PLANNING OF TRAINING AIRCRAFT FLIGHT HOURS

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Abstract

Maintenance of the training aircraft causes downtime of operations and thereby reduces the operational availability, which is crucial for flight planning in a training organisation. Manual daily planning within the fleet delivers suboptimal results and often causes discontinued flight of several aircraft that have to be maintained at the same time. Optimal maintenance schedule of training aircraft can be obtained by a sliding scale method. This paper presents a mathematical model of the sliding scale formulated by a mixed integer linear problem. Allocation of flight hours is optimised by using AMPL programming language, assuring that a sufficient number of aircraft are always available for training. The model can be used by a flight dispatch department in a training organisation as a basis for optimised planning and reduction of maintenance downtime.

Key words: *Aircraft maintenance, operational availability, allocating flight hours, sliding scale method, mixed integer linear problem*

1. INTRODUCTION

Aircraft maintenance is defined as the preservation, inspection, overhaul and repair of an aircraft, including the replacement of its parts. Regular and proper maintenance ensures that an aircraft meets an acceptable standard of airworthiness throughout its operational life (FAA, 2008), thereby assuring aircraft's safety, durability and economic efficiency. However, it also causes maintenance downtime and thereby reduces aircraft availability. Within a Flying Training Organisation (FTO), the mutual goal of chief flying instructor (in charge of flight planning) and maintenance department (responsible for maintenance planning) is to increase the level of aircraft availability.

Training aircraft are generally very simple models (usually with a small piston engine), but due to safety issues they have strictly defined short maintenance inspection intervals: they are maintained after every 50 flying hours. It takes 8 to 10 man hours to perform maintenance after 50 flying hours, while maintenance after 100 flying hours generally takes 16 to 20 man hours. This can present a serious impediment to availability of aircraft, especially during the peak of flight season (mostly from April to October), and flight hour allocation using manual techniques delivers suboptimal results.

This paper presents a model for optimal allocation of aircraft flying hours in a training fleet, with a goal to plan post-100-flight-hour inspection and maintenance activities in proper time intervals, and thus increase a number of training aircraft available at any given time. Mathematical model is formulated as a goal programming problem, and is developed by using mixed integer linear programming methodology (Hiller, Lieberman, 1995); AMPL programming language is used. This type of model is used by US Air Force for flight hour allocation in order to increase operational availability (Pippin, 1998) so that, according to the 75% Fully Mission Capable standard used in the US Army and the majority of other world armies, 75% of aircraft are always operationally ready. A similar model has been developed for establishing steady-state sequencing of helicopters into 200 hour phase maintenance of Croatian Air Force Helicopter Division (Bubić, 2009).

2. PROBLEM DEFINITION

In order to maintain an effective phase maintenance flow, chief flying instructor must balance his operation and training requirements against his maintenance effort. The flying instructors and dispatch office are responsible for the operational and training aspect while maintenance department is responsible for the aircraft maintenance. The chief flying instructor manages resources through flight hour allocation and maintenance management within a planning cycle. This paper uses weekly planning cycle as interval for planning of flight training and maintenance activities.

Sliding scale method and the flight hour availability diagram is an important tool for flight and maintenance planning. As the sliding scale method does not provide optimal results, this paper develops mixed linear integer programming model, within which sliding scale method is described using the following data:

- chief flight instructor's flight hour goal for planning cycle (one week), defined as minimum and maximum number of flight hours for the whole fleet;
- number of flight hours remaining until 100 hour check for each aircraft in the fleet;
- status of every 100 hour inspection;

- minimum and maximum flight hours for each aircraft in the fleet during the planning cycle (one week).

This paper presents the mixed integer linear programming method with penalties per hour of deviation that increases as the flight hour deviation from the desired goal line increases. The resulting aircraft flow should be as parallel as possible to the goal line and thereby provide a steady-state flow of aircraft into phase maintenance.

3. OPTIMISATION MODELING OF THE FLIGHT HOUR ALLOCATION PROBLEM

Firstly, a goal is set for a certain period of planning (week, month, etc.). Secondly, a current position of an aircraft is established within the planning schedule in regard to the remaining flight hours until planned maintenance activities. For each of the aircraft one position is assigned (j) and a plan is developed for the next flight hour allocation period. When determining the model parameters (upper and lower bounds for aircraft flight hours), the time spent on maintenance is taken into account. Parameters are different for every planned cycle. The current status of flight hours is needed for planning.

In order to formulate the problem, the following notation is introduced.

Indices:

- i – Aircraft
- j – Position of the aircraft on the fleet flow chart, $j = 1,..., n$
- k – Interval from the goal line, $k = 1,..., m$

Parameters:

- l – Minimum flight hour allocation for the fleet during planning cycle (hours)
- u – Maximum flight hour allocation for the fleet during planning cycle (hours)
- g_j – Goal for the aircraft assigned position j
- c_i – Flight hours remaining until phase maintenance due for aircraft i
- a_i – Maximum flight hours for aircraft i
- b_i – Minimum flight hours for aircraft i
- t_{ik} – allowed deviation within the k-th interval for aircraft i
- w_{ik}^{-} – penalty for flight hours below the goal line within the k-th interval for aircraft i
- w_{ik}^{+} – penalty for flight hours below the goal line within the k-th interval for aircraft i

Decision variables

- d_{ik}^{-} – The flight hours that aircraft *i* is below the goal line within the *k*–th interval
- d_{ik}^{+} – The flight hours that aircraft *i* is above the goal line within the *k*–th interval
- y_i – Flight hours for aircraft *i* during planning cycle
- x_{ij} – 1 if the aircraft *i* is assigned to the *j* position, 0 otherwise

$$\min \sum_{i=1}^{n}\sum_{k=1}^{m}\left(w_{ik}^{+}d_{ik}^{+} + w_{ik}^{-}d_{ik}^{-}\right)$$

$$c_i - y_i - \sum_{j=1}^{n} g_j x_{ij} \le \sum_{k=1}^{m} d_{ik}^{+} \qquad \forall i \qquad (1)$$

$$-\left(c_i - y_i - \sum_{j=1}^{n} g_j x_{ij}\right) \le \sum_{k=1}^{m} d_{ik}^{-} \qquad \forall i \qquad (2)$$

$$\sum_{j=1}^{n} x_{ij} = 1 \qquad \forall i \qquad (3)$$

$$\sum_{i=1}^{n} x_{ij} = 1 \qquad \forall j \qquad (4)$$

$$l \le \sum_{i=1}^{n} y_i \le u \qquad (5)$$

$$b_i \le y_i \le \min\{c_i, a_i\} \qquad \forall i \qquad (6)$$

$$0 \le d_{ik}^{+} \le t_{ik} \qquad \forall i, \forall k \qquad (7)$$

$$0 \le d_{ik}^{-} \le t_{ik} \qquad \forall i, \forall k \qquad (8)$$

$$x_{ij} \in \{0,1\} \qquad \forall i, j$$

The objective function is the sum of the penalised flight hour deviation from the goal line of all the aircraft in the fleet. The flight hour deviation penalty per unit is different depending on the deviation interval. Constraint (1) measures flight hour deviation above goal line for each aircraft *i*. Constraint (2) measures flight hour deviation below the goal line for each aircraft *i*. Constraint (3) ensures that each aircraft is only allocated one position within the fleet flow. Constraint (4) fills each position on the fleet flow chart with exactly one aircraft. Constraint (5) ensures that the sum of individual aircraft flight hours is between the upper and lower boundaries of the chief flight instructor's goal of the flight hours within the planning cycle. Constraint (6) ensures that individual aircraft fly the minimum required flight hours in the planning cycle and do not exceed maximum flight hours allowed, or exceed the remaining flight hours until phase maintenance is due. Constraints (7) and (8) limit the hours above and below the goal line in each penalty interval.

4. CASE STUDY

This section presents an example of flight hour allocation within an FTO with a fleet of six Cessna 172 aircraft, the most popular small training aircraft in the world.

Figure 1: Training aircraft Cessna 172

Real data resulting from manual planning on a weekly basis, for 4 weeks in May 2009, are presented in the following table.

Table 1: Total and individual flight hours per week in May 2009

Aircraft / Flight hours (FH)		1st week	2nd week	3rd week	4th week
AC-1	Total FH	1376	1406	1431	1469
	FH in the week	30	25	38	40
AC-2	Total FH	4230	4262	4299	4330
	FH in the week	32	37	31	36
AC-3	Total FH	1028	1038	1048	1063
	FH in the week	10	10	15	6
AC-4	Total FH	84	103	124	130
	FH in the week	19	21	6	5
AC-5	Total FH	5461	5476	5486	5491
	FH in the week	15	10	5	6
AC-6	Total FH	3375	3394	3421	3455
	FH in the week	19	27	34	21

Planning cycle is one week. The goal line is a straight line through the points equally set for six aircraft. Mandatory maintenance inspection for the aircraft is after 50 and 100 flight hours.

Aircraft AC-3 (shown as the first, or the leftmost, in the following graph in Figure 2) should have had 100 flight hours until maintenance, meaning that within the observed week AC-3 should have arrived – not necessarily at the beginning of the week – from the 100 hour inspection. Aircraft AC-6 (position 4 in Figure

2) should have been available 40 flight hours until 100 hour inspection, and its real status was that it had 25 flight hours available.

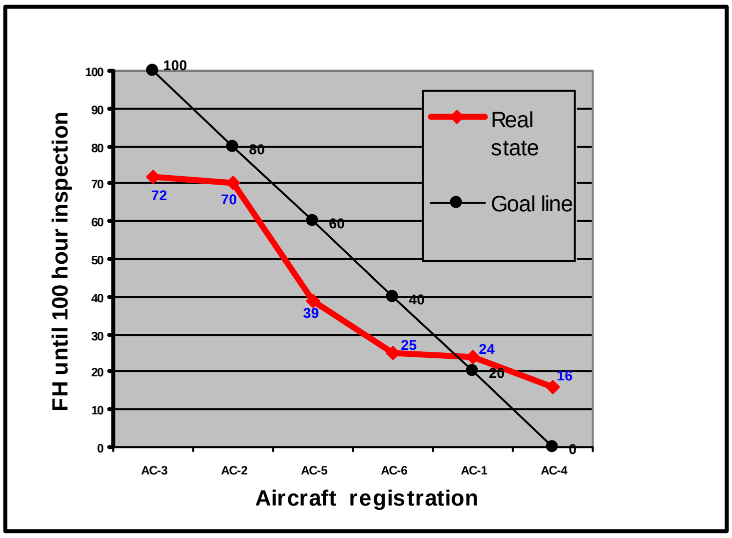

Figure 2: Available flight hours of the aircraft at the beginning of the 1st week

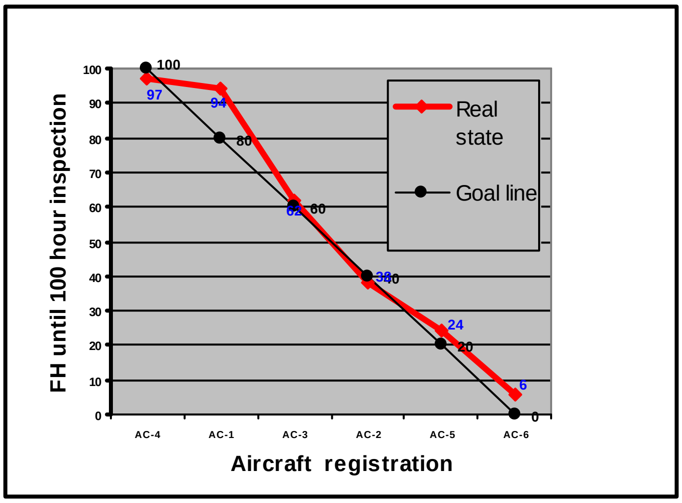

Figure 3: Available flight hours of the aircraft at the beginning of the 2nd week obtained by manual planning

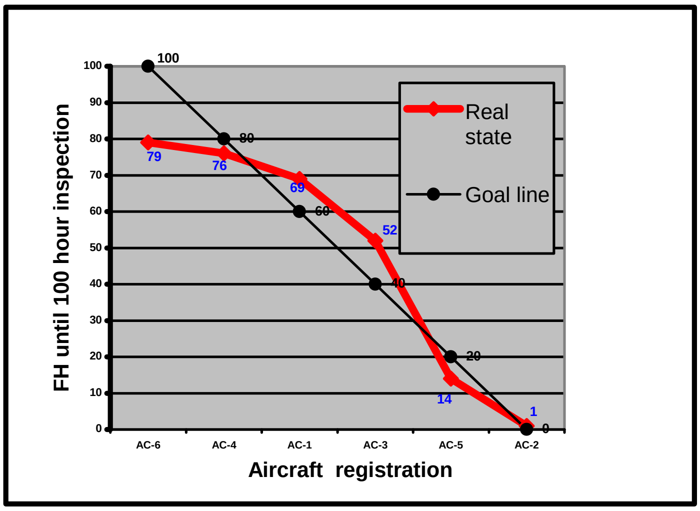

Figure 4: Available flight hours of the aircraft at the beginning of the 3rd week obtained by manual planning

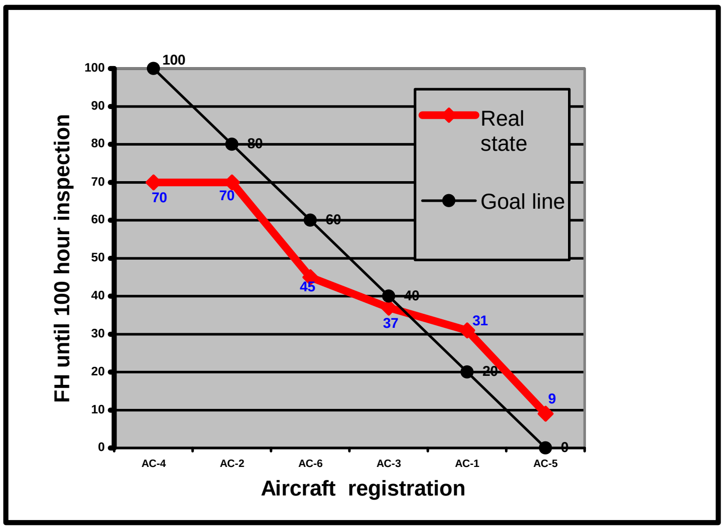

Figure 5: Available flight hours of the aircraft at the beginning of the 4th week obtained by manual planning

Graphs that follow, for the same 4 weeks in May 2009, were obtained by goal programming. They show flight time available until the obligatory 100 hour inspection at the end of the observed week, i.e. at the beginning of the following week. Time spent during 50 hour inspection (less comprehensive and shorter than 100 hour inspection) was also taken into account. All the intervals of deviation from the goal line are 10 hours; penalty for the first deviation interval is zero, for the second 10 hour is 10, and for the third deviation is 30. The parameters for the first week of planning were defined according to the input data for that week.

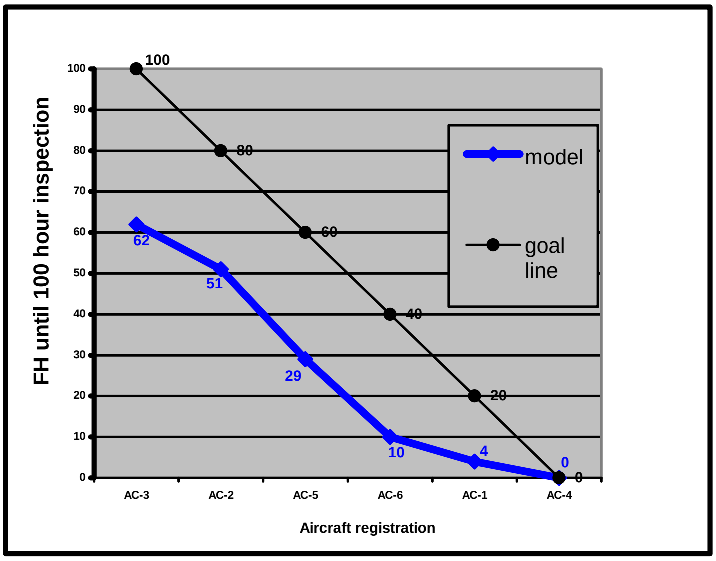

Figure 6. Available flight hours of the aircraft at the beginning of the 2nd week obtained by programming

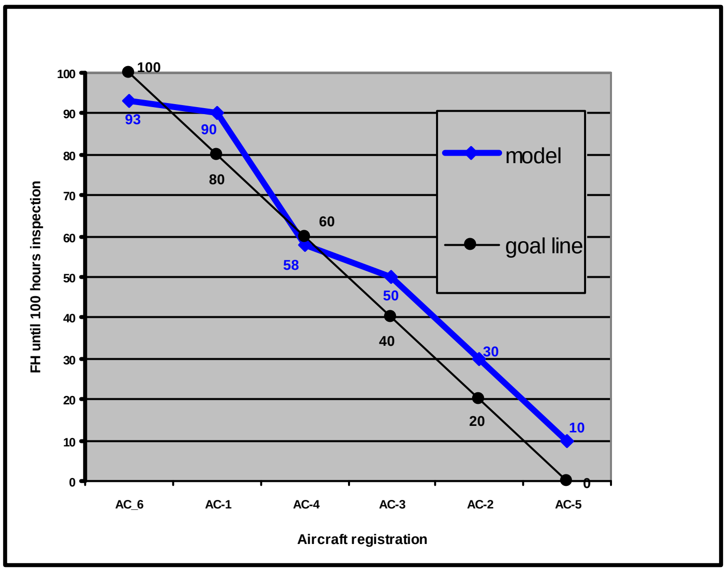

Figure 7. Available flight hours of the aircraft at the beginning of the 3rd week obtained by programming

Figure 7 shows the available flight hours of the fleet at the end of the 2nd, i.e. beginning of the 3rd week. Looking specifically at the data of aircraft AC-6: At that point, it had 93 flight hours available until 100 hour inspection, and was therefore occupying the position #1 at the beginning of the 3rd week. Aircraft AC-1 starts the 3rd week with 90 flight hours available and occupies position #2. Its goal was to have 80 flight hours available, which means that programming allowed the availability of 10 additional flight hours.

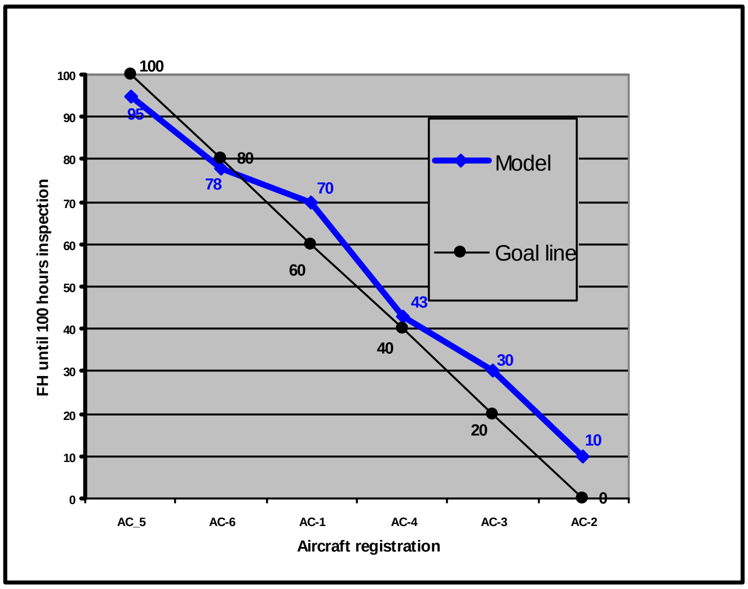

Figure 8. Available flight hours of the aircraft at the beginning of the 4th week obtained by programming

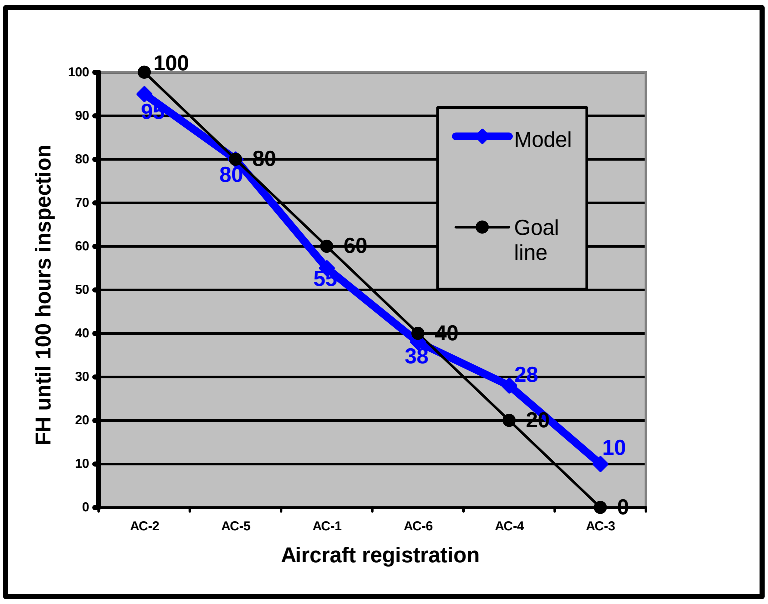

Figure 9. Available flight hours of the aircraft at the beginning of the 5th week obtained by programming

It can be seen that within four weeks of planning by using mathematical model the planned flight hours were approaching the goal line, and that deviations from each aircraft's goal are 10 hours at most, which is not penalised according to the model. During the observed four weeks the initial status of 2nd, 3rd and 4th week is within the allowed tolerance of the deviation from the goal line.

5. CONCLUSIONS

Maintenance requirements vary for different types of aircraft, however experience shows that aircraft need some type of preventive maintenance every 50 or 100 flight hours. Hours spent on maintenance have to be taken into account in a Flying training organisation, as during that period the aircraft in not available for training purposes. This paper analyses one month period during the flight training season divided into weeks. According to presented data, this kind of planning is a useful tool for flight planning in a training fleet. The results of the comparison justify further development and usage of the model in order to achieve higher operational availability.

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