Undergraduate Review

Volume 12 Article 9

2016

Comparison of Renting Training Aircraft Using Data Envelopment Analysis

Heather Dickerson

Recommended Citation

Dickerson, Heather (2016). Comparison of Renting Training Aircraft Using Data Envelopment Analysis. *Undergraduate Review*, 12, 37-43.
Available at: http://vc.bridgew.edu/undergrad_rev/vol12/iss1/9

Comparison of Renting Training Aircraft Using Data Envelopment Analysis

HEATHER DICKERSON

Abstract

Many elements are involved when a pilot is trying to decide which aircraft to pursue for rental. Uninformed new pilots decide to rent purely based upon the aircraft used for initial training, but once more variables are considered, the pilot will realize such an important decision must consider all aspects. Cost typically being the greatest determining factor, horsepower output of the engine, speed, the maximum load capacity, and the maximum altitude the aircraft is able to reach also tend to have a large effect on determining which aircraft will suit the needs of the pilot. Data Envelopment Analysis was used to compare ten of the most common training and rental aircraft to determine which model was most efficient given the constraints listed above. This model can show even the newest pilot which aircraft should be chosen to rent based on a few of the most common variables in flying.

Introduction

Compared to other modes of transportation, the history of aviation is much more recent, and fast evolving. The constantly progressing journey of developing aircraft successfully began by the Wright Brothers in 1860. They began with small toy schemed aircraft helicopters and by 1899 the Wright brothers began creating an aerodynamic control system for small aircraft. In the early 1900's they developed their first manned glider known as the "kitty hawk" and patented their aerodynamic control system. In 1903, the Wright Brothers broke records and set the pace for the future with their first ever twelve-second flight (Croche 2015).

Quickly after the Wright Brothers successfully got off the ground and back in one piece, the aviation industry "took off" and it was clear that the pilots needed to be trained to operate such a vehicle. Developers soon realized that pilots would have training that is more effective in aircraft designed for that purpose. Training aircraft has advanced throughout history with many more additional safety features than a typical aircraft (Davisson 1992). The use of sympathetic flight features and a basic cockpit organization allows training pilots to improve their navigation, real-time piloting, and flying abilities without the hazard of straining their abilities alone in a fully featured aircraft. Civilian pilots, specifically, are normally trained in a light aircraft, which is what this research project focuses on. Normally, training aircraft have two to four places for seating to accommodate the certified flight instructor and also the student pilot, as well as an additional person if necessary. These aircraft are adapted to tolerate the flight conditions executed during training flights. These training aircraft are then what an average new private pilot would be seeking to rent after they receive their certificate. In this research, ten of the most common rental aircraft are to be compared (Price 2015):

- Cirrus SR22 - SR22 (2003).
- Cessna 172 model R - C172R (1996).
- Cessna 152 - C152 (1979).
- Piper Warrior - PA 28-161 (1982).
- Diamond Katana - DA 20-C1 (2012).
- Piper Tomahawk - PA 38-112 (1978).
- Piper Arrow - PA 28R-200 (1973).
- Cessna 206 - C206 (1979).
- Mooney - M20J (2005).
- Cessna 182 model Q - C182Q (1979).

When pilots earn their pilot certificate, they have the skills and ability to purchase an aircraft. However, it is very costly to own and maintain a plane, so renting is often the only feasible option. Although there are many ways to compare what aircraft might be the best option, DEA Modeling is used in this paper in order to determine the most efficient choice of rental. In this research project, we are using cost of renting per hour as our input. Horsepower, maximum cruise speed in knots, service ceiling in feet, and maximum takeoff weight in pounds as outputs. Data for each was collected primarily by the Pilot Operating Handbook for each individual aircraft, and, more specifically, by using the performance sheets for each variable.

Literature Review

Charnes, Cooper, and Rhodes developed data Envelopment Analysis, or DEA. It soon became a popular modeling method is used worldwide to measure the efficiency of decision-making units or DMUs (Charnes 1978).

There are plenty of applications of DEA Modeling that compare efficiency of the commercial side of aviation, for example, Zhu, Lin, Yang, and Chang (2012) discussed managing airline efficiency utilizing resources such as fuel and salaries to maintain fleet size and load factor. Operational performance vs profitability in commercial aviation was compared by Tsikriktsis (2007). However, to our knowledge, it does not appear that any academic research papers using Data Envelopment Analysis has been written to aid in the selection of renting a training aircraft.

Data Envelopment Analysis Model

DEA can be used for research in evaluating efficiencies of any Decision Making Units (DMUs). Those DMUs could be some business processes such as service, purchasing or production process, which have multiple similar attributes. These attributes would contribute the transformation process to transform inputs (some attributes used/applied) to outputs (some attributes achieved). Below is the basic model.

Definition of Variables

Let Ek be the efficiency ratio of unit k, where K is the total number of units being evaluated.

Let Ee be the efficiency of the eth Decision Making Unit (DMU)

Let uj , with J= 1,2,...M be the coefficient for output J, where M is the total number of outputs being considered.

Let vi , with I=1,2...N be the coefficient for input I, where N is the total number of inputs being considered.

Let Ojk be the number of observed units of output m produced by service unit k during one time period.

Let Iik be the number of units of inputs n used by service unit k during one time period.

Objective Function

The objective of a DEA is to find a set of coefficient u associated with each output and a set of coefficient v associated with each input that will yield the highest possible efficiency for the service unit being evaluated.

In this case e is the index of the Decision Making Unit (DMU) being evaluated. The objective function is subject to constraints such that when the same set of input and output coefficients (uj and vi) is applied to all other DMUs being compared, no DMU will exceed 100 percent efficiency.

$$(1) \qquad Max\ E_e = \frac{u_1 O_{1e} + u_2 O_{2e} \ldots u_M O_{Me}}{v_1 I_{1e} + v_2 I_{2e} + \cdots v_N I_{Ne}}$$

Constraints

The constraints for which DMUs are held are as follows:

When applying linear programing to these constraints the objective function is rewritten as follows with the following new constraints:

$$(2) \quad \frac{u_1O_{1k}+u_2O_{2k}+\cdots u_MO_{MK}}{v_1I_{1k}+v_2I_{2k}+\cdots v_NO_{NK}} \leq 1.0 \; k = 1,2 \ldots K$$

For each service unit the constraints in equation 2 are reformulated in the format seen in equation 5.

Input and Output Variables Analysis

$$(3) \quad \max E_e = u_1O_{1e} + u_2O_{2e} \ldots u_MO_{Me}$$

$$(4) \quad \text{Subject to: } v_1I_{1e} + v_2I_{2e} + \cdots v_NI_{Ne} =$$

$$(5) \quad u_1O_{1k} + u_2O_{2k} + \cdots u_MO_{MK} - (v_1I_{1k} + v_2I_{2k} + \cdots v_NO_{NK}) \leq 0 \quad k = 1,2 \ldots K$$

This research is comparing what small training aircraft would be the best to choose for renting by comparing many different quantitative values. This can be visually seen in Table 1. The primary and focus input being the cost of rental per hour. Since various flight schools offer different rates throughout the United States, the input was a calculation of all available prices throughout the country added together and averaged for each of the ten aircraft (Archer 2015). Some rental agreements offer pricing without fuel, but since the majority of rental agreements are fuel inclusive, data was only taken from fuel inclusive agreements. Each input cost is rental price per hour.

The outputs used in this research include:

- Horsepower, which is the power of the engine output measured in units per amount of time.
- Maximum cruise speed in knots, which is the fastest the aircraft is able to travel in smooth air.
- Service Ceiling in feet, which is the highest altitude the aircraft is able to fly.
- Maximum takeoff weight in pounds, which is how much weight the aircraft can safely fly at above its standard empty weight.

This research collected data directly from that aircrafts Pilot Operating Handbook. All of the output variables are readily available and easy to find in the Pilot Operating Handbook. Horsepower is a straightforward number located within the "general" section of each Operating Handbook. Maximum cruise speed, service ceiling and maximum takeoff weight for all aircraft are all given numbers and cannot change. When an aircraft is produced, it goes through rigorous testing in order for the manufacturer to provide a buyer or renter with the information in the Operating Handbook. Data Table 1 contains all information in basic format to show the values of inputs and outputs for all DMUs.

Results

Out of the ten training aircraft compared in this DEA Model, two were found to be efficient. Within table 2, it can be seen for each objective value of 1.00, that aircraft was efficient. The Piper Tomahawk and Cessna 206 were both efficient. The DMUs with the objective value less than 1.00 are not efficient. Therefore, the remaining eight were not efficient. The eight aircraft were Cirrus SR22, Cessna 152, Cessna 172R, Piper Warrior, Diamond Katana, Piper Arrow, Mooney, and Cessna 182Q.

Recommended Improvements

For those training aircraft that were not efficient the shadow price indicated by the Excel solver results indicate how to improve the current inefficient one by referring to those efficient ones. Below are the improvements each aircraft needs to make so that they can be efficient within this group.

- For the Cirrus SR22, Maximum Cruise should increase from 178 to 224 knots, Max Takeoff Weight should increase from 3,400 to 4,143 pounds, and price of rental should decrease from $262 to $192.
- For the Cessna 152, Horsepower should increase from 110 to 127, Maximum Cruise should increase from 111 to 124

knots, Maximum Takeoff Weight should increase from 1,670 to 1,888 pounds, and price of rental should decrease from $90 to $84.

- For the Cessna 172R, Horsepower should increase from 160 to 164, Maximum Cruise should increase from 129 to 161 knots, Service Ceiling should increase from 13,500 to 19,072 feet, and price of rental should decrease from $125 to $109.
- For the Piper Warrior, Horsepower should increase from 160 to 164, Maximum Cruise should increase from 126 to 161 knots, Service Ceiling should increase from 11,000 to 18,194 feet, and price of rental should decrease from $112 to $108.
- For the Diamond Katana, Maximum Takeoff Weight should increase from 1,764 to 1,836 pounds, Service Ceiling should increase from 13,120 to 13,853 feet, and price of rental should decrease from $104 to $82.
- For the Piper Arrow, Maximum Takeoff Weight should increase from 2,650 to 2,692 pounds, Service Ceiling should increase from 15,000 to 16,557 feet, and price of rental should decrease from $142 to $124.
- For the Mooney, Maximum Cruise should increase from 174 to 183 knots, Service Ceiling should increase from 18,800 to 21,331 feet, and price of rental should decrease from $137 to $130.
- For the Cessna 182Q, Maximum Cruise should increase from 143 to 152 knots, Maximum Takeoff Weight should increase from 2,950 to 2,985 pounds, and price of rental should decrease from $160 to $140.

Conclusion

Data Envelopment Analysis was used to compare ten of the most common rental aircraft. This tool can assist a pilot in choosing the best aircraft to rent based on the model and the results. Although the results are not able to narrow down to only one aircraft, it should make the selection easier because it narrowed down to two from ten. The results could also assist the production companies in choosing which types of engines or materials to make to become competitive by referring to the results in this research. Due to limited resources and data available at this stage, some dimensions that a renter may be looking for were not included. For example, maneuverability of the aircraft might be important to some pilots who wish to do more aerobatic flying with their time rather than a pilot who is just sightseeing. The range of travel before fuel is required might also be of importance to a pilot who is looking to rent and travel long distances. With more information provided, the above model could be easily extended, which could be the direction of the future research.

References

Airplane Flight Manual Mooney M20J. (2005). Kerrville, TX: Mooney Airplane Company Inc. Archer, C. (n.d.). Rentals. In Archer Bravo. Retrieved December 17, 2015.

Cessna 152 Information Manual (pp. 1-135). (1979). Wichita, KS: The cessna aircraft company.

Cessna 172R information manual. (1996). Wichita, KS: The cessna aircraft company.

Cessna 180Q information manual. (1979). Wichita, KS: The cessna aircraft company.

Charnes, A., W. Cooper, & E., Rhodes (1978) "Measuring the efficiency of decision-making units," *European Journal of Operational Research.*

Cherokee Arrow Pilot's Operating Handbook. (1973). Vero Beach, FL: Publications Department.

Crouch, T. D. (2015). *Encyclopedia Britannica.*

Davisson, B. (1992, April). Defining the word "Perfect.". In *Is there such a thing as the perfect trainer?*

Diamond Aircraft Flight Manual (26th ed., pp. 1-342). (2012). London, Ontario: Diamond Aircraft Industries Inc.

Pilot's operating handbook and easa approved airplane flight manual for cirrus design sr22 (pp. 1-450). (2003). Deluth, MN: Cirrus design corporation.

Pilot's Operating Handbook Cessna 206. (1979). Witchita, KS: Cessna Aircraft Company.

Price, J. (n.d.). Save money on aircraft rentals. In *Let's Go Flying*!. Retrieved December 17, 2015.

Tomahawk Pilot's Operating Handbook. (1978). Vero Beach, FL: Publications Department.

Tsikriktsis, N. (2007). The effect of operational performance and focus on profitability: a longitudinal study of the U.S. airline industry. *Manufacturing & Service Operations Management,* 9(4), 506+.

Warrior II Information Manual (pp. 1-262). (1982). Vero Beach, FL: Piper Aircraft Corporation Publications Department.

Zhu, D.-S., Lin, C.-T., Yang, C.-J., & Chang, K.-C. (2012). Managing airline productivity using data envelopment analysis. *International Journal of Business Performance Management,* 13(3/4), 294.

About the Author

Heather Dickerson worked during the Fall 2015 semester to complete this research on selecting the most efficient training aircraft for rental using Data Envelopment Analysis under the mentorship of Dr. Xiangrong Liu (Management). She is graduating in May 2016 with a double major in Product Operations Management and Aviation Science.

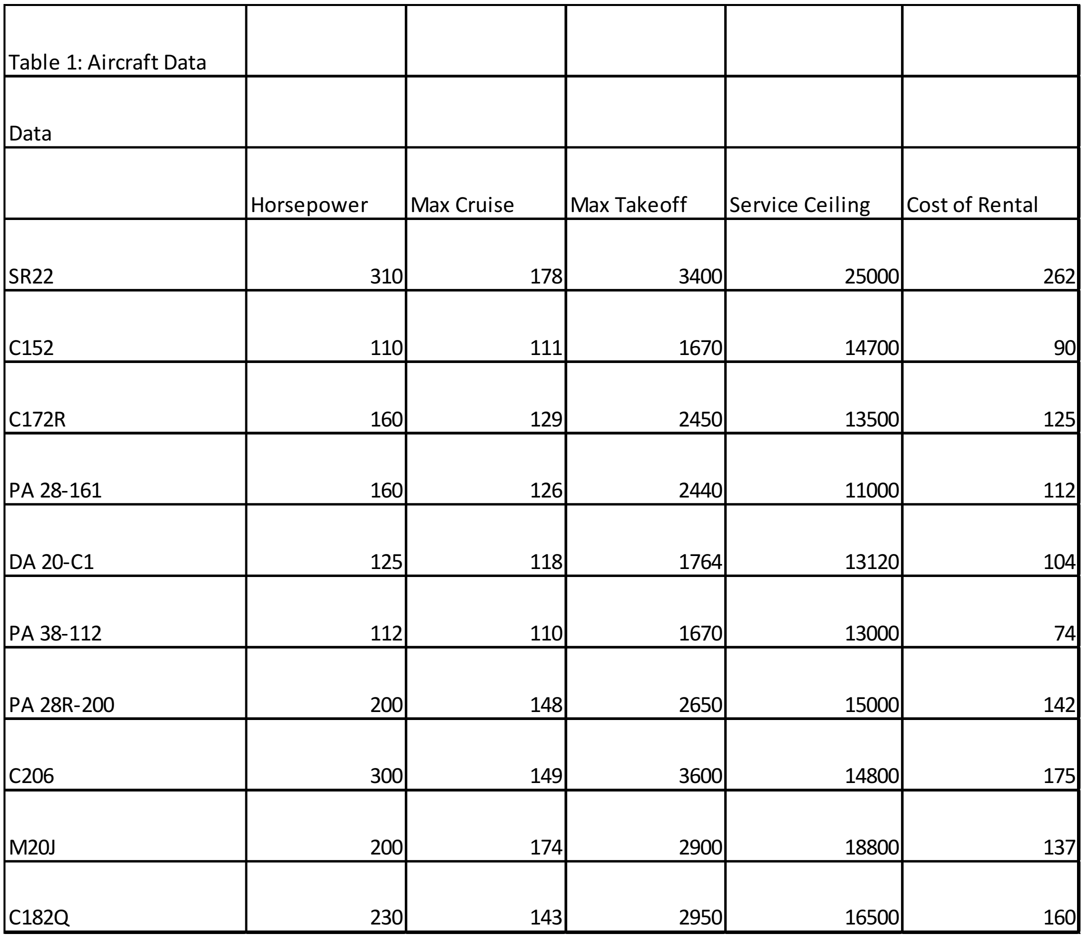

Table 1: Aircraft Data					
Data					
	Horsepower	Max Cruise	Max Takeoff	Service Ceiling	Cost of Rental
SR22	310	178	3400	25000	262
C152	110	111	1670	14700	90
C172R	160	129	2450	13500	125
PA 28-161	160	126	2440	11000	112
DA 20-C1	125	118	1764	13120	104
PA 38-112	112	110	1670	13000	74
PA 28R-200	200	148	2650	15000	142
C206	300	149	3600	14800	175
M20J	200	174	2900	18800	137
C182Q	230	143	2950	16500	160

Table 1: Aircraft Data					
Data					
	Horsepower	Max Cruise	Max Takeoff	Service Ceiling	Cost of Rental
SR22	310	178	3400	25000	262
C152	110	111	1670	14700	90
C172R	160	129	2450	13500	125
PA 28-161	160	126	2440	11000	112
DA 20-C1	125	118	1764	13120	104
PA 38-112	112	110	1670	13000	74
PA 28R-200	200	148	2650	15000	142
C206	300	149	3600	14800	175
M20J	200	174	2900	18800	137
C182Q	230	143	2950	16500	160

Table 2: Results	EXCEL OUTPUT									
	SR22	C152	C172R	PA 28-161	DA 20-C1	PA 38-112	PA 28R-200	C206	M20J	C182Q
OBJECTIVE	0.733160082	0.92974359	0.868502994	0.96535597	0.786820463	1	0.876223501	1	0.948606571	0.875886327
U1	0.00200814	0	0	0	0.004847776	0	0.003550484	0.001510371	0.001929306	0.003288329
U2	0	0	0	0	0.001532614	0	0.001122478	0	0	0
U3	0	0	0.000354491	0.000395638	0	0	0	0.000151914	0.00019405	0
U4	4.42547E-06	6.32479E-05	0	0	0	7.69231E-05	0	0	0	7.2467E-06
V1	0.003816794	0.011111111	0.008	0.00892858	0.009615385	0.013513514	0.007042254	0.005714286	0.00729927	0.00625
CONST1	0	0	0	0	0	0	0	0	0	0
CONST2	0	0	0	0	0	0	0	0	0	0
CONST3	0	0	0	0	0	0	0	0	0	0
CONST4	0	0	0	0	0	0	0	0	0	0
CONST5	0	0	0	0	0	0	0	0	0	0
CONST6	1.298608634	1.130769231	1.467065868	1.461077844	1.028384012	1	0.895046591	0	1.533742331	0.689439886
CONST7	0	0	0	0	0	0	0	0	0	0
CONST8	0.548519443	0	0	0	0.032736636	0	0.332515939	1	0.09406953	0.509275776
CONST9	0	0	0	0	0	0	0	0	0	0
CONST10	0	0	0	0	0	0	0	0	0	0