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An optimization approach to aircraft dispatching strategy with maintenance cost – A case study

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ABSTRACT

This paper presents an optimization approach to identify aircraft dispatching strategy at a flight training school. The strategy adopted by the school was to dispatch the aircraft which is closest to its scheduled maintenance. This strategy was examined and compared with other potential dispatching strategies. The paper presents a mixed integer linear programming model to identify the strategy that minimizes the total cost of scheduled maintenance. The analysis shows that the optimization approach can save 2%–5% on annual maintenance cost compared with other strategies. The model can equally be applied to rental cars or trucking companies.

1. Introduction

Embry-Riddle Aeronautical University (ERAU) at its Daytona Beach campus offers various aviation degree programs including flying single and multi-engine aircraft. The University has more than 1000 flight students, 41 Cessna 172 single engine and 6 Diamond multi engine aircraft as well as diverse simulators in its flight school. All of these aircraft are leased. The school has qualified crew who perform scheduled and unscheduled maintenance programs on all types of aircraft. On average, there are about 2700 flight training sessions for single engine aircraft per month. Each training session takes about 1.6–1.8 h. However, all flight training sessions are reserved on a 2-h time blocks to accommodate briefing, reports, etc. The flight Dept. at ERAU, is responsible for training, operation and maintenance of aircraft. It has set the scheduled maintenance program for every 50 flying hours for the Cessna 172 single engine aircraft. Of course, the maintenance scope and cost differ for each of these scheduled maintenance.

The current strategy of the flight Dept. for dispatching an aircraft to students is to utilize the one closest to its 50-h scheduled maintenance. The Dept. is, however, interested in exploring other assignment strategies resulting in lower maintenance cost and/or higher aircraft availability to students. This paper attempts to present a mathematical modeling approach to identify a dispatching strategy which results in minimum total annual maintenance cost and increased aircraft availability. This strategy is compared and contrasted with other strategies including the existing dispatching strategy. Section 2 provides a literature review of existing models applied to similar industries. Section 3 introduces parameters specific to this case. Sections 4–6 present the mathematical model, computation analyses and performance evaluations of various strategies. Finally, section 7 concludes this paper.

2. Literature review

This case study has some similarities to multiple asset management which has been extensively studied in the literature. In multiple asset management, the focus is to manage multiple resources to meet demand typically at different locations. Examples include rental cars (see for example Pachon et al., 2006, Li and Tao, 2010), rail cars (Papier and Thonemann, 2007; Bojovic, 2002) and truck assignments (Miao et al., 2009). In these research streams the focus is to assign multiple resources to a number of customers at different locations and at minimum cost. These studies do not address varying cost of maintenance with usage. They adopt a variety of network optimization models to satisfy demand at different locations. The literature on multiple resource allocation with varying cost is very scarce. The study by Hertz et al. (2009) considers varying maintenance cost in a rental car company. However, the scope of the research is completely different from this study. They propose an inventory control model to purchase new cars by examining the existing fleet to satisfy the demand.

Other related research studies include parallel machines scheduling (see for example Cheng et al., 2011 or Kubzin and Strusevich, 2006) where only one maintenance activity is allowed throughout the makespan.

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The commercial airlines' aircraft routing in the literature is primarily focused at maximizing utilization and route aircraft to hubs for schedule maintenance (Bazargan, 2010). In these models, maintenance is included as a side constraint to insure the aircraft is at the right hub for maintenance after certain number of flight hours (See for example Barnhart et al., 1998 or Li and Wang, 2005).

Although the above research works provide some information on standardized problems, they do not capture the scope and nature of the current case study where maintenance cost varies with usage. To the best of our knowledge, we are not aware of any similar study, where maintenance cost is the driving force to utilize a resource among multiple resources.

3. Aircraft maintenance cost

Maintenance activities are the backbone of successful aircraft operations. In the aviation industry, the role of maintenance is to provide safe and airworthy aircraft every day. The Cessna 172 aircraft are popular and extensively used for training flight students at different flight schools worldwide. The ERAU's flight Dept. utilizes 41 of these aircraft for training flight students.

Similar to cars, the types and scopes of scheduled maintenance programs vary with usage. This variation in maintenance programs lead to different cost depending on usage. In the aviation industry, a typical metric for aircraft usage, is tach times. Tach times, broadly defined as the number of hours that the aircraft engine(s) have been running. Throughout this paper, when hours are mentioned they are meant to be the tach times.

The flight Dept. requires scheduled maintenance to be performed for every 50 h of usage for Cessna 172 aircraft. It should be noted that the school's maintenance program is more stringent than those recommended by the manufacturer. The manufacturer's recommended maintenance program for Cessna 172 does not require scheduled maintenance for every 50 h of flight.

Fig. 1 presents the cost of scheduled maintenance (in US$) for this fleet of aircraft against these 50 h utilizations. The cost of maintenance includes labor and parts. As an example, the 50 h scheduled maintenance cost is $1085.38, for 100 h it is $1693.24, etc. This figure provides the maintenance costs for up to 2250 h. These cost figures repeat themselves every 2250 h. The flight Dept. continues to use these aircraft up to 7200 h where they are replaced with new ones.

There are currently 41 Cessna 172 aircraft available for training sessions. For any scheduled training there may be more than one aircraft available. In that case, the strategy that the flight Dept. adopts for aircraft dispatching is to utilize the aircraft which is closest to its scheduled maintenance. This algorithm is programmed into the flight dispatching system and automatically selects the aircraft for training based on their current flight hours. As an example, if there are two aircraft with 1587.2 and 2461.6 flight hours available for dispatching, the system dispatches the former since this aircraft has 12.8 h (1600–1587.2) while the latter has 38.4 h (2500–2461.6) left to its scheduled maintenance. The scope of this study is therefore to identify and evaluate other strategies. In particular, those strategies that minimize total maintenance cost and/or maximize aircraft availability. It should be noted that at peak times some training sessions are canceled because there is no aircraft available.

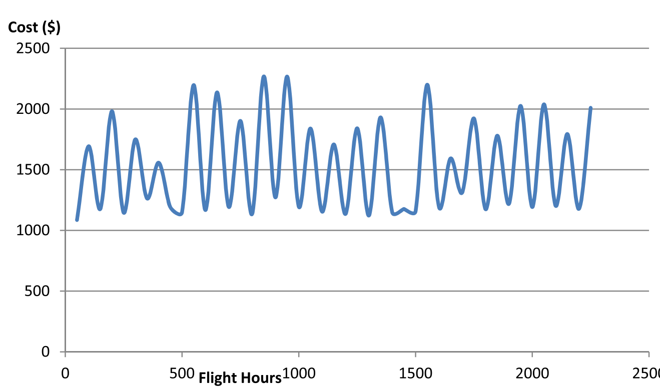

Fig. 1. Scheduled maintenance cost versus aircraft flight times.

4. Mathematical model

This section presents the mathematical approach to derive the strategies that lead to minimum dispatching cost and/or maximize aircraft availability as discussed earlier. The first model attempts to identify aircraft to be dispatched in an effort to minimize the total maintenance cost over the planning period. This model is then modified to address maximizing aircraft availability.

In this model we use the term *planning period* to signify the desired period of time for aircraft dispatching (for example in one year). This is the time period included in the model to minimize maintenance cost and maximize aircraft availability.

The description of the mathematical model is as follows:

Index:

J = index for aircraft (j = 1,...,A)
k = index for maintenance program (k = 1,...,K)

Decision variables:

x_j = hours added to aircraft j at the end of planning period

$$y_{k,j} = \begin{cases} 1 & \text{aircraft } j \text{ has reached maintenance } k \\ 0 & \text{Otherwise} \end{cases}$$

H_j = Total hours on aircraft j at the end of the planning period

Parameters

I_j = Initial total flight time hours on aircraft j at the beginning of planning period
$C_{k,j}$ = Cost of maintenance (in dollars) for maintenance k on aircraft j
$M_{k,j}$ = Scheduled hours for maintenance k on aircraft j
$p_{k,j}$ = Taking a value of 1 if maintenance type k has been performed on aircraft j at the beginning of planning period and 0 otherwise
T = Average flying time of a flight
ACT = Number of flight activities in the planning period
M = An arbitrary large positive number

Mathematical Model:

$$\text{Minimize} \quad \sum_{k=1}^{K} \sum_{j=1}^{A} \left(y_{k,j} - p_{k,j}\right) c_{k,j} \tag{1}$$

Subject to:

$$H_j = I_j + x_j \quad \forall j \tag{2}$$