Development of an Airport Choice Model for General Aviation Operations

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Abstract
The General Aviation Airport Choice model developed estimates General Aviation (GA) person-trips and number of aircraft operations given trip demand in the form of GA person trips from counties. A pseudo-gravity model is embedded in the model to distribute the inter-county person-trips to a prescribed set of airports in the US. The airport-to-airport person-trips are split into person-trips by three aircraft modes (single, multi and jet engine) using an attractiveness factor based on average occupancy, utilization and a distance distribution factor for each aircraft type and the number of aircraft based at each airport. The person-trips by aircraft type are then converted to aircraft operations using occupancy factors for each aircraft type.

The final output from the model are aircraft operations trip-tables by aircraft type between the airports in the model. The GA trips are estimated in order to provide a means of assessing the impact of GA activities on the National Airspace System. The model output may be used to assess the viability of GA aircraft serving as a competitive mode of transportation for intercity travel.
INTRODUCTION

A substantial amount of research work and studies have been conducted to model the behavior of travelers when selecting airports for travel. These studies aim at identifying factors that influence travelers’ decisions in the selection of origin and destination airports in order to develop models to estimate traffic volumes through airports. The ability to accurately predict or forecast demand in terms of passenger flows or aircraft operations is critical to the airport systems planning process. Demand determines the facilities that will be provided at the airport and also impacts the design of the air traffic control system. This paper gives an overview of an airport choice model that estimates the annual volume of general aviation operations through selected airports in the US.

The National Aeronautics and Space Agency (NASA) has recently proposed the development of an advanced general aviation aircraft called the Small Aircraft Transportation System (SATS). SATS is, according to NASA’s view, expected to fill a niche in the long distance transportation market by reducing travel times and increasing the level of utilization of the large network of general aviation airports in the US. The aim of NASA is to harness new developments in aircraft engine and airframe technology, communications and navigation to produce an ‘enhanced general aviation vehicle’ with near all-weather operations capability and the ability to utilize airports with minimally equipped landing facilities as described in the Strawman SATS program (1).

As a first stage in the development of SATS, Congress has mandated NASA to prove four technical capabilities:
1. Improve lower landing minima,
2. Allow high volume operations at non-towered airports,
3. Improve single pilot safety and
4. Allow seamless integration of aircraft into the en-route airspace system.

Though the above capabilities may be proven by developing technology, it also imperative to investigate the existence of demand for the mode of transport being proposed and its impact on the National Airspace System (NAS). The assessment of the demand and impact of implementing SATS was conducted using a multi-step planning process which is a standard modeling concept used in urban and intercity transportation planning (2). It involves the definition of a scenario, followed by inventory and travel studies. The traditional multi-step modeling process to study travel behaviors includes four major stages made up of the Trip Generation, Trip Distribution, Mode Choice and Trip Assignment (2). The process is shown schematically in Figure 1.

PURPOSE OF RESEARCH

During the mode split analysis mentioned diversion curves were developed to split the output from the trip distribution into trip tables for general aviation, commercial aviation and others (automobile, rail etc.). To determine the trip rates for commercial aviation the trip volumes from the O-D tables may be matched with data from the Official Airlines Guide (OAG) that contains detailed information on all commercial aviation flights.

However, for GA operations there is currently no credible database or means of predicting general aviation traffic flows through airports in the U.S. Hence the need to formulate a model to distribute GA trips from county centroids to airports. This led to the development of the General Aviation Airport Choice Model (GAACM) presented in this paper.

The GAACM computes National GA travel patterns between a prescribed set of airports in the model. This provides a tool to help assess the viability of implementing SATS as a competitive mode of transportation for intercity travel. The model falls between the mode choice and network analysis stage.

The input to the general aviation airport choice model is an [3091 x 3091] origin destination table of estimated general aviation person-trips from the centroids of 3091 counties in the continental US (this is the output from the mode choice process). The model seeks to generate the demand (in GA aircraft operations) through a database of 3346 selected airports in the US.

The first step in the model is to convert the person-trips between county centroids to person trips through airports. The person-trips through airports are then split into trips by three aircraft modes and then converted to aircraft trips by applying an occupancy factor. The baseline for this analysis is the year 2000. The output of the GAACM model is then fed into a network analysis models (e.g. TAAM, AOM/AEM) and provides a means of assessing the current impact of General Aviation activities on the National Air Space and the implications of deploying SATS as a
transportation system. The output will serve as a starting point to estimate future behaviors of various transportation modes when competition exists among them.

LITERATURE REVIEW OF AIRPORT CHOICE MODELS

The application of Random Utility Models (RUM) developed from economic theory to study “disutilities” associated with choosing from various alternatives has been applied in many airport choice models. These RU models in the form of Logit and Probit mode choice models have long been popular in transportation analyses to assess how users make decisions when comparing travel mode disutilities see Kanafani (3). More recently, the application of Fuzzy Logic to transportation modal and route choice models by Teodorovic and Vukanovic (4) extends this analysis incorporating uncertainty and allowing linguistic variables in the model.

Multiple Airport System Studies

The choice behavior of travelers when faced with the option of selecting from multiple origin and destination airport sets within the same region has also been investigated extensively. Most of the studies involved metropolitan areas served by multiple airport systems (MAS) and have concentrated on commercial aviation operations. MAS studies have been conducted in the San Francisco Bay area by Kanafani (5) and Mark Hansen (6); in the Washington D.C./Baltimore area by Skinner (7), Windle and Dresner (8); and in New York City by Augustinus and Demakopoulos (9). The studies have tried to estimate the fraction of passengers captured by competing airports within the same metropolitan area. Other airport choice studies have been conducted by Ashford and Benchemam (10) for airports in Britain; Innes and Doucet (11) for airports in rural New Brunswick, Canada; and Furuichi (12) for four major Japanese airports.

A study by Skinner (7) using a multinomial logit model in the Washington D.C./Baltimore area showed that the most significant factors influencing the utility of a passenger’s choice of airports are ground access cost and flight frequency. Windle and Dresner (8) in a later study of the Washington D.C./Baltimore area also used a multinomial logit formulation and considered variables such as access time, flight frequency and the effect of different ground access modes and parking on airport selection. They concluded that ‘airport access time and flight frequencies from area airports are the major determinants of airport choice’.

Innes and Doucet (11) used a binary logit model formulation in a study of the airport-choice behavior of individuals in rural areas with access to multiple departure airports. The aim of the study was to evaluate the importance of proximity of airports to the traveler in the selection of airports. They concluded from the study that air travelers were willing to travel significant ground distances in order to reach an airport where jet service was offered and that, among other factors, passengers prefer jet aircraft to propeller-driven aircraft and direct flights to flights with connections.

Furuichi (12) in his study of airport choice characteristics of international travelers from four major airports in Japan used a nested logit model. He concluded that both business and non-business international travelers place a higher value on access cost/time than line haul cost/time. The study results also indicated that air travelers placed a high value on flight frequency.

Hansen (6) proposed a positive feedback logit model to investigate the feedback effect of travel volumes on the attractiveness of airports in a in multiple-airport-systems (MAS). Kanafani (5) calibrated a logit route choice model for airports between the San Francisco and Los Angeles metropolitan areas. Separate models were calibrated for business and non-business trips. The utility expressions had variables for total travel time, schedule frequency on routes (measured as total weekly flights) and travel cost (coach air fare). Output from the model indicates business travelers are sensitive to schedule frequency and less sensitive to travel costs (fare). A comprehensive literature review of airport choice and ground access choice models undertaken by Lunsford (13) is available as a working paper from the Institute of Transportation Studies at UC Berkeley.

From the above it appears the dominant technique for airport choice models have been logit models. Also, among the various variables available for modeling air traveler choice decisions, access cost (measured either as time or distance) and flight frequency seem to be the preferred variables for use in the utility or regression expressions.
General Aviation Airport Choice and Demand Models

Ghobrial (14) developed an econometric airport choice model to forecast aircraft operations at general aviation airports. The model incorporated both socioeconomic variables of population and employment and supply variables related to the airport such as runway length, presence of control towers, presence of charter flights etc. The initial model had nine variables and after investigating for co-linearity between the independent variables three other regression formulations were developed.

Using regression analysis techniques GRA Inc. (15) also developed a model for estimating general aviation operations at non-towered airports using towered and non-towered airport data for the FAA Office of Aviation Policy and plans. The model incorporated both socioeconomic variables such as per capita income and non-agricultural employment data at the county level and airport specific variables such as aircraft based, proportion of single engine aircraft based at airports etc. Various formulations of the regression equation were investigated using stepwise regression techniques. The regression equation with the highest R^2 value had seven variables. The initial model had a dataset of 232 airports. A joint regression expression that included both towered and non-towered airport data and a dummy variable for towered/non-towered airports was used to estimate GA operations in 2,789 non-towered GA airports. The model output was compared to reported data from DOT Form 5010.

The Logistics Management Institute (16) also developed an aircraft utilization model to generate demand at 2,865 GA airports in the US. An initial attempt to develop an econometric regression model using population and average housing income was abandoned due to very low R^2 values and the difficulty of obtaining accurate GA data for all airports. The aircraft utilization model was developed using reported FAA regional utilization rates, landing rates, number of aircraft in region and number of based aircraft at each airport (for single, multi and jet engine aircraft types). The model estimated a total of approximately 11 million operations and 14 billion Transported Passenger miles for the baseline year 2000.

From the review of the literature is appears most of the airport choice models developed so far concentrate on commercial aviation and are regional in scope. Very few have attempted to model GA operations on a nationwide basis. One of the major constrains faced with modeling GA operations is the lack of detailed and reliable data on variables such as operations at airports, cost of operation and frequency, etc.

The regression technique was not used in the development of the GAACM airport choice model as it would be difficult to collect and estimate data for the variables to be included in the model over an extended period of time. In order to calibrate a discrete choice model there would be the need to conduct an extensive survey to capture general aviation travel patterns and costs not only for business and non-business trips but also for people living in metropolitan and non-metropolitan areas. It was not feasible to conduct the survey at this stage due to logistical, financial and time constraints. The approach chosen was to use a gravity model formulation in distributing trips to airports by developing attractiveness factors related to airport pairs and trip routes.

METHODOLOGY

The goal of the GAACM is to distribute the GA trips estimated in the mode choice process to airports in the database; then split the trips from the airports into trips by aircraft type and finally convert the person-trips into aircraft operations. This process is represented in Figure 2. The question to be answered in this analysis is:

- Given volumes of GA trips \( t_{ij} \) originating at the center of activity \( i \) (i.e., centroid of a county) and ending at a center of activity \( j \) find the most likely origin/destination airport pair (K and L) and the most likely mode of transportation (aircraft type) \( m \) selected by the traveler.

Input Data

In the mode choice stage of the transportation systems planning process a stratified diversion curve was developed to split the output of the trip-distribution process into person-trips by three modes: Commercial Aviation, General Aviation and Other modes (3). Each of these trip categories was further separated into business and non-business travelers for each mode. The output for GA business and non-business trips was however combined and used as input to the airport choice model.
Centroids

The initial input to the model is an inter-county person-trip table (3091 x 3091) of GA trips from the centroid of each county. Other attributes of the centroid used were the weighted center (longitude and latitude) and the area of each centroid.

Airports

There is the need to specify the set of airports to be included in the model. The source of information on the airports was the National Transportation Atlas Databases (NTAD 2001) compiled by the Bureau of Transportation Statistics using information from USDOT and other Federal agencies. In the NTAD there are 19,793 aviation facilities including airports, heliports, balloon ports, glider ports, seaplane bases, STOL-ports and ultra-light ports. In order to perform an analysis for GA operations today and into the future, a criteria was been developed to identify airports through which trips will be made. From the tables in FAA Advisory Circular 150/5325-4A (18) on a normal day 95% of aircraft in the US fleet can be accommodated at airports with runway lengths greater than or equal to 3000 feet. The criteria used in selecting facilities to be included in the model are that:

1. Designated as Public Use (PU) Airports
2. Have Paved Runways and
3. Have usable runway length of more than 3,000 feet.

Airport and runway data for the selected facilities was parsed from the database using ArcGIS, Microsoft Access and Excel. Data on the airports and runway information was first extracted separately and then merged using their ‘Site Nos.’ as an ID field / Primary key. The runway information for the airports is for the year 1998 while that for airports is for the year 2000.

Relevant fields extracted for each airport include airport ID, airport latitude and longitude, aircraft based at the airport by engine type (single, multi and jet engine), annual itinerant General Aviation operations, and a field indicating whether the airport is a towered or non-towered. It was noted that some of these airports did not have any based aircraft in any of the three categories. These airports were still left in the final data set as it is expected that as GA/SATS traffic grows there could be some activity at these airports in the future. The data is stored in a database as a structure array for further analysis.

Data Preparation

Airport-County Allocation

The first stage in the model is to ‘distribute’ the trip makers from the centroids of counties to the airports in the model. It is intuitive that trip makers make their decision from a ‘perceived’ set of available airports. Prior to the distribution process it was necessary to define this ‘perceived’ choice set of airports. In order to define the choice set of airports an influence area was defined and airports within that area serving as airports in the choice set.

For computational purposes, the initial influence area was set as 120% of the equivalent county radius. The radius of the county is derived from the area of the county. If there was no airport within this area of influence for a particular county the factor 1.2 is increased until an airport is associated with that county. All the output from this module is stored in a database.

Travel Distances

The access distances from each county to all the airports associated with it is computed and stored in a MATLAB structure array. The inter-county distance for all counties is computed and stored as a 3091 x 3091 matrix. The inter-airport distance (distance between each airport pair) is computed and stored as a 3346 x 3346 matrix. Other pertinent data such as the distance probability distribution, occupancy and utilization factors related to the three aircraft categories are all read and stored in the model database.

Trip Distribution (Pseudo-Gravity Model)

In converting the inter-county person-trip table (3091 x 3091 matrix) to GA aircraft operations between airports a model based on principles similar to the ‘gravity model’ (a synthetic model deriving its name from its analogy to Newton's law of gravity) used in trip distribution was embedded in the GA airport choice model. The gravity model
has been used extensively in travel demand modeling as a trip distribution tool Papacostas (19). It is expressed mathematically as

\[ Q_{ij} = k \frac{P_i A_j}{W_{ij}} \]

where \( P_i \) is the trip production from origin zone \( i \) and \( A_j \) represents the attractiveness of the destination zone. \( W_{ij} \) is the impedance between the zones and \( k \) is a constant. The underlying assumption of the model is that for a given volume of trips from an origin zone \( i \) the proportion of trips attracted to a destination zones is directly correlated to the trip production and attractiveness of the origin and destination zones respectively, and inversely correlated to distance between the zones. The attractiveness variable can be quantified as population, number or shopping centers etc. Depending on the scenario being analyzed, the impedance can be represented as cost or drive time. The model has a more general form

\[ Q_{ij} = P_i \frac{A_j F_{ij} K_{ij}}{\sum_A_j F_{ij} K_{ij}} \]

where \( F_{ij} \) is a travel time friction factor and \( K_{ij} \) is a socioeconomic adjustment factor.

In the pseudo-gravity model formulation employed in the GA airport choice model, the origin county serves as the origin zone (from which trips emanate) and the sets of airport pairs associated with each origin/destination county pairs as destinations (to which trips are distributed). For an origin county \( i \) with \( K \) airports associated with it and a destination county \( j \) with \( L \) airports associated with it and given the trip volume between the counties is \( t_{ij} \). An attractiveness factor \( A_{ijKL} \) is defined as

\[ T_{ijKL} = t_{ij} \times \frac{\sum A_{ijKL}}{\sum_i A_{ijKL}} \]

where \( T_{ijKL} \) is the trips between airport \( K \) and \( L \). The attractiveness factor is further decomposed into two factors Relative Distance (RD) and Aircraft Based (ABsd) at the airport. The expression has the form

\[ A_{ijKL} = \frac{ABsd_{ijKL}}{RD_{ijKL}} \]

where \( \alpha_1 \) and \( \alpha_2 \) are parameters to be calibrated in the model. The volume of trips attracted to airport pairs is assumed to be directly correlated to volume of aircraft based at the airport pairs under consideration and inversely correlated to the relative trip distance.

The \( ABsd \) factor is formulated in the model as

\[ ABsd_{ijKL} = ABsd_{ik} \times ABsd_{jl} \]

where \( ABsd_{ik} \) and \( ABsd_{jl} \) represent number of aircraft based at the airport pairs being considered for the selected origin and destination county pair respectively.

The Relative Distance factor is formulated as

\[ RD_{ijKL} = \frac{IntCounty_{ij}}{AccessDist_{ik} + EgressDist_{jl} + IntAir_{KL}} \]

where \( IntCounty_{ij} \) is the great circle distance between the weighted centroids of the two counties under consideration,

\( AccessDist_{ik} \) is the great circle distance from the weighted centroid of the origin county to ‘origin county airport(s)’,
**EgressDist** is the great circle distance from the weighted centroid of the destination county to the ‘destination county airport(s)’ and

**IntAir** is the great circle distance between the two airports.

The formulation of the pseudo-gravity model is based on an underlying assumption that travelers faced with a choice of different routes will tend to take the route with the shortest travel time and would travel through facilities with greater volumes of travel services (e.g. number of aircraft based at the airport, frequency of trips to destination, etc.).

To a limited extent the model seeks to mimic the effect of access time/distance and flight frequency (level of service) that have been identified in earlier studies. However, for GA airports flight frequency is not relevant because GA is an on demand service. For this reason we substitute flight frequency for number of aircraft based at the airport.

The relative distance attractiveness factor aims at distributing more trips to routes that had a shorter length for selected county pairs. The airport attractiveness factor distributes more trips to origin-destination airport pairs that have ‘more aggregate services’.

The output from the ‘gravity’ model is person-trips between each airport in the database and is in the form of a 3346 x 3346 table (see Figure 2)

### Splitting Person-trips (by aircraft type)

The table of aircraft person-trips between airports is further split by aircraft mode (single, multi and jet engines). Factors considered in splitting the trips between the various aircraft types include the number of each aircraft type based at the airport, reported average annual utilization rates and occupancy values for the different aircraft types and a trip distance distribution profile. The form of the expression used for the distribution is written mathematically as

\[
T_{ijKL}^m = T_{ijKL} \times \frac{\sum\sum ABsd_{KL} \times Ut^m \times Occ^m \times DDist^m}{ABsd_{KL} \times Ut^m \times Occ^m \times DDist^m}
\]

the superscript \(m\) represents aircraft mode (i.e. single, multi or jet engine)

\(T_{ijKL}^m\) is trips from county \(i\) to county \(j\) through airport \(K\) and \(L\) using mode \(m\)

\(ABsd_{KL}\) is the number of the selected aircraft type aircraft based at the origin airport,

\(Ut^m\) is the level of utilization of the aircraft (source GAATA, explained below),

\(Occ^m\) is the average occupancy of each of the aircraft types (source GAATA, explained below),

\(DDist^m\) is a value obtained from the distance probability distribution for mode ‘\(m\)’ (the derivation of this distribution is outlined below).

### Utilization and occupancy Factors

Aircraft Occupancy and Utilization factors were obtained by adjusting values derived from those reported by the General Aviation and Air Taxi Activity Survey (GAATA) (20). Table 1 shows the aircraft occupancy and utilization factors employed in our analysis.

### Development of a Probability Density Function

According to data published in the General Aviation and Air Taxi Activity Survey (20) the U.S. general civil aviation fleet consists of about 185,000 fixed wing aircraft made up of approximately 172,000 piston-engine aircraft, 6,000 turboprops and 7,000 jets. Each of these aircraft groupings have different range and performance features that makes them unique as modes of travel. Single engine aircraft have typical cruise speeds ranging from 120 to 175 mph within a range of 500 to 1,200 miles; turboprops and multi engines cruise between 200 to 350 mph and have
ranges of 600 to 1,500 miles. Turbojets have cruise speeds ranging from 400 to 600 mph. (National Research Council Special Report (21)).

As one would expect, there are overlaps in the performance and the use of these aircraft that warrants the development of a stochastic model to assign trips generated by the airport choice model. It is clear that the trip length will be a deciding factor in selecting which aircraft type will be used for a trip. The use of a distance distribution variable in the aircraft attractiveness seeks to account for this phenomenon. Generally more jet aircraft will be used for longer trips and more single engine types for shorter trips.

A Weibull distribution developed by LMI and George Mason University for the LIMNET-SATS model (16) was modified and used in the analysis. The distribution was constructed by selecting twelve samples from the FAA’s Enhanced Traffic Management System database (22), which contains flight plan information for IFR flights in the National Airspace System. The data collected was approximated with a Weibull distribution. The form of the probability and cumulative density function can be expressed mathematically as (16),

\[ f(x; \delta, \lambda) = \frac{\lambda}{\delta} \left( \frac{x}{\delta} \right)^{\lambda-1} e^{\left( \frac{x}{\delta} \right)^{\lambda}}, \quad x \geq 0, \delta > 0 \]

\[ F(x; \delta, \lambda) = 1 - e^{\left( \frac{x}{\delta} \right)^{\lambda}}, \quad x \geq 0, \delta > 0 \]

where \( \delta \) and \( \lambda \) are the Weibull scale and shape parameters, respectively.

The expression to estimated parameters for the single, multi and jet engine aircraft types respectively are as follows,

\[ f(x; \delta_s, \lambda_s) = \frac{1.15}{237} \left( \frac{x}{237} \right)^{0.15} e^{\left( \frac{x}{237} \right)^{1.15}}, x \geq 0 \]

\[ f(x; \delta_m, \lambda_m) = \frac{1.16}{289} \left( \frac{x}{289} \right)^{0.16} e^{\left( \frac{x}{289} \right)^{1.16}}, x \geq 0 \]

\[ f(x; \delta_j, \lambda_j) = \frac{1.14}{826} \left( \frac{x}{826} \right)^{0.14} e^{\left( \frac{x}{826} \right)^{1.14}}, x \geq 0 \]

The modified probability density function is shown in Figures 3. The aircraft split process yields three 3346 x 3346 airport-to-airport person-trip tables for each aircraft type (see Figure 4).

**Converting Person-trips to Aircraft-trips**

In order to assess the impact of aircraft operations on airports in the NAS there is the need to convert the airport-to-airport person-trips to aircraft operations. This is done using average aircraft occupancy factors. The expression is written as:

\[ Ops_{ijkl}^m = \frac{T_{ijkl}^m}{Occ_{ijkl}^m} \]

\( Ops_{ijkl}^m \) is the aircraft operations by aircraft type from a selected origin county \( i \) to a destination county \( j \) through airport \( K \) in origin county and airport \( L \) in destination county.

The operations by aircraft type are one-way trips. A return-trip table is generated by adding the trips departing and arriving at each airport to derive a return trip table. The total aircraft operations can be obtained by doubling the number of return trips since we assumed that all trips have a return portion to their originating county. The cells in the arrays labeled ‘Production’ (last row) and ‘Attraction’ (last column) represent the number of operations to and from each airport in the model.
The output from this stage yields three 3346 x 3346 airport-to-airport aircraft operations trip tables for each aircraft type (see Figure 2).

**Model Calibration**

The model is calibrated by comparing estimated trip volumes of towered airports from the model with reported values by from the FAA Terminal Area Forecast. This calibration only accounts for towered airports because the Terminal Area Forecast (TAF) statistics are in general not very reliable for non-towered airports.

The model calibrating parameters are $\alpha_1$ and $\alpha_2$. Initially a pair of values is selected for the calibrating parameters, the main MATLAB script is run and the estimated aircraft operations for towered airports as from the model is compared with the reported itinerant operations from NTAD data and in the process the Root Mean Square Error (RMSE) is computed. The procedure is repeated for a range of pairs of values for the calibrating parameters ($\alpha_1, \alpha_2$). The run corresponding to the minimum root mean square error is selected.

Upon determining the appropriate value for the calibrating parameters, the model is re-run to obtain the airport to airport person-trip table. The final output is three 3346 x 3346 airport-to-airport aircraft operations tables. This serves as input for the network analysis stage of the GA transportation modeling process.

**Pseudo Code for Airport Choice Model**

The outline of computations in the model is presented below

for $\alpha_1 = 0:0.01:2$
for $\alpha_2 = 0:0.01:2$
    for $i = 1:3091$
        for $j = 1:3091$
            for $K = 1:K$ (origin airports)
                for $L = 1:L$ (destination county airports)
                    Compute $ABsd_{ijkl}$
                    Compute $RD_{ijkl}$
                    Compute $A_{ijkl}$
            Next K
        Next L
    Compute $T_{ijkl} = t_{ij} \times \sum_k \sum_l A_{ijkl}$
    Compute $T^m_{ijkl} = T_{ijkl} \times \frac{ABsd_{kl} \times Ut^m \times Occ^m \times DDist^m}{\sum_k \sum_l ABsd_{kl} \times Ut^m \times Occ^m \times DDist^m}$
next j
next i
Sum $T^m_{ijkl}$
Compute RMSE for towered Airports
Save $\alpha_1$, $\alpha_2$, and RMSE\textsubscript{ab}$
next $\alpha_1$
next $\alpha_2$
Select best RMSE\textsubscript{ab}$
Re-run model to estimate operations at airports.
DISCUSSION

Model Output

During the calibration stage, the model was run for $\alpha_1$ and $\alpha_2$ each running from 0 to 2 with a step-size of 0.1. The minimum RMSE was obtained for values of ‘0.8’ and ‘0’ for $\alpha_1$ and $\alpha_2$ respectively. As $\alpha_1$ is associated with the attractiveness factor related to Aircraft Based and $\alpha_2$ is related to Relative Distance factor the implication is that with the current form of the model the choice of trip makers is more sensitive to the Aircraft Based attractiveness factor than the Relative Distance factor.

A summary of total aircraft operations estimated from the model is shown in Table 2 and Figures 4. The results show high trip volumes for single engine aircraft (as expected) compared to the two other modes. Nevertheless, jet aircraft show some gain in the number of total operations and flights.

By combining the person-trip tables and aircraft operation tables the Transported Passenger Miles (TPM) for GA operations in the year 2000 was estimated as 3 billion.

An inspection of a probability distance distribution reconstructed using aircraft operations estimated by the model shows a profile and shape is fairly close to the theoretical Weibull distribution used to split the trips by aircraft type. Though the shape for the jet operations curve is irregular, this can be attributed to insufficient data points as relatively few GA trips (15%) are made using that mode. The distributions (see Table 2) show expected travel distances of 447, 587, and 1084 nautical miles for single-engine, multi-engine, and jet aircraft, respectively. The probability density function for the theoretical distribution and that estimated from aircraft operations from the model is shown in Figures 3 and 5 respectively.

The model estimates that 59% of current GA traffic is routed through control-towered airports (which account for only 14% of airports in the model). For the same airports selected in the model, statistics compiled from the NTAD database indicated 53% of GA traffic is routed through those airports (see Table 4). A sample of the output from the model is shown in Table 3.

RECOMMENDATIONS

A few shortcomings can be identified for the form of the model as it currently stands:

- It is proposed that in the future a discrete choice model be developed to model GA operations due to certain attributes these types of models possess over synthetic models (see Otuzar (23) for summary of some of these attributes).
- Different formulations need to be investigated for the pseudo-gravity model as the value of 0 obtained for $\alpha_2$ in the current formulation suggests access time is not critical in the travelers’ decision-making process. This is counterintuitive.
- The current model assigns trips without considering performance characteristics and trip distance. A sub-model is being developed that considers trip distance in assign trips and breaks trips with long stage lengths into two or more legs by considering the performance characteristics of aircraft types.
- It is also proposed that the current analysis be conducted at census tract level to improve accuracy of the model.
- Access and Egress distances are used in place of access and egress times and number of aircraft based at airports is used in place of GA operations due to difficulty of obtaining drive times. In subsequent studies there will be the need to look at the possibility of considering other predictive variables and also incorporating drive-times by employing GIS based tools.
- The current output for each airport is in the form of annual operations which can be broken down into daily operations. A time of day departure schedule can be derived and the output fed into air traffic network models such as TAAM, AOM/AEM (Virginia Tech.) and LIMNET-SATS developed by LMI to assess the impact of GA operations on the NAS.
- In order to use the output for the model in aircraft network models mentioned earlier the annual trips first need to be converted to daily trips and a time-of-day departure schedule needs to be developed for each airport.

CONCLUSIONS

- The number of person-trips estimated using the GAACM in the year 2000 amounted to 6 million. The number agrees with the results of a top down analysis performed by LMI using TAF and GAATA data.
Based on the above it is believed that the model is credible enough to be used as a means of estimating General Aviation aircraft operations at the national and regional levels.

The output from the model may be used in further analysis to derive macroscopic measures of effectiveness such as travel time benefits, noise impacts, fuel and energy usage, non-user economic benefits, air transportation system congestion and delays etc. These metrics are critical for decision support and policy making at regional and national levels.

A validation study examining individual airport operations is the next step in the development of this model. The challenge is to find reliable field data of GA airport operations to validate the model.
Figure 1 Layout Transportation Systems Analysis Framework
Pseudo-Gravity Model: Converting County-to-County Person-Trips to Airport-to-Airport Person-Trips.

Splitting Airport-to-Airport Person-trip by Aircraft Type.

Convert Airport to Airport Person-trips by mode to Airport to Airport Aircraft Operations using Aircraft Occupancy Rates.

Figure 2: Overview of steps in Airport Choice Model
Figure 3: Modified Weibull Distribution (Original Distribution Developed by LMI).
Figure 4: Model Output: Aircraft Operations and Hours Flown by Aircraft Type.
Figure 5: Distance Frequency Distribution using Estimated Values from Model.
### TABLE 1: Aircraft Type Factors (used in deriving Aircraft Attractiveness)

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Average Occupancy (Persons)</th>
<th>Average Annual Utilization (hours) MODEL</th>
<th>Average Annual Utilization (hours) GAATA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Engine</td>
<td>1.7</td>
<td>128</td>
<td>133</td>
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<tr>
<td>Multi Engine</td>
<td>2.4</td>
<td>170</td>
<td>170</td>
</tr>
<tr>
<td>Jet Engine</td>
<td>3</td>
<td>320</td>
<td>385</td>
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</tbody>
</table>
### TABLE 2: Model Output: Estimated Values by Aircraft mode

<table>
<thead>
<tr>
<th>Aircraft Type</th>
<th>Average Stage Length (mi)</th>
<th>Total Hours Flown</th>
<th>Total Trip Distance (mi)</th>
<th>Total Operations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Single Engine</td>
<td>447</td>
<td>6,980,000</td>
<td>1,030,000,000</td>
<td>8,318,000</td>
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<tr>
<td>Multi Engine</td>
<td>587</td>
<td>2,760,000</td>
<td>759,000,000</td>
<td>4,776,000</td>
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<tr>
<td>Jet Engine</td>
<td>1,084</td>
<td>1,210,000</td>
<td>652,000,000</td>
<td>2,302,000</td>
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<td><strong>TOTAL</strong></td>
<td><strong>10,950,000</strong></td>
<td><strong>2,441,000,000</strong></td>
<td><strong>15,396,000</strong></td>
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</tr>
<tr>
<td>LOCID</td>
<td>ST_NAME</td>
<td>FULL_NAME</td>
<td>CNTL TWR</td>
<td>SINGLE ENGINE</td>
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<td>352</td>
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<td>ALABAMA</td>
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<td>WAIMEA-KOHALA</td>
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<tr>
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<td>HAWAII</td>
<td>LANAI</td>
<td>0</td>
<td>0</td>
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<tr>
<td>HDH</td>
<td>HAWAII</td>
<td>DILLINGHAM AIRFIELD</td>
<td>0</td>
<td>260</td>
</tr>
</tbody>
</table>

| SUM   |        |           |          | 8,317,832.00 | 4,776,024.00 | 1,301,928.00 | 15,395,784.00 |
TABLE 4: Operations through Towered and Non-Towered Airports

<table>
<thead>
<tr>
<th></th>
<th>% GA Operations (Model Estimates)</th>
<th>% GA Operations (NTAD 2001)</th>
<th>Number of Airports</th>
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<tbody>
<tr>
<td>Towered Airports</td>
<td>59%</td>
<td>53%</td>
<td>474</td>
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<tr>
<td>Non-towered Airports</td>
<td>41%</td>
<td>47%</td>
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<td>Sum</td>
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<td>3346</td>
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Acknowledgements

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REFERENCES