].

Barlas, Y. (1996). Formal aspects of model validity and validation in system dynamics. *System Dynamics Review*, 12(3), 183-210.

Basso, L.J. & Zhang, A. (2007). Congestible facility rivalry in vertical structures. *Journal of Urban Economics* 61 (2), 218–237.

Basso, L.J. & Zhang, A. (2008). On the relationship between airport pricing models. *Transportation Research B* 42 (9), 725–735.

Basso, L.J. & Zhang, A. (2010). Pricing vs. slot policies when airport profits matter. *Transportation Research B* 44, 381–391.

Basso, L.J. (2008). Airport deregulation: effects on pricing and capacity. International *Journal of Industrial Organization* 26 (4), 1015–1031.

Bel, G. & Fageda, X. (2010). Privatization, regulation and airport pricing: an empirical analysis for Europe. *Journal of Regulatory Economics* 37, 142–161.

Castillo-Manzano, J.I. (2010). Determinants of commercial revenues at airports: Lessons learned from Spanish regional airports. *Tourism Management* 31, 788–796.

Czerny, A.I. (2006). Price-cap regulation of airports: single-till versus dual-till. *Journal of Regulatory Economics* 30 (1), 85–97.

Forrester, J.W., 1958. Industrial dynamics: A major breakthrough for decision markers. *Harvard Business Review* 36 (4), 37-66.

Forrester, J.W., 1961. *Industrial dynamics*. Cambridge, MA: MIT Press.

Forrester, J.W., 1994. System dynamics, systems thinking, and software. *System Dynamics Review* 10 (2/3), 245–256.

Forsyth, P., Gillen, D., & Knorr, A et al. (2004). *The economic regulation of airports*. Ashgate Publishing Limited, England.

Francis, G. Humphreys, I., & Ison, S. (2004). Airports’ perspectives on the growth of low-cost airlines and the remodeling of the airport–airline relationship. *Tourism Management* 25 (4), 507–514.

Fu, X. & Zhang, A. (2010). Effects of airport concession revenue sharing on competition and social welfare. *Journal of Transport Economics and Policy*. 44 (2), 119–138.

Fu, X. Lijesen, M. & Oum, T.H. (2006). An analysis of airport pricing and regulation in the presence of competition between full service airlines and low cost carrier. *Journal of Transport Economics and Policy* 40, 425-447.

Fu, X. Homsombat, W. & Oum, T. H. (2011). Airport-airline vertical relationships, their effects and regulatory policy implications. *Journal of Air Transport Management* 17, 347-353.

Fuerst, F., Gross, S., & Klose, U. (2011). The sky is the limit? The determinants and constraints of European airports commercial revenues. *Journal of Air Transport Management* 17, 278-283.

Gillen, D., Oum, T.H., & Tretheway, M.W. (1988). Airport pricing policies: an application to Canadian airports. *Proceedings of the (US) Transportation Research Forum* 1988, 28-34.

Gillen,D. (2008). Air travel demand elasticities: concepts, issues and measurement.

Gillen, D. (2011). The evolution of airport ownership and governance. *Journal of Air Transport Management* 17, 3-13.

Graham,A. (2008). *Managing Airports: An International Perspective*, third ed. Elsevier, Oxford.

Graham, A. (2006). Assessing the economic challenges facing regional airports in today’s environment: turning these challenges into opportunities. Presentation given at the *Global Airport Development Conference*, Rome, dates?.

Graham, A. (2009). How important are commercial revenues to today’s airports? *Journal of Air Transport Management* 15, 106-111.

International Air Transport Association. (1997). IATA Policy on User Charges Aspects of the Commercialization of Airports and Air Traffic Service Entities. *International Air Transport Association*, Montreal.

International Air Transport Association. (2007). Estimating air travel demand elasticites, published by....

Ivaldi, M. Sokullu, S. & Toru, T. (2011). *Airport price in a two sided framework: an empirical analysis*, available at < http://idei.fr/doc/conf/csi/papers_2011/ivaldi.pdf> [accessed Jun 20, 2011].

Kratzsch, U. & Sieg, G. (2011). Non-aviation revenues and their implications for airport regulation. *Transportation Research E* 47, 755-763.

Lei,Z. & Papatheodorou, A. (2010). Measuring the effect of low-cost carriers on regional airports’ commercial revenue. *Research in Transportation Economics* 26, 37–43.

Lu, C.C. & Pagliari, R.I. (2004). Evaluating the potential impact of alternative airport pricing approaches on social welfare. *Transportation Research E* 40, 1– 17.

Manataki, L.E, & Zografos, K.G. (2009). A generic system dynamics based tool for airport terminal performance analysis, *Transportation Research C* 17, 428–443.

Minato, N., Morimoto, R. (2011). Designing the commercial sustainability of unprofitable regional airports using system dynamics analysis, *Research in Transportation Business & Management* issue? Pages?

Nastasi, A. & D'Alfonso, T. (2010). *Vertical Agreements between Airports and Carriers*. Technical report, Department of Computer and System Sciences, Sapienza Università di Roma, available at <http://ojs.uniroma1.it/index.php/DIS_TechnicalReports/article/download/.../8913>. [accessed April 20, 2011].

Oum, T.H.,W.G.Waters II and J.S. Young. (1992). Concepts of price elasticities of transport demand and recent empirical estimates: An interpretive survey, *Journal of Transport Economics and Policy* 26: 139-154.

Oum, T., Zhang, A., & Zhang, Y. (1993). Inter-firm rivalry and firm specific price elasticities in deregulated airline markets. *Journal of Transport Economics and Policy* 27, 171–192.

Oum, T. Zhang, A. & Zhang, Y. (1995). Airline network rivalry. *Canadian Journal of Economics* 4, 836–857.

Oum, T., Waters, W., Fu, X. (2000). Transport demand elasticities. In: Button, K., Hensher, D. (Eds.), *Handbook of Transport Modelling*. Elsevier, New York, pp.197–210.

Oum, T., Yu, C. (2004). Measuring airports' operating efficiency: a summary of the 2003 ATRS global airport benchmarking report. *Transportation Research E* 40 (6), 515–532.

Oum, T.H. Zhang, A. & Zhang, Y. (2004). Alternative forms of economic regulation and their efficiency implications for airports. *Journal of Transport Economics and Policy* 38 (2), 217–246

Oum, T.H. & Fu, X. (2008). Impact of airports on airline competition: focus on airport-airline vertical relations. Joint Transport Research Centre, *International Transport Forum*, OECD, available at <http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200817.pdf>. [accessed May 20, 2011].

Oum, T., Yan, J., Yu, C. (2008). Ownership forms matter for airport efficiency: a stochastic frontier investigation of worldwide airports. *Journal of Urban Economics* 64 (2), 422–435.

Peterson, R.M., Bittel, R.H., Forgie, C.A., Lee, W.H., & Nestor, J.J. (2007). Using USCAP's analytical models, the transportation security administration balances the impacts of aviation security policies on passengers and airlines. *Interfaces* 37 (1), 52–67.

Richmond, B.M. (1993). Systems thinking: critical thinking skills for the 1990s and beyond. *System Dynamics Review* 9 (2), 113–133.

Schieritz, N., & Milling, P.M. (2003). Modeling the forest to modeling the trees: a comparison of system dynamics with agent-based simulation. *21st System Dynamics Conference*, July 20 - 24, 2003, New York, U.S.A.

Senge, P. (1990). *The Fifth Discipline: The Art and Practice of the Learning Organisation*. Currency Doubleday, New York.

Starkie, D. (2002). Airport regulation and competition. *Journal of Air Transport Management* 8 (1), 63–72.

Starkie, D. (2005). Making airport regulation less imperfect. *Journal of Air Transport Management* 11, 3–8.

Starkie, D. (2008). The airport industry in a competitive environment: A United Kingdom perspective. *Joint Transport Research Centre*, International Transport Forum, OECD, available at <http://www.internationaltransportforum.org/jtrc/DiscussionPapers/DP200815.pdf > [accessed April 20, 2011].

Sterman, J.D. (2000). *Business Dynamics: Systems Thinking and Modeling for a Complex World*. McGraw-Hill, Boston.

Suryani, E., Chou, S.Y. & Chen, C.H. (2012). Dynamic simulation model of air cargo demand forecast and terminal capacity planning, *Simulation Modelling Practice and Theory* 28, 27-41.

Van Dender, K. (2007). Determinants of fares and operating revenues at US airports. *Journal of Urban Economics* 62, 317–336.

Vogel, H., Graham, A. (2006). A comparison of alternative airport performance measurement techniques: a European case study. *Journal of Airport Management* 1, 59–74.

Yang, H.J. & Zhang, A.M. (2011). Price-cap regulation of congested airports. *Journal of Regulatory Economics* 39, 293-312.

Zhang, A. & Zhang, Y. (1997). Concession revenue and optimal airport pricing. *Transportation Research E* 33 (4), 287–296.

Zhang, A. & Zhang, Y.(2003). Airport charges and capacity expansion: effects of concessions and privatization. *Journal of Urban Economics* 53 (1), 54–75.

Zhang, A., Fu, X., & Yang, G. (2010). Revenue sharing with multiple airlines and airports. *Transportation Research B* 44, 944-959.

Zhang, A.M. & Zhang, Y.M. (2006). Airport capacity and congestion when carriers have market power. *Journal of Urban Economics* 60, 229–247.

Zhang, A.M. & Zhang, Y.M. (2010). Airport capacity and congestion pricing with both aeronautical and commercial operations. *Transportation Research B* 44, 404–413.