Management Capabilities Analysis of Aircraft Exploitation Process

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The following paper presents management aspects of aircraft exploitation process. The key element in planning connections network is including the necessity to perform technical services. The issue becomes complex when air carrier operates in a considerable number of airports whereas technical service can be effected only in few. It is important then to manage aircraft properly in order to achieve a high rate of technical efficiency.
Keywords: operation process, maintenence process, aircraft.

1. INTRODUCTION

Difficult time caused by economic crisis forced air carriers to economize. One of the alternatives to limit expenses evoked by air traffic disruptions is a manner of management of aircraft exploitation process. Air carrier possesses summer and winter flight schedules. Application process is still very complex. Despite its recurrence, connections network is repeated week in week out and the probability of traffic disruptions is different. They occur due to: random incidents at airports, or weather conditions. However, they are quite often induced by aircraft servicing process.

2. CONNECTIONS NETWORK MODELLING PROBLEMS

The main objective of air carrier is to perform a considerable transportation job. It is necessary for the connections network to be designed in a way which enables the transport of maximum number of passangers. One must also take into consideration the constraints owing to the access to air infrastructure [1]. The issue has been examined by numerous researchers. First analyses concerning air connections along with their modelling have been presented in [2]. The notion is further discussed in [3] by means of a daily scheduling model of aircraft exploitation process. Inexpensive air lines only as a last resort decide to use large airports where the probability of traffic disruptions, due to the number of operations performed in a port, is high. Such a situation occurs when: a carrier possesses servicing base (operative) at a particular airport (e.g. Ryanair – Dublin), or a city does not have an alternative airport where a carrier can perform air connections (e.g. Warsaw).

Figure 1 presents a diagram of the estimated air services demand on one of the weekdays between airport A and ports B, C, D.

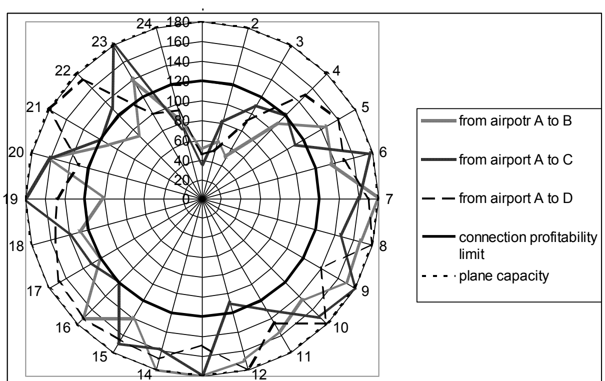

Fig. l. Estimated air services demand at particular hours on one of the weekdays, between airport A and ports B, C and D. Own analysis.

Similar diagrams need to be designed for connections from airports B, C and D. It can be noticed that it is unprofitable to operate flights between 12a.m. and 3a.m., therefore this time is most often intended for technical servicing.

Air services demand can be noted as follows:

$$FNZ = (X, Y, g.00, g.59) \quad (1)$$

where:

FNZ – the number of consecutive flight (FN1, FN2….)

g.00- start of take-off interval;

g.59 – end of take-off interval.

X – port of departure;

Y – port of arrival; Assuming there are no take-offs performed between 12a.m. and 3a.m., we receive 63 flight options for a single airport (three airports, twenty one feasible departure times). Flights are operated from four airports which gives the total number of 252. The function of flights scheduling simulation objective looks like following:

$$\sum_{N} lp_z \rightarrow \max \quad (2)$$

where:

lp_z-number of passengers in z-other flight;

N- total number of flights performed by aircraft.

The algorithm for devising connections network will be presented in later papers, while here the focus is on one of the ways to optimise aircraft exploitation process. Figure 2 shows a weekly connection network of two airplanes.

Having devised the aircraft exploitation process it is essential to plan servicing process. Repeatedly, such a situation also takes place with airlines where in the first instance connections network is modelled and afterwards maintenance inspection is planned. Assuming such a course of procedure leads to a situation where exploitation of maximum intervals between particular maintenance inspections becomes highly problematic due to ports servicing constraints.

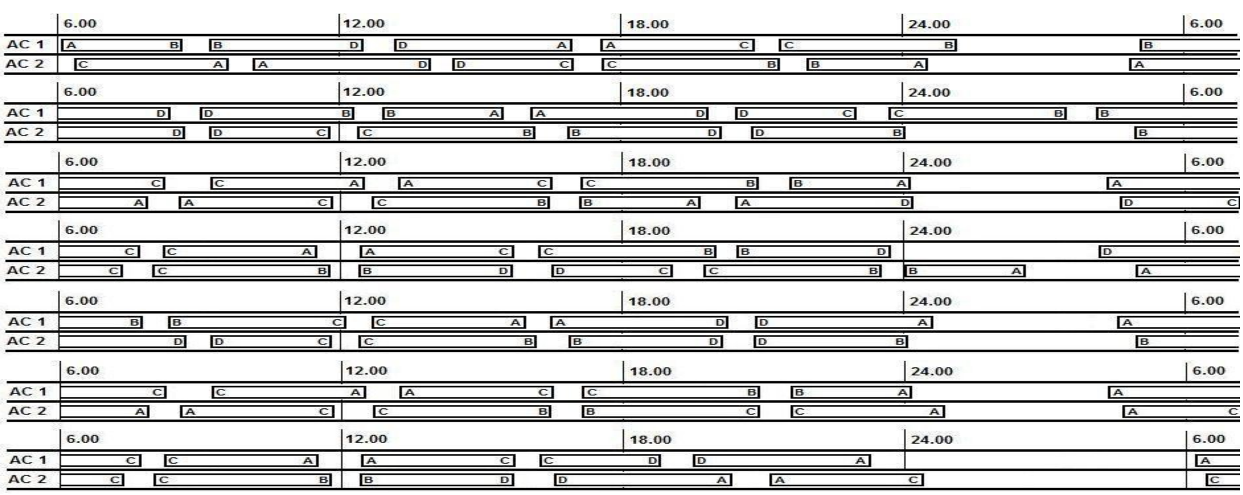

Fig. 2. Connections network with a maximum degree of aircraft capacity. Own analysis

3. AIRCRAFT MANAGEMENT CAPABILITIES

With such connections network and an attempt to introduce one of the basic technical servicing (D-check) it is necessary to delay three flights (fig. 3). The delay will be proportional to servicing duration time. D-check service type is run with a maximum interval of 48 hours. It must be assumed that a carrier is capable of operating technical maintenance only in airport A.

In certain cases it can be noticed that the intervals come to less than 24hours. The method presented in the paper, which assumes maximum exploitation of time intervals to operate all services, will encompass certain presumptions:

minimal changes in the connections network which will cause a drop in the number of passengers by less than 1%.
flights delay possibility – the delays however can only be about 20mins.

Selection of such presumptions is not incidental. Decreasing the number of passengers by 1% is practically imperceptible. One must remember that data which the simulation bases on is estimated. There can be a paradoxical situation where a change of connections network will cause the increase in the number of passengers. From passenger's point of view a 20 minutes' delay does not affect his mood in a negative way. Consecutive stages of passenger's migration at an airport (tickets, safety measures, waiting in departure lounge, way to the plane) make the 20mins delay imperceptible. Additionally, if the intensity of a carrier's aircraft take-offs at a particular airport is high, while the passenger can continuously observe aircraft migration spots, estimated maximum delay will barely be noticeable.

One must also remember that ground service time is dependent on a few factors. One of them is the number of passengers. The lower the number the shorter service time. It is also important whether ground service encompasses fuelling etc. An aircraft in airspace is subject to weather conditions. If it is found in favourable air masses the flight time between airports can shorten (however, it can also lengthen in unfavourable conditions). Therefore in the ground service process as well as in certain situations during the flight, there are latent time reserves which may cause a 20mins delay to level even during a single flight.

It should be noticed that a working week has 7 days, connections network is determined for a week, whereas technical maintenance must be done every other day. To obtain maximum interval aircraft should have technical maintenance performed on even days of odd weeks, and odd days of even weeks. It is impossible to achieve merely through arranging connections schedule, unless at the end of each day airplanes land in airport A. Such a situation would cause the number of carried passengers to drop by more than 1% (the drop could be tenfold greater). It is therefore necessary to modify the schedule moderately. It must be noticed that at least one airplane nearly on all days (except for the second day) performs a final landing in airport A. The modification will result in one airplane being serviced on each day. The following alteration should be made in connections schedule conforming to figure 4.

It must be noticed that two connections have been changed. Last two flights of plane AC1 have been transferred onto plane AC2, without the necessity of delay. Whereas AC2 flight from airport D to B has been substituted for flight from D to A and transferred onto plane AC1. Consequently, morning flight of plane AC1 from port B to C had to be changed to a flight from A to C. Such an alteration did not change air services demand because the flights had a similar anticipated demand.

Such a connections schedule, with only one plane out of two finishing flights in base port, enforces an exchange of transportation tasks between airplanes. The exchange is unnecessary only on the day when two planes end up in airport A. One must remember about the assumptions made (maximum flight delay cannot exceed 20 minutes). Transportation tasks exchange can be performed in airports marked in figure 5.

Assumed connections schedule allows the transfer of transportation tasks from airplane AC1 to AC2 in marked spots. Problematic are days 1 and 3 because there is no possibility to change tasks without connections schedule interference. With the first day it would be most accurate to schedule AC2 flights 30minutes earlier whereas for AC1 30 minutes later. According to the assumption that air services demand is stable with the time period from g.00 to g.59, such change will not affect the demand and in fact it will allow tasks change between the two airplanes on day 1. More complex is day 3. connections schedule is specifically arranged. Three flights run by AC2 plane (flights from A to C, from C to B, and from B to A) are repeated after about 4hrs on plane AC1. Within this time interval transportation tasks exchange is impossible. The change must be done before or after a specific flight set. It is impossible to do it after because it would require an extra flight from D to A which consequently would result in no time for maintenance. It could be possible to cancel last flight from A to D. Unfortunately, such an operation is impossible because it would cause considerable drop in the number of passengers carried as well as a long waiting period to perform transportation tasks.

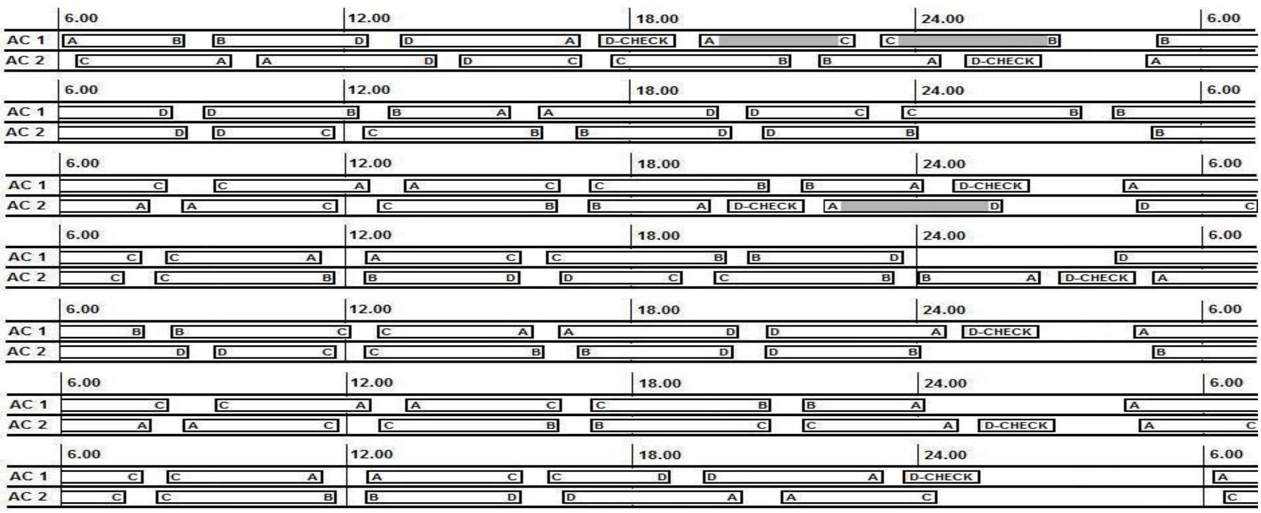

Fig. 3. Alterations to connection network issuing from technical maintenance requirement. Own analysis

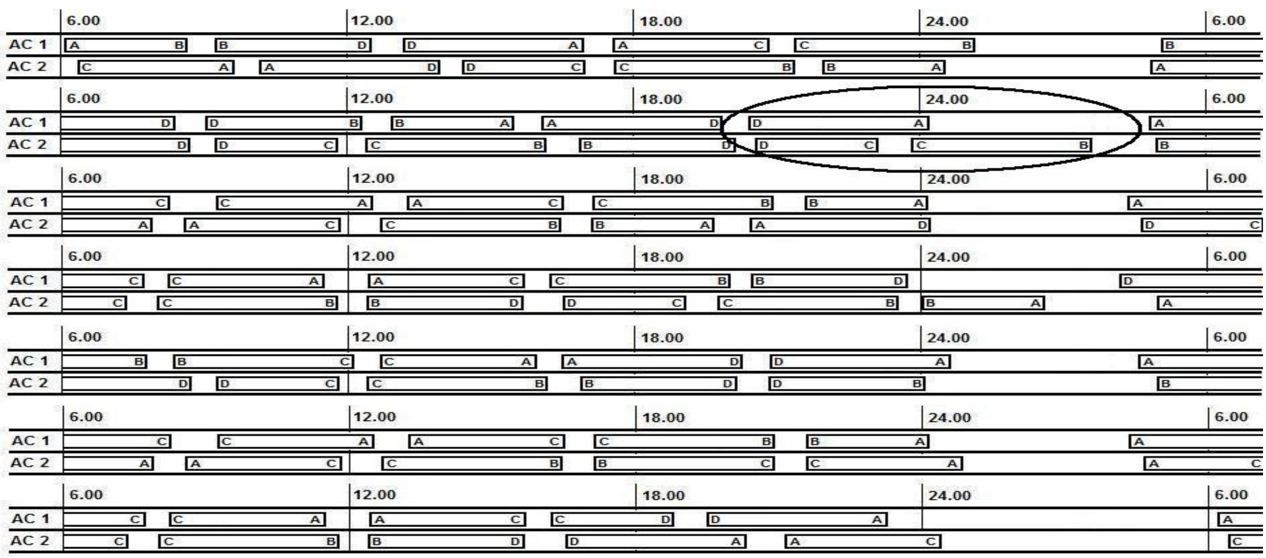

Fig. 4. Connections schedule modification as a means of technical services guarantee. Own analysis

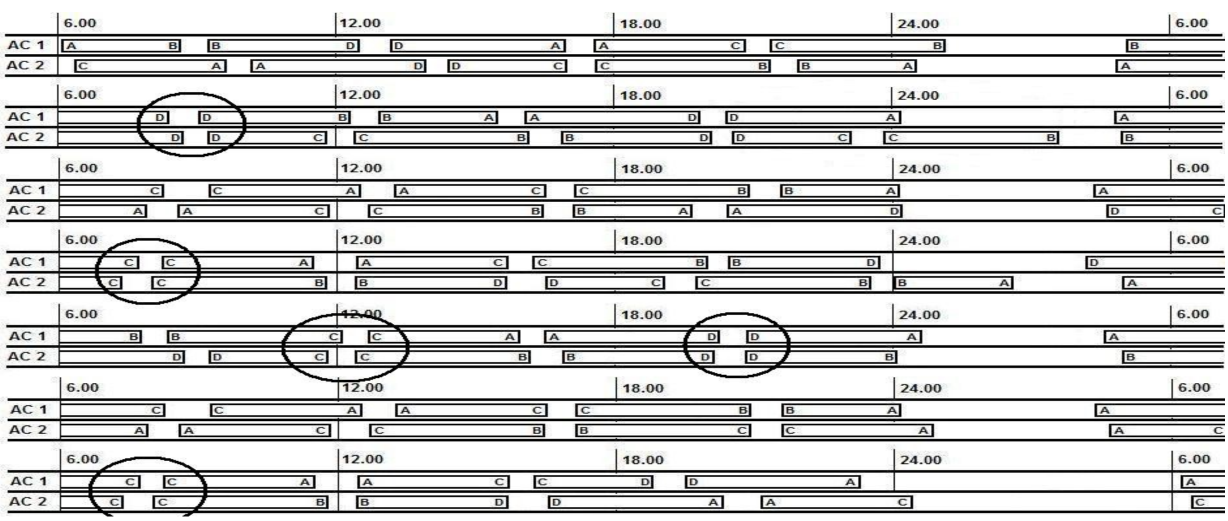

Fig. 5. Transportation tasks exchange spots between airplanes. Own analysis.

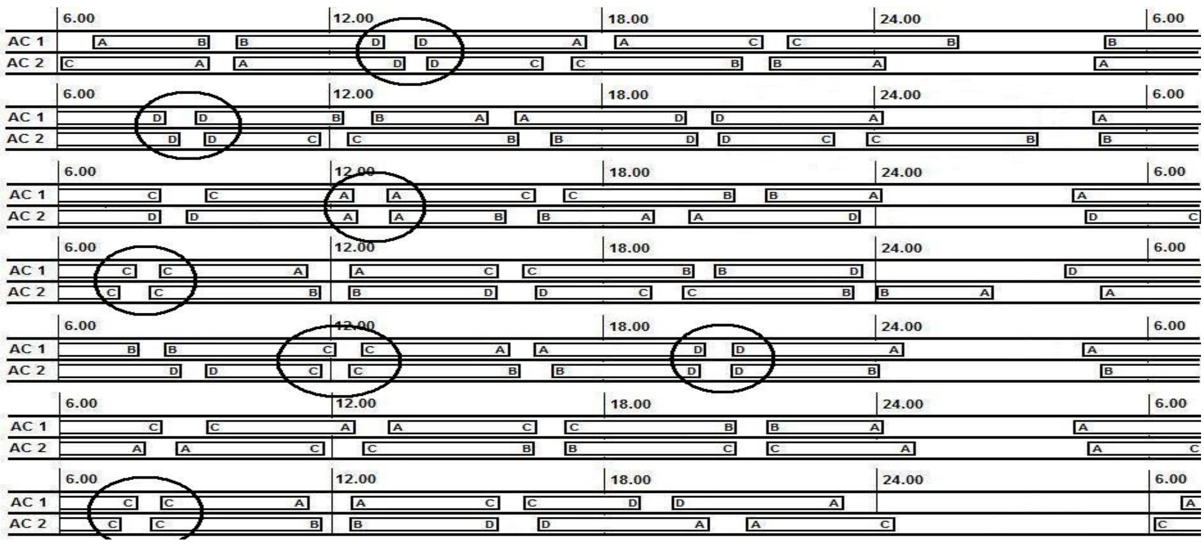

Fig. 6. Another connections schedule modification. Own analysis.

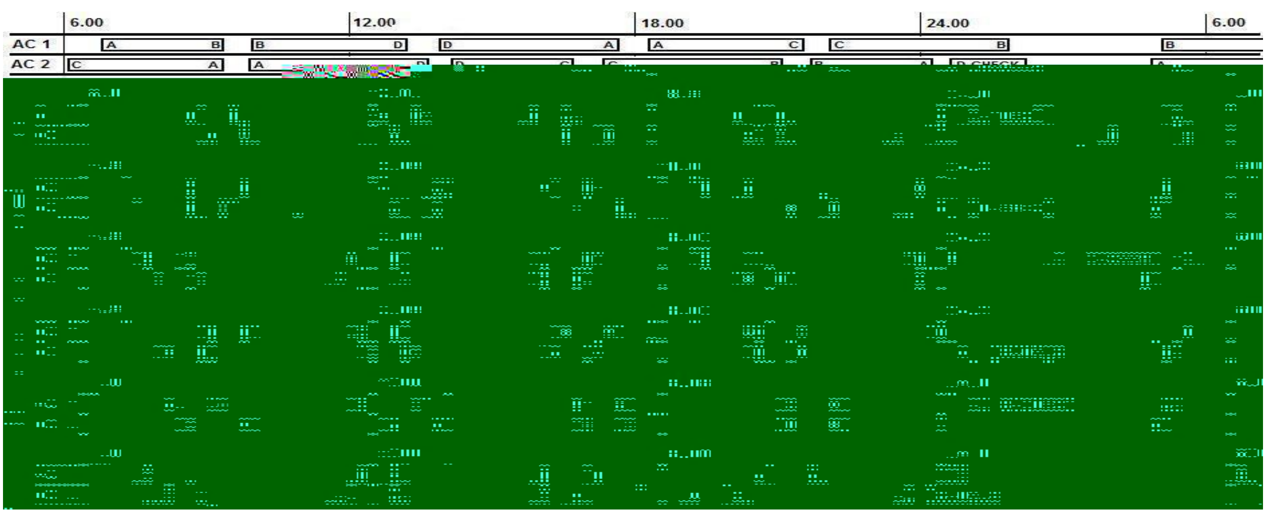

Fig. 7. Connections schedule with determined technical maintenance. Own analysis.

The only solution is to make the first flight from airport B to D (as presented in fig. 5 the flight from B to A complicates the situation, flight from B to C would require the next connection to be directed to port A, thus two airplanes at the same time would perform flights on the same route). Introducing successive changes for that airplane, namely flights from D to A and from A to B will inconsiderably diminish estimated demand. Figure 6 presents a rearranged connections schedule and transportation tasks exchange potentials.

This way of modelling a connections schedule makes it simple to arrange services using maximum interval. Figure 7 presents connections schedule with transportation tasks exchanged between airplanes and scheduled services.

It must be noticed that when compared with original schedule, in the altered one no flight must be delayed due to maintenance works. Another advantage of such modelling is the use of maximum intervals between servicing, which can consequently lead to limiting its costs. A disadvantage of flights rescheduling can be a drop in the number of passengers, however, as mentioned earlier, it is not a rule.

Exploitation process of two airplanes, for originally defined connections schedule, and exploitation process presented in figure 7 will be verified by means of aircarrier performance assessment model which is presented in figure 8.

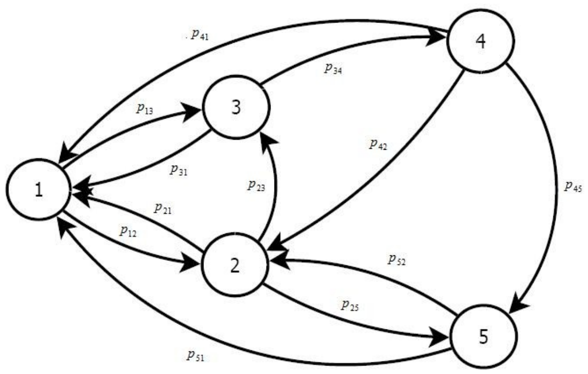

Fig. 8. Aircraft exploitation process diagram. 1-Transportation tasks performance wait stage, 2-service stage before flight, 3-flight stage, 4-service stage after flight, 5-technical maintenance stage.

Transitions probability matrix for the diagram will look as follows:

$$P = \begin{bmatrix} 0 & p_{12} & p_{13} & 0 & 0 \\ p_{21} & 0 & p_{23} & 0 & p_{25} \\ p_{31} & 0 & 0 & p_{34} & 0 \\ p_{41} & p_{42} & 0 & 0 & p_{45} \\ p_{51} & p_{52} & 0 & 0 & 0 \end{bmatrix} \quad (3)$$

We consider aircraft exploitation process as discrete in stages and time. A system of equations in a full-time schedule of employed Markow's chain assumes the following form:

$$\pi_1 = p_{21} \cdot \pi_2 + p_{31} \cdot \pi_3 + p_{41} \cdot \pi_4 + p_{51} \cdot \pi_5, \quad (4)$$

$$\pi_2 = p_{12} \cdot \pi_1 + p_{42} \cdot \pi_4 + p_{52} \cdot \pi_5, \quad (5)$$

$$\pi_3 = p_{13} \cdot \pi_1 + p_{23} \cdot \pi_2, \quad (6)$$

$$\pi_4 = p_{34} \cdot \pi_3, \quad (7)$$

$$\pi_5 = p_{25} \cdot \pi_2 + p_{45} \cdot \pi_4. \quad (8)$$

As well as normalizing equation:

$$\pi_1 + \pi_2 + \pi_3 + \pi_4 + \pi_5 = 1 \quad (9)$$

Process probability distribution can be evaluated in regard to employed Markow's chain and process stages duration estimated values. Estimated values can be calculated from the following equations:

$$E(T_1) = \int_0^\infty td[F_{12}(t) + F_{13}(t)] \quad (10)$$

$$E(T_2) = \int_0^\infty td[F_{21}(t) + F_{23}(t) + F_{25}(t)] \quad (11)$$

$$E(T_3) = \int_0^\infty td[F_{31}(t) + F_{34}(t)] \quad (12)$$

$$E(T_4) = \int_0^\infty td[F_{41}(t) + F_{42}(t) + F_{45}(t)] \quad (13)$$

$$E(T_5) = \int_0^\infty td[F_{51}(t) + F_{52}(t)] \quad (14)$$

Calculations above result in determining marginal probability. It can be expressed in the following form:

$$P_{ij} = \lim_{t \to \infty} P_{ij}(t) = P_j = \frac{\pi_j E(T_j)}{\sum_{i \in S} \pi_j E(T_j)}, \quad (15)$$

Marginal probability rate for particular stages assumes the following form:

$$P_1 = \frac{\pi_1 E(T_1)}{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4) + \pi_5 E(T_5)}, \quad (16)$$

$$P_2 = \frac{\pi_2 E(T_2)}{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4) + \pi_5 E(T_5)}, \quad (17)$$

$$P_3 = \frac{\pi_3 E(T_3)}{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4) + \pi_5 E(T_5)}, \quad (18)$$

$$P_4 = \frac{\pi_4 E(T_4)}{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4) + \pi_5 E(T_5)}, \quad (19)$$

$$P_5 = \frac{\pi_5 E(T_5)}{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4) + \pi_5 E(T_5)}, \quad (20)$$

Marginal rate of efficiency can be noted as follows:

$$K_d = P_1 + P_2 + P_3 + P_4 = \\ = \frac{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4)}{\pi_1 E(T_1) + \pi_2 E(T_2) + \pi_3 E(T_3) + \pi_4 E(T_4) + \pi_5 E(T_5)}. \quad (21)$$

After the suggested mathematical model representing aircraft exploitation process and connections schedule performance evaluation rates, one should compare initial exploitation process (fig. 3) with rescheduled one (fig. 7). Table 1 presents results comparison.

Table 1. Aircraft exploitation processes rates comparison

	Exploitation process as per fig. 3	Exploitation process as per fig. 7
π_1	0,055	0,055
π_2	0,304	0,305
π_3	0,304	0,305
π_4	0,304	0,305
π_5	0,033	0,03
$E(T_1)$	212	222,5
$E(T_2)$	15	15
$E(T_3)$	196	196
$E(T_4)$	15	15
$E(T_5)$	112,5	112,5
P_1	0,14	0,15
P_2	0,055	0,055
P_3	0,7	0,7
P_4	0,055	0,055
P_5	0,05	0,04
K_d	0,95	0,96

It must be noticed that through small modification to the connections schedule it is possible to increase the efficiency rate. The increase was possible due to reduction of technical services.

4. CONCLUSION

The issue of service operations planning for a determined connections schedule, with maximum time exploitation between the services is very complex. The research paper discusses applying subtle modifications to connections schedule with certain priorities maintained, which have been presented in detail in section 3. The optimization was conducted for one type of service. Further actions will aim at achieving maximum time exploitation between services for all technical inspections which are presented in section 3 (table 1). Subsequently the model will be extended over a higher number of aircraft. Another step will be the introduction of random disruptions due to various factors: weather conditions, unplanned technical services (the notion discussed in [5]), traffic disturbance in air space (discussed in [1] and [6]). Next the model will be verified on one of the low-costs carriers airfleet.

It is also important to solve the issue of transportation tasks exchange between airplanes. If we expect an airplane to land in a designated airport there must be a possibility of change between particular airplanes during one day. The optimum solution would be to gather all airplanes in one airport and at one hour. The problem is the maximization of connections schedule because for each airplane two connections are constrained. Air services demand will diminish. It is highly required then to arrange connections schedule so that such a situation does not happen.

The issue of transportation tasks exchange between airplanes, in order to make an airplane perform its final landing in services port, is extremely difficult.

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