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A Simulation of Optimal Model on Fractional Aircraft Ownership (FAO) Management

Novriana Sumarti[1,✉], **Ida B.P. Brahmandita**[2], **Muhammad A. Aqsha**[2]

[1]Industrial and Financial Mathematics Research Group, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Ganesha 10 Bandung, Indonesia
[2]Master of Mathematics Study Program, Faculty of Mathematics and Natural Sciences, Institut Teknologi Bandung, Ganesha 10 Bandung, Indonesia

novriana@itb.ac.id ✉, iberama22@gmail.com, muhammadalifaqsha@gmail.com

Abstract

Compared to owning a private jet, Fractional Aircraft Ownership (FAO) concept is a cheaper alternative for very mobile business persons who want to travel in comfort. The aircraft is owned by a number of customers (referred to as "owners") and the flight hours of its operation are shared based on each owner's portion. In this research, we do the simulation of an FAO company with very large demands with 27 cities of destination, which are commonly visited by business people in Indonesia. We derive flight demands stochastically from the owners and create optimal flying schedules based on the demands. Using the calculation of fixed and variable costs, we can determine the optimal flight pairings that minimized the operational cost. Eventually, we can determine the number of aircraft needed to be owned by FAO so the business will profit.

Keywords: *Optimization, Flight Scheduling, Stochastic Simulation, Aviation Industry, Mathematical Modelling, Investment.*

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1 Introduction

Traveling by airplane is an effective and efficient form of transportation in reaching cities that are far from each other. Especially in an archipelagic country such as Indonesia consisting of 17,504 islands. Problems of aviation industry has been widely taken up as research problems in order to find optimal ways in operating the related business. In [4], the survey made among 249 airline businesses showed significant differences in terms of risk and estimated cost of capital. A significant interaction between investment analysis and the way projects were financed was found, where airlines did not seem to use the most advanced technology on the market very often in spite of more sophisticated technologies being used.

Due to observation showing that many large fractional jet airlines had not been profitable, the authors in [13] discussed various strategic planning issues, such as aircraft maintenance, staff turnover, demand growth, and differentiation. Their impact on resource utilization and profitability were analyzed. Using the column generation procedure, the pricing problem by finding the shortest path in each crew network was solved in 1,2,3-day planning horizons respectively.

Some numerical methods are commonly utilized for solving optimization problems. Having implemented the method of Simulated Annealing using data of Garuda Indonesia, a national airline company in Indonesia, paper [12] solved the aircrew-assignment problem and its computational aspects that served 42 domestic and international destinations. The results showed the minimum number of the aircrew needed and its optimal allocation for operating the flights that balanced the flying and duty hours for each crew.

Authors in [6] derived mathematical expressions for the cockpit crew labor regulations and solved the optimization problem of nonlinear integer programming for finding the minimum value of mean relative deviations of the total flight time from the ideal flight time. The data being used was crew classes in the cockpit of Garuda Indonesia and the method being used is the simulated annealing method.

In [8], a goal programming of selecting optimal pairings covering all provided flights was solved by heuristic method like Bat Algorithm (BA), which was mimicking the bat behaviour, so the operational cost such as crew cost could be minimized.

A modification of the optimization problem could be made so it would propose a more realistic solution. In [11], the aircrew assignment problem was solved with constraints derived from the implemented regulations, such as flying time, resting time, the total number of takeoffs, and the number of holidays and workdays. Data being used was of a one-month full flight schedule from a big airline in Indonesia. Using a simple fuzzy logic approach, the paper proposed to find a new flying time tweaked from the existing regulation as in [12], so it can have better results on the personnel cost and evenly distribute the assignments.

A recent paper [5] proposed an optimization model

$OF_i(k)$ is the paid annually and calculated from the aircraft's share-price of owner$-i$ and depended on the number of aircraft being utilized q,

$$OF_i(q) = \frac{1}{5}\alpha_i q P_1,$$

where P_1 is the price of one aircraft. Each owner needs to pay it in 5 years, because the ownership contract is 5 years. The cost MF_i is paid monthly for maintenance cost, insurance, salary for pilots and aircraft staffs. The amount of this cost is proportional to the share owned. Let P_2 is unit cost USD for management per share owned, then

$$MF_i = 16\alpha_i P_2.$$

The cost HF_i is paid annually for paying the hours being occupied for fuel and operational cost. Let P_3 be the cost rate USD per hour.

$$HF_i = h\alpha_i P_3.$$

The yearly income of FAO is

$$\begin{aligned} I(q) &= \sum_{i=1}^{n} OF_i(q) + 12MF_i + HF_i \\ &= \sum_{i=1}^{n} \alpha_1 \left(\frac{q}{5}P_1 + 12(16)P_2 + hP_3\right) \end{aligned} \tag{10}$$

FAO spends 2 types of expenses; fixed cost T_1 and variable cost T_2 depending on the flying time FT. The fixed cost T_1 only depends on the number of aircraft owned by FAO, where are based on [3]. Total fixed cost is defined by

$$FC(q) = qT_1. \tag{11}$$

The operational cost OP per day consist of the Parking Cost Pr and Landing Cost Ld at all discussed airports. For some routes, aircraft sometimes cannot fly directly to their destination, and must make a transit if the distance traveled exceeds the cruising range. There are additional cost of transit TC, consisting of parking cost and landing cost. Therefore, the operational cost of a pairing p on a certain day d can be determined using the following formula

$$OP_{pd} = T_2\left(FT_{pd}\right) + Pr_{pd} + Ld_{pd} + TC_{pd}. \tag{12}$$

The other component of the variable cost is outsourcing cost when the owned aircraft will be over-occupied by the owners requests. Let OTC_d be the outsourcing cost which is the rental price of an aircraft from other companies at day d. The unit cost is assumed to be the same for all outsourcing companies, which is $Rt = 3,350$ USD per hour of the flying time. The outsourcing cost is defined by

$$OTC_d = FTO_d \times Rt, \tag{13}$$

where FTO_d in hour(s) is the remaining flying time that cannot be covered by the usage of q existing aircraft. Here we choose the pairing that served by outsourcing aircraft such that its flying time is the lowest, because the cost for rent an aircraft from an outsourcing company is more expensive than the operational cost for flying the company's owned aircraft.

Finally we can define total of cost in a year by this following equation

$$C(q) = FC(q) + \sum_{d=1}^{365}\left(\sum_{\tilde{p}=1}^{n\tilde{p}} OP_{\tilde{p}d} + OTC_d\right). \tag{14}$$

Note that $\sum_{\tilde{p}=1}^{n\tilde{p}} OP_{\tilde{p}d}$ is the total cost of the optimal pairing in day d.

At the end of year 5, we will evaluate the price of the existing aircraft in order to know the final value of the asset of FAO. Based on Airline Disclosure Guide, generally aircraft assets are depreciated over 15 to 25 years with residual values between 0 to 20 percent. Suppose we take the median, so it means the price is depreciated over 20 years with residual values of 10 percent. If the sale price of an aircraft is P_1 when it is bought at the beginning of year 1, then the estimated yearly depreciation cost is equal

$$D = \frac{P_1 - 10\%P_1}{20} = 0.045P_1. \tag{15}$$

If it is assumed that the depreciation goes as in a decreasing line, so at the end of year 5, the price of aircraft will become $P_1 - 5D$.

5.2 Rate of return

To value an investment whether it is profitable or not, one of the observable indicators is the rate of return r. Commonly if this rate is higher than the inflation rate, it is considered a good investment. In FAO investment, efficient pairings of routes to serve the daily request of owners will reduce the cost. The highest expense in this investment is buying the aircraft. Therefore, we simulate the model of FAO defined in the previous sections in order to answer the optimal number of the aircraft.

Let $R(q,r)$ be a function containing the number of aircraft q and the rate of return r. Let $C_j(q)$ be the total cost of the year. It is assumed that the annual income is paid at the beginning of the year, and the operational cost is recorded at the end of the year. The rate of return r is the desired solution or the root of the equation $R(q,r) = 0$.

$$\begin{aligned} R(q,r) = I(q) - qP_1 + \sum_{j=1}^{4} \frac{I(q) - C_j(q)}{(1+r)^j} \\ + \frac{q(P_1 - 5D) - C_5(q)}{(1+r)^5} \end{aligned} \tag{16}$$

Let $\tilde{R}(q)$ be kind of inverse function with respect to r. We can write the optimisation problem of investment is

$$Max_q r = \tilde{R}(q). \tag{17}$$

It is only possible to estimate the solution of problem (16) numerically, by using the root finding method. Solutions to the problem (17) are concluded from the results of the simulations.

6 Numerical Simulation

Implementation of the FAO model is using data in Indonesia, but the chosen currency is USD to make financial data easier to write. The type of aircraft being used is Phenom 300 with 6 to 8 passengers, where the maximum speed is 859 km/hour, and the weight is 6350 kg [2, 1]. It has been used at an average speed of 80% of its maximum speed. We conduct simulations for the total flight time of hours to be 800 and 640 hours.

Using the number of airports $m = 27$, the generated number of routes is 702 routes, where the airplane flies less than or equal to 8 hours per day. Due to this limitation on a single flying time, there are only 2 cities that can be served for one request. Some routes have a flying time more than the limit so there should be a transit airport between the departure and destination airports.

Table 4: Data for Income (10)

Item	Cost (USD)
P_1	8,760,000
P_2	7,832
P_3	1,566

In this simulation, we assumed that there are 5 owners who had owner share as follows:

$$S_1 = \frac{2}{16}, S_2 = \frac{2}{16}, S_3 = \frac{3}{16}, S_4 = \frac{4}{16}, S_5 = \frac{5}{16}$$

The parameter values in equation (10) are shown in the Table 4. The fixed and variable costs are written in Tables 5 and 6.

Table 5: Data for Fixed Cost (11)

Item	Cost (USD)
Crew Salaries	208,000
Hangar	29,700
Insurance	32,888
Recurrent Training	26,200
Modernization	20,000
Navigation Chart Service	3,742
Refurbishing	18,900
Computer Maintenance Program	3,250
Weather Service	700
Total (T_1)	343,380

Table 6: Data for variable Cost (12)

Item	Cost (USD)
Fuel	787
Maintenance Labor	68
Engine Restoration	92
Crew Expenses	70
Supplies	33
Total (T_2)	1030

Based on the simulations, the average expected total cost $C(q)$ per year in USD is shown in Figure 5, where the management has q aircraft. The cost for the number of aircraft $q = 1$ tends to be the highest among the others. Because there are rental expenses of some outsourcing aircraft that must be provided to serve the owner's requests. For other values of q , we can see that the total cost is a little bit decreasing for $q = 2$ and $q = 3$. Furthermore, the cost tends to increase for the number of aircraft $q = 4$ and $q = 5$. This is due to the increase of fixed costs that include the total price of all aircraft bought by FAO management. Based on the simulation result, the minimum cost is achieved when $q = 3$.

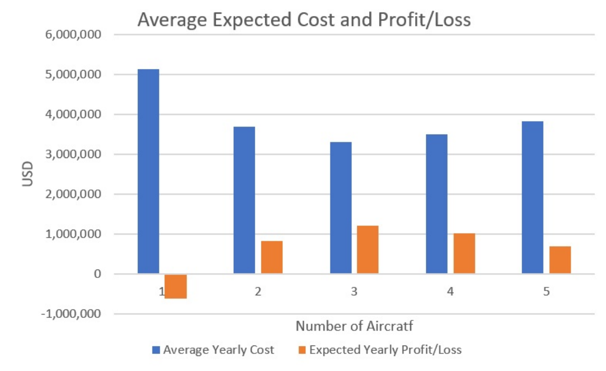

Figure 5: Average Cost and Profit per year

The average expected profit per year with q aircraft in USD based on the simulations is shown in Figure 5. The calculation is summation of the profit for 5 years, and it is not considering the time reference when the profit being produced. The maximum profit is expected when $q = 3$.

Table 7: Rate of return $h = 800$ hours

Nb of aircraft	ROR per year (%)
1	-31.754
2	0.308
3	0.125
4	-2.072
5	-3.665

Now we calculate the rate of return (ROR) per year using equation (16), where the result is shown in Table 7. If FAO has 1, 4, or 5 planes, then FAO management will suffer losses when fulfilling the owner's request. On the other hand, if FAO has 2 or 3 planes, then FAO will make a profit, with the biggest ROR for having 2 aircraft. So the optimal number of aircraft that FAO must have is 2 aircraft. However, the ROR is very small so it will discourage investors to make FAO as their business.

Now using the same income, we consider having lesser total flight time being committed, which is 640 hours per year. As shown in Table 8, the rate of return per year tends to increase when the total flight hours are reduced. This is because when the total flight hours are reduced, the number of requests from the owners will also decrease. As a result, daily variable costs will

Table 8: Rate of return $h = 640$ hours

Nb of aircraft	ROR per year (%)
1	2.213
2	6.607
3	2.194
4	-0.937
5	-2.805

decrease and this causes expected total cost also decreases. Reduction of the total cost can lead to increases in the profit and the rate of return. Table 8 shows the total flight time per year is 640 hours, and FAO owning 2 planes will expect to have a rate of return of 6.607% per year.

7 Conclusion

FAO is a concept of joint aircraft ownership among a number of business people. This research wants to estimate the profit FAO management if the joint aircraft charter scheme is implemented in Indonesian data with very large number of airports being observed. The simulation is run using the python programming language and using Google Collab. We want to use the GPU accelerator so that the computation time is faster.

In this research, a stochastic scheme has been successfully built to generate requests from FAO owners. To optimize cost and time, an optimization model to determine optimal pairing has also been successfully built. Based on the assumption and the calculations in the simulation, the number of aircraft that provided the optimum profit and rate of return is 2 aircraft. Having total flight hours of 800 hours per year, the expected rate of return is 0.308 %. For total flight hours of 640 hours, FAO will be able to get an expected rate of return of 6.607%.

In the future, the research can be continued with the different provisions of shares of ownership and find the optimal form of the type of ownership that makes the most profit among others. For the application in the real world, the FAO management could think of the appropriate total flight hours so the obtained profit is acceptable.

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