A Simulation Approach to Airline Cost Benefit Analysis

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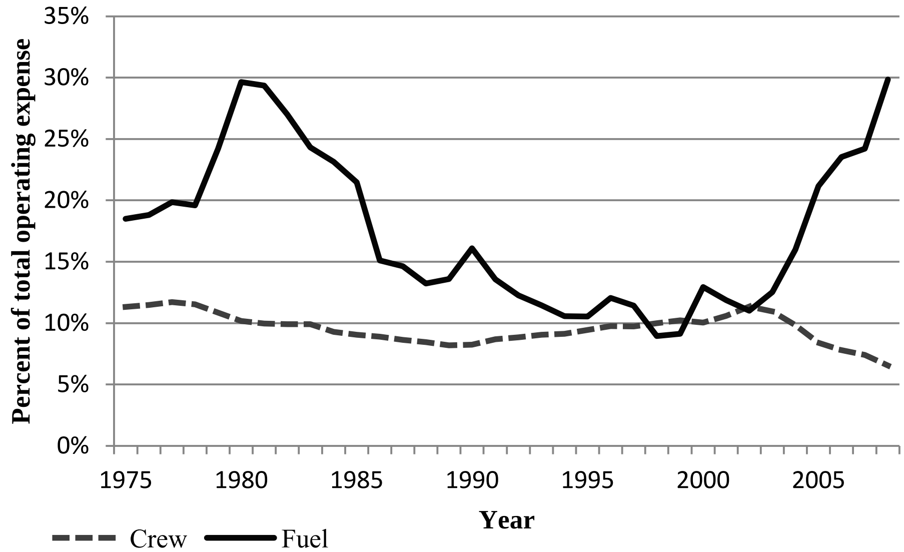
In this paper we conduct a cost benefit analyses using simulation for an Airline. This study pertains to using Towbarless Towing Vehicles (commonly referred to as supertugs) to transport aircraft to and from the terminal to airline's maintenance hangar facility at their hub. This study attempts to investigate the possibility of reducing costs through saving jet fuel by adopting supertugs and identify if their high purchasing costs are justified. This study adopts simulation to analyze the annual savings by studying the numbers needed, as well as the utilization and operation cost for these supertugs. The results are very encouraging, enabling the airline to clearly evaluate their cost and benefits for purchasing new supertugs.

INTRODUCTION

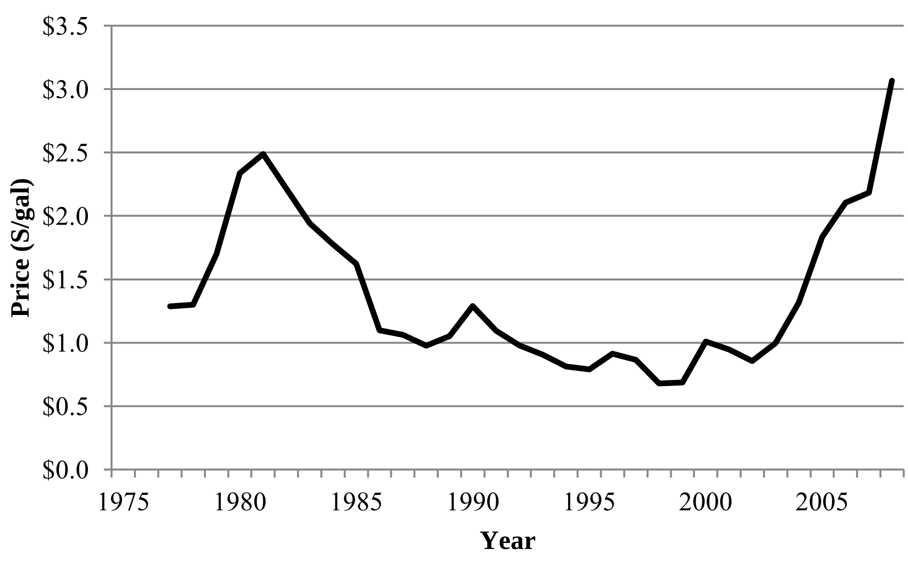
The recent surge in fuel prices continues to impose an enormous impact on airlines throughout the world. This impact has resulted in bankruptcies, significant reduction in number of flights, services and operations among airlines globally (Bazargan 2010). For the airlines, fuel and crew are the two major components and drivers of operating cost. Figure 1 presents the fuel and crew cost as a percentage of total operating cost for all US airlines. As the figure suggests, fuel cost has been the primary and dominant driver of operating cost for US airlines over the last 30 years.

FIGURE 1
CREW AND FUEL COST AS A PERCENTAGE OF TOTAL OPERATING COST



Just a one percent increase in jet fuel prices, translates to $530 million for the US airline industry. Figure 2 presents average jet fuel prices over the same time period (Air Transport Association 2011).

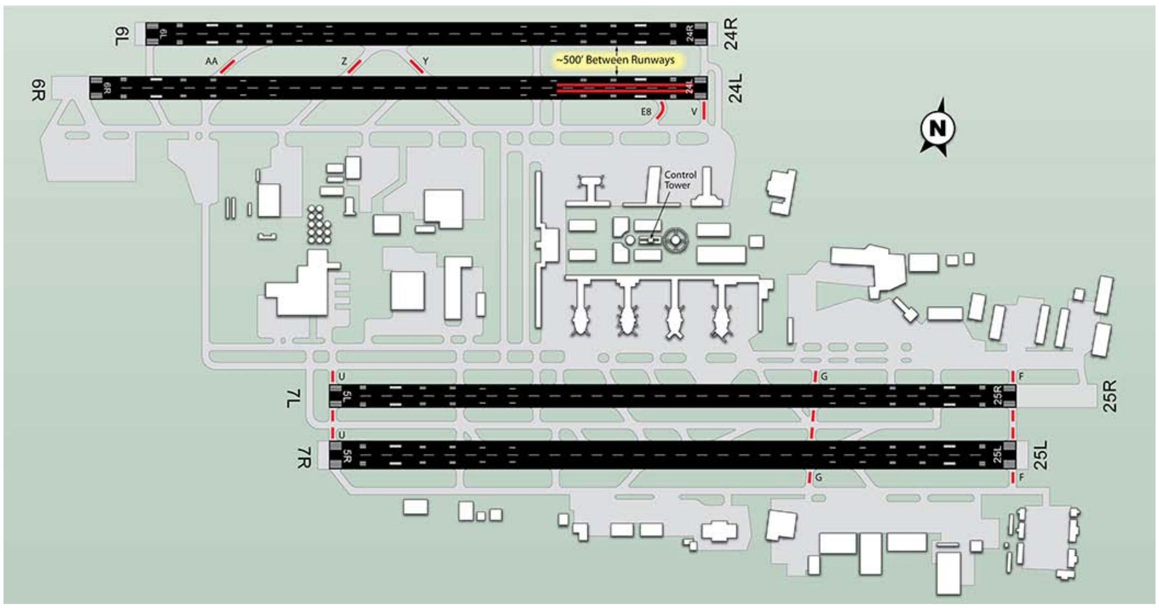
FIGURE 2
AVERAGE ANNUAL JET FUEL PRICES



As the prices of jet fuel continues to increase, an airline initiated a study with Embry-Riddle Aeronautical University to conduct a feasibility study aimed at utilizing Towbarless Towing Vehicles (referred to as supertugs) to transport aircraft to and from the terminal to airline's maintenance hangar facility.

Bazargan, et. al. (2006) conducted a similar study for AirTran Airways adopting supertugs at the airline's hub in Atlanta. This study investigated the possibility of reducing costs through saving jet fuel. Numerous airlines already use these supertugs to move aircraft at their airport hubs. Currently, the airline does not have any supertugs at their hub. The airline, on a typical day of operation at their hub, has 71 flights (see figure 3). On average, out of these 71 arriving flights, 23 are scheduled for maintenance after they unload passengers and bags at the gates. The airline operates a diverse set of fleet and therefore impose constraints on arriving gates/terminals and hangar access gates.

FIGURE 3
TERMINAL AND HANGAR FACILITY LAYOUT AT THE HUB AIRPORT



The airline was interested in addressing the following questions:

- Considering the high purchasing cost of the supertugs, are there any economic justifications for purchasing them? If so, what is the payback period of the investment?
- How many of these supertugs, if economically justified, are needed for the airline's taxi operations at their hub?

Considering the stochastic and dynamic nature of the problem in terms of number of aircraft arriving and needing maintenance at the hub, taxi times, maintenance times and fuel prices, we considered simulation to be an appropriate approach to answer these questions.

SIMULATION MODELING

Simulation modeling has received a lot of attention for airline operations in recent years. Cleophas et. al. (2009), Lee, et. al. (2007), Gosavi, et. al. (2007) report application of simulation to revenue management, flight scheduling and overbooking to name a few. We, however, are not aware of a specific reported simulation study for using supertugs except Bazargan et. al.(2006).

Simulation modeling has become an extremely important tool in analyzing dynamic and complex systems. Pidd (2004), Law (2006) and Kelton, et. al (2009) provide a good overview of simulation modeling and its application in various industries.

Arena Simulation modeling (Rockwell Software) was adopted for the simulation of the Airline's operations at their hub. We developed a simulation model to capture the current status (base scenario) where the aircraft taxi to/from the hangar on their own power.

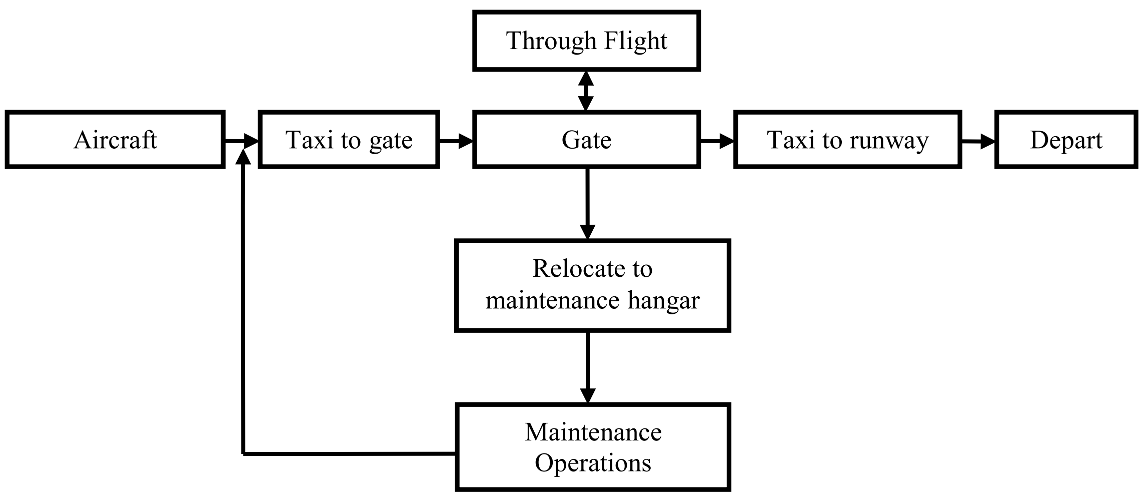
(a) Base Scenario

The following steps briefly describe the logic for this process:

- The aircraft arrive to the system according to the daily schedule of operations at the hub.
- Based on the type of the fleet, they taxi to their designated terminal/gate.
  If the aircraft is not due for maintenance it will depart the system based on its scheduled departure time.
- If the aircraft is due for maintenance, it taxis towards the hangar after passenger and baggage unload. The taxi time depends on the type of fleet, time of the day and traffic.
- The aircraft receives the scheduled/unscheduled maintenance at the hangar.
- The aircraft taxis back to the terminal/gate for its next departure.

The following figure shows the flowchart for this process. It should be noted that all the taxi and maintenance times are stochastic and depend on the type of fleet.

FIGURE 4
A SIMPLE FLOWCHART OF THE OPERATION PROCESS



Some of the assumptions and parameters for this simulation model are:

- **Turnaround Time –** Indicates the time between arrivals of an aircraft to a gate until its next departure. This time includes unloading/loading passengers, baggie, fuel, etc. Based on the type of fleet and historical data, this time varied stochastically from 45 minutes to 1.5 hours.
- **Hangar Taxi Time:** The time that it takes for aircraft to taxi from/to terminal and the hangar. Again, depending on fleet, traffic, and gate within the terminals, this time can range from 3 to 7 minutes.
- **Maintenance time:** The time that an aircraft spends at the hangar depends on the type of the maintenance that the aircraft is scheduled to receive and can vary from 5 to 8 hours.
- **Distance between terminals and hanger**: The average distance between the terminals and the hangar is about 1.5 km.

- **Taxi costs per minute:** Only jet fuel and labor were considered for this cost. The average cost per minute ranged from $15-$25 per minute depending on fleet.

The base model, representing current practices, was run to simulate for one year of operations. This model is based on the current operations where aircraft taxi to and from the maintenance hangar, on their own powers using jet fuel. Enough replications were made to reduce the 95% half width intervals for major key performance measures to less than 0.1%. The following table presents some of these metrics:

TABLE 1
ANNUAL PERFORMANCE MEASURES FOR BASE SCENARIO

Metrics	Values
Total taxi time in hours	1024
Total number of aircraft visiting the hangar	5991
Total taxi cost between terminals and the hangar	$1,270,173

(b) Supertug Scenario

A separate simulation model was developed based on utilizing supertugs to tow the aircraft. The logic remains the same except when the aircraft needs to taxi between the terminals and the hangar a supertug is requested. The following assumptions were made for this model.

- **Attach/detach supertug to aircraft time**: represents the time that it takes to attach or detach the aircraft to the tow tug. This time can vary from 4-10 minutes.
- **Loaded supertug time**: The time that it takes to move the aircraft between the terminals and hangar with the tow tug attached. This time can vary from 10 to 17 minutes.
- **Unloaded supertug time**: The time that it takes for the tow tug to move between the terminals and hangar without any aircraft attached to it. This time can vary from 4 to 8 minutes.
- **Loaded supertug cost:** The average cost of towing an aircraft with a supertug is assumed to be $5.50/minute. This cost includes fuel and labor.
- **Tow tug purchasing price:** The purchasing cost of tow tug depending on options is about $600,000.

The simulation model was run to simulate one year of operations. We run the model with 1, 2 and 3 supertugs. The following table presents the performance measures for this scenario:

TABLE 2
KEY PERFORMANCE MEASURES FOR UTILIZING DIFFERENT NUMBER OF TUGS

Metric	1 tug	2 tugs	3 tugs
Total annual operating cost	$246,066	$267,746	$272,793
Average waiting time (hours)	0.7	0.1	0
Average tug utilization	54%	28%	18%
Total loaded times (hours) in a year	1864	1876	1889
Total unloaded times (hours) in a year	595	810	838

Table 2 presents total cost of operations with 1, 2 and 3 supertugs. The average waiting times and utilizations with different number of tugs are also shown. The loaded and unloaded times represent the total number of hours that the supertug(s) is/are towing an aircraft or riding without any aircraft attached to them to and from maintenance hangar and terminals in one year respectively. We see that these numbers exceed significantly compared to total taxi time of aircraft in table 1. This is because the supertugs with aircraft typically have lower speed than aircraft taxing on its own power. These times do not include attach/detach times.

FINANCIAL ANALYSES AND RECOMMENDATIONS

To study the economic viability of purchasing supertug(s), we use two major financial metrics, payback period and net present values over 10 years of useful supertug lives.

(a) Payback Period

The payback period provides an indication of the time (in years) that it takes to recover the initial investment.

$$\text{Payback period} = \frac{\text{Initial investment}}{\text{Net annual cash flow}}$$

The initial investment represents the cost of supertug(s) and net annual cash flows are the savings that supertug(s) generate annually. The following provides the payback periods in years for different number of supertugs based on the financial figures presented in last section.

TABLE 3
PAYBACK PERIODS IN YEARS

Number of Tugs	1 tug	2 tugs	3 tugs
Payback periods (years)	0.59	1.20	1.80

According to this table, on average the payback period for each supertug is about 7 months! This payback time will decrease as the jet fuel prices increase.

(b) Net Present Values

The net present value is a metric that identifies the net cash flows of a project over a number of years discounted to today's cash values. For this metric, we considered the discount rate to be 15% and the life of a tow tug to be 10 years. The following table presents the net present values of purchasing and utilizing 1, 2 or 3 supertugs.

This table clearly shows a significant positive net present values for 1, 2 and 3 supertugs. Both financial metrics discussed in this section confirm that purchasing and utilizing supertug(s) is a beneficial and a cost saving strategy for the airline. The main question is how many supertug(s) the airline needs, to have a smooth and viable operation. Tables 2 and 4 present the utilization and NPVs for the three options. According to table 4 purchasing 1 supertug is the most rewarding strategy as it has the highest NPV. However, utilizing only 1 supertug results in relatively high utilization of the tug and long waiting times on the part of the aircraft. The waiting time for a supertug is on average 0.7 hours (42 minutes) when only one supertug is available. The simulation results indicate that some aircraft had to wait for up to 5 hours for the supertug. This excessive waiting time can generate difficulties for the airline in terms of delays, manpower scheduling at the hangar and gates availability. If two supertugs are utilized the average waiting time is reduced to 0.1 hours (6 minutes) with maximum of 0.5 hours (30 minutes).

Accordingly, based on the various cost, utilization and waiting times, this study recommends purchasing and utilizing two supertugs for the airline at their hub.

TABLE 4
NPV OF PURCHASING AND UTILIZING SUPERTUG(S)

Year	1 tug	2 tugs	3 tugs
0	$ (600,000)	$ (1,200,000)	$ (1,800,000)
1	$ 890,527.83	$ 871,675.65	$ 867,286.96
2	$ 774,372.02	$ 757,978.83	$ 754,162.57
3	$ 673,366.98	$ 659,112.02	$ 655,793.54
4	$ 585,536.50	$ 573,140.89	$ 570,255.25
5	$ 509,162.17	$ 498,383.38	$ 495,874.13
6	$ 442,749.72	$ 433,376.85	$ 431,194.90
7	$ 384,999.75	$ 376,849.44	$ 374,952.08
8	$ 334,782.39	$ 327,695.16	$ 326,045.29
9	$ 291,115.13	$ 284,952.32	$ 283,517.64
10	$ 253,143.59	$ 247,784.62	$ 246,537.08
NPV	$ 4,539,756.08	$ 3,830,949.18	$ 3,205,619.45

CONCLUSION

The simulation analysis proved to be a valuable and a powerful tool for businesses decisions. The major key performance measures were identified through two simulation models. One model simulates the current practices where the aircraft taxi on their own powers. The other model focuses at utilizing supertug(s) for towing aircraft. The metrics from these models highlight the various performance measures by utilizing 1, 2 or 3 supertugs. Two financial metrics are adopted to examine the economic viability of purchasing the supertugs. These metrics show that such an investment will translate into large savings for the airline. The study considers the net present values and waiting times to recommend the number of supertugs that the airline should consider to purchase.

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