

Design of a Primary Flight School Decision Support System

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Abstract – There is a growing shortage of commercial pilots in the aviation industry. Flight schools provide a necessary, but insufficient, link in producing pilots. Rising prices associated with aircraft lead to higher training costs. It is possible that this burden associated with training significantly influences the declining number of students completing flight training. This paper details the development of a system to assist flight schools in choosing the lowest-cost combination of aircraft type and quantity at a static level of demand for training. A stochastic queuing model covering the costs for a ten-year life-cycle is developed for the decision support system. Stochastic characteristics are derived from historical data from a flight school. The model accounts for recurring and non-recurring costs for aircraft operation.

Index Terms - flight school, primary training aircraft, decision tool, stochastic, simulation.

CONTEXT

I. Pilot and Flight Schools

Pilots are people who have been authorized to operate aircraft by the United States Government through the Federal Aviation Administration (FAA) or through the Armed Services. Under the FAA, civilian pilots are categorized by certificates which assign limitations to their holders. These certificates, in order from most limited to least, are for student, recreational, light sport, private, commercial, and airline transport pilots (ATP).

Flight Schools are the mechanism by which individuals become pilots. They come in three categories: private, university, and military. A private flight school is an entity owned and operated as a for-profit organization. A university flight school is attached to an accredited university program. A military flight school is a center where the armed forces train recruits in aircraft operations. This project focuses on private flight schools.

Private flight schools come in two types, each labeled for the set of FAA regulations under which they have the authority to train pilots: Part 141 and Part 61. Both sets of regulations define minimum requirements for pilot training and certification [6]. A Part 141 school is FAA certified and has FAA certificated flight instructors. Greater FAA oversight and more rigorous training criteria afford students the option of earning a certificate in less amount of time than at a Part 61 school [9]. Part 61

schools are not FAA certificated, featuring only flight instructors with FAA certification and a more relaxed training regimen. Both types require potential pilots to meet the same standards of performance.

Figure 1 details the order in which certificates are obtained and the current delta cost range of each stage in the process. [3]. To obtain a given certificate, the potential pilot must also obtain each preceding certificate. First, a student would earn a private license at a minimum requirement of 35 flight hours under Part 141 regulations [6]. Once a pilot has a private certificate, that pilot can obtain an instrument rating, requiring 50 hours of cross-country flight time. Following the instrument rating is the commercial certificate, which authorizes a pilot to be paid to fly. This requires 190 hours for students under 141 regulations. After obtaining a commercial certificate, pilots can work up to the 1500 hours needed before earning an ATP license. Many pilots choose to earn hours by working as a Certificated Flight Instructor (CFI), training other pilots. A pilot also needs multi-engine and jet engine ratings to become an ATP.

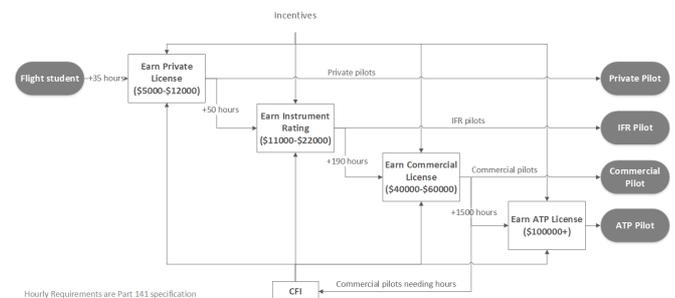


FIGURE 1
TYPICAL ATP PROGRESSION

II. Number of Pilots is Decreasing

In 1999, the total number of active pilot certificates in the United States was 635,465. As of 2013, the number of active certificates had dropped to 599,086 a decline of 6% [5]. The number of original certificates being issued per year at the student level has also decreased since 1990. Less student pilot certificates are being issued which indicates a shrinking pool of individuals looking to earn private certificates. Because earning a private certificate is required for earning an airline transport pilot certificate, this also indicates a shrinking quantity of pilots able to earn the latter.

The CFI are also in decline, with the certificate following the trend of decreasing issuance. There exists a 38% drop in the number of CFIs being certified from 1990 to 2009 [4].

III. Existing Pilots Are Aging

As the number of new pilots decreases, the average age of pilots is increasing. Figure 2 [5] depicts the age distribution for all pilot license holders, from students to ATP, in 1999 and 2013. As shown in Figure 2, the age group with the most pilots in 1999 was 40-44. In 2013, over a decade later, the age group with the most pilots was 55-59. Additionally, the total number of pilots decreased from 635,465 in 1999 to 599,086 in 2013, which totaled in a 6% decline of pilots. A concern here is that the younger group of pilots does not contain as many individuals as it did in 1999. This suggests that after retirement and other attrition in current pilots, there may not be enough pilots to satisfy future demand. Since there is already a decline in the number of new pilot licenses being issued and in the total number of pilot license holders, it is likely that the average age of pilots will continue to increase.

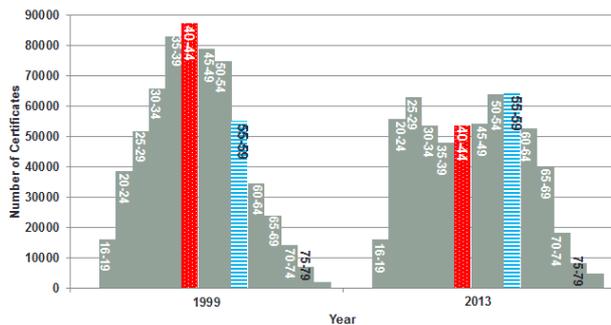


FIGURE 2
LICENSE HOLDERS ARE AGING

IV. Aircraft Costs

The cost of obtaining a private pilot certificate has increased uninterrupted since 1990 [1]. There appears to be an approximate correlation in the price of aviation gasoline, typically used to fuel primary training aircraft, which has nearly doubled over 20 years [2]. While the price of obtaining a private pilot certificate seems to follow the trend in aviation gasoline prices, the correlation is not directly proportional indicating other factors influencing cost. Such factors include cost of obtaining and maintaining aircraft for student pilots to use. Many of the primary trainers currently used by flight schools are getting older, incurring additional maintenance costs and preventing the planes from flying. Figure 3 shows where fuel price and maintenance would fit into aircraft operations by a flight school. Since some of the costs recur even when the plane is not being flown, such as tie down space to store the aircraft, the more an aircraft is flown the less it costs to keep at the margin.

Greater use of the aircraft also spreads use-based recurring costs out over greater revenue streams.

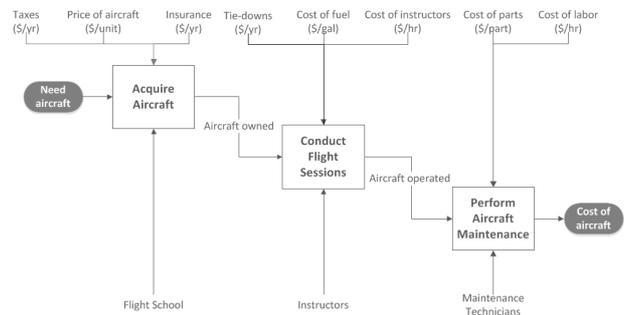


FIGURE 3
AIRCRAFT OPERATIONS COST MODEL

STAKEHOLDER ANALYSIS

I. Private Flight Schools and Flight Students

Flight schools have the objective of making a profit by training flight students. They employ certificated flight instructors and maintenance technicians. The main tension is keeping costs affordable for students to train but charging enough to make a profit.

Flight students have the objective of earning a pilot license. The main tension is earning a license at an affordable cost from the flight schools.

II. Certificated Flight Instructors and Maintenance Technicians

Certificated Flight Instructors (CFIs) and Maintenance technicians are employed by flight schools. CFIs hold at least a Commercial Pilot Certificate and have been authorized by the FAA to train students. This position is considered to be a steppingstone to other positions, such as an ATP. CFIs have the objective of earning a salary by training students. Many have the objective of building up their hours in flight to reach 1500 hours, which is needed for the ATP license. The main tension is the low wage they are paid by the flight schools.

Maintenance technicians are employed by flight schools. Their objective is to earn a salary by maintaining flight school's aircraft. The main tension is the low wage they are paid by the flight schools.

III. Aircraft Manufacturers and Airlines

Aircraft manufacturers and Airlines are secondary stakeholders and outside the scope of this project. The objective of aircraft manufacturers is to earn a profit by manufacturing and selling aircraft to flight schools. Airlines have as an objective to employ pilots. The main tension is that they hire CFIs as ATP pilots once they have accrued 1500 hours in flight but it can be difficult for flight schools to find qualified CFIs to hire for student pilot training.

PROBLEM AND NEED STATEMENTS

I. Gap Analysis

Utilization rate is the time in flight for a single engine aircraft over its total time available. Better performing schools have a higher utilization rate. Lower utilization rates correlate with higher costs of operations. As the time flown per month increases, cost of operating aircraft increases. Schools with low utilization costs have higher costs of operating aircraft and schools with higher utilization have lower cost of operating aircraft and they perform better financially. Schools with low utilization rates cannot reduce the costs of aircraft operation and therefore cannot profit as much as schools with high utilization do.

II. Problem Statement

The hypothesis is that acquiring and maintaining aircraft are a major factor contributing to higher prices at flight schools, leading to lost customers and struggling businesses. Higher prices result in fewer students willing to go to school. As the price of training increases, the number of student decreases. When the number of students decreases, the price increases.

III. Need Statement

With the higher prices of obtaining a license resulting in lower utilization rates of aircraft at flight schools, there is a need to reduce the acquisition and maintenance costs of aircraft used in training new pilots.

METHOD OF ANALYSIS

I. Design of Experiment

In order to assist flight schools in making decisions relevant to the operation of aircraft, the Java programming language was used to provide a software package that can take user inputs, simulate the process of flying and maintaining the aircraft under a flight training environment, and return the amount of flight time, the amount of maintenance time, and the flow of money associated with both. The simulation contains three main functions: an events scheduler, an events executor, and a cost counter that each execute in that order on a repeating basis, the length of which is determined by a simulation time received from the user. Figure 4 shows the processes that occur inside the simulation during a single scheduled unit of time.

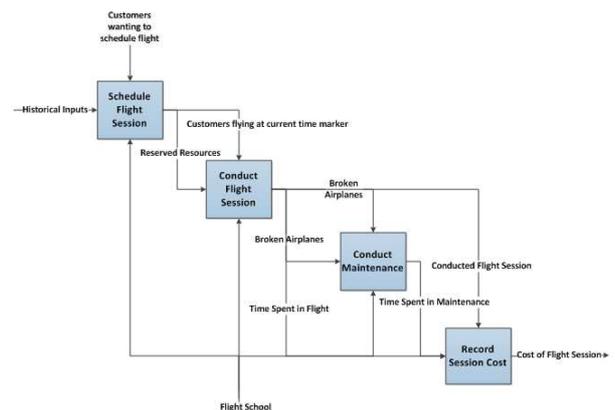


FIGURE 4
SIMULATION PROCESS FOR ONE TIME UNIT

II. Scheduling Events

First the simulation creates a blank schedule of the same length as the input time interval, broken up into time units equaling one hour of time each. Resource pools for aircraft and instructors as well as a list of events to be run during that hour exist within each slot. The simulation iterates through these time slots one at a time, first scheduling future events that may take place at any point in the schedule between the current hour and the last hour.

While scheduling events, the simulation uses historical flight data to generate hourly session arrival intervals, session arrival quantities, and session durations for two types of events: flight sessions and maintenance sessions. Flight sessions are students arriving for a flight lesson, are completely stochastic, and demand one aircraft and one instructor. Maintenance events are inspections, overhauls, or unexpected service to be performed on one aircraft. Inspections and overhauls arrive according to scheduled conditional statements, while unexpected service is stochastically determined.

Before any stochastically determined events arrive, the simulation runs a check on the number of hours in an inspection or overhaul counter for each aircraft in a global resource pool. If the number of hours on the aircraft inspection counter exceeds 100 hours, an inspection maintenance event is generated that will take 36 hours to complete and the aircraft is made unavailable in each of the hourly resource pools for that number of hours starting immediately and the counter is set to zero. If it exceeds the user-determined number of hours for an engine overhaul on the overhaul counter, an overhaul maintenance event is generated that will take 504 hours to complete and the aircraft is made unavailable in each of the hourly resource pools for that number of hours starting immediately and the counter is set to zero.

After determining when an event arrives, the simulation runs a check to see if there are sufficient resources available in the desired time slot and adds the event to the list of events occurring at that hourly time slot

if it can be supported, decrementing each of the used resource pools by one. If the arriving event is a flight session and there are insufficient resources, it is ignored. If the event is a maintenance event and there are insufficient resources to add it to the list of concurrent events, the flight session associated with the affected aircraft is replaced with the maintenance session, and the instructor resource pool is incremented by one.

III. Executing Events

During each hour slot, the simulation also checks the associated list of events to see if there are any sessions to be run and, if so, runs them. The simulation iterates down the list of events and adds to a counter. If the event is a flight session, one hour of time is added to a total flight time counter and one hour is added to both the inspection and overhaul counters for the specific aircraft used. If the event is unexpected maintenance, it adds one hour of time to an unexpected maintenance counter. If the event is scheduled maintenance, it determines whether or not that maintenance was an overhaul, adds one unit to the relevant counter, and adds one hour of time to an expected maintenance counter.

IV. Counting Costs

After the simulation has run through the length of time to be simulated, it repeats the process for a user-determined number of repetitions, storing the time spent in flight, the time spent in maintenance, the number of inspections, and the number of engine overhauls for each one. The average of these values is then taken and stored. The simulation then performs a series of arithmetic operations that multiply each of the stored values by a unit cost associated with them.

First, the flight time is multiplied by the fuel consumption rate of the tested aircraft, the local price of 100LL aviation gasoline, and the amount paid to instructors. Next, the time spent in unexpected maintenance is multiplied by the shop-rate, followed by the duration of the simulation being multiplied by tie-down price per hour, per aircraft. The resulting fees are summed and returned to the user, along with the number and type of tested aircraft, as the cost of operations over the simulated length of time.

V. Assumptions and Limitations

The simulation of flight operations assumes the following to be true:

- All scheduled flight sessions are student sessions
- Rate of demand for services is static
- Scheduled maintenance does not interrupt flight sessions
- CFIs are always available for use
- CFIs are only paid when they fly
- Hourly rate of renting the aircraft is the same across types

- Hourly rate for performing maintenance is the same across aircraft types
- Flight school services are available 24 hours per day and 365 days per year
- All revenue comes from flight students
- Price of fuel is static

The model also features several limitations. The first involves the scheduling of flight inspections and engine overhauls being determined after the simulation has run through the duration of the scheduler. This means that there is potential for the maintenance time and flight time for a single aircraft to exceed the number of hours simulated for under certain conditions. This remains a useful data point, however, because it illustrates that the level of demand cannot physically be met by that number of simulated aircraft.

Another limitation lies with the assumption that a given CFI is always available for use. In reality, a CFI may be on vacation or sick, and thus not available to instruct a student.

RESULTS

I. Maintenance Time when Varying Number of Aircraft

Given a fixed expected demand, defined as the expected number of flight sessions in a year, the experiment iterates through an increasing number of aircraft available to the school for flight sessions. The size of the pool is reported back as a ratio between the number of students and the number of aircraft, referred to as a Student-Aircraft (S/A) ratio. Figure 5 shows that the number of hours spent in maintenance for a single aircraft increases as the S/A ratio, featuring 300 students, increases when unhindered by the number of instructors.

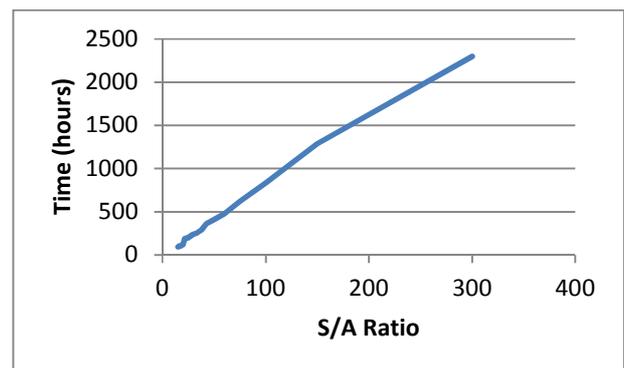


FIGURE 5
MAINTENANCE TIME PER YEAR VS. S/A RATIO FOR A CESSNA 172M

This behavior is the result of the occurring flights being spread among an decreasing number of available aircraft as the number of students using each aircraft goes up. Less demand on a single airframe decreases the rate at which unscheduled maintenance arrives and, more

critically, reduces the number of Federally mandated inspections that must be carried out within a given amount of time. Figure 6 totals the amount of time the aircraft is out of idle, and displays the change in percentage of that time which is spent in maintenance as the S/A ratio increases.

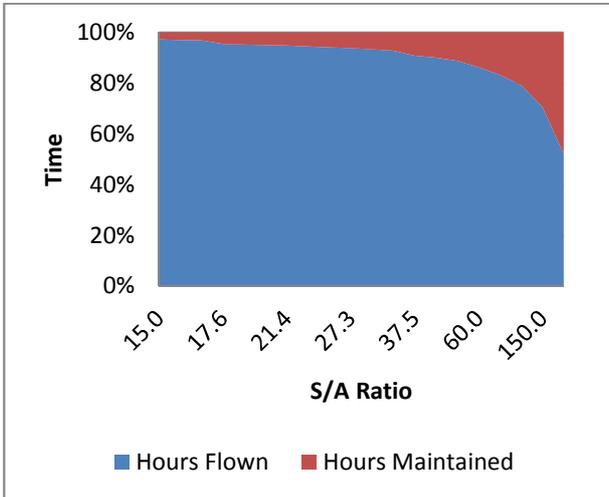


FIGURE 6
MAINTENANCE VS. FLIGHT TIME PERCENTAGE PER YEAR VS. S/I RATIO FOR A CESSNA 172M

The reduction in maintenance time per aircraft allows each one to be more available for flights, which allows demand to be met.

II. Profit when Varying S/I and S/A

Maintenance is the driving force behind cost of operations. Because time spent in maintenance is affected by S/A and S/I ratios and because costs play a role in determining profit, profit can be illustrated as a function of both S/A and S/I ratios. Figure 7, below, provides a three-dimensional visualization of a landscape so governed.

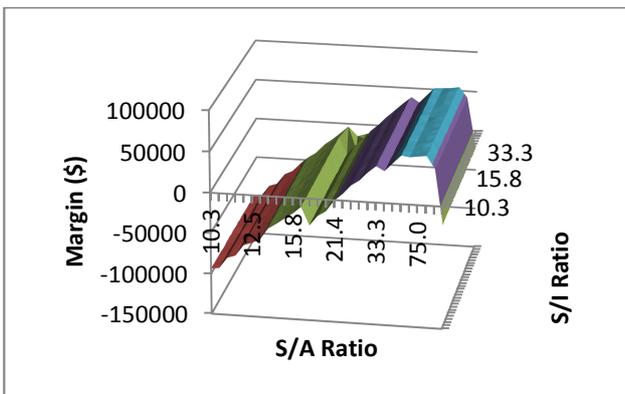


FIGURE 7
PROFIT MARGIN PER YEAR USING A FLEET OF CESSNA 172M

Profit visibly peaks when S/A is around 100 students for each aircraft. The S/I ratio appears to have little to no influence on profits, primarily because there are no steady state costs associated with having an instructor available. Figure 8 provides a close up inspections of these trends when uninhibited by the other resources.

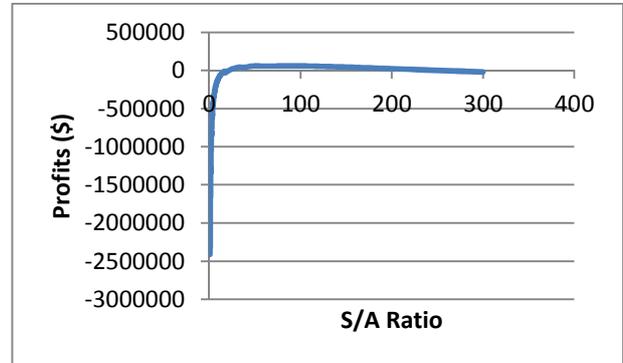


FIGURE 8
PROFITS PER YEAR USING A FLEET OF CESSNA 172M VS. S/A

Profits start in the negative zone when S/A is equal to one because, for this test, there are 300 students. Thus, to reach an S/A ratio of one there must also be 300 aircraft. Cost of insurance on each aircraft outstrips earned revenue quickly to the left of the peak. To the right of the peak, profits begin a downward trend as S/A ratio increases due to increased demand per aircraft and correspondingly increased required maintenance and lower availability.

III. Profits of Varied Aircraft Types

Given the conditions tested, Table 1 shows the resulting peak profit and corresponding S/A ratio from simulating flight school operations with homogenous fleets of varied aircraft models.

TABLE I
MAX PROFITS FOR VARIED AIRCRAFT

Aircraft	Maximum Profit (\$)	S/A Ratio where max profits occur	S/A Ratio where profits break even
Cessna 162	100347	100	14.3
Van's RV-12 (10%)	89353	50	13.6
Van's RV-12 (20%)	86002	50	13.6
Cessna 172S	77943	100	21.4
Cessna 152	73873	50	15-18.75
Diamond Eclipse	65944	50	15-18.75
Cessna 172M	59696	100	23.1
Piper Archer II	53057	50	23.1
Cessna 172SP	23332	50	25.0

With the same price charged to students for each aircraft, the Cessna 162 shows itself as the most profitable option with an S/A ratio of 100. The result is heavily influenced by the historically long MTBF and modest fuel consumption rate of roughly 6 gallons per hour in flight.

IV. Utility Analysis

The utility analysis was used to determine which of the considered primary training aircraft overall has the highest interval between maintenance, lowest fuel consumption, lowest maintenance duration, and lowest maintenance-to-flight ratio as seen in Figure 9. The Java program simulated one year of operations for a primary training aircraft four times and each time varied either the maintenance interval, fuel consumption, maintenance duration, or maintenance-to-flight ratio while keeping the others characteristics constant. Then, weights were assigned to each of these four categories based on how much they altered the profits from the aircraft over one year of simulated data compared to the results of a typical aircraft. Values were assigned to each of the considered aircraft based on their historical performance. The results of this sensitivity analysis show that the aircraft with the best performance characteristics is the Cessna 172S followed by the Cessna 162, Van's RV-12 10%, Cessna 152, Van's RV-12 20%, Cessna 172M, Piper Archer II, Diamond Eclipse, and lastly the Cessna 172SP.

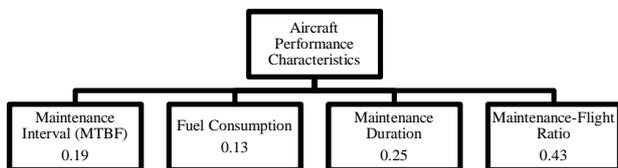


FIGURE 9
VALUE HIERARCHY

CONCLUSION AND RECOMMENDATIONS

1. Student-to-Aircraft ratio and, therefore, the number of aircraft play a much larger role than S/I in determining the profitability of a flight school's operation.
 2. Large quantities of time in maintenance results in lower profits
- Recommend flight schools place a higher value on tailoring fleet size to fit their demand.

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