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 provided by a real-world flight school. The model accounts for recurring and non-recurring costs for aircraft operation.

The results of the simulation indicate that a flight school should operate between three and six aircraft when the expected total rate of demand for services is six flights per day, depending on type of aircraft. The results display that demand rate per aircraft plays a large role in determining the optimum number of aircraft because a higher demand on a single aircraft increases the number of hours it must fly. An increased number of hours flown per aircraft results in an increased amount of time spent being maintained, decreasing its availability and increasing its operational overhead. The variance among the optimum number of aircraft is the result of differences in Mean Time Between Failures (MTBF), Mean Time to Repair (MTTR), and fuel consumption across the types.

Keywords: flight school, private pilot, primary training aircraft, decision tool, stochastic, simulation

1. Context

1.1 Pilots 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. This project focuses on private flight schools, which are owned and operated as a for-profit organization.

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 [4]. 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 a common way in which a student progresses throughout the pilot training process in order to earn an Airline Transport Pilot (ATP) license. Figure 1 also shows the current delta cost range of each stage in the process. [3]. 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 1,500 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.
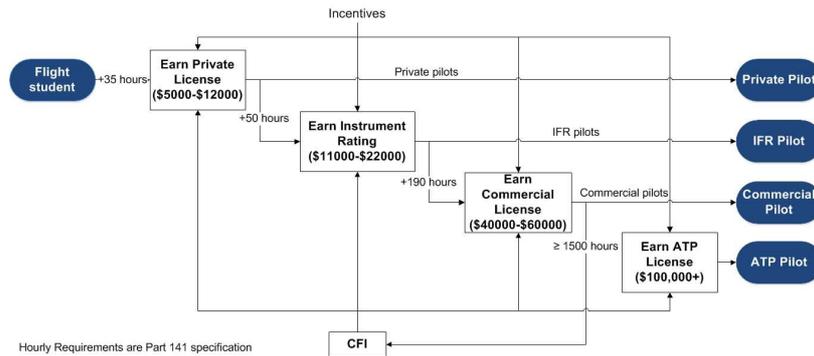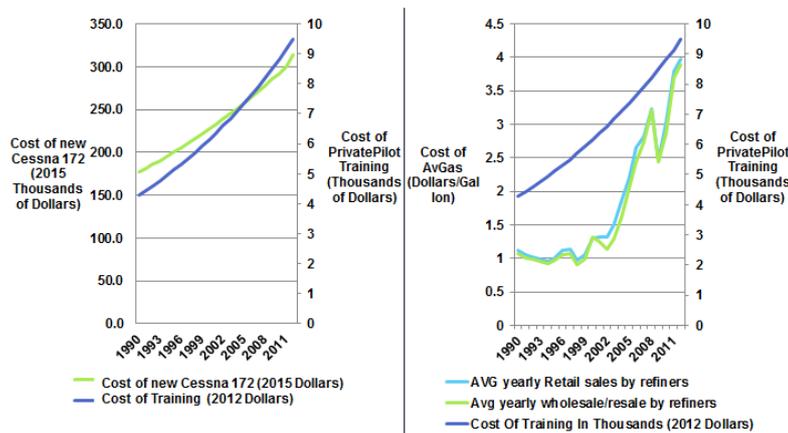
Figure 1: Pilot Training Life Cycle

There exists a belief that the number of pilots needed by the aviation industry is exceeding the supply and that a major hindrance to the creation of new pilots exists at the level of primary training [3]. Primary training is the process by which student pilots are educated by Certificated Flight Instructors (CFI) at flight schools with the goal of earning a Private Pilot certificate, after which point they may continue training to eventually become Commercial or Airline Transport Pilots (ATP).

1.2 Higher Component Costs Increase Price of Training

The cost to earn a private pilot license has increased significantly as seen on Graph 1 below. The cost has increased from $4,270 in 1990 to $9,476 in 2012 [1]. There are several component costs contributing to this price increase such as the cost of insurance for planes at flight schools, the hourly cost of maintenance for these aircraft, the cost of aviation gasoline, and the cost of the primary training aircraft. Graph 1 compares the cost of private pilot training to the increase in the price of a new Cessna 172, which is a popular primary training aircraft. In 1990, the Cessna 172 cost about $175,000 in 2015 dollars and increased to about $315,000 in 2012 [7,8]. Graph 1 also compares the cost of private pilot raining to the cost of aviation gasoline. In 1990, it cost $1.02 and in 2012 it cost $3.92 [2].


Graph 1: Pilot Training Life Cycle

## 1.3 Decrease in Pilot Throughput and Number of Flight Schools

As the price of pilot training has increased, the number of pilots earning flight certificates has decreased. In 1990, about 90,000 new student certificates were issued while only about 50,000 were issued in 2013 as seen in Graph 2 [5]. The number of private pilot licenses decreased from about 40,000 to 16,000. The number of new ATP

pilots has remained relatively constant. However, the process from becoming a flight student to an ATP takes many years. Therefore, it is probable that a similar decreasing trend can be expected from ATPs in the future.
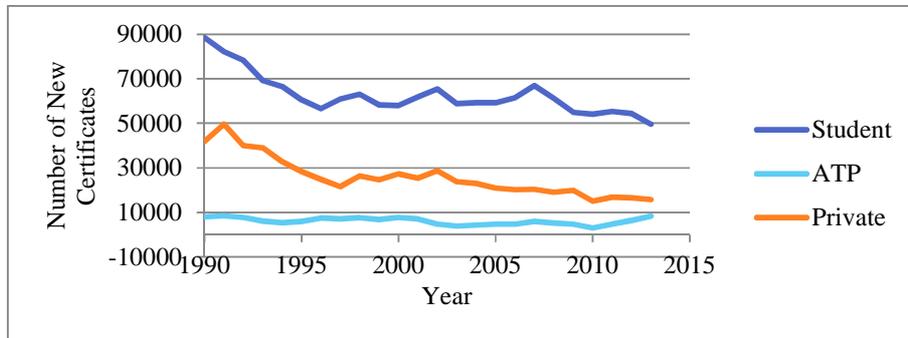
Graph 2: Decrease in Number of New Pilot Certificates

In conjunction with fewer flight students earning certificates, the number of flight schools has also decreased. Since 2005, there has been a 13% decrease in the number of flight school enterprises in the United States. This decrease accounts for a loss of 150 flight schools [9].
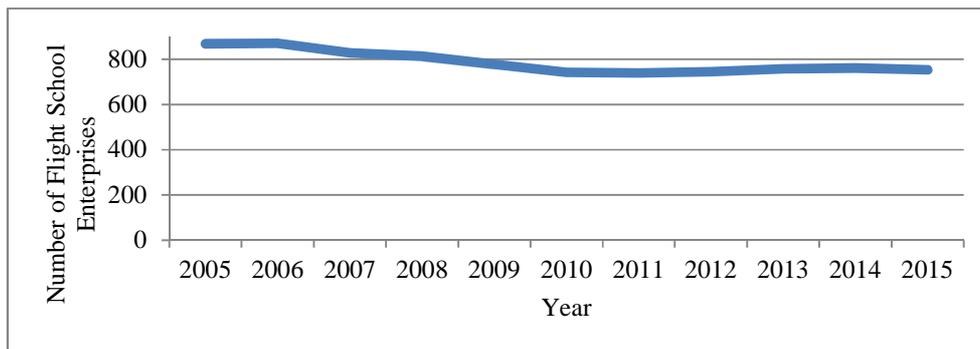
Graph 3: Decrease in Flight School Enterprises

2. Problem and Need Statements

2.1 Problem Statement

The hypothesis is that increased operating cost of aircraft is contributing to higher prices at flight schools, leading to lost customers and struggling businesses.

2.2 Need Statement

With the higher prices of obtaining a license resulting in lower pilot throughput at flight schools, there is a need to assist schools in reducing the costs associated with operating the aircraft used in training new pilots.

3. Stakeholder Analysis

3.1 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.

3.2 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.

3.3 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.

4. Method of Analysis

In order to assist flight schools in making decisions affecting what type of aircraft they run, a model was developed to simulate the operations of a homogeneous fleet of aircraft. The simulation accepts a set of behavioral characteristics for the aircraft type comprising the fleet, including expected fuel consumption, mean time between failures (MTBF) and mean time to repair (MTTR), and uses them to stochastically determine aircraft flight scheduling and costs of executing those flights. The simulation provides information to develop a set of cost-performance and utilization curves which are analyzed and used to generate a utility score for a given aircraft type.

4.1 Design of Experiment

The experiment was arranged in an array testing the usage and associated costs against the number of aircraft as well as the number of CFI. By Table 1, the experiment would increment through a range for the number of aircraft for a single number of instructors, repeating itself 100 times to reduce the impact of stochastic variations in the results. The experiment would record that result, increment the number of CFI by one, and repeat the procedure. After iterating through the full set of CFI, the aircraft type was changed and the experiment started again.

Table 1: Design of Experiment

Case	# A/C	# CFI
1	1-300	1
2	1-300	2
3	1-300	3
.	.	.
.	.	.
.	.	.
30	1-300	30

4.2 Results

The results, shown for a Cessna 172M, suggest that a single aircraft is more dependent upon the number of aircraft rather than the number of instructors, with costs increasing with the Student-Aircraft Ratio.
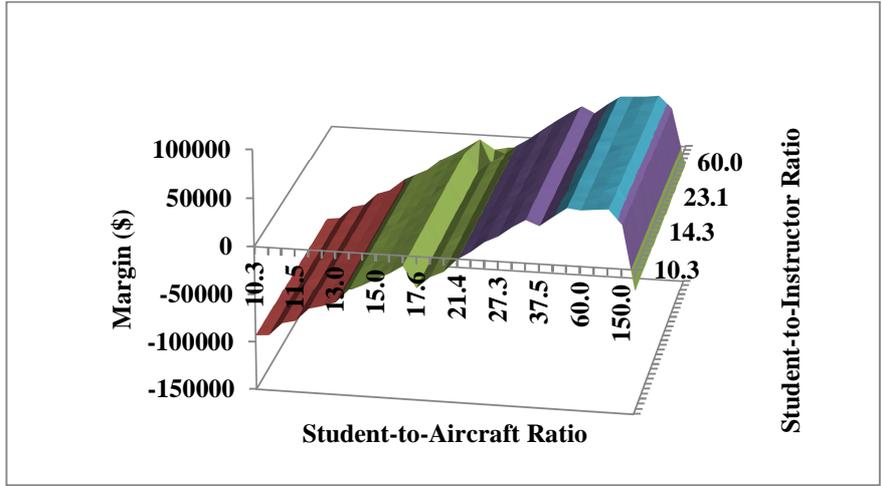
Figure 2: Cessna 172M Profit

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 .

Maintenance is also shown to increase with S/A ration, contributing to the higher costs and lower profits.
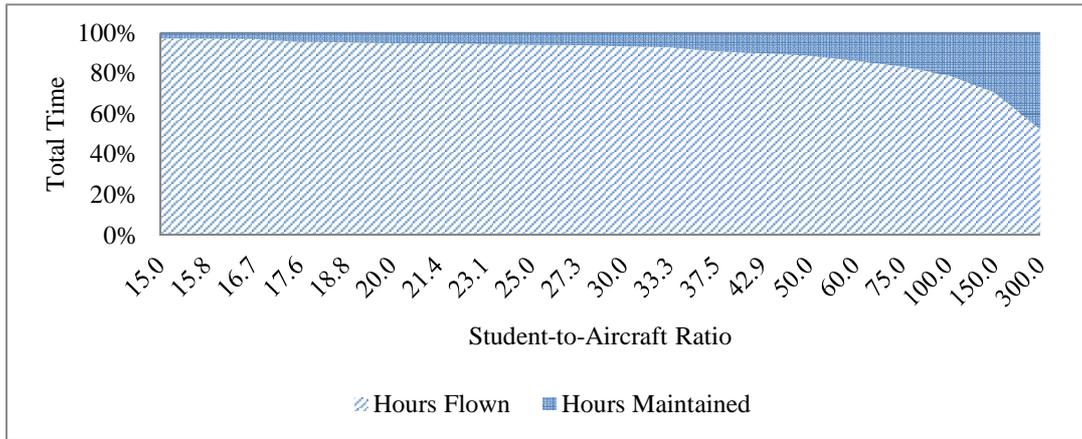

Figure 3: Hours Flown vs. Hours Maintained

4.3 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.
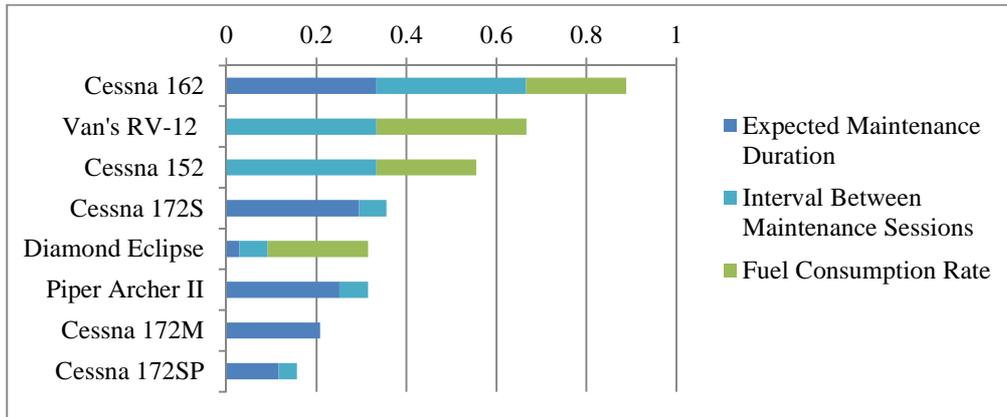
Figure 4: Utility Analysis

5. 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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