AIRLINE PROFIT ESTIMATION MODEL IN CASE OF PURCHASING NEW SLOTS FOR ROUTE NETWORK EXPANSION

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ABSTRACT

If an airline today wants to operate at certain airport it is necessary to possess an airport slot. Therefore, the quality of service of an airline in a sense of number of routes and frequencies will depend on the allocation of slots at congested airports. The model and algorithm presented in this paper are developed with the goal to create a new flight schedule that consists of all flights already operated by an airline as well as the flights assigned to new slots (purchased at the secondary market), where the airline's revenues should be maximized while all the assumptions and the operational constraints must be satisfied. The model outputs are: the new flight schedule, estimation about the number of years neceded to refund the initial outlay for purchasing the new slots and the number of potential connections that airline could realize if it introduces the new slots.

Keywords: airport slots, airline profit, decision-making model

INTRODUCTION

In a period after the deregulation of the U. S. airline industry in 1978, the airlines were faced with a remarkable market change, where new possibilities appeared, but the challenges, too. Such deregulation caused that the airlines were free in their choice of networks, tariffs, frequencies on the routes and service quality, and therefore they had opportunity to become more competitive. The most important advantage of the deregulated airline market was the chance for the airlines to optimize their networks. The airline network is the main product that is offered to the customers and, along with the flight schedule, they are the main generators of an airline's revenues and costs. Therefore, the service quality offer to customers mostly depends on the quality of those two products.

Growing imbalance between air transport demand activities and available airport capacities to meet such demand, results in increasing number of congested airports worldwide. This

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directly impacts on airline industry causing serious operational disruptions, with significant number of delayed flights, as well as limited network expansion. Both lead to the significant economy penalties and the airline revenue loss.

To solve the arising problem certain capacity control was introduced at the airports in USA in early ‘70s, which later took real form in Europe. The capacity control is introduced in a form of a slot that is defined as permission given by a coordinator to use the full range of airport infrastructure necessary to operate an air service at a coordinated airport on a specific date and time for the purpose of landing or take-off as allocated by a coordinator (Council Regulation No 95/93, 1993). According to this the total airport capacity is divided in time slots and an airline that possess certain slot has right to operate at that airport. The number of available airport slots depends on runway capacity, terminal capacity and gate capacity. In practice, a limitation factor for the number of available slots most of the time is the capacity of the runways. An airport slot, usually covers the time of 15 to 30 minutes when an airline can arrive or depart from an airport. The airport slot differs from the Air Traffic Control slot which represents the time when an airline can perform landing/take-off from the runway and it is allocated by the Air Traffic Control.

The current slot allocation system worldwide is based on International Air Transport Association (IATA) system and the process of allocation is held twice a year at the IATA Scheduling Conference. The airport slots in Europe are subject to the Airports Slot Allocation Regulations 1993 (95/93) and the purpose of the Regulation is to provide consistency within EU air transport policy, to maintain effective competition at EU airports and to ensure compatibility between intra-EU arrangements and world-wide procedures for allocating slots.

In the last decade, the current IATA system of slot allocation and the EC slot regulation have been very criticized by the experts because of their rigid rules and are considered to be inefficient. Also, scarce airport capacity become an important market entry barrier and as such protects incumbents from competition (De Wit, 2008). So they support the idea of introduction of market mechanisms that would be based on airline’s willingness to pay for slots. The most important argument for introduction of market mechanisms is that allocating airport slots to airlines that are most willing to pay for them will bring important social benefits, because they will use slots in the best possible way from aspect of social welfare.

This would also help an airline in achieving its goal - network optimization, by buying those slots that most fit into its flight schedule as well as passenger demand. In contrary, the lack of wanted slots may lead to airline revenue loss resulted by incapability of meeting passengers’ requests.

In the following section it is described the secondary slot market, its advantages and contribution to the airlines with hub-and-spoke (HS) networks. The third section illustrates the model and heuristic algorithm for creating a new flight schedule due to the existing and new slots (purchased at secondary slot market) possessed by the airline. In section four the input data used for the model validation are presented. The section five tests the validity of this model and provides the main results. Finally, the section six presents the main conclusions of the work and points out the areas of the future research.

SECONDARY SLOT MARKET

Due to the basic economic theory, every open market leads to the same result; those who possess scarce resources start to use them more efficiently or withdraw and allow others to compete on their behalf. According to this theory, allowing airlines to trade slots legally would create an internal slot market which would, further improve slot mobility and their efficient use.

The secondary slot trading has many advantages such as more efficient use of slots, improved slot mobility, acquiring financial resources, etc. In addition, for airlines with hub-and-spoke (HS) networks, secondary slot trading would be an alternative way for gaining new slots and possibility for concentrating more flights in waves at their hubs. Bearing in mind the characteristic of HS network that the number of potential connections at a hub airport increases exponentially with the increase in the number of markets served from a hub, one can say that concentrating flights at the hub would bring significant benefits for an airline and also a possibility to exploit economy of scope and density (Starkie, 2003). The benefits for passengers would be in greater choice of destinations and more frequencies along existing routes so they could fit better to their request for travelling. For an airline in a competitive market secondary trading can bring positive results, because if flight schedule does not fit to passenger’s requests this could lead to passenger diversion to competition and significant loss in revenue to that airline.

According to the Regulation “slots may be exchanged, one for one, between air carriers”. But, the text of the current Regulation is silent on the question of exchanges with monetary and other consideration to reflect differences in value between slots at different times of day and other factors COM(2008)227.

So far, European airlines traded their slots at the “grey market”, mostly at the airports in Great Britain. The one of the main barrier in the secondary slot market legalisation in EU is certainly the issue of the slot property rights. Although according to the EU slot regulation definition a slot is a permission to the airline to use the airport infrastructure, the recent Commission’s decision in COM(2008)277 to tolerate the secondary trading at EU airports implicitly confirms the slot property fights of the airlines (De Wit, 2008).

The slot prices at this “grey market” were set *ad hoc* through many negotiations between the airlines, direct participants in the trades. In such environment, there are still airlines which are not so comfortable, doubtful about lawfulness of such trading and not confident about the status of the purchased slots, so the secondary slot market in Europe is still limited and slot prices are not being set according to the market rules. As a result the slot prices are often higher and only available for the ″big players″ i.e. to airlines willing to pay those slot prices, (Mott MacDonald, 2006).

Although, there is no general rule for setting slot prices, there are certain factors that have important influence on them: time of the day, perimeter rules, use restrictions, number of slots held, airline regulations, ATC constraints, transport demand, etc. (Gillen, 2006)

There is little information about financial aspects of the trades at secondary markets at airports in Europe and USA, but some price values paid for the slots at those airports are known and their assessment resulted in following conclusions (Gillen, 2006):

- the slot price at Heathrow airport is between £4-6 million and

- the slot price at Washington National airport is around $1 million.

Significant difference in the slot prices at those two markets is a result of absence of legal market in Europe and considerable lower number of transactions at this market comparing with the number of transactions in USA, where secondary slot market exists since 1986 (more then 10 years longer then in Europe).

Legal secondary slot market would lead in a slot prices to be set at demand level and it would be more available to all airlines. In addition, it would be easier for airlines to get all information about slots that can be purchased at the moment and at what price. Furthermore, as pointed out by De Wit (2008), the secondary slot trading at hub airport may contribute to a hub redesign since the opportunity costs of the peak slots will be an extra incentive for the hub airline to redesign the connection waves. This would be very important for strategic planning of an airline.

MODEL AND HEURISTIC ALGORITHM

Assuming that an airline wants to improve its flight schedule by adding new slots to its portfolio (slots purchased at secondary market), the role of the proposed model in this paper would be to enable an airline to calculate if that purchase is profitable. The aim of the model is to create a new flight schedule consisting of all the flights already operated by the airline as well as the flights assigned to new slots, where the airline revenues needs to be maximized and all assumptions and operational constraints must be satisfied. The flights assigned to new slots are chosen from a set of flights *F''* that consists of the destinations not served by an airline. The model calculates a profit of a flight schedule, and the profit difference between the new flight schedule (D_1) and the existing schedule without new slots (D_0) can be considered as the gain or loss (R_D) of adding new slots:

$$R_D = D_1 - D_0 \tag{1.1}$$

The model output is the new flight schedule as well as the number of potential connections that airline could fulfil if introduces the new slot(s). Taking into account that each slot is determined by the time and date, different slots will make different number of potential connections on that airport.

The profit of a flight schedule (D) is determined by mathematical function and calculates the difference between the realized revenues from sold passenger tickets and operational costs, (1.2).

Most of the airlines have more then one fare on their flights, but to cover all the fares that airlines offer to passengers is very complex and sometimes impossible because they do not want to reveal all the fares. This is why it is assumed that are three different fares on each flight i that belongs to set of flight (F) (set of all flights from flight schedule): business fare ($c_1(i)$), economy full fare ($c_{2F}(i)$) and economy discount fare ($c_{2D}(i)$).

Due to the ICAO (International Civil Aviation Organisation) standards, airline costs are divided into the direct operational costs (DOCs) and indirect operational costs (IOCs)[2]. DOC

[2] http://www.icao.int/icao/en/atb/fep/forms.htm

should include all costs attributable to the type of aircraft operated and in the model they are converted into a block-hour direct operating cost (*BHDOC(i,j)*) for each aircraft type *j* that belongs to set of aircraft (*A)* from an airline fleet. IOCs are very hard to measure, so it is assumed that they depend on DOC and the type of flight (1.6), (Gvozdenović ,1995).

$$D=\sum_{i\in F,\, j\in A}\begin{bmatrix}\left(c_1(i)\cdot p_1(i)+c_{2F}(i)\cdot p_{2F}(i)+c_{2D}(i)\cdot p_{2D}(i)\right)-\\-(BHDOC(i,j)+IOC(i,j))\end{bmatrix} \tag{1.2}$$

$$p_{2F}(i)= p_2(i)^*\, \mathrm{P}(Q_i) \tag{1.3}$$

$$p_{2D}(i)= p_2(i)^*\, (1-\mathrm{P}(Q_i)) \tag{1.4}$$

$$IOC(i,j)=cat(j),\ i\in F,\ j\in A \tag{1.5}$$

$$cat(j)=\begin{cases}0.5\cdot BHDOC(i,j), & \text{regional}\\ 0.8\cdot BHDOC(i,j), & \text{continental}\\ 1.0\cdot BHDOC(i,j), & \text{intercontinental}\end{cases},\ i\in F,\ j\in A \tag{1.6}$$

$p_1(i)$ – number of passengers in business class on flight i, $i\in F$

$p_2(i)$ – number of passengers in economy class on flight i, $i\in F$

$p_{2F}(i)$ – number of passengers that paid full fare tickets in economy class on flight i, $i\in F$

$p_{2D}(i)$ – number of passengers that paid discount fare tickets in economy class on flight i, $i\in F$

$P(Q_i)$ – probability that maximum *Q* passengers will pay full price tickets in economy class on flight i, $i\in F$

Each flight *i* from the set of flights *F* is determined with: departure airport (*o(i)*), arrival airport (*d(i)*) (from set of airports *AP*), departure time (*DT(i)*) and arrival time (*AT(i)*).

Additional assumptions and operational constrains are:

1. the new slot is introduced in existing seasonal flight schedule (original flight schedule);
2. it is not allowed that addition of new flights cause any change on flights in original flight schedule;
3. the airline fleet consists of different type of aircraft and each aircraft type is characterized by certain capacity and operational costs;
4. the aircraft from the same type has equal capacity;

5. turnaround time at specific airport is determined for each aircraft type;

6. ferry flights are not allowed in a new flight schedule;

7. there are no spare aircraft in airline fleet;

8. the crew constraints are not considered;

9. the airport working hours must be taken into account – all flights must be realized during this working hours.

The problem of creating a flight schedule is very complex and belongs to decision-making problems. So, it is applied a heuristic algorithm for creating a new flight schedule where the airline revenue needs to be maximized and all assumptions and operational constraints must be satisfied.

The processes in proposed algorithm are divided into three steps: flight selection, aircraft selection, the number of potential connections and estimated pay off period for investment. The corresponding flow chart of the model is presented in Fig. 1.

Flight selection

The first step is for creating new flight schedule i.e. for selecting a flight *i* that is going to be assigned to the new slot. The flight *i* is selected from the set of flights *F''*, which consists of all departure/arrival flights that satisfy the condition: the flight *i* must be between the hub airport of an airline and new destination, not operated by the airline before. For all flights covered by set *F''* the estimated daily passenger demand must be provided.

The estimated revenue per flight from the set of flights *F''* is determined according to the estimated daily passenger demand per flight and estimated average ticket price (1.7).

Assuming that *T* is the departure/arrival time of flight *i* then all the passengers that want to travel in a time period (T-Δt, T+Δt), (Teodorović, 1988), i.e. all the passengers that want to start or finish their trip in this time period, will decide to choose this flight *i*, (1.8). The parameter *T* represents the time of the new slot and *Δt* is passenger attraction period and is defined by a user.

Airport slot is also defined by a location and it is assumed that a new slot is for the airport that is a hub airport for an airline. This is because HS airlines organize its flights into the flight waves at their hubs. Therefore it is assumed that they will improve the quality of service (more connections and frequencies) exactly at these airports. It is, also, possible for an airline to purchase a slot at the airport other then hub and in that case it is assumed that an airline will use that slot for a flight that connects that airport with the airline's hub.

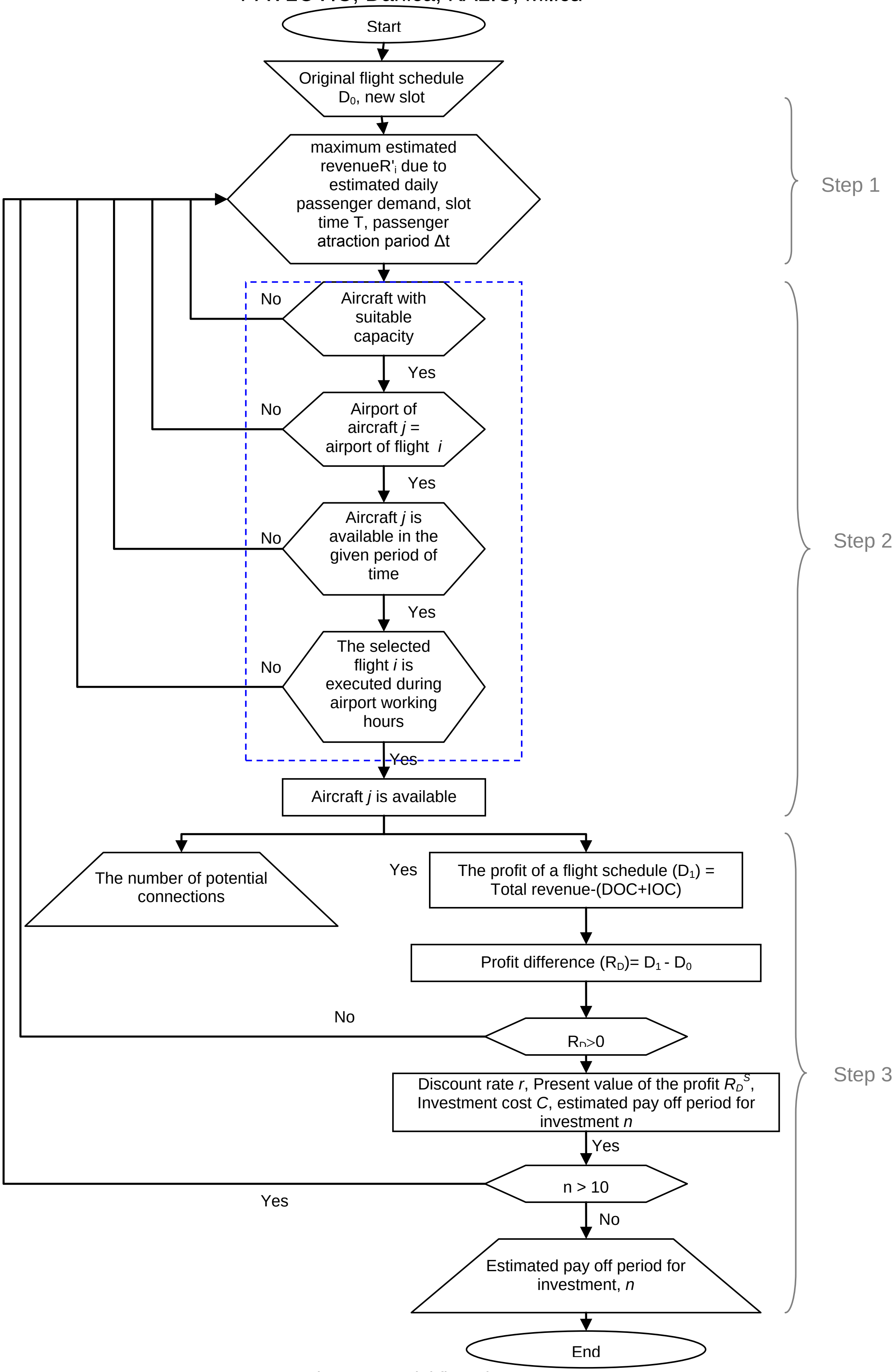

Figure 1. Model flow chart

The potential flight *i* for the new slot is selected according to maximum estimated revenue per flight ($R_i^{'}$) that airline could achieve if flight *i* is introduced into the flight schedule. As mentioned before, the airline revenues are estimated on the basis of the estimated demand for flight *i* (pax_i) (Teodorović, 1988), and the time of departure/arrival slot (*T*):

$$\max R_i^{'} = c_i \cdot pax_i \qquad i \in F'' \qquad (1.7)$$

where $$pax_i = \int_{T-\Delta t}^{T+\Delta t} h_i(T) \partial T \qquad i \in F'' \qquad (1.8)$$

$R_i^{'}$ – estimated revenues per flight *i*, $i \in F''$

c_i – average ticket price on flight i, $i \in F''$

pax_i– estimated number of passengers on flight *i*, $i \in F''$

$h_i(T)$ – passenger demand per unit of time on flight *i*, $i \in F''$

Aircraft selection

If a flight *i* that satisfy all the conditions above exists, the second step comes next where the available and corresponding aircraft is been searched. The criteria for selecting an aircraft from an airline' fleet are the following:

1. The capacity of aircraft *j* must be equal or higher than the estimated number of passengers on the flight *i*, $i \in F''$, $j \in A$[3]. In order to avoid that the aircraft with to high capacity in terms of the estimated number of passengers on the flight *i*, could be selected, the additional constrain is introduced. The formulation of this constrain is that the capacity of aircraft *j* must be equal or lower than estimated number of passengers on the flight *i* increased for 25%, $i \in F''$, $j \in A$, (1.9). This constrain is defined according to the practices of some airlines that tend to change the aircraft categorisation (short, mid and long haul aircraft) once the average load factor on the certain flight reached the 75%, but due to the user preferences this upper bound can be changed.

$$1{,}25 \cdot pax_i \geq cap(atype\ (j)) \geq pax_i \qquad (1.9)$$

A – set of aircraft

TYPE – set of aircraft types

cap(atype (j)) – the capacity of aircraft type *j*, $j \in A$, $atype(j) \in TYPE$

[3] University of Belgrade, Faculty of Transport and Traffic Engineering (2004). Airline Schedule Optimization – Project report

pax_i – estimated number of passengers on flight *i*, $i \in F''$

2. The airport where the aircraft *j* is located and the origin airport of the flight *i* must be the same in the moment of departure of the flight *i*, $i \in F''$, $j \in A$.

3. The aircraft *j* must be available (have no earlier assigned flights) during a time period necessary for preparing an aircraft *j* for flight *i* at airport *k*, for executing flight *i* by aircraft *j* from airport *k* to airport *m*, turnaround time at airport *m*, for return flight *i* by aircraft *j* from airport *m* to airport *k* and turnaround time for next flight at airport *k*, $i \in F''$, $j \in A$, $k \in AP$, $m \in AP$ (*AP* - set of airports):

$$AT_j(z) \le ta(l,k)+t(i,j)+ta(l,m)+t(i,j)+ta(l,k) \le DT_j(w) \tag{1.10}$$

where

$ta(l,k)$ – turnaround time of aircraft *l* at airport *k*, $l \in TYPE$, $k \in AP$

$t(i,j)$ – flight time of flight *i* by aircraft *j*, $i \in F''$, $j \in A$

$AT_j(z)$ - arrival time of flight *z* by aircraft *j*, $z \in F$, $j \in A$

$DT_j(w)$ – departure time of flight *w* by aircraft *j*, $w \in F$, $j \in A$

4. the selected flight *i* for the new slot must be executed during airport working hours:

$$opn(k) \le ta(l,k)+t(i,j)+ta(l,m)+t(i,j)+ta(l,k) \le cls(k) \tag{1.11}$$

$$opn(m) \le ta(l,k)+t(i,j)+ta(l,m)+t(i,j)+ta(l,k) \le cls(m) \tag{1.12}$$

where

$opn(k)$, $opn(m)$ – the start of working hours at airports *k* and *m*, $k, m \in AP$

$cls(k)$, $cls(m)$ – the end of working hours at airports *k* and *m*, $k, m \in AP$

If at least one of the conditions is not satisfied, then the next flight with maximum estimated revenue per flight is selected. If there are more then one aircraft that satisfy the defined conditions above, the aircraft with lower DOC is selected. If still there are more then one aircraft, the aircraft already engaged that day has a priority (increasing utilization) and further, if there are more such aircraft, the one first found is selected because crew constraint is not considered.
If the aircraft *j* that satisfies all the conditions above exists in the airline's fleet, the next step in algorithm is the calculation of the estimated airline's profit using (1.1) that could be realized if the new flight schedule is accepted and the number of potential connections.
If R_D is negative number (instead of profit an airline will gain a loss), then the next flight with maximum estimated revenue per flight would be selected. R_D can be negative number, because the flight *i* is selected by maximum estimated revenue, but if the operational costs of

the assigned aircraft are higher then estimated revenue then the profit of the new flight schedule is lower then the profit of original one and the airline will realize loss.

Number of potential connections

As mentioned before, the additional model output is the number of potential connections that airline could realize if introduces the new slots i.e. the new flight *i*. A connection is a sequence of flights such that for every pair of consecutive flights in the sequence a certain compatibility conditions are satisfied for the pair. The conditions are (Mashford, 2001):

1. The destination of the first flight must equal the origin of the second flight.
2. The departure time of the outgoing flight must be later than the arrival time of the incoming flight.
3. The departure time of the outgoing flight must be no later than the arrival time of the incoming flight plus some margin.

Denote the compatibility condition by Φ. Then Φ may be defined by

$\Phi(i, j)$ =TRUE if

$$\text{destination of flight } i = \text{origin of flight } j \text{ and} \tag{1.13}$$

$$\text{MIN} \leq \text{departure time of flight } j - \text{arrival time of flight } i \leq \text{MAX}, \tag{1.14}$$

$\Phi(i, j)$ =FALSE otherwise,

for $i \in F''$ and $j \in F$ or $i \in F$ and $j \in F''$ depends if the new flight is incoming or outgoing.

Here 0 < MIN < MAX and MIN and MAX are numbers to be determined by the user (an airline). MIN represents the shortest time for passengers to disembark from one aircraft and to board another. This should take into account luggage handling and may allow for a safety margin in case the incoming plane is late. MAX is the longest period that one would want a passenger to wait while still being considered to be forming part of a single connection. The number of potential connections is determined as a set of all flights *i* where $\Phi(i,j)$=TRUE.

Estimated pay off period for investment

The third step in the algorithm is determined by estimation of the number of years necessary to refund the initial outlay for purchasing the new slot. Purchasing a new slot at the secondary market has the characteristics as all other form of investments and it is that all investment costs are in the present while the revenues are expected in the future (an airline can expect the revenue from a new slot i.e. from the flight assigned to it, not until the next season). Also, the revenue in the future is not worth as the same amount of revenue in the present because of existing interest rate and inflation rate that have to be taken into account.

This is why the process of discounting is applied to determine the present value of future revenues.

In this model, the future revenue is actually the estimated profit realized by adding new slot (flight), R_D. The present value of the profit R_D^S, realized after *t* years after the new flight is introduced, is therefore calculated according to the next formula, (Petrović, 1998):

$$R_D^S = \sum_{t=1}^{n} \frac{R_{Dt}}{(1+r)^t} \qquad (1.15)$$

r – the discount rate,

n – number of years,

R_{Dt} - estimated profit realized in the t^{th} year of using the new slot and is given by:

$$R_{Dt} = R_D \cdot N_w \qquad (1.16)$$

N_w – number of weeks in one seasonal flight schedule (summer season has 31 weeks and winter season has 21 weeks)

Due to the selected value of the discount rate, the number of years necessary to refund the initial outlay for purchasing the new slot will vary, and the higher the discount rate is the longer period will be necessary for refunding the outlay and vice versa. The value of the discount rate is also the reflection of the risk level that certain investment has, the higher the discount rate, the higher the risk of investment is. To take into consideration different level of risk, it is chosen four, often used, values of the discount rate in this model and they are: 8%, 12%, 16% and 20%.

According to (1.15) obtained value of R_D^S represents the airline' willingness to pay for a certain slot today, with assumption that that amount will be paid off in the future (for defined period of time). The obtained value of R_D^S is then compared with the slot price *C* and when those two values are equal the pay off period for new slot is determined.

The model is also using a formula (1.17) for internal rate of return (*r*) to determine the discount rate which makes the present value of the revenues exactly equal to the present value of the cost for *n* years (Petrović, 1998):

$$\sum_{t=1}^{n} \frac{R_{Dt}}{(1+r)^t} - C = 0 \qquad (1.17)$$

The obtained value of internal rate of return (*r*) represents the maximum value of discount rate that can provide the investment return for certain period of time.

Having in mind that airline industry is very dynamic, the pay off period longer then 10 years will be to long and it is not going to be accepted. In that case, the process is returned to the step one and the next flight with maximum estimated revenue per flight is selected.

The model is taking into the consideration influence of change in the realized profit per year (R_D). This is because the airline industry is the cyclic in the nature and dependable on the world economic climate. Therefore, five scenarios are defined:

- **Scenario 1 –** the realized profit (R_{Dt}) is decreasing 10% per year.
- **Scenario 2 –** the realized profit (R_{Dt}) is decreasing 5% per year.
- **Scenario 3 –** the realized profit (R_{Dt}) is constant.
- **Scenario 4 –** the realized profit (R_{Dt}) is increasing 5% per year.
- **Scenario 5 –** the realized profit (R_{Dt}) is increasing 10% per year.

INPUT DATA

The model was tested on the real data from one European, mid-sized airline. It is an airline with HS network system, different types of aircraft in the fleet, serving different types of routes (short, mid and long distance), and its hub belongs to coordinated airports.
The data used in the model refers to realized daily flight schedules in June 2006 (from 01.06. to 30.06.). The selected airline follows the pattern of organizing its flights into the flight waves at hub airport and it is shown in Figure 2.
The actual data used for testing the model includes all necessary data that refers to: all flights in the observed period, all aircraft in the airline' fleet, passengers, fares and operational costs.

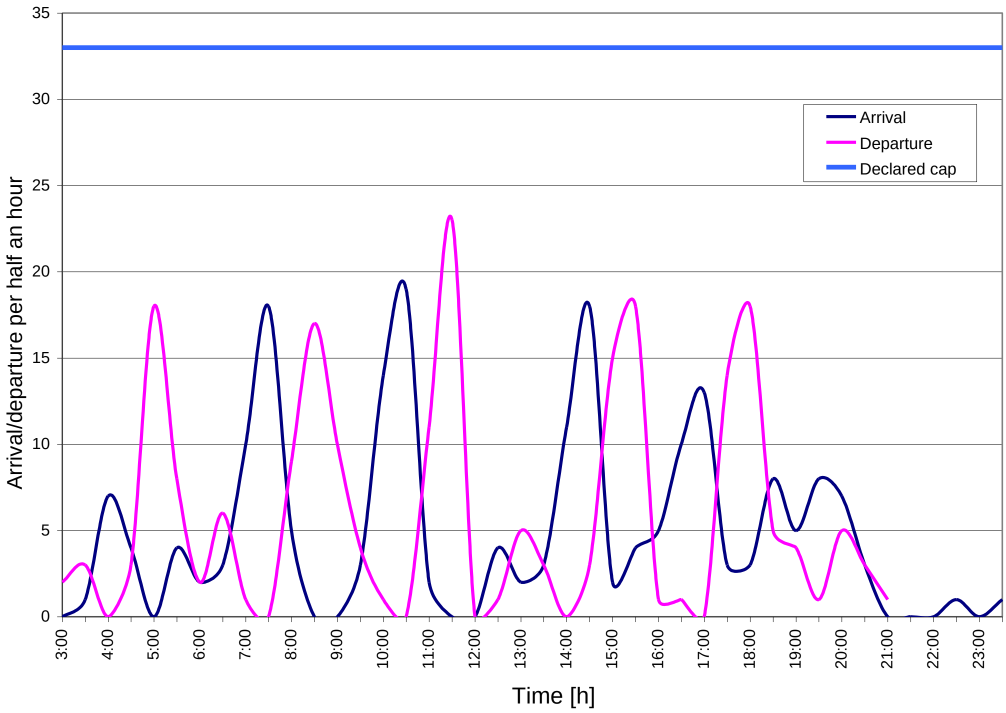

Figure 2. Operation of the network carrier at an coordinated airport during one day period

In case of absence of certain data, additional assumptions would be introduced:

- The full-discount fare ratio in economy class for each aircraft in airline' fleet is determined by author as follows:
    - 20% of seats in economy class are at full price,
    - 80% of seats in economy class are at discount price.
- Passengers are buying tickets at the discount price as long as they are available. When these tickets are sold passengers are starting to buy tickets at the full price.
- The data on scheduled maintenance checks for aircraft were not available. Therefore it is assumed that each aircraft in the airline fleet is available during the observed period.

As noted earlier, the average slot price at airports in USA is around $1 million and at Heathrow airport is between €4-6 million. If secondary slot trading in Europe becomes legal, one can expect that slot prices would decrease as a result of increased supply and demand for slots. But what the real price of a slot at the secondary market is going to be is hard to predict, because the legalisation of the market is not the only factor that influence it.
However, one of the input data for the proposed model is the slot price as an initial investment cost, *C*. For that purpose it is assumed that minimum slot price will be €1 million and maximum slot price is determined by the airline' maximum willingness to pay in observed period.

COMPUTATIONAL RESULTS AND ANALYSIS

<u>The purchased slot at secondary market is for the hub airport of the airline. It is departure slot at 11^{30}h for a date 01.06.</u>
The original flight schedule is determined by a slot date and it is a daily flight schedule for Thursday on 01.06.2006. The original flight schedule consists of 488 flights, scheduled and charter, and for their realization it is used 95 aircraft from the airline fleet. The realized profit of the original flight schedule is calculated using (1.2) and equals to:

D_0 = 1,107,184.00 €

The selection of a flight *i* for the new slot is done from the set of flights *F''* that includes all departure flights at the hub airport to new destinations, not operated by the airline earlier. Selected new destinations and corresponding estimated demands are provided by the Department of the network development.
The passenger attraction period is Δt = ±90 min regards to 11^{30} h, that is in total 3 hours and covers the time period between the end of the second departure wave and the beginning of the forth departure wave, (Figure 2).
Using (1.8) it is determined the estimated number of passengers that want to travel from the hub airport to any given destination from *F''* in the observed time period. The obtained flight *i*

with maximum estimated revenue R_i according to (1.7) is the flight from hub airport to Liverpool airport (LPL) and equals to:

$R_{HUB-LPL}$=26,459.00 €

The estimated revenue $R_{HUB-LPL}$ is calculated due to the estimated number of passengers from hub airport to the LPL, $pax_{HUB-LPL}$=96 and estimated average price ticket on this flight, $c_{HUB-LPL}$=276.00 €.
The revenue for the flight in opposite direction is also estimated according to (1.7) and (1.8) and equals to:

$R_{LPL-HUB}$=22,356.00 €

The estimated number of passengers in opposite direction is $pax_{LPL-HUB}$=81
The aircraft for chosen flights needs to satisfy following conditions: cabin capacity for at least 96 passengers (estimated passenger number), but no higher then 125 (the chosen upper bound is 30% of estimated number of passengers, to cover all the aircraft for short haul routes), the aircraft must be located at the hub airport at 10^{45} h and has no assigned flights in the time period between 10^{45} h and 17^{04} h. The aircraft that satisfies all the conditions from above is an aircraft Fokker 100 with registration number XXLVE.
The realized profit of the new flight schedule is calculated and equals to:

D_1 = 1,129,087.00 €

If the new flight schedule is accepted, the gain for an airline per year is obtained using (1.1) and (1.16) and equals to:

R_D = 21,903.00 € (per week) and

R_{Dt} = 658,509.50 € (per year)

The number of connections that can be achieved introducing the new flight HUB-LPL is 36. This number represents the total number of flights that are arriving to the hub airport in time period from 09^{00} h (the beginning of the third arrival wave) till 11^{05} h (25 min is minimum connecting time at the hub airport).
The estimated profit per year, R_{Dt}, is further used in (1.15) for calculating the present value of the profit R_D^S for different values of the discount rate and for each scenario. The obtained values of the present value of the profit for different periods are presented in the following Figures 3-7. Those values actually reflect the airline's willingness to pay for those slots today, with assumption that such amount would be paid off in the determined period of time. Prolonging the pay off period, the airline's willingness to pay increases, but with descending rate, except when the annual profit increases 10% and discount rate is 8%, Figure 7.
As mentioned above, it is assumed that the minimum slot price will be €1 million and in that case, the initial investment cost, C, is than equal to the price of the slot (presented with the red line on Figure 3-7). If now this value of the total investment cost is compared with the airline' willingness to pay for each pay off period the following conclusions can be drawn:

- **Scenario 1:** if estimated profit per year is decreasing 10% annually, the airline' willingness to pay €1 million for this slot would reach this amount in the 3rd year from the moment of investment, while the discount rate is no higher then 20%, Figure 3. For lower values of discount rate this amount of €1 million would be reached earlier, e.i. if discount rate is 8% the airline would be willing to pay €1 million for this slot in the 2nd year from the moment of investment. The obtained value for the airline' maximum willingness to pay for this slot, in observed period of 10 years, is about €3.1 million, at discount rate of 8%.

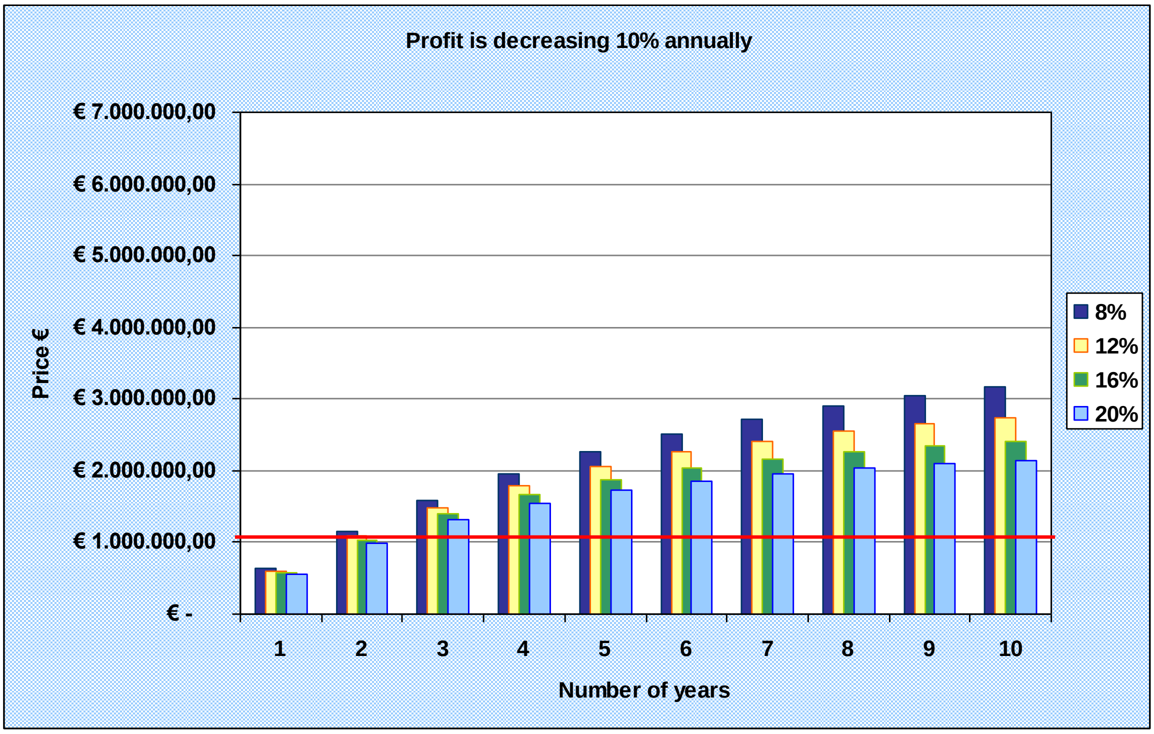

Figure 3. Scenario 1: The present value of profit at different values of discount rate

- **Scenario 2:** if estimated profit per year is decreasing 5% annually, the airline would be willing to pay €1 million for this slot in the 2nd year from the moment of investment, while the discount rate is up to 20%, Figure 4. The airline's maximum willingness to pay for this slot, in observed period of 10 years, is more then €3.7 million, at discount rate of 8%.

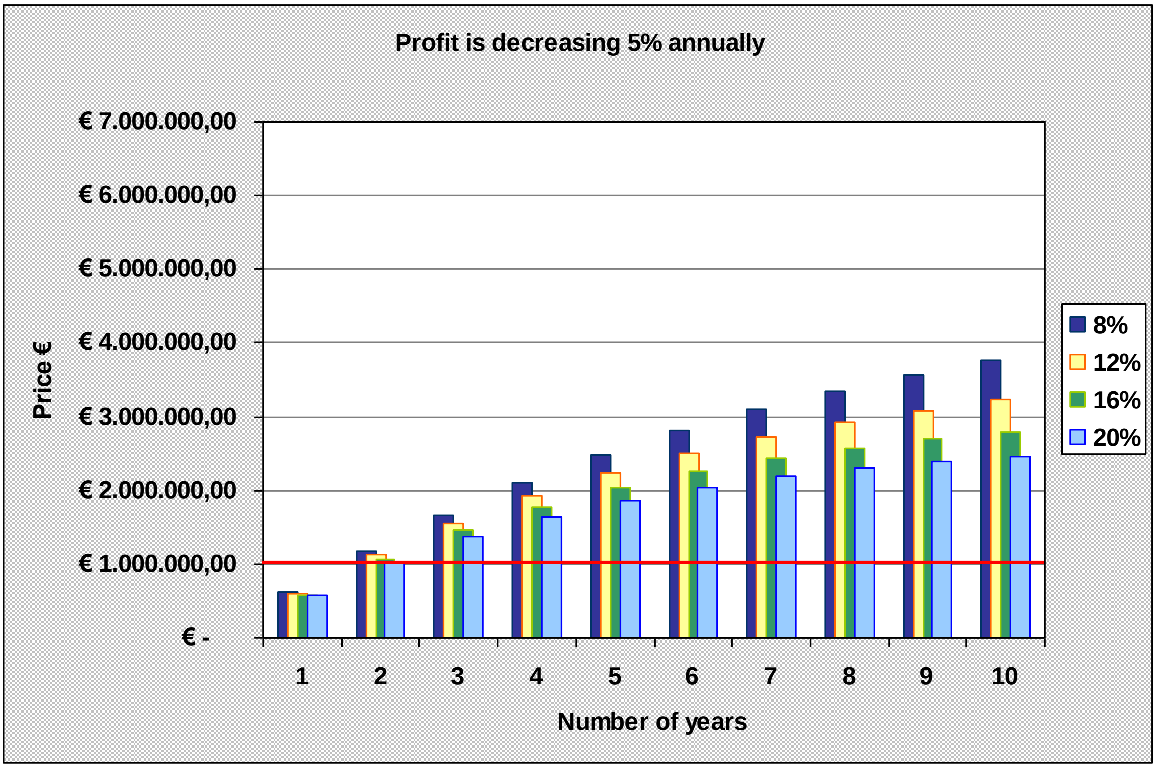

Figure 4. Scenario 2: The present value of profit at different values of discount rate

- **Scenario 3:** if estimated profit per year is constant, the airline's willingness to pay €1 million for this slot would reach this amount in the 2nd year from the moment of investment, while the discount rate is no higher then 20%, Figure 5. The airline's maximum willingness to pay for this slot, in observed period of 10 years, is about €4.5 million, at discount rate of 8%.

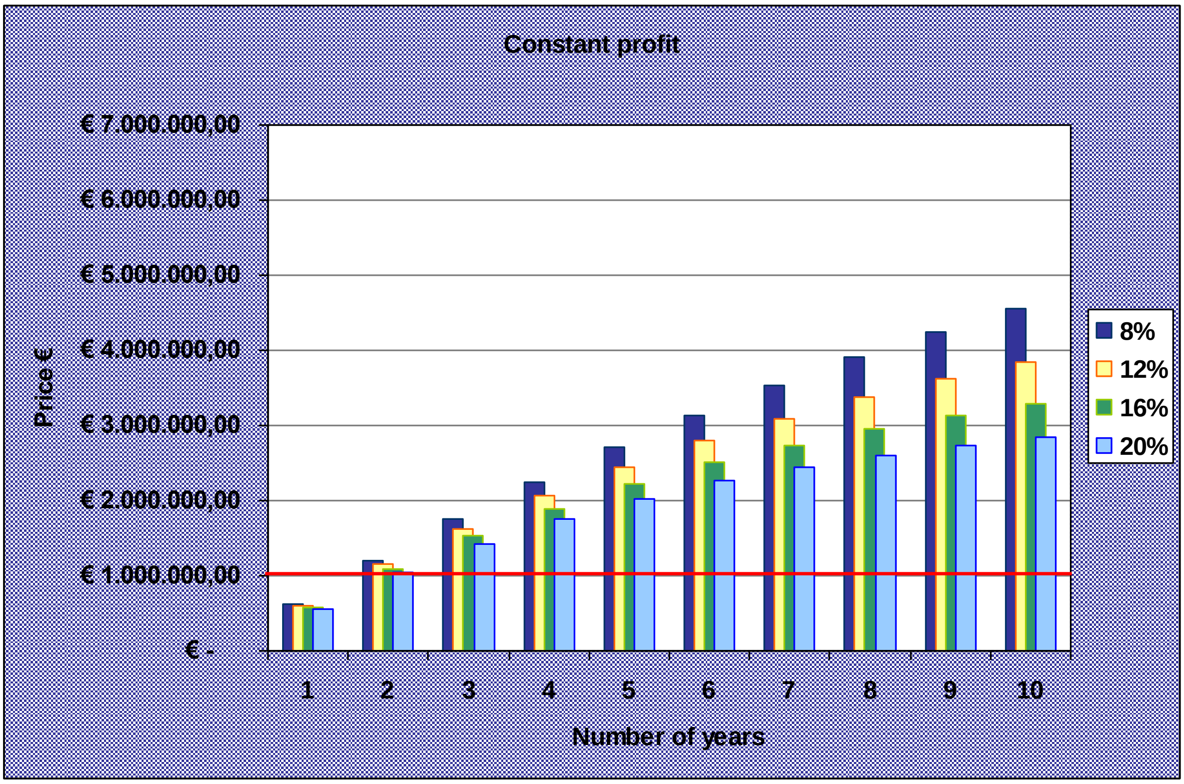

Figure 5. Scenario 3: The present value of profit at different values of discount rate

- **Scenario 4:** if estimated profit per year is increasing 5% annually, the airline would be willing to pay €1 million for this slot in the 2nd year from the moment of investment, while the discount rate is up to 20%, Figure 6. The airline's maximum willingness to pay for this slot, in observed period of 10 years, is about €5.5 million, at discount rate of 8%.

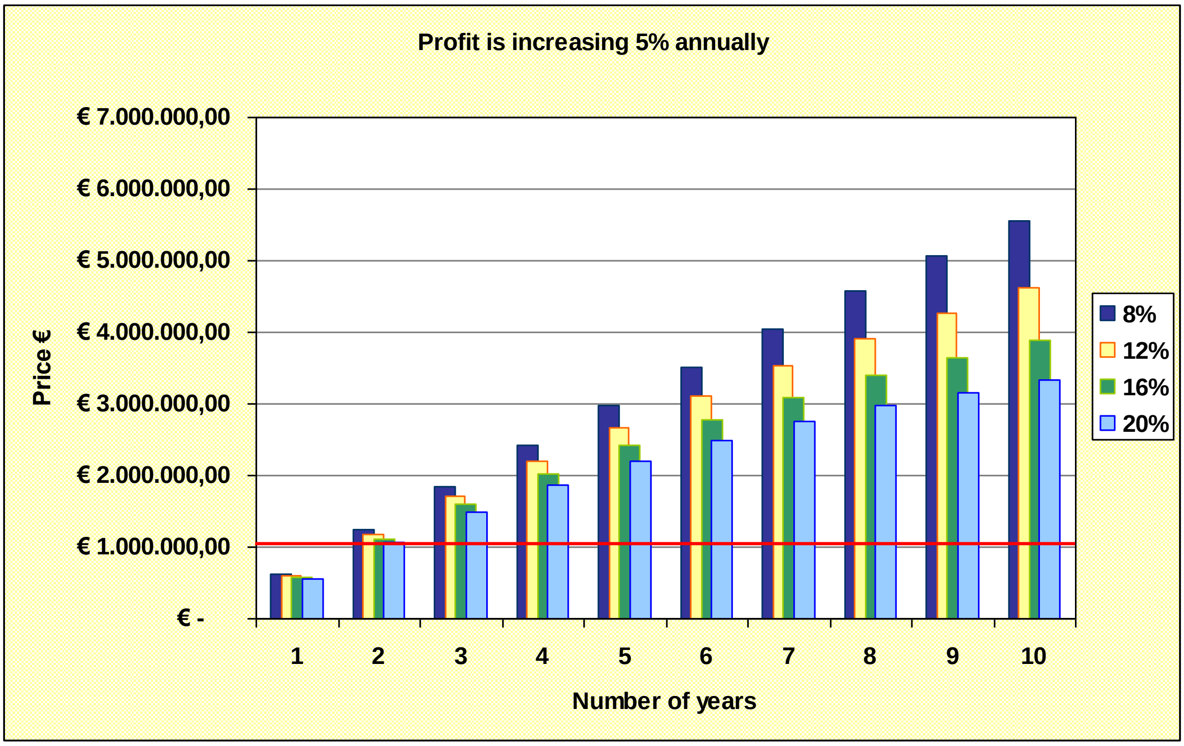

Figure 6. Scenario 4: The present value of profit at different values of discount rate

- **Scenario 5:** if estimated profit per year is increasing 10% annually, the airline's willingness to pay €1 million for this slot would reach this amount in the 2nd year from the moment of investment, while discount rate is up to 20%, Figure 7. The airline's maximum willingness to pay for this slot, in observed period of 10 years, is about €6.8 million, at discount rate of 8%.

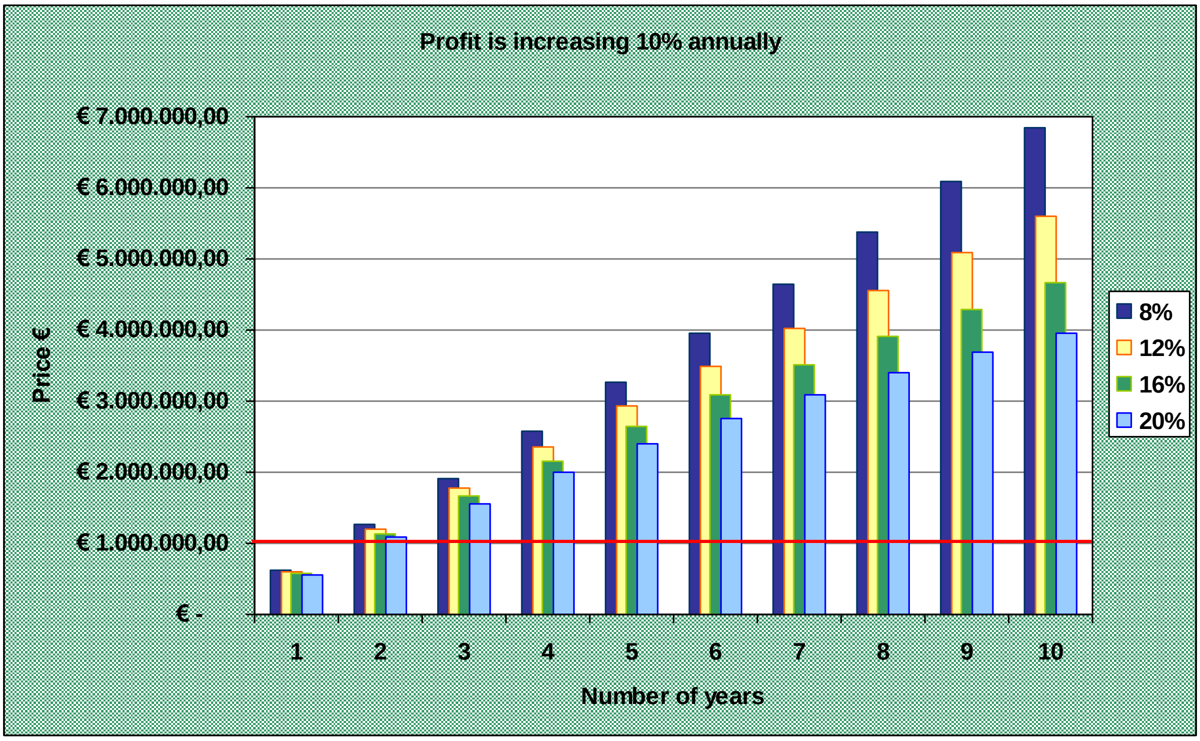

Figure 7. Scenario 5: The present value of profit at different values of discount rate

According to the results presented above, one can conclude that the maximum price that this airline is willing to pay for a slot at the hub airport for this flight is about €6.8 million, in determined period of ten years. If the slot price at secondary market is equal or lower then this value, there would be the feasible solution proposed by the model. In opposite, if the slot price at secondary market is higher then this value, the selected flights would be rejected, the process is returned to the step one and the next flight with maximum estimated revenue per flight is selected.

Analyzing the present value of profit, it can be concluded that the present value of profit has low sensitivity regarding to the different values of the discount rate. Namely, in the observed period of ten years, if the discount rate is increased by 50% (e.i. from 8% to 12%) the present value of profit will decrease by no more then 18%, for all scenarios.

However, the present value of profit has very high sensitivity regards to the different trends of the profit. In other words, if profit increases 10% annually, the present value of the profit would be 50% higher regards to the present value of profit in the case when the annual profit is constant, all for the period of ten years. When the profit trend is negative, annual decrease in profit by 10% would result in up to 30% decrease in the present value of profit for ten years, regards to the present value of profit in the case when the annual profit is constant. All the values described above are for the case when discount rate is 8%. Increasing the value of discount rate, the influence of the profit trend on the present value of profit is decreasing.

Analyzing results, in all scenarios the pay off period is two years from the moment of investment, for discount rate up to 16%. Therefore this period of time is further used in (1.17) to determine the internal rate of return for each scenario, i.e. to determine the discount rate for each scenario that makes the present value of the profit R_D^S equals to the investment cost *C.* According to (1.17), the determined internal rates of return are:

- Scenario 1: **19.18%**
- Scenario 2: **21.14%**
- Scenario 3: **23.07%**
- Scenario 4: **24.96%**
- Scenario 5: **26.80%**

The determined internal rates of return for each scenario represent the maximum values of discount rates that could provide the investment return for given period of time, i.e. for two years. If the discount rate is lower than the determined internal rates of return, the present value of the profit will be higher than investment cost for the period of two years and vice versa.

CONCLUSION

The economic expansion and market liberalization worldwide initiated intensely increasing demand for air transport that resulted in the large number of airports to be faced with excessive demand. Today it is necessary for an airline to possess an airport slots if wants to operate at certain airports. Therefore, the quality of service of an airline in a sense of number of routes and frequencies will depend on the allocation of slots at congested airports. Due to the limited possibilities that current slot allocation system offers, the legal secondary slot market enables the airlines to get additional slots for improving their networks and flight schedules. For airlines with HS networks, that would be an alternative way for gaining new slots and possibility for concentrating more flights in waves at their hubs i.e. improving flight waves according to lower connecting time and increased number of transfer passengers.

The model and algorithm presented in this paper are developed with the goal to create a new flight schedule that consists of all flights already operated by the airline as well as the flights assigned to new slots (purchased at secondary market), where the airline revenue needs to be maximized while all assumptions and operational constraints must be satisfied. The model outputs are the new flight schedule, the number of years necessary to refund the initial outlay for purchasing the new slots and the number of potential connections that airline could realize if introduces the new slots. The proposed solutions by the model are feasible according to aircraft availability for new flights, to realized profit for an airline and finally, to acceptable pay off period for purchased slots.

The proposed model is applicable on all airlines, but the most useful for the airlines with HS network systems and financially weaker airlines that do not want to take to many risks. Also, it would be useful to small and mid-sized airlines that want to enter the new markets or to strengthen their position at the existing markets. This type of decision-making model would be very useful in improving the airline strategic planning. This would enable an airline to do some quick and inexpensive examinations if buying new slots is profitable or not.

FURTHER RESEARCH

The proposed model covers only limited number of factors and constrains that have influence on the flight selection for the new slot, but it is planned to extend the model in the future research. Among other factors, the net effects of new flight introduction and the influence on the competition. Net environmental impacts could be modelled, too, if new services are operated airline cost of additional CO_2 and NO_x could be estimated. Also, in the proposed model it is assumed that adding new flights could not cause any change on flights in original flight schedule. This is not the case in the practice where some changes are allowed in the purpose of flight schedule optimisation. Therefore some improvements of the proposed model are possible in this segment, too.

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