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Modelling the estimation of the airline profit in case of purchasing new slots for increasing flight frequency

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Abstract

To achieve network optimization, most airlines depend on slot allocation process. The secondary slot market enables airlines to get additional slots for improving their networks and flight schedules. The idea of developing the model presented in this paper was not just to help in selecting the flight(s) for new slot(s) that maximizes the airline's revenue, but to estimating the number of years necessary for refunding the initial outlay for purchasing that slot. The essence of the model is to help an airline to check if the purchasing of new slot(s) is profitable or not in the case when new slot(s) is used for increasing the flight frequency on existing route.

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

1. Introduction

The increased number of congested airports worldwide 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 the 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 possesses certain slot has right to operate at that airport at that time. 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.

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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 is an important market entry barrier and as such protects incumbents from competition (De Wit & Burghouwt, 2008).

So they support the idea of introducing the market mechanisms (secondary slot trading[2]) that would be based on airline's willingness to pay for slots (Mott MacDonald & European Commission, 2006). 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 the airline revenue loss, resulted by incapability of meeting passengers' requests.

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 into the waves[3] at their hubs. By doing this, an airline will want to contribute to hub strength in terms of share of slots, departures and destinations served, as well as achieving high levels of network connectivity (the number and quality of connections offered). According to the Burghouwt and Wit (2005) the trend towards increasing temporal concentration is detected i.e. the major European airlines have followed this strategy and implemented the wave-system structures at their major hubs.

Bearing in mind 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 temporal and spatial concentration of traffic would bring significant benefits for an airline and also a possibility to exploit economy of scope and density, as well as high station resource utilization, premium yields from local traffic, local marketing strength and, at slot-constrained airports, protection behind a significant structural barrier to entry (Starkie et al., 2003).

In liberalized and deregulated competitive environments, networks and flight schedules are more dynamic than they were when the market was regulated. Rapidly changing competitive environments demand tactical responses, increases or reductions in frequencies, the rerouting of services in particular origin and destination markets, and the introduction or withdrawal of routes. For many airlines, frequency domination is a key scheduling objective, particularly in business segment. The more frequencies an airline offers in a given market, the greater is the possibility that the timing of one of its departures will be close to when a potential passenger wants to travel (Holloway, 2003). In some markets the influence of small differences in departure times on consumer behaviour has provided powerful incentives for airlines to increase frequencies (Crandall, 1995). Cao and Kanafani (2000) analyzed the relationship between rescheduling of flights and airline profit. They proposed a minimum-cost flow model that gives a new optimal schedule under conditions of rescheduling specific flights at specific time slots and therefore calculating the value of specific time slot at specific airport runway. Pavlovic and Kalic (2010) proposed the model for estimating the airline's willingness to pay for a new slot(s) to improve the flight schedule in the case of opening new route and the following research is the extension of this work.

If an airline wants to improve its flight schedule adding new slots in its portfolio (the slots purchased at secondary market), the role of the proposed model in this paper would be to enable an airline to investigate if that investment is profitable. The proposed model designs a new flight schedule with additional flights assigned to the new slots, but with constrain to build frequencies on existing routes. The additional flights are chosen according to the potential revenue, aircraft availability, operating costs and period of return the investment.

The following 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. Section 3 presents the data used for the model verification. Section 4 provides the main results of experiment (numerical example). Finally, Section 5 presents the main conclusions and points out the areas of the future research.

2. Model and Heuristic Algorithm

An airline's network is the main product offered to the customers and, along with the flight schedule they are the main revenue and cost drivers. Assuming that an airline wants to improve its flight schedule by adding new slots to

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[2] Legal secondary slot market exists at USA airports since 1986. At the European airports secondary slot market became legal in 2008, before that it functioned as "grey" market.

[3] The flight waves describe groups of aircraft that are scheduled to arrive at a hub and then depart again within a given period of time, so allowing passengers to make any of large number of connections.

its portfolio (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 (Pavlovic, 2009). 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. All flights assigned to new slots are chosen from the set of flights *F'* that consists of the destinations served by an airline. The model calculates a profit of the flight schedule. 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, (1):

$$R_D = D_1 - D_0 \tag{1}$$

The model output is the new flight schedule, the number of potential connections induced by new flight and pay-off period for the 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*) in this paper is mathematically defined by (2) and represents the difference between the revenue from sold passenger tickets and costs. Most airlines have more then one fare on their flights, but to cover all the fares that an airline offers in the market is very complex and sometimes impossible because they do not want to reveal all the fares. This is why it is assumed that there are three different fares on each flight *i* that belongs to the set of flight *F* (the set of all flights from flight schedule): the business fare ($c_1(i)$), the economy full fare ($c_{2F}(i)$) and the economy discount fare ($c_{2D}(i)$). Due to the ICAO (International Civil Aviation Organisation) standards, airline costs are classified into the direct operational costs (DOCs) and indirect operational costs (IOCs). DOC 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 flight *i* and each aircraft type *j* that belongs to the set of aircraft (*A)* from an airline fleet. IOCs are very hard to measure, so it is assumed that they depend on DOCs and the type of flight, (Gvozdenovic, 1995) and expressed by (5) and (6).

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

$$p_{2F}(i) = p_2(i) * P(Q_i) \tag{3}$$

$$p_{2D}(i) = p_2(i) * (1 - P(Q_i)) \tag{4}$$

$$IOC(i,j) = cat(j),\ i \in F,\ j \in A \tag{5}$$

$$cat(j) = \begin{cases} 0.5 \cdot BHDOC(i,j), & \text{regional} \\ 0.8 \cdot BHDOC(i,j), & \text{continental} \\ 1.0 \cdot BHDOC(i,j), & \text{intercontinental} \end{cases} \quad ,\ i \in F,\ j \in A \tag{6}$$

Where: $p_1(i)$ – number of passengers in the business class on the flight i, $i \in F$, $p_2(i)$ – number of passengers in the economy class on the flight i, $i \in F$, $p_{2F}(i)$ – number of passengers that paid full fare ticket in the economy class on the flight i, $i \in F$, $p_{2D}(i)$ – number of passengers that paid discount fare ticket in the economy class on the flight i, $i \in F$, $P(Q_i)$ – probability that maximum *Q* passengers will pay full fare ticket in the economy class on the flight i, $i \in F$.

Each flight *i* from the set of flights *F* is determined with: origin airport (*o(i)*), destination airport (*d(i)*) (from the 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 adding new flights cause any change on the flights in the original flight schedule; 3) in the period $\pm \Delta t$ (determined by a user) it is not allowed existence of the same flight in the daily flight schedule as selected one for the new slot; 4) the airline fleet consists of different types of aircraft and each aircraft type is characterized by certain capacity and operational costs; the aircraft of the same type have equal capacity; 5) the aircraft turnaround time depends on the aircraft type and the airport where the turnaround occurs; 6) ferry flights (flights with no passengers) are not allowed in the new flight schedule; 7) there are no spare aircraft in the fleet; 8) the airport working hours must be taken into account – all flights must be realized during these working hours.

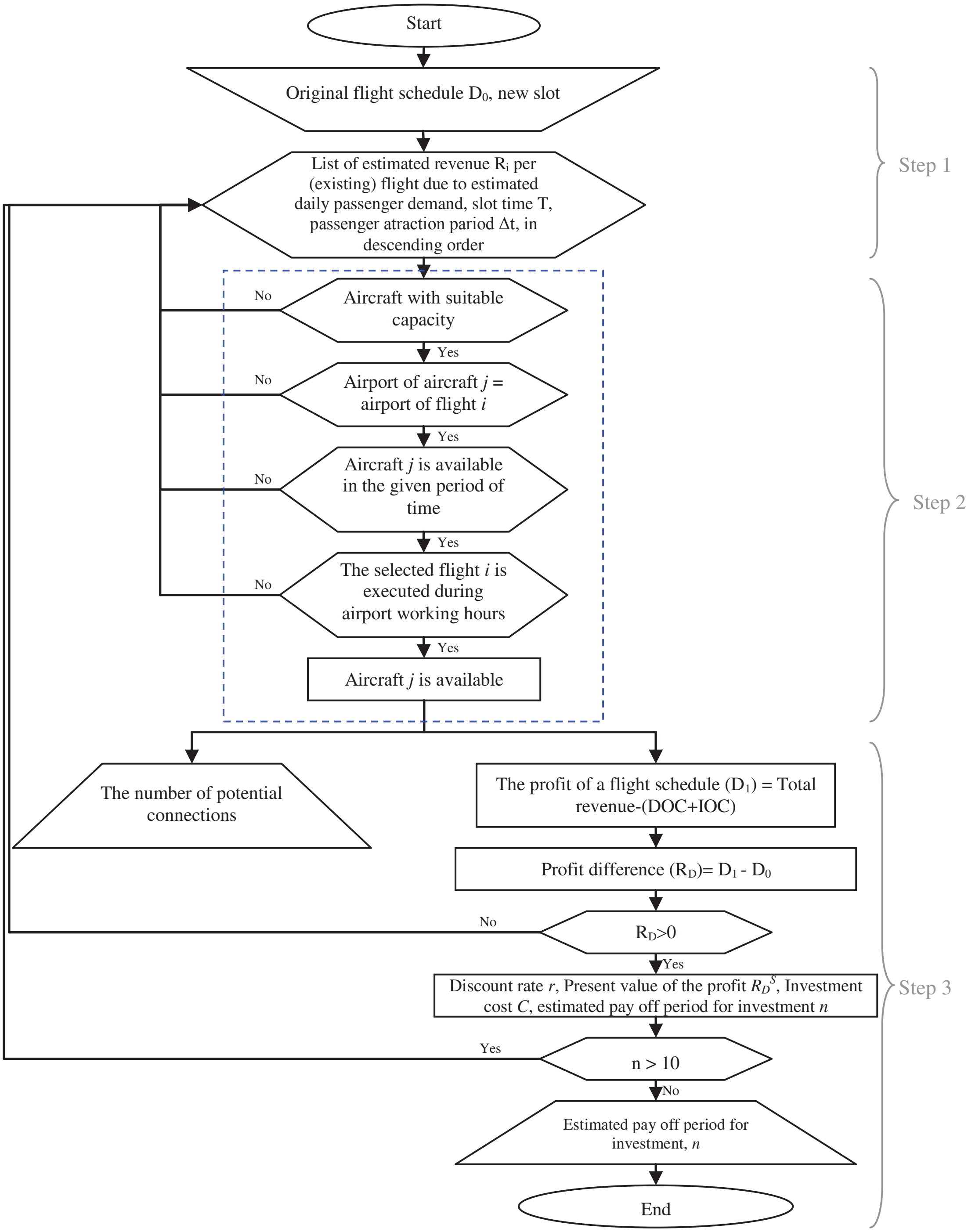

Figure 1 Model flow chart

Due to the complexity in the flight schedule designing and the nature of the defined problem, the heuristic algorithm is applied. The proposed heuristic algorithm consists of three steps: flight selection, aircraft type selection and calculation of estimated pay off period for investment. The corresponding model flow chart is presented in Figure 1.

2.1. Flight selection

The first step is for designing a new flight schedule i.e. for selecting the flight *i* that is going to be assigned to the new slot. Each airport slot is defined by certain time of the day therefore the first criterion for selecting the flight *i* is determined by that time. The flight *i* is selected from the set of flights *F'* ($F' \in F$) which consists of all departure/arrival flights (depends if it is departure/arrival slot) already operated by an airline in the same day as the slot day. The estimated revenue per each flight from the set of flights *F'* is determined according to the estimated daily passenger demand per flight *i* and ticket fares per classes (7). Assuming that *T* is the departure/arrival slot time of the flight *i* then all the passengers that want to travel in the 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*, (9). The parameter *T* represents the time of the new slot and *Δt* is the passenger attraction period and is defined by a user.

An airport slot is also defined by the location and it is assumed that a new slot is for an airport that is the 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 (spatial concentration).

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 the flight that connects that airport with the airline's hub.

When the set of flights *F'* is determined by the time and location, the potential flight *i* for the new slot is selected according to the maximum estimated revenue per flight (R_i) that airline could realize if the flight *i* is introduced into the flight schedule. The airline revenue is estimated due to the estimated demand for the flight *i* (pax_i) and the time of departure/arrival slot (*T*):

$$\max R_i = c_1(i) \cdot p_1^*(i) + c_{2F}(i) \cdot p_{2F}^*(i) + c_{2D}(i) \cdot p_{2D}^*(i) \quad (7)$$

where $$p_1^*(i) + p_{2F}^*(i) + p_{2D}^*(i) = pax_i \quad (8)$$

and $$pax_i = \int_{T-\Delta t}^{T+\Delta t} h_i(T) \partial T \quad (9)$$

$$p_1^*(i) = P(W_i) \cdot pax_i \quad (10)$$

$$p_2^*(i) = p_{2F}^* + p_{2D}^* \quad (11)$$

$$p^*2F(i) = p^*2(i) \cdot P(Qi) \quad (12)$$

$$p^*2D(i) = p^*2(i) \cdot (1-P(Qi)) \quad (13)$$

Where: $p^*_1(i)$ – the estimated number of passengers in the business class on the flight i, $i \in F'$, $p^*_2(i)$ – the estimated number of passengers in the economy class on the flight i, $i \in F'$, $p^*_{2F}(i)$ – the estimated number of passengers that paid full fare ticket in the economy class on the flight i, $i \in F'$, $p^*_{2D}(i)$ – the estimated number of passengers that paid discount fare ticket in the economy class on the flight i, $i \in F'$, $P(W_i)$ – the probability that maximum *W* passengers will buy tickets in the business class on the flight i, $i \in F'$, $h_i(T)$ – the passenger demand per unit of time on the flight i, $i \in F'$.

Due to the constraint (3), the selected flight must satisfy the following conditions:

$$i^* = max(R_i),\ i \in F' \quad (14)$$

$$o(i^*) = o(j), \qquad i^* \in F',\ j \in F \quad (15)$$

$$d(i^*) = d(j), \qquad i^* \in F',\ j \in F \quad (16)$$

$$DT(j) + \Delta T \le DT(i^*)$$

$$DT(i^*) \le DT(j) - \Delta T, \qquad i^* \in F',\ j \in F \quad (17)$$

If this conditions are not satisfied by the selected flight i, then the next flight with the maximum estimated revenue per flight is selected.

2.2. Aircraft selection

If flight i that satisfies all constrains above exists, in the second step the available and corresponding aircraft type 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, $i \in F'$, $j \in A$. In order to avoid that the aircraft with to high capacity regards to the estimated number of passengers on the flight i, could be selected, the additional constrain is introduced, that the capacity of the aircraft j must be equal or lower than the estimated number of passengers on the flight i increased by 25%, $i \in F'$, $j \in A$, (18). 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.

$$1.25 \cdot pax_i \geq cap(atype\,(j)) \geq pax_i \qquad (18)$$

A – the set of aircraft, $TYPE$ – the set of aircraft types, $cap(atype(j))$ – the capacity of aircraft type j, $j \in A$, $atype(j) \in TYPE$, pax_i – the 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 (i.e. has no earlier assigned flights) during a time period that is a sum of the time periods necessary for preparing the aircraft j for the flight i at the airport k, for executing the flight i by the aircraft j from the airport k to the airport m, turnaround time at the airport m, for return flight i by the aircraft j from the airport m to the airport k and turnaround time for the next flight at the airport k, $i \in F'$, $j \in A$, $k \in AP$, $m \in AP$ (AP - the set of airports):

$$AT_j(z) \leq ta(l,k)+t(i,j)+ta(l,m)+t(i,j)+ ta(l,k) \leq DT_j(w) \qquad (19)$$

where $ta(l,k)$ – the turnaround time of the aircraft l at the airport k, $l \in TYPE$, $k \in AP$
$t(i,j)$ – the flight time of the flight i by the aircraft j, $i \in F'$, $j \in A$
$AT_j(z)$ - the arrival time of the flight z by the aircraft j, $z \in F$, $j \in A$
$DT_j(w)$ – the departure time of the flight w by the aircraft j, $w \in F$, $j \in A$

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

$$opn(k) \leq ta(l,k)+t(i,j)+ta(l,m)+t(i,j)+ ta(l,k) \leq cls(k) \qquad (20)$$

$$opn(m) \leq ta(l,k)+t(i,j)+ta(l,m)+t(i,j)+ ta(l,k) \leq cls(m) \qquad (21)$$

where $opn(k)$, $opn(m)$ – the start of working hours at the airports k and m, $k, m \in AP$
$cls(k)$, $cls(m)$ – the end of working hours at the 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 DOCs 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. If R_D is negative number then the next flight with the maximum estimated revenue per flight would be selected. R_D can be negative number, because the flight i is selected by the maximum estimated revenue, but if the operational costs of the assigned aircraft are higher then the estimated revenue then the profit of the new flight schedule is lower then the profit of original one and the airline will realize loss.

2.3. Number of potential connections

An additional model output is the number of potential connections that airline could realize if introduces the new slot 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 & Marksjo, 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 $\Phi(i,j)$. Then $\Phi(i,j)$ may be defined by

Φ(i ,j) =TRUE if

destination of flight i = origin of flight j and *(22)*

MIN ≤ departure time of flight j − arrival time of flight i ≤ MAX, *(23)*

Φ(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. 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 Φ(i,j)=TRUE.

2.4. Estimated pay off period for investment

If an aircraft that satisfies all the conditions, mentioned earlier, exists in the airline's fleet the next step in the algorithm is the 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 forms of the investments and that is: all investment costs are in the present while the revenues are expected in the future (an airline can expect the revenue from the new slot i.e. from the flight assigned to it, not until the next season) and the revenue in the future is not worth as the same amount of revenue in the present because of the existing interest rate and the inflation rate. This is why the process of discounting is applied to determine the present value of future revenues.

$$R_D^S = \sum_{t=1}^{n} \frac{R_{Dt}}{(1+r)^t} \qquad (24)$$

r – the discount rate, n – the number of years, R_{Dt} - the estimated profit realized in the t^{th} year of using the new slot and is given by:

$$R_{Dt} = R_D \cdot N_w \qquad (25)$$

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

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 (24) 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 equation (26) which determines the internal rate of return (r), i.e. the discount rate which makes the present value of the revenues exactly equal to the present value of the cost for n years:

$$\sum_{t=1}^{n}\frac{R_{Dt}}{(1+r)^{t}}-C=0 \tag{26}$$

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 expressed in years. Having in mind that the 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 this model. In that case, the process is returned to the step one and the next flight with the 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.

3. Input Data

The model was tested on the real data from one European, mid-sized airline. Because of the data confidentiality the name of the airline and the registration numbers of the aircraft will not be used. It is an airline with the HS network system, with different types of aircraft in the fleet, serving all types of routes and its hub belongs to the coordinated airports. The selected airline follows the pattern of organizing its flights into the flight waves at the hub airport. The actual data received from the airline and used for testing the model are from the year 2006 and includes all necessary data that refers to: all flights in the observed period (the detailed daily flight schedule), all aircraft in the airline's fleet, and the number of passengers on the flights, as well as ticket fares and aircraft operational costs (cost per minute of flight). The daily passenger demand on each flight from the flight schedule was determined according to the historical data that covers three consecutively months, also received from the airline. The daily demand is determined separately for business and for economy class.

One of the input data for the proposed model is the slot price as an initial investment cost, C. The slot prices at the existing secondary slot market were set *ad hoc* through many negotiations between the airlines, direct participants in the trades. There is a 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): (1) the slot price at Heathrow airport is between £4-6 million and (before legalisation); (2) the slot price at Washington National airport is around $1 million. For the purpose of the verification it is assumed that the minimum slot price will be €1 million and the maximum slot price will be determined by the airline's maximum willingness to pay in the observed period.

4. Computational Results and Analysis

The purchased slot at the secondary market is for the hub airport of the airline. It is departure slot at 08:10 AM for the date 01.06. The original flight schedule is determined by the slot date and it is a daily flight schedule for Thursday on 01.06.2006. The realized profit of the original flight schedule is calculated using (2) and equals to D_0 = 1,107,184.25 €.

The selection of the flight i for the new slot is done from the set of flights F' that includes all departure flights at the hub airport in that day (charter flights are left out). The passenger attraction period is $\Delta t = \pm 120$ min regards to 08:10 AM, that is in total 4 hours and covers the time period between the end of the first departure wave and the beginning of the third departure wave. Using (9) 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 the maximum estimated revenue R_i according to (7) is the flight from the hub airport to Frankfurt airport (FRA) and equals to $R_{HUB\text{-}FRA}$=22,987.00 €. The estimated revenue $R_{HUB\text{-}FRA}$ is calculated due to the estimated number of passengers from the hub airport to the FRA, $pax_{HUB\text{-}FRA}$=99. The revenue for the flight in opposite direction is also estimated according to (7) and (9) and equals to $R_{FRA\text{-}HUB}$=22,767.50 €. The estimated number of passengers in the opposite direction is $pax_{FRA\text{-}HUB}$=118.

An aircraft for chosen flights needs to satisfy the following conditions: the cabin capacity must be for at least 118 passengers, but no higher then 154 (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 07^{25} h and has no assigned flights in the time period between 07:25 AM and 11:56 AM. An aircraft that satisfies all the conditions from above is the aircraft A321 with registration number XXLBB.

The realized profit of the new flight schedule is calculated and equals to D_1 = 1,128,458.75 €. According to (1) and (25), the gain for the airline would be R_D = 21,274.50 € (per week) and R_{Dt} = 21,274.50 · 31 = 659,509.50 € (per year). The number of connections that can be achieved introducing the new flight HUB-FRA is 30. The estimated profit per year, R_{Dt}, is further used in (24) 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 2-5. 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 2. As mentioned above, it is assumed that the minimum slot price is €1 million and in that case, the initial investment cost, C, is than equal to the price of two slots, due to the fact that to operate at Frankfurt Airport the airline needs to posses the corresponding slot (presented with the red line on Figure 2-5).

In the best case scenario, at the discount rate of 8% and profit increase of 10% the airline' willingness to pay €2 million for two slots would reach this amount in the 4th year from the moment of investment, Figure 2. Also, at Figure 2 it can be seen that the airline's maximum willingness to pay for these slots, in observed period of 10 years, is about €6.6 million, under assumed conditions. Lowering the annual profit, the period for returning the investment would increase and the airline's maximum willingness to pay for these slots would decrease. Increasing the discount rate, this change is more rapid, Figure 3-5, and under unfavourable conditions, where the annual profit is decreasing 10% per year and the discount rate is 20%, the airline' willingness to pay €2 million for two slots would reach this amount in the 9th year from the moment of investment, Figure 5.

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% (i.e. 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 the discount rate is 8%. Increasing the value of the 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 five years from the moment of investment, for minimum discount rate of 8%. Therefore this period of time is further used in (26) 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 (26), the determined internal rates of return are: 11.85% (Scenario 1), 15.63% (Scenario 2), 19.37% (Scenario 3), 23.07% (Scenario 4) and 26.73% (Scenario 5). 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 five 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 five years and vice versa.

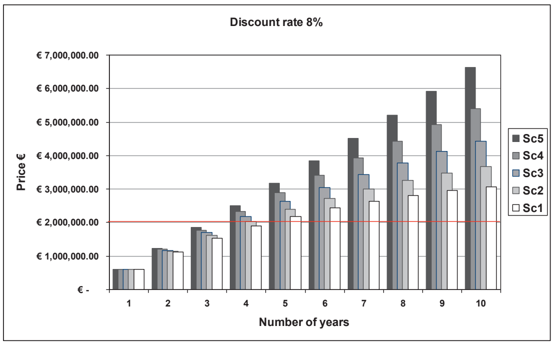

Figure 2 The present value of profit at discount rate of 8% and different scenarios

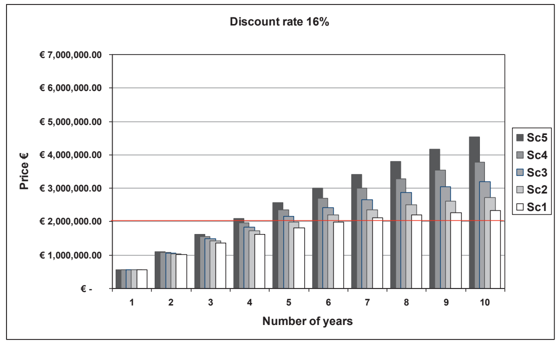

Figure 3 The present value of profit at discount rate of 12% and different scenarios

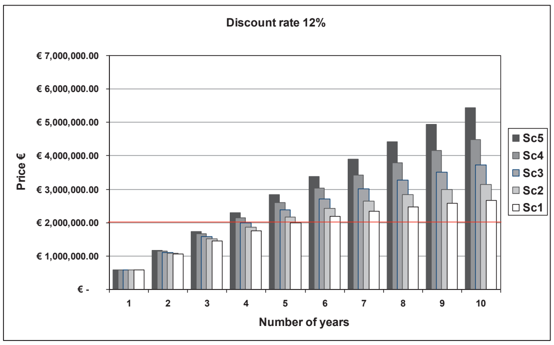

Figure 4 The present value of profit at discount rate of 16% and different scenarios

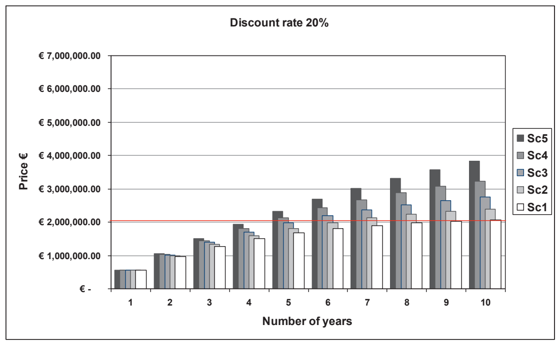

Figure 5 The present value of profit at discount rate of 20% and different scenarios

5. Conclusion

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 the 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 the aircraft availability for the new flights, the realized profit for an airline and finally, the 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 for 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 for 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.

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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References

Burghouwt, G. & De Wit, J. (2005). Temporal Configurations of European Airline Networks. *Journal of Air Transport Management*, 11, 185-198

Cao, J.M. & Kanafani, A. (2000). The value of runway time slots for airlines. *European Journal of Operational Research* 126 (3), 491-500

Crandall, R.L. (1995). The Unique US Airline Industry. In Jenkins, D. (ed). *Handbook of Airline Economics.* McGraw-Hill, New York

De Wit, J. & Burghouwt, G. (2008). Slot Allocation and Use at Hub Airports, Perspectives for Secondary Trading. *European Journal of Transport and Infrastructure Research*, 8(2), 147-164

Gillen, D. (2006). Slot Trading in North America, *EUACA Seminar on Secondary Trading Amsterdam Airport*. Schiphol

Gvozdenovic, S. (1995). Aircraft, Part 1. University of Belgrade, Faculty of Transport and Traffic Engineering (FTTE), Belgrade

Holloway, S. (2003). Straight and Level: Practical Airline Economics. *Ashgate Publishing Limited.* Gower House, Croft Road, Aldershot, Hampshire GU11 3HR, England

Mashford, J. S. & Marksjo, B. S. (2001). Airline Base Schedule Optimisation by Flight Network Annealing. *Annals of Operations Research,* 108, 293-313, Netherlands

Mott MacDonald & European Commission (2006). Study on the Impact of the Introduction of Secondary Trading at Community Airports. Volume 1 – Report. Mott MacDonald. Surrey

Pavlovic, D., (2009). Airport slots and airline profit. *M. Sc. Thesis.* University of Belgrade, Faculty of Transport and Traffic Engineering (in Serbian – Aerodromski slotovi i profit avioprevozioca)

Pavlovic, D. & Kalic, M. (2010). Airline profit and airport slots: route network expansion. *12th World Conference on Transport Research (WCTR).* Lisabon, Portugal. No 2376

Starkie, D., Bass T. and Humphreys, B. (2003). A Market in Airport Slots. *IEA, The Institute of Economic Affairs*, London

Teodorovic, D. (1988). Air transportation models. University of Belgrade, FTTE, Belgrade

The Council Of The European Communities (1993). Council Regulation (EEC) No 95/93 on common rules for the allocation of slots at Community airports

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