Using Predictive Analytics For Corporate Shuttle Decisions

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Agenda

• Introduction
• Background
• Problem Statement and Data Used
• Three Scenarios
• Methodology and Approach
• Three Scenarios Examples
• Proposed Further Research
• Questions
Introduction

Travel is a cost to business

- Commercial airlines operate from **congested hubs** offering **less direct options**.
- Companies are **beholden to commercial schedules and availability**.

Companies operating corporate air shuttles control the locations and schedule with direct flights for their travel demand.
• Airline Deregulation Act of 1978 incentivized airline consolidation and centralization of operations to hub-and-spoke system (Dempsey & Goetz, 1992).

• Of the 5,000 airports in the U.S., less than 10% have form of commercial airline service; 70 with major hubs (Cannon & Richey, 2012; Quilty, 2005; NBAA, 2015; Sheehan, 2003).

• Corporate air shuttles optimize travel and increase available employee productivity time.
  – Business jet and turboprop aircraft numbers rose from 7,081 in 1980 to 21,256 by 2013 (GAMA, 2014).

• Cost/benefit analysis is limited to historical data for projecting forecasts.
Problem Statements

• Analyzing the benefits of corporate air shuttle operations hinges on the assumption of the estimated productive timesaving benefit as measured by the net savings of time with a labor cost factor applied.

• New shuttle startups have limited or no historical data to base assumptions for analyzing options.

• Is there a better way to measure the value of time?

Money
Time
Value
Data Sources

• Corporate shuttle operators
• Bureau of Transportation Statistics
• General Aviation Manufacturers Association
• National Business Aviation Association
• Transportation Research Board
• Surveys, interviews, aviation conferences
• AirMarkets agent-based modeling software simulation
Three Scenarios

New Entrants

Executive Operators Expanding Use of Current Assets into Shuttles

Current Shuttle Operators Optimizing Operations
Data Collected

• Eight surveys submitted out of 17 requests made.
• Companies represent diversified industries: retail clothing, technology and heavy-equipment manufacturing, chemical and petroleum production, and medical transportation.
• Most companies were listed on the Fortune 500 with revenues ranging between $11B and $56B, and number of employees between 19,000 and 106,000.
• Private companies utilizing shuttles were smaller than the lower range in both revenues and employees.
• Weekly flight schedules ranged between 1 – 150 flights.
• Aircraft sizes between small turbo-props to large passenger jets.
Methodology

• Survey questions formed.
• Survey administered to CSWG volunteer participants.
• Data analyzed using agent-based methodology model to generate results.
• Within model, individual passenger agents measure travel options using a utility function.
  – Measures the contribution of various factors of a specific travel itinerary against other itineraries serving the same market.
• The utility calculation provides the probability of use for the available options.
• Comparison is made between the compensatory value each option.
• Results compared with break-even analysis method for shuttle operations.

Utility function enables making the optimal choice for travel between options
Agent-Based Modeling

- Agent-Based Modeling (ABM) represents consumer behaviors for all travelers in all origins and destination for all modes of travel around the world.

- An ABM produces probabilities of demand, market-by-market, mode-by-mode, with schedules and revenues, based on consumer behaviors and preferences.

- The results support decisions by aircraft OEMs, fleet operators, airport authorities, and investors.
Significance of our Approach

• Theoretical
  – Agent-based modeling can be adapted to analyze business travel requirements that would benefit from corporate shuttle utilization, and is more sensitive than cost/benefit analysis for determining opportunities.

• Practical
  – Increased utilization of corporate shuttles optimizes business travel by minimizing travel costs and travel times, and increasing flexibility where businesses travel non-stop.
The Value of a Flight Option

- Passengers choose to make an air trip by selecting from available itineraries
  1. Commercial, scheduled airlines
  2. Shuttle/Charter services

- Four itinerary properties determine the value of an itinerary
  1. The cost of the fare
  2. The value of time
     - The duration of the trip
     - The difference between desired departure time and available departure time
     - The overall length of the journey of which this trip is a part
  3. The comfort of the cabin
  4. The number and kinds of stops
The Value of Money

- Different people value money differently.
  - The very wealthy do not consider cost as important as those with moderate income.
- The effect of changes in fare depends on the size of the fare.
  - A increase of $100 to a $200 fare is different than an increase of $100 to a $1000 fare.
- Very often the value of money is inversely related to the value of time.

Value of Time vs. Value of Money

Data represents choices of 5,000 passenger agents
The Value of Time 1: Trip Duration

• The most direct time dimension associated with travel is the **duration** of the trip.
  • Measured from door-to-door.
  • Includes any time associated with connections or other stops along the way.
• Duration is adjusted by the base duration (the shortest itinerary) in the market.
  • Duration has less of an effect if the shortest itinerary is still quite long.
• A working “average” value of time for a business trip is $200 per hour.
  – For high level executives, it can be more than $10,000/hr.
The Value of Time 2: Journey Length

• How much weight is put on time also depends on the overall journey length.
• For longer journey’s, say over 21 days in total duration, the value of the duration of a specific flight diminishes.
• For a short-term journey, the length of the air trip can be significantly more important.
The Value of Time 3: Ideal Schedule Delay

- All travelers have an ideal time for a specific trip.
- The penalty for being late is usually different than the penalty for being early.
- There is an indifference interval around the ideal time where the actual departure is close enough to the ideal.
- Charter/Shuttle services generally do not have any associated schedule delay
  - Executives and internal work schedules are adjusted to accommodate the shuttle schedule

The closer a particular itinerary is to the ideal departure/arrival time, the better.
The Disutility of Stops and Cabin Comfort

- The Disutility associated with intermediate stops.
  - Scheduled service has an associated disutility if stops are required.
  - The penalty for direct connections – those between airplanes from the same airline – is less than for indirect connections, between different carriers.

- Cabin comfort includes space, privacy, and amenities such as in-flight service, and noise levels.
  - On commercial carriers, 1st class is always better than economy class.
  - For shuttle or charter services, cabin comfort is always better than 1st class, for no other reason than increased privacy.

Air shuttles minimize disutility associated with non-direct flights and commercial cabins
Cost/Benefit Analysis

• Utility models allow a more sophisticated analysis of costs and benefits, especially when comparing alternatives.
  – Since money is a part of the utility computation, and other factors (e.g. time) are as well, it is possible to compute the dollar value of a change in the other factors.
  – For example, if one travel alternative takes longer than another, the dollar value of the time difference can be calculated.

• The calculation becomes finding the change in dollar value which makes the utility equal for both options.
The utility described used in AirMarkets is a *random* utility model.

- Random utility models do not assume that everything is known about the total utility associated with each choice — there is a *random* term in the model.
- Each available option is assigned a *probability* of being chosen.

Then the so-called *compensatory value* of an option is the fare change that makes the *probability* of each option equal for a given passenger.

For more detail regarding the underlying models used by AirMarkets, click [here](#) to delve into the Science.

Compensatory value = benefit in time, money and comfort using shuttle service.
Scenario 1: New Entrant

- Does business meet the economic success criteria for a feasible option for their employee travel needs using some form of corporate air shuttle.
- They need a guide to the statistically relevant factors for consideration of a corporate air shuttle operation.
- They need to understand implementation options, i.e. charter, capacity purchase agreements, fractional ownership, leasing options, full ownership of aircraft.
- Also considered are service management: outsourcing management of the operation, in house flight department, or augmented with current corporate flight department.
- Operations will be analyzed under FAR 91, 125, 135, 121.
Scenario 1: New Entrant Example

- For a new shuttle service, option 1 is the proposed shuttle, and option 2 is commercial air service.

- The compensatory value for each option using the AirMarkets utility equations is calculated for every potential user of the shuttle. The total benefit is the sum of compensatory values (cost savings) for all potential users.

- Example (from an AirMarkets run): A daily shuttle, single 50-seat aircraft for 100 employees from Memphis to Tampa (2:00 flight), using nominal costs for the shuttle service and air fares (exact compensatory value dependent on type and number of aircraft used).

Total compensatory value of $127,256/year
Scenario 2: Expanding Use of Executive Aircraft

• The flight operations department wants to determine if they are able to utilize current capacity on executive aircraft for augmenting travel requirements on appropriate city pairs compared to scheduled airline service.

• Options
  – Because this operation is already familiar with Federal aviation requirements flight operations is looking to expand its utilization of current aircraft
  – Should they increase or replace current aircraft with more or larger aircraft that are more versatile in multiple roles, such as executive transport as well as corporate air shuttle operations.
Scenario 2: Expanded Executive Operations Example

• The differentiation between executive and professional time/comfort is identified and calculated.

• The total benefit is the sum of compensatory values for all potential users.

• For the 100 employees from Memphis to Tampa, assume 10 are executive level personnel with very high value of time, and the employees as in the first example. Six, 18-passenger aircraft considered using nominal costs for the shuttle service and air fares, expanding the availability of shuttle service.

• The analysis can be repeated with various aircraft and service options. Exact compensatory value dependent on type and number of aircraft used.

Total compensatory value of $54,221/year
Scenario 3: Optimizing Current Shuttle Operations

- Current shuttle operations can be optimized vis-à-vis commercial airline options by computing an optimal schedule given the travel needs of the corporate shuttle customers.
- Flight operations can also use the optimization analysis to substantiate the value of their operations with key data for senior management stakeholders.
- New shuttle routes (city-pair markets) can be proposed and evaluated given the operational requirements of the firm and the availability of scheduled air service.
Scenario 3: Shuttle Optimization Example

• The timing and routing of shuttle operations can be optimized using agent-based modeling genetic algorithm techniques. These methods generate an optimized air travel configuration using specified aircraft, where the optimization function is the utility compensatory value.

• For example, in the Memphis-Tampa case, additional service Memphis-Charlotte (1:40 flight), given current commercial air travel options and assuming 40 employees.

• The analysis can be repeated with various aircraft to determine the optimum aircraft configuration as well as the optimum flight configuration.

Additional compensatory value of $71,113/year.
Summary

• Agent-based modeling provides ability to predict value of corporate shuttle travel over commercial alternatives by capturing a more nuanced definition for the value of time, considering
  – Fare costs
  – Value of time
  – Cabin comforts
  – Number and types of stops

• The three scenarios analyzed reflect measurable benefits to:
  – New Entrants
  – Expanding Executive Asset Use
  – Optimization of current shuttle operations

Agent-based modeling measures the compensatory value using corporate shuttles
Proposed Further Research

- While the AirMarkets simulation provides a discrete value for measuring time, further research is needed to apply the model to specific operations for greater accuracy.
- Examining operations under FAR 91, 125, 135, & 121 to determine significance under unique cost structures.
- Applying the AirMarkets research both domestically and worldwide to air travel solutions apart from commercial operations.
- Research informed by further analysis of scenarios.
Appendix: The Science
The utility passenger $i$ uses to evaluate itinerary option $j$ is given by

\[
V(i, j) = \beta_f(i) \ln f(j) + [\beta_d(i) + \beta_{bd}(i) \ln d_{base}] d(j)
\]

\[
+ [\beta_{16}(i) X_{16}(j) + \beta_{710}(i) X_{710}(j) + \beta_{1120}(i) X_{1120}(j)] d(j)
\]

\[
+ \beta_{dc}(i) N_{dc}(j) + \beta_{ic}(i) N_{ic}(j) + \beta_{1st}(i) X_{1st}(j) + \beta_{ec}(i) X_{ec}(j)
\]

\[
+ G(\tau(i) - t(j))
\]

where the function $G$ is the \textit{ideal schedule delay}, defined as

\[
G(\tau(i) - t(j)) = \begin{cases} 
\beta^G_E(i) \frac{(t(j) - \tau(i) - a + 1)^{\lambda_E} - 1}{\lambda_E} & \tau(i) - t(j) < -a \\
0 & -a < \tau(i) - t(j) < b \\
\beta^G_L(i) \frac{(\tau(i) - t(j) - b + 1)^{\lambda_L} - 1}{\lambda_L} & \tau(i) - t(j) > b 
\end{cases}
\]
Itinerary Utility Variables

- \( f(i) \) = fare for itinerary \( i \)
- \( d(i) \) = duration of itinerary \( i \)
- \( d_{base} \) = shortest duration in the market
- \( X_{16}(i), X_{710}(i), X_{1120}(i) \) = dummy variables for trip journey structure
- \( N_{dc}(i) \) = number of direct connects (same airline or alliance) in itinerary \( i \)
- \( N_{ic}(i) \) = number of indirect connects (different airline or alliance) in itinerary \( i \)
- \( X_{1st}(i), X_{ec}(i) \) = dummy variables for the cabin used by itinerary \( i \)
- \( G(…) \) = ideal schedule delay disutility function

The coefficients \( \beta(i)'s \) are random variables with empirical means and standard deviations derived from extensive passenger research (Parker, 2010).
The Utility Equation
Broken Down

- The fare term: \( \beta_f(i) \ln f(j) \)

- The duration terms: \( [\beta_d(i) + \beta_{bd}(i) \ln d_{base}]d(j) \)

- The journey duration terms: \( [\beta_{16}(i)X_{16}(j) + \beta_{710}(i)X_{710}(j) + \beta_{1120}(i)X_{1120}(j)]d(j) \)

- The stops terms: \( \beta_{dc}(i)N_{dc}(j) + \beta_{ic}(i)N_{ic}(j) \)

- The cabin terms: \( \beta_{1st}(i)X_{1st}(j) + \beta_{ec}(i)X_{ec}(j) \)
The function $G$ is the schedule delay disutility, which represents the disutility (negative utility) of not traveling when desired. It consists of an early and late disutility curve and an indifference window around the ideal.
The Two Option Compensatory Value

• In general, the calculation is simply finding the change in dollar value which makes the utility equal for both options.

• Suppose alternative 1 has a utility of \( F(1) + C(1) \), and alternative 2 has a utility of \( F(2) + C(2) \), where \( F \) is the dollar variable (e.g. fare) and \( C \) is the total utility of all other factors in the utility.

• Then the change in the dollar variable \( F' \) needed to make the two options equivalent is simply

\[
F' = F(1) - F(2) + C(1) - C(2)
\]
After computing the utilities \( V(i,j) \) of a passenger \( i \) for option \( j \), the probability that \( i \) will choose \( j \) is given by:

\[
\Pr[\text{passenger } i \text{ choosing option } j] = \frac{e^{V(i,j)}}{\sum_{k=1}^{n} e^{V(i,k)}}
\]

For the AirMarkets utility function \( V(i,j) \), this means that the compensatory value between option 1 and option 2 is given by

\[
F'(i) = f(1) - f(2) \left[ \frac{e^{C(1)}}{e^{C(2)}} \right]^{\frac{1}{\beta_f(i)}}
\]

where \( C(1) \) and \( C(2) \) are the non-fare utilities associated with each option.
References


