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A Review and Application of Aviation Forecasting for Airport Planners

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A REVIEW AND APPLICATION OF AVIATION FORECASTING
FOR AIRPORT PLANNERS

by

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An Independent Study on Aviation Forecasting

Submitted to the Graduate Faculty

of the

University of North Dakota

in partial fulfillment of the requirements

for the degree of

Master of Science

Grand Forks, North Dakota
May
2016

This independent study, submitted by Robert Sims in partial fulfillment of the requirements for the Degree of Master of Science in Aviation from the University of North Dakota, has been read by the Advisor under whom the work has been done and is hereby approved.

_____

Kimberly A. Kenville, Ph.D., C.M.

This independent study is being submitted by the appointed Advisor as having met all of

the requirements of the School of Graduate Studies at the University of North Dakota and is

hereby approved.

_____

Wayne Swisher

Dean of the School of Graduate Studies

_____

Date

Permission

Title   A Review and Application of Aviation Forecasting for Airport Planners

Department   Aviation

Degree   Masters of Science in Aviation

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Robert Sims

May 01, 2016

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Abstract

Forecasting is a common method of predicting facility requirements at airports. Statistical methods used in forecasting are often simple and do not require advanced statistical analysis. However, while forecasting methodologies may be simple, the assumptions necessary for those methodologies to work correctly are not always properly addressed. For example, linear regression is often used as a method of generating aviation forecasts but is reliant on the correct selection of independent variables. In order for a forecaster to produce a reliable forecast, care must be taken to select appropriate variable and comply with any additional assumptions of the methodology they select. This paper seeks to further explore those assumptions and how they influence the methodology that best fits a given airport and its forecast.

Introduction

The use of forecasting is well known through many industries as a way to anticipate and prepare for facilities, staffing, and fiscal needs. Long term airport planning generally follows three initial steps. First, the existing infrastructure at the airport is accounted for, the future levels of aviation activity are determined, and finally, it is determined what facilities requirements will best suit the forecasted demand. As can be seen, forecasting aviation activity plays a pivotal role in determining the future needs of an airport. While the methodologies used in airport master plans are generally not overly complex, based on FAA guidance, the assumptions they are based on may not be properly accounted for. The purpose of this paper is to examine the assumptions and methodologies present in some of the common forecasting methods in the aviation industry.

Statement of the Problem

A common approach to aviation forecasting is the application of statistical methodologies to historical or current data in order to predict future trends. As a result, any flaw in the methodology or in the data will be reflected in the forecast. Examples of this may be as simple as forecaster bias, such as an overly optimistic outlook (Milch, 1976), or poor historical data may be combined with sound methodology to produce an incorrect forecast (ACRP, 2007). Some methods that are commonly applied to aviation forecasting, such as linear regression, are dependent upon the analysis being performed on data that meets particular criteria (Field, 2008) which may be either inadequately addressed or omitted entirely.

Research Questions

This study will seek to answer the following questions:

1) What type of data is necessary for a given methodology?

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2) What are fundamental the underlying assumptions associated with common methodologies in aviation forecasting?

3) How do aviation industry trends affect forecasting?

Limitations

This paper is limited in its scope of statistical methodology by selecting the more common methods used within the aviation industry. A review of guidance material and master plans were conducted to determine what methodologies should be examined within the scope of this paper. Some of the guidance included the ACRP Synthesis 2, *Airport Aviation Activity Forecasting,* (2007) and various FAA publications such as Advisory Circular 150/5070-7, *The Airport System Planning Process* (FAA, 2015), Aerospace Forecast (FAA, 2015), and Terminal Area Forecast (FAA, 2014) as well as additional industry guides (GAMA, 2015; GRA, 2001). In addition, the researcher reviewed the forecasting methodologies of seventeen master planning documents or supplemental material by eleven separate firms done for airport around the country. It was determined by the researcher that the following methodologies should be reviewed as industry standard:

- Linear Trend Line

- Linear Regression

- Market Share

- Compound Annual Growth Rate

While there may be application from this paper beyond these methodologies it is neither the intent or scope of this paper.

Literature Review

This section is divided into two parts. The first will examine a selected group of variables that are commonly used in airport planning. The second will discuss existing guidance particular to aviation planning from government and industry groups.

Selected Variables

The study of aviation and is relationship with particular variables is virtually exhaustive (ACRP, 2007; Carson, Cenesizoglu & Parker, 2011; Cline, Ruhl, Gosling, & Gillen, 1998; GRA, 2001; Hanninen, 2004; Li & Trani, 2014; Vasigh, 2013). Variables commonly utilized in master plans and covered in the guidance discussed in the following sections.

Socioeconomic Variables. Models using explanatory variables to predict future operations can be sorted into two separate groups, geo-economic factors (also known as socioeconomic factors) or service related factors (Carson, 2011). Each of these variables may be used to derive dependable forecasts but this paper will focus on the selection, application, and considerations of socioeconomic factors. Service-related factors can provide valuable input but planners may encounter difficulty in attaining this type of information as some of it may be proprietary or difficult to measure in a scalable fashion. Air service is a good example of this, as person A may rate an air carrier an eight out of ten and person B a four, but that does not mean that the person A necessarily thought that service was twice as good as person B (Fields, 2011). Due to accessible information and comparison value, this section will focus on the use of socioeconomic factors to produce aviation activity forecast.

When performing a forecast for a particular region it should be considered that a singular airport will not be impacted in the same way by a given variable. In other words, one airport may prosper as a result of a rapidly growing population while another airport with a similarly prolific

population may not be positively affected to the same level (Carson, 2011). Carson (2011) went on to show that compared to conducting an aggregate forecast for a region the sum of ad hoc forecasts is typically more accurate, therefore demonstrating the regional sensitivity to a similar influence. While this may seem intuitive it is an important illustration that the dynamics of each airport may be different.

Of the many variables that are used for forecasting population is nearly ubiquitous in linear regression. It can stand to natural reason that the more populous an area is, the more the airport would be utilized. Although this is intuitive, additional items like market maturity and the infrastructure of an airport may limit the effect the surrounding population can have on airport activity (ACRP, 2007)

As an example of this, it was found that population growth was a less accurate predictor as compared to job growth in the area for attracting and keeping commercial air service (Mills, 2016). It can be argued that this is a reflection of the natural relationship between an airport and its surrounding environment. If an airport is a connection to the national airspace system and assist in driving commerce, then its influx and potential for commerce should be evaluated to determine future operations. Although, this may not be true for areas that are primarily driven by leisure travel.

As population forecasts are used to determine airport operations if a strong correlation is found it stands to reason that consideration should be given to the accuracy of the population forecast in question. Tayman, Smith, and Rayer (2010) examined decennial census data from 1900 to 2000 for 2,482 counties in the US and found that there are fairly consist errors depending on population size. While small areas are typically forecasts for stronger growth than is realized, this is the opposite for large areas. This error is found to be present when the population of an

area is below 30,000 although more prominent when below 20,000. The sensitivity of population forecast should be considered when relying on an external population forecast as the independent variable.

Government Regulation. Arguably, one of the most influential factors in aviation activity may be government legislation. One of the most well-known impacts of the government on the air carrier industry was the Airline Deregulation Act of 1978. The deregulation of the air carrier industry dramatically changed the scope of air service in order to promote service at reasonable charges, increase competition between air carriers, and promote safety in air commerce while encouraging further growth in association with the needs of the United States, the Postal Service, and national defense (Airline Deregulation Act of 1978). A detailed look at how successful the act was in completing its goals has been a topic of much discussion, though the impact this legislation had on aviation is self-evident.

As a direct offshoot of this decision the Essential Air Service (EAS) program was established. Described in 49 U.S. Code § 41731 – 41748, *Small Community Air Service*, the EAS was instituted to ensure that small communities remained connected to the national airspace system that would otherwise be economically unfeasible for air carriers to provide service. This is done through the use of subsidies to selected air carriers (DOT, 2016).

Legislation may also correct an unintended impact to the aviation community. Congressional hearings in the mid 1980's revealed that the decline of general aviation the preceding period was due largely to rising liability costs (Schwartz and Lorber, 2002). While there are numerous studies arguing the merits on the impacts from the General Aviation Revitalization Act (Kovarik, 2008; Rice, 2004; Kister, 1998) it appears to the researcher that the general industry views the act as beneficial to general aviation.

There are other examples of legislation impacting the industry, such as The FAA Modernization and Reform Act of 2012 and Airline Safety and Federal Aviation Administration Extension Act of 2010 however a full coverage of the impact of legislation is beyond the scope of this paper. Given the impact of legislation on aviation it is pivotal to be aware of legislation posed to impact aviation and how it may affect industry activity.

Fleet Mix. Although influenced by the other factors discussed in this section consideration should also be given to the general aviation fleet mix as it changes. The type of aircraft is a large determinant of airport facilities. An example of the recent change in the general aviation fleet is the indication of a preference variating from single engine aircraft to turbine powered business aircraft (FAA, 2015; GAMA 2016). This can partially be seen in Figure 1 which shows the comparison between billing and units shipped, indicating the recent change in the general aviation fleet.
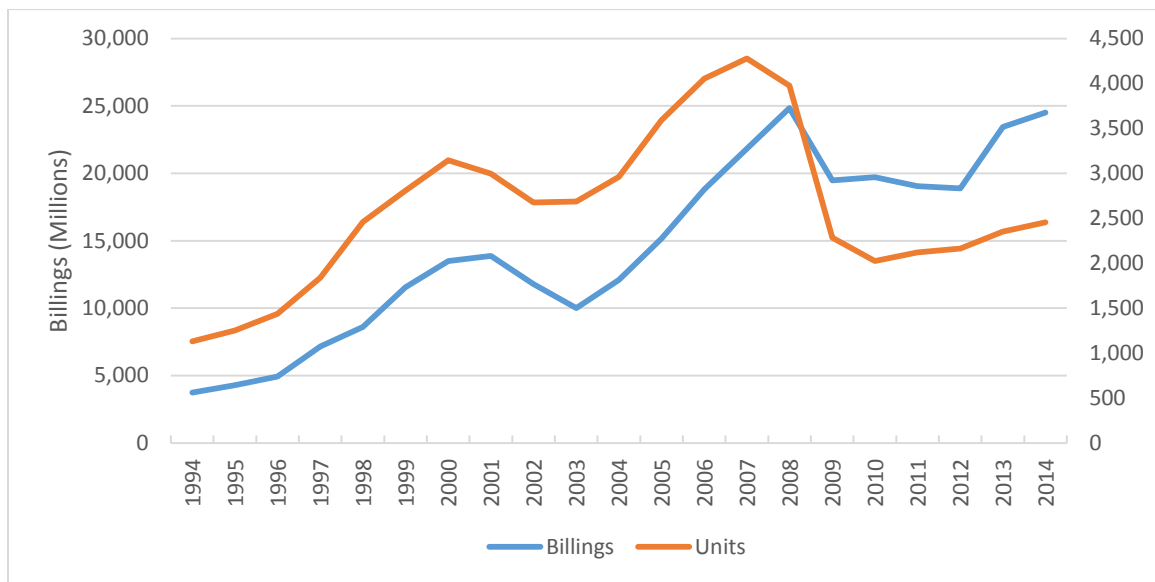
Source: GAMA 2015 General Aviation Statistical Databook & 2016 Industry Outlook

Figure 1. Units shipped verses billings.

Guidance

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As aviation forecasting is a staple of the industry there is a wide variety of guidance provided throughout the industry. Many of these sources were used throughout this paper and some, such as ICAO's manual on air traffic forecasting (2015), presents a more advanced analysis less common in master planning, based on researcher review. This section will serve to summarize these pieces while establishing a foundation of common industry practices for the remainder of the paper to build on and serve as a *guide to the guides*.

Federal Aviation Administration. The Federal Aviation Administration (FAA) offers a variety of material to aid airport planners. Their material is covered below.

Aerospace forecast. The Aerospace Forecast is produced by the FAA every year and covers a broad range of influential factors that affect aviation activity. This Forecast covers economic activity both within the US and internationally. The 2015 report summarizes the recent GDP growth, unemployment rate, the cost of oil, and some international factors. As this paper focuses on US activity only those aspects of the Airspace Forecast will be discussed.

The 2014 Aerospace Forecast points to the economic growth as the primary driver of aviation activity. The review of economic factors in 2014 generally point to modest growth and sums up the US economic situation as follows. 2.8 million jobs were created during 2014, the best figure since 1999. This is combined the falling unemployment rate to 6.1% in the third quarter of 2014 compared to 9.0% in 2011 Q3. As an aside, this has continued to fall and is currently at 4.9% (Bureau of Labor Statistics, 2016). The price of oil, at the time of this report, had been relatively steady from 2011 to 2014.

There are three distinct trends that the Aerospace Forecasting points to that are shaping the commercial air carrier industry:

- Industry Consolidation and Restructuring

- Capacity discipline in response to external shock

- Proliferation of ancillary revenues

Available Seat Miles (ASM), simply the number of seats on a given aircraft multiplied by the miles that aircraft flies, is considered a strong indicator for business aviation. It is pointed out that ASMs have generally grown at 4% a year with only two years of decline between 1978 and 2000. However, in 2014 the mainline carrier group provided 6.3% less capacity than it did in 2007. This reduction in ASM is considered a function of the merger of airlines and reduction in service which in turn has had implications on the size of aircraft being used and load factors.

Mainline carriers are retiring older, less fuel efficient aircraft, and bringing in new aircraft such as variants of the Boeing 737 and Airbus 320. Regional carriers are likewise responding by beginning to phase out the 50 seat aircraft, namely the CRJ 200, to replace them with aircraft ranging from 70 – 90 seats. This decrease in fleet size is presently limited (as the total commercial U.S. fleet has decreased a mere 57 aircraft from 2013) but is expected to continue. GA aircraft are following a similar trend. However, much of the information presented in the Aerospace Forecast gleans heavily from the General Aviation Manufacturers Association (GAMA) materials and so will be presented in that section.

Finally, the Aerospace Forecast also names risks to the forecast. As economic activity is considered to be the underlying driver of aviation activity any changes in economic activity, such as recession, will greatly vary the forecast. Terrorism creates known volatility in aviation activity, as best realized after the September 11th, 2001 attacks, but also in the attempted bombing of the Northwest airliner in 2009.

Fuel price is a more regular influence when compared to often singular cataclysmic events. The rise in oil price of 155% from 2004 and 2008 contributed, in conjunction with the

economic downturn, to the decrease in aviation activity. Finally, there is the consideration that the growing concern of environmental impact could potentially restrict the ability of the aviation sector to grow at an unconstrained rate. In summary, this document takes a macroscopic view of the many factors influencing aviation and its growth.

Terminal Area Forecast (TAF). One of the most well-known forecasting reports within the aviation community is the Terminal Area Forecast (TAF) produced by the FAA. The TAF is used to assist the FAA in meeting its planning, budgeting, and staffing requirements while also serving as an aid for aviation personnel and planners to use as a basis for planning airport improvements. The TAF has evolved over the past decades both in consideration of external forecasts and factors.

Over time the TAF methodology has shifted from a broad assumption of steady growth based on the broad growth indicators to a deference on local trends and reliance on ad hoc forecasting (Milch, 1976). Domestic enplanements are forecast using origin and destination passenger demand forecast based on regression analysis the following data as independent variables (TAF, 2015):

- Fares

- Regional Demographics

- Regional Economic Factors

International enplanements, cargo operations, general aviation, and enplanements at facilities with fewer than 100,000 enplanements rely on time series analysis. This is also supplemented with consideration of historical data, T-100 segment data, and operations per based aircraft to produce the forecast for every airport in the National Plan of Integrated Airport Systems (NPIAS), which is covered in greater detail in the following section.

National Plan of Integrated Airport Systems (NPIAS). Submitted to Congress every two years, and made publically available, the NPIAS, identifies public use airports considered important to national air transportation. This includes the national airport system, the role they serve, and the amounts and types of airport developments eligible for Federal funding under the airport improvement program (AIP) over the next five years.

Perhaps most relevant to planners is the summation of industry trends provided. For instance, in the 2015-2019 report it points out that between 2009 and 2013 the number of aircraft have declined by approximately 7%, the number of public use landing areas have declined 1%, and the number of pilots have increased 1%, alluding to the change in fleet mix mentioned in the beginning of this paper. However, portions of this trend originated before the 2008 recession. Between 2000 and 2013 there has been a 15% reduction in total air traffic while air taxi/commuter operations are down 30% (FAA, 2015).

Despite the reduction in air traffic over the past thirteen years the FAA projects that aviation activity will grow slowly over the long term, citing the September 2001 attacks, rising fuel cost through the early 2000s, and global recession as the isolated catalysts for the trends since the turn of the century. This macroscopic view of the aviation industry can aid the planner in determining applicable trends at the local level. As national trends tend to be felt in some degree on the local level Table 1 displays the forecast as projected by the NPIAS.

The economic impact of civil aviation on the U.S. economy. Mainly a compilation of the economic measures of aviation within the US, this report is generally released annually. Covering not only passenger and cargo transportation but other forms of commercial aviation and general aviation as well, this source is intended for policymakers and industry officials, but is also useful for planners. Able to provide a more holistic view of the aviation impact beyond

the immediate area, it is best taken in conjunction with its supplement *The Economic Impact of Civil Aviation on the U.S. Economy – Economic Impact of Civil Aviation by State* for more localized information.

Table 1. NPIAS Forecast Summary.

Criteria	2013	2034	Annual Growth
Enplanements (millions)			
Domestic	654.3	961.90	1.90%
International	85.1	187.60	3.80%
Total	739.3	1,149.50	2.10%
Airport Operations (thousands)			
Air Carrier	12,776.00	22,110.40	2.60%
Commuter/Air Taxi	8,803.60	8,570.30	-0.10%
General Aviation	25,808.90	28,599.80	0.50%
Military	2,552.20	2,551.90	0.00%
Total	49,940.70	61,932.40	1.00%
Air Cargo Revenue Ton Miles (millions)			
Domestic	12,375.20	16,400.50	1.40%
International	22,437.20	64,591.10	5.20
Total	34,812.40	80,991.60	4.10%
Active Aircraft			
Piston	137,965	126,865	-0.40%
Turbine	22,085	36,420	2.40%
Rotorcraft	10,385	17,895	2.60%
Light Sport	2,110	4,880	4.10%
Experimental/Other	30,320	39,640	1.28%
Total	202,865	22,5700	0.50%

Source: 2015 - 2019 NPIAS Report
Notes: FAA Fiscal years

International Civil Aviation Organization (ICAO). Similar to the ACRP Synthesis 2, the *ICAO Manual on Air Traffic Forecasting* provides a survey of techniques used in aviation forecasting along with the advantages and disadvantages of each. This manual presents the available techniques, methods and procedures for their application, and finally, case studies with additional ad hoc methodologies. This source is more mathematically inclined and instructive than many of the other large survey of techniques intended for public use and consultation. This

manual has been used as a source for the following chapters on statistical methodology but would be a useful beginning point for moving beyond the scope of this paper into more detailed forecasting techniques.

Transportation Research Board. The Transportation Research Board is a multifaceted research group that describes their mission as "…to provide leadership in transportation innovation and progress through research and information exchange, conducted within a setting that is objective, interdisciplinary, and multimodal." (TRB, 2015) One groups under umbrella that are related to this paper is discussed below.

Airport Cooperative Research Program (ACRP). The ACRP is a division of the applied research program that is intended to develop practical solutions to problems faced by airport operators (TRB, 2001). Guidance offered by the ACRP includes how to account for uncertainty in future airport activity, forecasting of the GA fleet and specific approaches to on conducting aviation activity forecasting. The ACRP Synthesis 2, *Airport Aviation Activity Forecasting,* is a staple of aviation forecasting and used as a primary source in the original planning of this paper. Specific guidance from this report is offered in their respective sections throughout this paper.

General Aviation Manufacturers Association (GAMA)

GAMA is an international trade association with more than 90 of the manufacturers of GA aircraft and components around the world. While GAMA offers many studies and publications one of the more relevant for aviation planners is the General Aviation Statistical Databook & Industry Outlook. Issued annually, this is publication is not only a source for recent trends in aviation but provides information on shipments and billings, turbine aircraft operators, the U.S. pilot population, airports, safety data, and international activity. Information is

particularly useful to planning via extrapolation, for instance, shipments are typically a better indicator of future trends than current active aircraft, which may be retired at any time.

This year's document indicates that the piston fleet growth is slowing while shipments of turbine aircraft continue to increase, though at a slower rate than in previous years (GAMA, 2016). It can be seen in Figure 2 below that in 2008 piston driven aircraft have begun to decline while turbine powered aircraft have continued a slow, but relatively steady, growth. This is thought to be in part a factor of the decrease in recreational pilots, due to the cost of ownership for an aircraft, and the rise of business aviation as the prominence driver of general aviation.
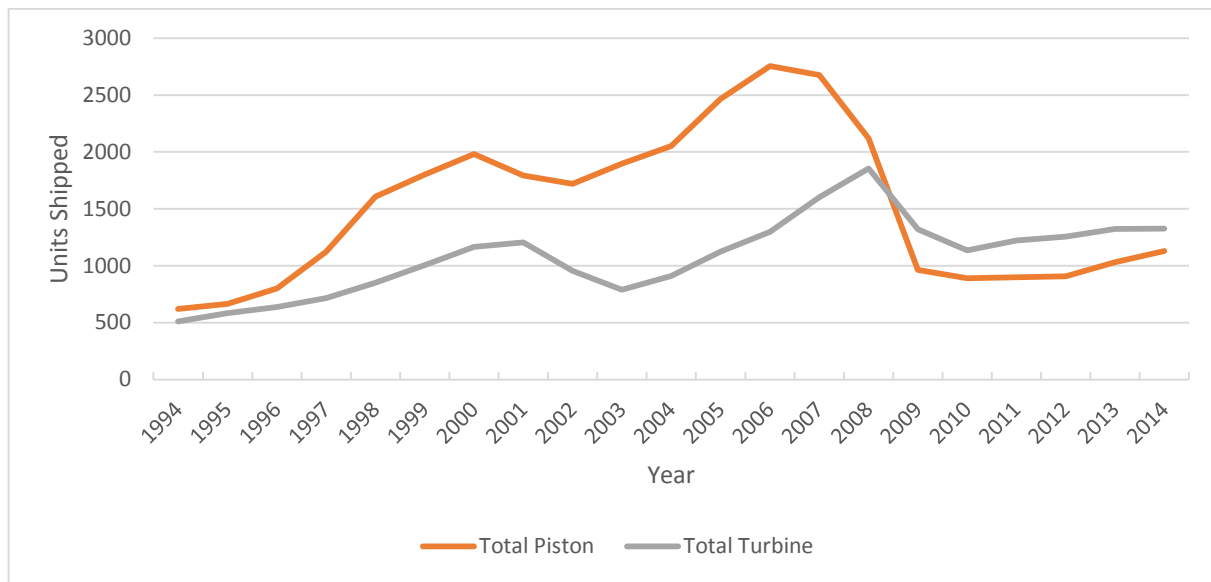
Source: GAMA 2015 General Aviation Statistical Databook & 2016 Industry Outlook

Figure 2. General aviation units shipped by type.

Review of Statistical Principles

Statistics used for forecasting, particular in airport master plans, does not tend to be terribly advanced. Instead, forecasting for airports is far more reliant on an accurate representation of driving factors than overly complex methodologies. This is apparent by examining recent master plans in addition to the guidance offered to forecasters. (ACRP, 2007; ICAO 2006). As a result, this section will cover the following basic statistical principles and methods as necessary for their application.

- Line of Best Fit

- Correlation

- Linear Trend Line

- Linear Regression

Line of Best Fit

At the heart of many of the forecasting methodologies is the "line of best fit". Shown below in Figure 3, the line of best fit is used as the basis for correlation, trend lines, and linear regression (Field 2008, Freedman 1998, Wheelan, 2013). Explained simply, the line of best fit is the line which will result in the least space from each data point. Going into how the line of best fit is determined is beyond the scope of this paper. Some textbooks on statistics even omit this due to the complexity of solving it by hand and the availability of software that is capable of producing the line of best fit. As a quick summation, it is found by squaring each data point against a line, and the line which minimizes the difference between each data point and the line, is selected as the line of best fit (Field, 2008). This can easily be done in Microsoft Excel 2016, which was used to produce Figure 3.

Once the line of best fit is established, some estimation of how well it fits the data need to be ascertained. For reference, this value is found using the following formula.

$$\frac{n(\Sigma xy) - (\Sigma x)(\Sigma y)}{\sqrt{[n\Sigma x^2 - (\Sigma x)^2][n\Sigma y^2 - (\Sigma y)^2]}}$$

The resulting value is known as R and will be covered in the following subsection.
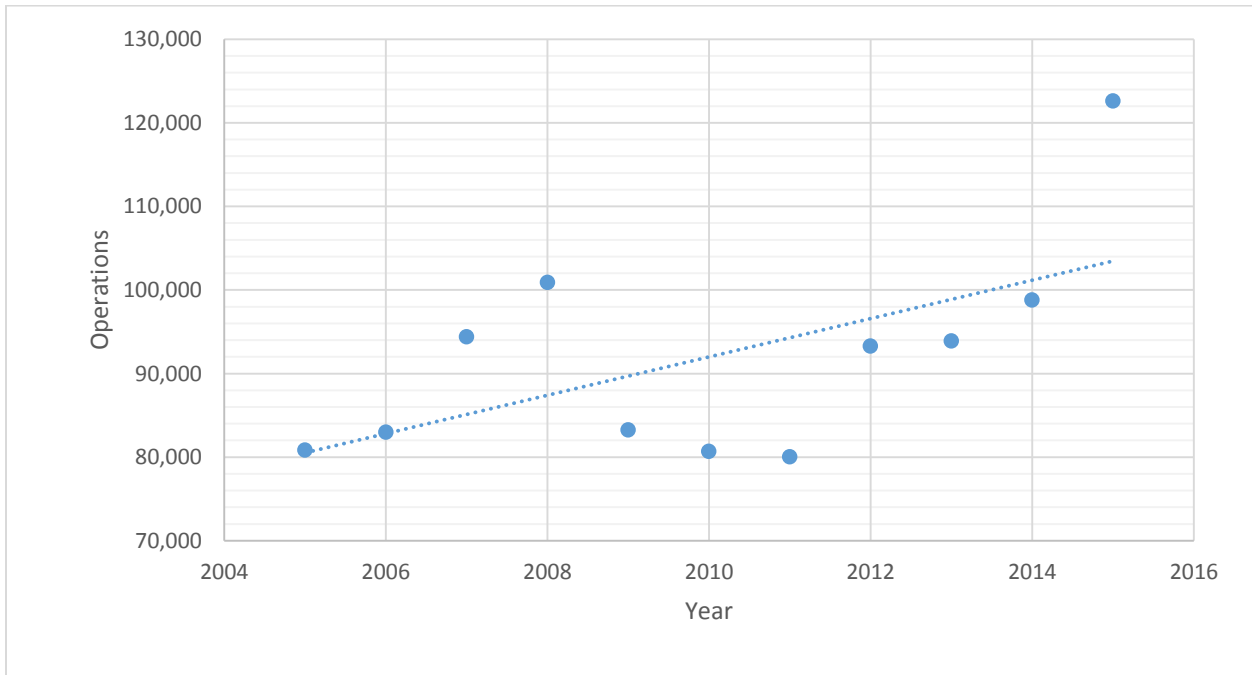
Figure 3. Illustration of the line of best fit.

Correlation

The correlation coefficient, often abbreviated R, is the measure of how well the line of best fits represents the data associated with it. The R value will fall between 0, meaning that the line does not represent the data whatsoever, to a value of 1, which means that the line is a perfect representation of the data (Freedman, 1998). This value can then be expanded upon. By squaring R we are able to obtain Pearson's correlation coefficient. Field (2008) explains the difference between the two values this way:

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"The correlation coefficient provides us with a good estimate of the overall fit of the regression model, and R2 provides us with a good gauge of the substantive size of the relationship."

In other words, the initial R value tells us how well the line fits the data and the R^2 value indicates how well the two variables are associated.

Regression

This line of best fit is the basis for linear regression. While the above example uses historical operations as compared to years, linear regression is the comparison of two variables, such as operations and population. A scatterplot for two variables can easily be created in excel. Linear regression can be described as a line of best fit from the resulting scatterplot. In Figure 4 below, a line of best fit has been created for the population as compared to airport operations. By displaying the R^2 value the relationship between the variables can be determined.

The following tables and figures in this section are the results of an analysis of the county population as compared to airport operations done in Excel 2016. Field (2008) explains that the R^2 value of 0.279 would mean that 27.9% of the variance in operations can be explained by population and 72.1% is left unexplained by the model.
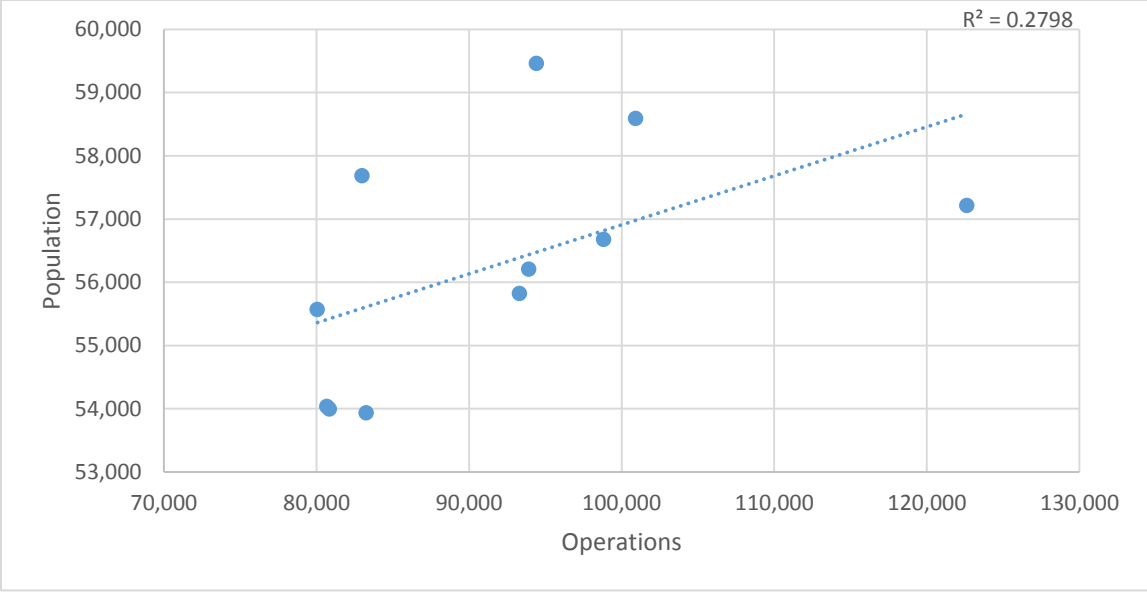
Figure 4. Population and operations regression.

This section will examine the output of Excel 2016 when conducting a linear regression analysis. This will enable an explanation of relevant tables and data while further discussing the methodology. The first output table is the regression statistics table as shown in Table 2. The multiple R value is a simple correlation between population and operations and squaring this value results in the appropriately titled R^2 value. As discussed in the previous section, this explains the variation in the dependent variable (operations) by the independent variable (population). Observations simply indicates the number of data points in the analysis. The discussion of Adjusted R^2 (R^2 with degrees of freedom taken into account) and standard error are not immediately applicable to conducting linear regression for forecasting and are therefore beyond the scope of this paper.

Table 2. Regression Statistics.

Criteria	Value
Multiple R	0.52894491
R Square	0.27978271

Adjusted R Square	0.19975857
Standard Error	11413.8255
Observations	11

The next output is shown in Table 3. This is normally used to conduct an analysis of variance (ANOVA) and is not directly related to the forecasting covered here. However, one useful element table for the purposes of this paper is the F value. The F value is a useful indication of how well a regression model can predict an outcome compared to the error within that model. The F value should at least be greater than one to indicate that the model has significant prediction capabilities as compared to the error in the model (Field, 2008)

Table 3. ANOVA.

Crtieria	df	SS	MS	F	Significance F
Regression	1	455472650	455472650.1	3.496229	0.09432559
Residual	9	1172478719	130275413.2		
Total	10	1627951369			

Finally, Table 3 displays the components needed to actually turn regression analysis into a forecast. The formula below is used to predict a Y value based the Intercept (b_0) and X variable (b_1) below. In short this formula below tells us that for every singular change in population there is an expected 3.6 increase in operations.

$$Y = (b_0 + b_1X_1) + E$$

This coefficient can be further tested with a *t-test*. The t-test examines how well the coefficient (b_1) predicts change in the model. This is done through comparing the observed coefficient to the standards error in the following formula.

$$\frac{b_{observed}}{SE_b}$$

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The t-test compares what would be a very poor predictor, zero, to the coefficient in the

model and the difference can then be compared to known values in order to determine their

significance. These values are found in any standard statistics textbook. However, excel also

displays this value as the P-value as seen in Table 4. If the observed significance is less than .05

the predictor is considered to make a significant contribution to determining the value of Y, the

dependent variable. In this example below a significance of .09 is seen, which would be only a

marginal contribution and could only be recommended based on further support.

Table 4. Coefficient Data.

Criteria	Coefficients	Standard Error	t Stat	P-value
Intercept	-111195.76	108718.5	-1.02	0.333113
X Variable	3.60963721	1.93047256	1.863	0.094326

Application of Common Methodologies

This section is intended to aid the forecaster in the selection of a methodology appropriate for a given forecast. When determining what forecasting method would be suited at a given airport several factors should be considered. This is discussed in the following section.

Linear Trend Line

This methodology uses the same method as linear regression but instead uses time as a variable. In this way, it uses historical data to forecast future activity (Field, 2008). As this forecasts takes places insulated from external information it is generally required to have both reliable historic data and reason to believe that the current trends influencing the airport in question will not deviate (ICAO, 2006).

As linear trend line forecasting only uses historical data it does not require the additional information that many other methodologies of forecasting do (such as local socioeconomic data, national trends, etc.). This can be particularly useful when additional information is either unavailable or considered inaccurate. Because of this it allows linear trend forecasting to be conducted relatively simply, quickly, and with little additional information.

Due to this methodology being "self-contained" and not relying on outside data it usually is not reliable for long term forecasting. It does not take into account external factors such as socioeconomic trends or expected changes in policy that may affect future airport operations. As a result, this method is best used when historical data is stable so that the R^2 value is near .9 and there are no major changes expected in the airport or surrounding region.

Linear Regression

Regression is used as a forecasting staple in many industries. Forestry, utility demand, (such as water and energy) dairy products, and highways, in addition to aviation, all utilize

regression analysis in some form to determine what level of products and infrastructure is needed to meet future demand (Jebaraj, 2004; Hanninen, 2004; Schmit, 2006; Tayman, 1998, NCHRP, 2012).

One of the main advantages of linear regression is that it enables a forecast to be generated based on variables which are often more readily available and can be predicted with better. Information that is often used to determine airport enplanement, operations, and based aircraft (such as population and income) are often forecasted at the local, regional, and federal levels. This level of repetition assists the airport planner as they are potentially able to use well established and often well researched data.

In the energy industry, Jebaraj (2004) takes a comprehensive look at energy planning models using identifying independent variables such as GDP, resource availability, and infrastructure investment, to name a few. While much of this study is beyond the scope of this paper or not directly applicable to aviation forecasting one notable aspect is the analysis of correlations used in an earlier work to establish the relationship between aspects of energy use and factors such as national income and the standard of life (Natarajan, 1990). The applicable illustration is that understanding the correlation of potential independent variables for use in regression analysis is an integral part of producing a reliable regression model. Variables used in forecasting should be selected on the affluence and driving factors particular to the airport in question.

There are many studies on the methods used to predict operations at GA airports however one stands out as regularly cited in airport master plans and prepared for and referenced by the FAA. A GRA (2001) study built on a 2000 (Hoekstra) study intended to develop a linear regression model used to predict airport operations at non towered airports. Non towered GA

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airports pose a difficult problem for planners as accurate counts for airport traffic are difficult to find and future operations are subsequently difficult to predict.

The GRA study expanded the initial considered variables. While the initial study considered population and county employment, GRA additionally recognized that the airport's position within the county and surrounding population density will further affect airport activity. In other words, if the airport is within county X but near the border of counties X and Y then using data solely from county X will likely not be the best representation of airport activity. Next, based aircraft were examined both in the context of the proportion of based aircraft in the region and the complexity of those aircraft. Finally, the number of flight schools and location of the airport was considered. The resulting formulas are often incorporated into master plans as a potential forecast (Coffman, 2011).

Although linear regression is one of the most useful tools a planner can employ, there are several underlying statistical assumptions that are not always directly addressed when building a regression model. Arguably two of the most common errors used in linear regression are 1) multicollinearity and 2) a nonlinear relationship in the data. Multicollinearity (or autocorrelation) is the concept of two or more of the independent variables having a high level of correlation with each other. In other words, multicollinearity occurs when the independent variables being used are so closely related to each other they are strongly affected by each other. This is important as one of the assumptions of linear regression is that all variables being used are independent from each other (Freedman, 1998). A good example of this would be using both the total population of a city and the population ages $20 - 60$ (or any other proportionally large section of the population). While one of these variables is often a preferred independent variable in linear regression using both of them would create a forecast that is fundamentally flawed. While

intuition is often enough to prevent strong cases of multicollinearity there are two notable ways

of testing to ensure data does not contain this error. The first can be done before linear regression

is performed by running a simple correlation test on all of your independent variables. A

correlation of .90 or above between any two variables is a strong indication that there is an

instance of multicollinearity and the data should not be used. Additional common errors in linear

regression can be found in Table 5.

Table 5. Linear Regression Common Errors.

Error	Description
Multicollinearity	Independent variables should not have a high level of correlation.
Nonlinear Relationship	Data should be linear in nature.
Causation	A high correlation does not mean that one variable is causing the other.
Reverse Causality	Correlation only mean that variable X and Y are related, it does not say which may affect the other.
Confounding Variables	Extra variables may be affecting both independent variables
Unrealistic Extrapolation	Making predictions to far out of the historical data may lose accuracy

Source: Wheelan, 2013; Li, 2014

Market Share

The market share methodology considers airport activity as a portion of a larger whole.

Typically, an aggregate total will be taken from an overarching forecast and activity will be

forecast as a share of the total. Depending on the size of the airport to be forecasted national,

regional, or local aggregate totals may be used as the parent whole. However, as the market share

of an airport may change over time it should first be verified that there is a steady relationship

over a long time period between the parent data and dependent airport. As this forecast considers

activity as a whole, this assists in making it somewhat more resilient towards volatility in the

larger market, provided that changes to the parent aggregate market is initially assumed.

Compound Annual Growth Rate

This method projects future operations by determining past growth rates and applies this CAGR to future operations. This method is similar to the linear trend line as it relies purely on historical data and can be used when additional data is either scarce or unreliable. This presents the advantage of being able to quickly produce a forecast with a limited amount of data. Again, this methodology is similar to the linear trend line with one additional weakness. As the CAGR for the historical data is taken (usually for the previous ten years) any recent spikes or dips in historical operations can greatly affect future forecasts. However, the CAGR selected for this can be derived not only from historical growth but also projected CAGR from planning documents such as the FAA TAF or a state's aviation plan.

Summary

The methodologies covered here represent the most common forms of forecasting in aviation master planning. However, each method is able to be enhanced or changed as seen in several of the sources listed in this section. As a summary of the information presented here Table 6 contains the main strengths and weakness for each method as identified throughout this section.

Table 6. Comparison of Forecasting Methods.

Method	Strengths	Weaknesses	Notes
Trend Line	Does not require external data Can be produced quickly	Does not consider external factors Typically, not accurate for long-term forecast	This is a comparatively simple forecast that is often used for short term forecasting
Linear Regression	Can demonstrate relationships of external variables Able to consider a variety of external factors	Susceptible to statistical errors Does not show causation but instead a relationship	See Table 4 for more information
Market Share	Does not require extensive external data	A steady relationship needs to be demonstrated	As this method does not require external data it is a useful method when only historical information is available
CAGR	Can use CAGR from a number of sources Does not require historical data	Does not consider changing dynamics at the airport	This should be used in stable areas where a constant growth rate is expected.

Conclusion

Throughout the discussion and Table 6 the types of data considered for a forecast have been discussed. While it is a natural assumption that the data used to generate a forecast should be accurate it is often more difficult to determine how accurate that information is and what its influence on an airport may be. For instance, this paper has shown that when conducting aviation forecasting at a small GA airport it is often beneficial to use job growth data instead of population data as an independent variable. Care should also be taken if the airport is near a political border such as a county or state, as influential variables may be located outside of these boundaries. The statistical assumptions in the data set should be carefully evaluated before the data is used to generate a forecast. A good example of this is using nonlinear data for linear regression. As linear regression assumes the analysis is being conducted with linear data, this will not produce a reliable forecast. Finally, this paper summarizes the trends that influence aviation. A shift to turbine aircraft and the decreasing popularity in singe engine aircraft should be accounted for. Practically, this means that a forecast produced for an airport should generally align with the expected future trends unless that forecast can be strongly supported.

It is the goal of the researcher for this paper to provide illumination for the methodology commonly used in aviation forecasting. This paper should act as an overview of the basic statistics needed for forecasting methodologies, the application of those methodologies, and a source of sources for further research into the field of aviation planning. The external research used in this paper demonstrates the many complexities that are often unnoticed by a quick examination of the forecasting used in airport master plans. Through consideration of well selected variables and well applied statistical methods it is the goal of this paper to aid forecasters in producing accurate forecast within the aviation industry.

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