Aircraft Valuation In Dynamic Air Transport Industry

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ABSTRACT

Aircraft valuation and the projection of its future price is an intricate process. This paper provides a comprehensive review of aircraft valuation. It presents a methodology that will more accurately measure return on investment, improve the efficiency of managing operating costs, and more effectively determine yield analysis. The value of an aircraft depends on internal factors that are directly related to the aircraft's documentation and specifications. Some examples of these are age, aircraft size, seat capacity, fuel efficiency, and technical status. In addition, the aircraft price depends on the external factors, such as market demand and its elasticity, fuel cost, and environmental regulations. The external factors are extremely important because they indicate where in the aviation industry cycle the aircraft is and this, in turn, has the greatest impact on aircraft value. The theoretical value calculated in this paper is highly responsive to the assumptions underlying the valuation model.

Keywords: Aircraft valuation, Asset valuation, Discount cash flow model, Boeing 737/767, Airbus 320/330

INTRODUCTION

With deregulation of the airline industry, commercial airlines must adjust to the risks of volatile prices and cost components in the competitive marketplace. One of the major assets of airlines is the value of the aircraft that they are flying. Therefore, it is critically important to develop a methodology for estimating an aircraft's value. However, estimating an aircraft value is a complex process. Factors determining an aircraft's value not only include the physical characteristics of the aircraft, such as size, age, seat capacity, fuel efficiency, and physical condition, but also include maintenance status and maintenance documentation; operating expenses and revenue; demand and its elasticity; inflation rates and interest rates; fuel cost; safety issues and regulation; and finally, environmental regulations. In addition, other exogenous factors, such as the event of September 11, 2001[1] and predatory competition by other airlines, can significantly alter the demand for certain types of aircraft and therefore change the estimated value.[2] For instance, there is an increase in demand for old wide-body aircrafts when there is a capacity shortage or significant diminution in fuel costs. On the other hand, technological progress that reduces the operating costs of new aircraft, or environmental regulations that restrict older aircraft, or higher fuel prices, would have damping effects on value of old wide-body aircraft.[3] In addition, since the value of an aircraft depends on its operating costs, older aircraft are retired when the break-even load-factor is too high to generate enough revenue to cover operating costs. These operating costs are mainly determined by fuel efficiency, range, seat capacity, maintenance expenditures, and airport fees. In general, higher operating costs result in lower aircraft value. Recent decades, however, have seen a marked lowering of operating costs through several factors that have contributed to an increase in energy efficiency; among these are aerodynamic improvements and improvements in engine thrust.

Additionally, wear and tear of an aircraft is appraised on the basis of flight hours and on the number of cycles. This can vary significantly since the same type of aircraft can be operated on different routes with different

[1] In the period immediately after 2001, values of the B737-300 fell to record lows with some even being scrapped. Aircraft Value News, April 20, 2008.
[2] Aloha Airlines filed for Chapter 11 bankruptcy protection on March 12, 2008. The airline said, it was unable to generate sufficient revenue due to what it called "predatory pricing" by Mesa Air Group Inc.'s go! airline

distances and varying number of landings per hour. Macro-economic factors are also extremely important because they indicate the aviation industry cycle, and this can have the greatest impact on aircraft values. All of these factors make aircraft valuation a complex and dynamic process

In this paper, we use popular narrow-body and wide-body aircraft manufactured by both Boeing and Airbus and employ a modified Discounted Cash Flow (DCF) model that is based on financial theory. The theory assumes that the value of an investment can be estimated from the future cash flows that the investment is expected to generate. We conclude that the discounted cash flow model provides the best estimate of aircraft value. However, since many factors are considered in the DCF model, small variations in these factors can significantly affect the theoretical value of any aircraft.

The paper provides a comprehensive review of aircraft valuation. It presents a methodology that will more accurately measure return on investment, improve the efficiency of managing operating costs, and more effectively determine yield analysis. As such, it should provide the basis for an improved negotiating position for the purchase or lease of new or used aircraft. Additionally, it also provides quantitative evidence to determine when an aircraft should be retired and replaced.

LITERATURE REVIEW

The question of valuing commercial aircraft has not been explored in any great depth by researchers in academia. Gibson and Morrell (2003) explored the actual practice regarding aircraft financial evaluation. They propose the Net Present Value (NPV) approach (with close attention to the choice of discount rates to flesh out investment/financing interactions), the use of Monte Carlo analysis to quantify risk up front, and Real Options Analysis (ROA) to better understand the value of flexibility to aircraft operators. They suggest that a better approach to value uncertainty is to use a moderate cost of capital, either using market measures, or, utilizing broad, long-term regional benchmarks[3]. They then surveyed the use of sophisticated asset valuation strategies by airlines to evaluate the benefits of their risky investments in aircraft. An advanced method of risk-adjusted return is utilized and substantial interaction is considered. This included cash (rather than accounting) based returns. The method adjusts returns for the time value of money, and demonstrates the increase in value for the investors and interest payments for the lender. This research provided a significant contribution to aircraft financial evaluation, particularly in the areas of risk and cost of shareholder equity estimation. Substantial interactions were identified between the investment analysis and the way the projects were financed. These authors concluded that while they find substantial use of the more sophisticated techniques in aircraft financial evaluation, airlines do not appear to consistently use the most advanced techniques in the market. In addition, they claim that, among cash-based measures, the use of NPV to estimate the value of an aircraft is now about the same as the Internal Rate of Return (IRR). This has probably come about by advances in the knowledge of the techniques to estimate the cost of capital.

In another look at an asset valuation model, an options-based analysis of the large aircraft market is surveyed by Clarke, Miller and Protz (2003). These authors argue that in order to determine the strategic value of infrastructures, it is necessary to calculate the value of the options that it brings. The methodology described here combines financial and real options theory and it uses a Monte Carlo simulation in a system dynamics framework to determine this value. This methodology overcomes some of the weaknesses associated with standard real options analysis, such as the selection of the underlying asset and the inclusion of market dynamics. It can be used to evaluate a wide array of investments under uncertainty. Some examples are expenditures in research & development (R&D) for a new aircraft model by an aircraft manufacturer and improvements in the air traffic control (ATC) infrastructure for the National Airspace System (NAS).

In another field, Breidenbach, Mueller and Schulte (2006), compare property and market betas for both private real estate (using the NCREIF Index) and public real estate (using the NAREIT Index), so that investors can have a more accurate risk premium beta or benchmark for their decisions. Their goal in this study was to develop a model based on the capital asset pricing model (CAPM) that will allow investors to derive their required rate of return for individual property types in specific markets. The required rate of return is an important component in

[3] such as those identified in Dimson, Marsh and Staunton (2002).

achieving risk adjusted returns.[4] More specifically, this paper concentrates on the development of meaningful beta proxies for the application to the CAPM, examining current approaches used in the industry to calculate market risk premiums, as well as suggesting improvements.

In the final survey, an exact Bayes test of asset pricing models with application to international markets is researched by Avramov and Chao (2006). The paper develops and implements an exact finite-sample test of asset pricing models with time-varying risk premiums using posterior probabilities. This procedure is applied to international equity markets by testing and comparing the International Capital Asset Pricing Model (ICAPM) and conditional ICAPM versions of Fama and French (1998). Specifically, this approach allows one to simultaneously compare the performance of multiple asset-pricing specifications, both nested and non-nested, and optimally combine those models into one general weighted model that could be useful for making investment decisions under uncertainty. Conclusions about this asset valuation articles are difficult to draw since the researchers have used various pricing models to test subject matter in diverse areas.

Vasigh and Erfani (2004) identified internal factors, such as the aircraft specification and age, and external factors, such as the state of the economy and inflation rate, that affect the theoretical value of an aircraft. Operating costs and revenues have a major impact on the theoretical value. They argue that the expected theoretical value of an aircraft is, to a great extent, dependent on the expected net cash flows that can be generated from the use of the aircraft. Future generation of net cash flow depends on factors affecting revenue and costs and how those factors are expected to change. However, the value of an aircraft is also determined by the relationship between supply and demand. Although there is one single market, similar aircraft may be traded at significantly different prices.

Often company valuations are calculated using the dividend discount model. Expected future net cash flows in the form of dividends are discounted to estimate the value of the company. Foerster and Sapp (2005) conclude that the dividend discount model explains the value of equity for a large mature dividend paying company. This model can be extended to aircraft valuation. The profits generated by an aircraft over time can be considered as net cash flows which can be discounted to estimate the theoretical value of an aircraft.

AIRCRAFT SELECTION AND DATA

The results in this paper are based on a sample of quarterly data. The necessary data was collected using the front end application from Back Aviation Solutions. We accessed the Form 41 as well as the Fleet data base. Relevant expense and revenue data for the four aircraft were collected for the time period starting with the first quarter of 1995 to the fourth quarter of 2005. The information was obtained for two different aircraft; Boeing and Airbus. We have also selected two different poplar models (narrow body and wide-body) for each manufacturer. Data sets were obtained for all the quarters for the A320-200, as of the first quarter of 2000 for the B737-700LR, as of the second quarter 2000 for the A330 and as of the third quarter 2000 for the B767-400. Unfortunately, Back Aviation Solutions gave no breakdown of the financial information for the A330 aircraft model. Also, the fleet size for both wide-body aircraft types selected is rather small, distributed among a few airlines only.

Note that the equations presented below have a number of terms that cancel out when the equations are multiplied out. The reason for this is the fact that we disaggregated the revenue and expense data as much as possible. This disaggregation gave us the ability to separate specific components of the data so that we could calculate the sensitivity of the overall theoretical value of the aircraft to changes in specific components of revenues and costs. The following main factors were defined: Passenger and cargo revenues, direct expenses (e.g. personnel, fuel), maintenance, depreciation and amortization, general administrative cost and other transport related expenses. For a complete example of a data set please refer to Table 11 in the Appendix. Some of the figures had to be calculated as they were not directly available (total gallons consumed), not segregated by aircraft type (servicing, sales and general expense) or were dependent on others (e.g. total block hours). Table 3 in the Appendix provides more detail on these calculations:

[4] The capital asset pricing model of William Sharpe (1964) and John Lintner (1965) marks the start of asset pricing theory (resulting in a Nobel Prize for Sharpe in 1990).

a. Boeing Aircraft

Boeing received the first order for a 737-100 (737 program) in 1965. In 1991 Boeing started the 737X program (next generation)[5] on which the current versions of 737s are based on. According to Air Transport Intelligence's web site[6] 297 airlines operate 737s and 4,061 aircraft versions are in service. The three top airlines operating 737 aircraft are Southwest Airlines (451), Continental Airlines (258) and Ryanair (105). The Boeing 737-700 model was launched in 1993. Currently there are about 705 aircraft of this model in service.

The wide-body aircraft 767 from Boeing is in service with 98 airlines. According to Air Transport Intelligence, the current total of aircraft in service is 825. The three top operators are Delta Air Lines (107), American Airlines (75) and All Nippon Airways (56). The model selected is the 767-400ER which was launched in 2000.

b. Airbus Aircraft

Airbus started its A320 program in 1984 with the A320-100. A newer version the A320-200 was introduced in 1988.[7] Based on information retrieved from Air Transport Intelligence, 138 airlines operate a fleet of 1,476 Airbus A320 models. The three top airlines operating A320s are JetBlue Airways (88), US Airways (75) and Northwest Airlines (73).

To compare the Boeing 767 with a model from Airbus, the A330 was selected. This model is the only wide-body from Airbus that is operated by an US airline. The A330 was launched in 1993 (A330-200) followed by the A330-300 around 1998. According to Air Transport Intelligence's web site, 57 airlines currently operate a total fleet of 394 Airbus A330 model. The three top operators are Emirates (29), Cathay Pacific (26) and Northwest Airlines (20).

Table 2 in the Appendix summarizes some characteristics of all aircraft models selected. The current operators of each aircraft model are given for the United States only because only financial data of US carriers was obtainable (through Back Aviation Solution's Form 41 application). For a complete list of codes for the US carriers please refer to table 10 in the appendix.

THEORETICAL VALUATION MODEL

In this section, we develop our theoretical aircraft valuation model. Financial theory indicates that the value of an investment is estimated from the future cash flow that such an investment is expected to generate. A commonly used approach is the discounted cash flow (DCF) model. The generic model requires a present value calculation of projected future cash flows (e.g. dividends and earnings). In order to apply the DCF model, future cash flows have to be projected. For aircraft valuation, revenues (cash inflows) generated by passengers and cargo/freight transport have to be estimated. These estimates can be complex and require several assumptions. To calculate the revenue per aircraft type, the total revenue passenger mile (RPM) was calculated and added to the revenue ton mile (RTM) (multiplied by the cargo yield). For narrow body aircraft the yield is lower because the freight has to be hand loaded due to the fact that no containers can be loaded mechanically. The wide-body aircraft can be loaded with cargo containers using lifts to load them onto the aircraft. Therefore, the cost is lower which results in a higher yield. Based on the cargo yield analysis per aircraft model the average industry cargo yield was used for the narrow body models. For wide-body aircraft models the cargo yield was estimated by weighting the overall cargo yield for airlines that operate the respective aircraft model.

All of the data are available per aircraft-fleet only. In order to determine the revenue and expense for individual aircraft the figures were divided by the average number of aircraft in service. This number is also

[5] New generation include, 737-600, 737-700, 737-800 and 737-900 airplane models.
[6] All fleet information as obtained from www.rati.com on May 16, 2006
[7] The A-320 family comprises four aircraft that share the same cockpit, have the same cabin cross-section and fly with the same operating procedures.

available through Back Aviation Solutions' Form 41 application. In the case of theoretical aircraft valuation the cash inflow generated can be defined as:

$$TR = \beta \times \left[\left(\frac{RPM}{\beta} \times RRPM \right) + \left(\frac{RTM}{\beta} \times RRTM \right) \right] \quad (1)$$

Where:

TR = total revenue
β = block hours[8]
RPM= Revenue passenger mile[9]
RTM= Revenue ton mile[10]
RRPM = revenue per revenue passenger mile (passenger yield)[11]
RRTM = revenue per revenue ton mile (cargo yield)[12]

In addition to estimating the cash inflows, cash outflows must also be estimated. These include operating expenses as well as non-cash expenses, such as amortization and depreciation. Operating expenses for an aircraft include fuel cost, flight personnel expenses, maintenance cost, indirect costs and flight equipment capital costs as well as expenses for marketing, sales, and general administration. Many of these factors depend on how many seats are offered for travel in the market (available seat miles) as well as on how long the aircraft is used on a daily basis (block hours). Based on these cost factors, the estimated cash outflow may be defined as:

$$TC = ASM \times \left\{ \left[\frac{\theta \times \frac{\gamma}{\beta}}{\frac{ASM}{\beta}} \right] + \left[\frac{\frac{\lambda}{\beta}}{\frac{ASM}{\beta}} \right] + \left[\frac{\frac{\mu}{\beta}}{\frac{ASM}{\beta}} \right] + \left[\frac{\iota}{ASM} \right] + \left[\frac{\varpi}{\frac{ASM}{\beta} \times \beta} \right] \right\} + Admin \quad (2)$$

Where:

TC = total costs
Admin= administration costs, such as servicing, sales, and general cots
ASM = available seat miles[13]
θ = fuel cost per gallon
γ = gallons of fuel consumed
λ = flight personnel costs
μ = cost of maintenance (labor and materials)
ι = indirect costs
ω = capital cost per aircraft day
k = cost of capital (required rate of return / risk of the estimated cash flow)
t = year
n = expected aircraft life
ι = indirect costs
ω = capital cost per aircraft day

[8] Typically includes taxi time plus airborne time.
[9] One fare-paying passenger carried one mile.
[10] One ton carried one mile.
[11] A measure of unit revenue, calculated as the gross revenue generated per RPM.
[12] RRTM is a measurement of revenue earned on the movement of a ton of freight over one mile,
[13] One seat transported one mile.

The resulting net cash flow (inflows minus outflows) is the profit generated by an individual airline utilizing that specific aircraft for 1 year. Each of these periodic net cash flows represents value received by the buyer of the aircraft. However, a net cash flow received further in the future has less value to the buyer today. Therefore, the future net cash flow needs to be discounted to determine today's value of that specific cash flow. The sum of all these discounted future net cash flows represents the value of the asset and the maximum amount the buyer should be willing to pay for it. This study utilizes the DCF model and defines the theoretical aircraft valuation by the following equation:

$$V_{aircraft} = \sum_{t=0}^{n} \frac{\left(\left\{ \beta \times \left[\left(\frac{\text{RPM}}{\beta} \times \text{RRPM} \right) + \left(\frac{\text{RTM}}{\beta} \times \text{RRTM} \right) \right] \right\} - \left[\text{ASM} \times \left\{ \left[\frac{\theta \times \frac{\gamma}{\beta}}{\frac{\text{ASM}}{\beta}} \right] + \left[\frac{\frac{\lambda}{\beta}}{\frac{\text{ASM}}{\beta}} \right] + \left[\frac{\frac{\mu}{\beta}}{\frac{\text{ASM}}{\beta}} \right] + \left[\frac{\iota}{\text{ASM}} \right] + \left[\frac{\varpi}{\frac{\text{ASM}}{\beta} \times \beta} \right] \right\} + \text{Admin} \right] \right)_t}{(1+k)^t} \quad (3)$$

METHODOLOGY

As pointed out in the previous section the theoretical value of an aircraft depends on the potential future net cash flows. Calculating the periodic future cash inflows and outflow requires certain assumptions and estimates. The forecasting of the periodic aircraft revenues and expenses depends on factors such as the state of the economy, currency exchange rate, inflation and the age of the aircraft.[14] With the increase in maintenance (due to aging aircraft) operational expenses will increase accordingly. Operating expenses will also increase when market fuel prices increase.[15] In addition, if the aircraft is operated longer hours per day, fuel consumption will increase resulting in higher fuel costs. The changes in fuel cost are also dependent on the fuel efficiency of the aircraft. A continuous improvement in fuel efficiency reduces the gallons consumed per block hour. On the other hand, more ticket sales (thus increasing the load factor) or higher ticket prices increase revenues. Tables 4 and 5 summarize the assumptions and estimates of changes in certain factors for each aircraft model. The first column in Tables 4 and 5 represents the cumulative overall growth rate for the 30 year period. This rate is an extrapolation of the previous five-year growth rate for the factor in question. So that, for example, the daily utilization rate in hours can be expected to grow about a 10th of 1% for the 30 year period and gallons per block hour can be expected to decrease by about a half of 1% over the same time period and so forth.

An aging aircraft generally requires more maintenance. Therefore, the rate at which the maintenance costs increase should usually be higher than the rate at which general costs increase. In order to get an estimate of the maintenance cost, data for major US airlines operating the respective aircraft types were collected and analyzed. Factors retrieved (all for the calendar year 2005) are total maintenance expense, number of aircraft and the average individual fleet age. Based on these values, a base maintenance figure as well as the annual increase per aircraft is predicted. Afterward, the annual change rate is estimated.

Another factor that has to be estimated is the rate at which the periodic net cash flows are discounted to derive their value today. This rate reflects the current market rate of return adjusted by the risk of the investment. Commonly, the required rate of return is estimated as a function of the firm's weighted average cost of capital (WACC).[16] The WACC reflects both the current market rates of return as well as the risk specific to the company. The formula defining the weighted average cost of capital is:

$$k = \text{WACC} = w_d k_d (1-T) + w_e k_e \quad (4)$$

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[14] In 2007, Airbus reporting a loss of over a Billion Euro due to the weakness of the dollar is said to be under pressure to secure higher prices for new aircraft.

[15] April 18, 2008, the price of crude oil reached $114.53 per barrel on the New York Mercantile Exchange and setting another record.

WACC is calculated by multiplying the cost of each capital component by its proportional weighting and then summing.

Where:

w_d = proportion (weight) of debt financing
k_d = cost of debt
ke = cost of equity
w_e = proportion (weight) of equity financing
T = corporate tax rate

Applying the WACC method is effective for determining the necessary rate of return at which to discount the expected net cash flows (Lloyd and Davis, 2007). However, to obtain a valid net present value (and subsequently a correct theoretical asset value), the investment or asset discounted under the WACC method must have a risk similar to the average risk of the firm's existing investments. This is probably more true for the airline industry than most others because the principal existing investment is the aircraft fleet.

APPLICATION OF THE MODEL AND SIMULATION

Applying Equation 3 defined earlier, the theoretical value of an aircraft can be estimated. In a net present value framework, the longer the period of time over which an annuity occurs, the greater the sensitivity of the present value of that annuity to uncertainty in the variation in
revenue, cost, and interest rate.

In general, there are two ways that the results from the empirical present value exercise described above can be applied and evaluated. We can observe the actual price of an aircraft in the market and see how close the calculated theoretical value comes to this price, or we can calculate the sensitivity of the theoretical valuation of the asset to changes in the price of the input factors (revenue or costs). The first method is essentially a benchmarking procedure that provides an estimated theoretical value (under the assumptions of the model) to compare with a list price for the aircraft. This is a type of absolute valuation based on the assumed future revenues and costs of the aircraft and is an application of the benchmarking potential of the technique. That is, if the assumptions are reasonably accurate, it provides a base value for the asset for sale or a theoretical economic (as opposed to accounting) value of the asset for business decision-making. By providing such an economic value, this can materially aid in managerial financial decisions that involve the sale or purchase of capital assets in a timely manner. The second method, on the other hand, is more of a relative valuation that determines the most critical of the input assumptions. This approach can also aid in managerial financial decisions by identifying those inputs that have the largest impact on the value of the asset. That is, it might give the financial decision maker a quantitative method to evaluate the impact of a specific decision such as, for example, the installation of winglets to increase fuel efficiency. Both methods are instructive and we will demonstrate each in turn. Table 1 provides the minimum and maximum list price for each of the four aircraft for which the present value was calculated using equation 3.

Table 1: Theoretical Values for each of Four Aircraft

Aircraft Type	List Price				
	Minimum	Maximum	Average	Theoretical value	% Difference
A320	73.2	80.6	76.9	68.4	6.56
A330	176.3	185.5	180.9	155.8	11.63
B737	57.0	67.5	62.25	44.7	21.58
B767	154.0	169.0	161.5	150.0	2.60

As the Table 1 shows, in all cases the discounted net present value approach produced values that were less than the 2008 minimum listed sale price for all of the aircraft. For example, the Boeing 737 -- 700 had a theoretical net present value of $44.7 million whereas the minimum sale price was $57 million. This represents a 21.5% decline in the theoretical vs. the list price of the aircraft. Thus, the theoretical valuation may represent a cyclical decline in the financial condition of the aviation industry, or it may represent the increase in price (decrease in present value) for some of the inputs (in this case most likely fuel). For the A320, the difference between the theoretical valuation and the minimum sales price is 6.5%. On the other hand, the theoretical value of the wide bodied 767 – 400ER is much closer to the minimum list price. In this case, the theoretical difference amounts to only a decline of 2.6%, while the difference for the A330 is about 11.63%. The average difference for the four aircraft amounts to about 10%. While the differences are of course subject to the assumptions outlined above, they are close enough to the minimum list price to validate the present value approach as a reasonable first approximation to the valuation of an asset using this technique. In any event, the final sale or purchase price will always be a function of market equilibrium and the bargaining power of the buyer and the seller. However, the method described above appears to give at least a reasonable "lower end" valuation for the capital asset.

The second way by which the present value technique can be applied is to calculate the sensitivity of the present value to changes in input prices. As mentioned, this provides financial information on the relative value of price changes for either costs or revenues. Table 6 in the Appendix presents the resulted variations in present value of the aircraft for 1% increase or decrease in various input factors. As Table 6 shows, changes in the passenger yield have the largest impact on the present value of the aircraft. This is clearly a result of the compounding value of increased revenue over the relatively long lifespan of an aircraft as a capital asset. On the other hand, a 1% increase in fuel cost has a bigger impact than the same 1% increase in maintenance costs and so forth. Different results and figures will be obtained if the percentages used to forecast revenue and expense are varied.

Another way of looking at these changes is to use the well-known concept of elasticity. Elasticity measures the percent change in one factor relative to the percent change in another, so that it is a measure that is free of units. Point elasticity measures a relative change at a particular point whereas arc elasticity measures the change over some larger amounts and is calculated as the average relative change. The formula for arc elasticity is calculated as follows:

$$E = [\Delta v/(v_1 + v_2)]/[\Delta x/(x_1 + x_2)] \quad (5)$$

Where:

E = arc elasticity of theoretical aircraft value
v = theoretical aircraft value
x = input variable

The corresponding theoretical aircraft values at each level are computed for a +/- 1% increase/decrease in the input factor (Table 6) and the arc elasticity of each factor for every aircraft model is calculated. The results are tabulated in Table 7 in the Appendix. As Table 7 clearly shows, block hour usage has the highest impact on the present value of the aircraft. With a 1% increase in block hours producing an approximately 24% increase in the present value of the aircraft. A good real world example of this is Southwest Airlines which has the highest block hour usage rate among the major airlines and is also consistently profitable. As mentioned earlier, passenger yield is also a major contributor to present value and this shows up in Table 7 as an approximate 18% increase in present value for a 1% increase in passenger yield. Table 7 also shows that fuel costs have a bigger impact on present value than maintenance costs. Finally, we note that a 1% increase in the discount rate produces a 7.4% decrease in the present value of the aircraft. The reason for this of course is the fact that we are comparing the present value of the aircraft as an asset to other possible investment opportunities in the economy and, as the rate of return on those investment opportunities increases, the value of the aircraft as an asset will decrease.

Tables 8 and 9 contain the theoretical aircraft values obtained by applying the different growth rates in various input factors. The change in present value is calculated for the applicable growth rate contained in the tables while all other factors are held constant at year 2005 values. The factor studied is increased or decreased by a fixed percentage based on the previous year’s value. Then the theoretical aircraft value is estimated by applying Equation 3. For factors other than the discount rate, a discount rate of 12% is applied to obtain today’s value of the periodic cash flows (present values). The theoretical aircraft values in Tables 8 and 9 in the Appendix are calculated for new aircraft only. Keeping the useful life-time for an aircraft at thirty years, a one year old aircraft will generate less net cash flows (29 periods only). Therefore the aircraft’s theoretical value will be less. Calculating the value of the aircraft at each of the thirty periods a valuation trend can be plotted. Applying the same rules as for Table 8 and Table 9, the graphs for each factor and aircraft model can be generated. As the tables show, the present value of the aircraft can vary greatly depending on the changes in the input variables. However, it is also clear that tables and figures such as these should be helpful in various financial decisions that might accompany the purchase or disposal of an aircraft as an asset. For example, suppose that an airline is employing a 737 on a specific route where the passenger yield has been dropping over some period of time. This could come about through increased competition or regulatory constraints (noise restrictions, etc.) or a decrease in population or any number of other factors. At the same time maintenance costs, fuel costs and personnel costs have all been increasing and both of these trends are expected to continue. The airline could use equation 3 with the appropriate extrapolations of the decreasing revenues and increasing costs (from historical data) and conclude that this aircraft will become non-profitable in the near future. At this juncture the airline might decide to switch the aircraft to another route, retire the aircraft, attempt to lease it, or sell it. The airline would still use judgment and experience in the final decision, but it would have some quantitative evidence to support that decision.

CONCLUSION

This research has utilized a modified DCF model to forecast the net cash flows generated by an aircraft over time. We included factors, such as revenue per passenger mile, revenue per ton mile of cargo, available seat miles, block hours, fuel consumed, flight personnel labor rate, maintenance and material costs, expected economic life, indirect costs, and capital cost per aircraft day to forecast net cash flows. These net cash flows are then discounted at an appropriate cost of capital to estimate the theoretical value of an aircraft.

The authors then compared the actual price of an aircraft in the market to see how closely the calculated theoretical value came to this price. In general, the average deviation was approximately 10% less than the actual price. This value provided a benchmarking procedure that was an acceptable first approximation to the value of the aircraft.

Following this, we calculated the sensitivity of the theoretical valuation of the asset to changes in the price of the input factors (revenue or costs). This method provided a type of absolute valuation based on the assumed future revenues and costs of the aircraft and is an application of the benchmarking potential of the technique.

Since the air transport industry is in a dynamic environment, it is quite likely that one or more of the base assumptions may change and this, in turn, will change the theoretical value of an aircraft. Therefore, the theoretical valuation was calculated for different discount rates, fuel costs, maintenance costs, passenger yields, and block hours. In order to calculate the possible outcomes, all factors, except one, were kept constant. The variable factor was then rotated among the factors. The results of the calculations showed that significant changes in the theoretical value of aircraft can be attributed to modest change in the discount rate, fuel cost, and passenger yield.

This paper provides a comprehensive review of aircraft valuation. It presents a methodology that will more accurately measure return on investment, improve the efficiency of managing operating costs, and more effectively determine yield analysis. As such, it should provide the basis for an improved negotiating position for the purchase or lease of new or used to aircraft. Additionally, it also provides quantitative evidence to determine when an aircraft should be retired and/or replaced.

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APPENDIX

Table 2: Characteristics of All Selected Aircraft Models

			A330		
	A320- 200	**B737-700**	**-200**	**-300**	**B767-400**
Launch	1988	1993	1998	1993	2000
Normal Seating	164	126	293	335	243
Range, miles (max. payload)	2,167	5,179	7,674	5,179	4,315
Speed (mach)	0.78	0.79	0.82	0.86	0.80
In Service (world/US)	1,448/348	705/317	203/9	186/20	37/37
US-Operators (for decoding please refer to appendix)	B6-87 NW-73 Ted-57 UA-40 US-77 U5-13 Virgin-1	FL-23 AS-22 AQ-8 CO-36 WN-228	NW-9	NW-11 US-9	CO-16 DL-21

Table 3: Calculated Factors

Factor	Calculation
Total Block Hours	Daily Utilization x 365.25
Gallons Consumed	Gallons per Block Hour x Total Block Hours
Passenger Revenue	RPM x overall passenger yield
Cargo Revenue	RTM x overall cargo yield
Aircraft Fuel	Gallons consumed x Fuel cost (price per gallon)
Servicing, Sales and General Expense	Allocated bases on ASM

Table 4: Factors Forecasting for Narrow-Body Aircrafts

	Airbus A320-200			Boeing 737-700LR		
Factor	**%**	**Year 2005**	**Year 2034**	**%**	**Year 2005**	**Year 2034**
Daily utilization (hours)	0.10	11.63	11.97	0.10	11.65	11.99
Gallons per block hour	-0.05	793.49	782.07	-0.05	709.43	699.22
Fuel cost ($ per gallon)	2.00	1.67	2.97	2.00	1.31	2.32
RPM (millions)	0.05	204.71	207.70	0.05	159.76	162.10
Passenger yield (cents)	1.25	11.92	17.09	1.25	11.92	17.09
RTM (millions)	0.01	20.81	20.87	0.01	16.50	16.54
Cargo yield (cents)	1.25	70.18	100.61	1.25	70.18	100.61
Direct maint. ($)	3.75	1,677,664	4,879,329	7.10	734,221	5,357,781
All other factors (costs)	2.00			2.00		

Note: Base is the year 2005. For every year the previous year's figure is increase by the percentage listed (compounding) for a total of thirty year (estimated asset life-time)

Table 5: Factors Forecasting for Wide-body Aircrafts

	Airbus A330			Boeing 767-400ER		
Factor	**%**	**Year 2005**	**Year 2034**	**%**	**Year 2005**	**Year 2034**
Daily utilization (hours)	0.10	13.85	14.26	0.10	14.26	14.68
Gallons per block hour	-0.05	1,858.69	1,831.92	-0.05	1,651.91	1,628.12
Fuel cost ($ per gallon)	2.00	1.73	3.07	2.00	1.73	3.07
RPM (millions)	0.05	546.56	554.50	0.05	500.79	508.10
Passenger yield (cents)	1.25	11.99	17.19	1.25	11.99	17.19
RTM (millions)	0.01	71.50	71.71	0.01	64.35	64.54
Cargo yield (cents)	1.25	39.50	56.63	1.25	48.00	68.82
Direct maint. ($)	12.45	700,000	21,034,024	12.65	830,000	26,259,277
All other factors (costs)	2.00			2.00		

Note: Base is the year 2005. For every year, the previous year's figure is increase by the percentage listed (compounding) for a total of thirty year (estimated asset life-time).

Table 6: Net Aircraft Value Trend Changes

		Discount Rate +/- 1%	**Fuel Cost +/- 1%**	**Maintenance +/- 1%**	**Pax Yield +/- 1%**	**Block Hour +/- 0.1%**
Narrow Body						
A320-200	+	(5,403,299)	(4,593,908)	(1,771,206)	17,973,531	1,940,246
	-	6,166,951	4,019,128	1,490,406	(15,821,149)	(1,941,626)
B737-700	+	(3,843,702)	(3,223,495)	(1,253,484)	14,047,544	1,578,608
	-	4,386,930	2,820,178	1,076,017	(12,327,185)	(1,558,858)
Wide-body						
A330	+	(12,994,586)	(13,254,621)	(2,850,478)	48,316,101	4,643,621
	-	14,831,102	11,596,238	2,410,339	(42,398,980)	(4,585,520)
B767-400ER						
	+	(12,753,537)	(12,140,706)	(3,496,076)	44,273,757	4,554,906
	-	14,555,985	10,621,686	2,954,928	(38,851,689)	(4,497,915)

Note: Aircraft valuation variances are based on the assumption that all factors are kept constant but the factor studied. For factors other than the discount rate, the discount rate was estimated to be 12%.

Table 7: Arc Elasticity for Each Aircraft and Factor

	Discount Rate	**Fuel Cost**	**Maintenance**	**Pax Yield**	**Block Hour**
Narrow Body					
A320-200	-7.40	-6.16	-2.24	17.19	24.35
B737-700	-7.40	-6.06	-2.32	18.48	27.57
Wide-body					
A330	-7.40	-7.56	-1.52	18.73	24.07
B767-400ER	-7.40	-6.99	-1.95	17.75	24.06

Table 8: Impact on Theoretical Aircraft Value of New Narrow-body Aircrafts by changing One Factor, Holding all Others Constant

		Theoretical new aircraft value ($)	
Factor	**Applied growth rate**	**Airbus A320-200**	**Boeing 737-700LR**
Discount rate	**12%**	**77,781,963.66**	**55,335,193.94**
	9%	*99,205,431.77*	*70,575,003.77*
	10%	*91,028,573.62*	*64,758,314.94*
	11%	*83,948,914.28*	*59,722,124.29*
	13%	*72,378,664.80*	*51,491,491.49*
Fuel cost (price per gallon)	**2%**	**70,232,334.77**	**50,037,701.50**
	1%	*74,251,462.71*	*52,857,879.84*
	1.5%	*72,308,001.14*	*51,494,174.01*
	3%	*65,638,426.44*	*46,814,206.02*
	5%	*54,293,482.80*	*38,853,582.54*
Maintenance expenses A320-200; B737-700LR;	**3.75%; 7.10%**	**73,008,644.28**	**50,192,221.55**
	1%; 1%	*76,730,504.74*	*54,876,051.79*
	2,5%; 4%	*74,872,627.23*	*53,070,329.46*
	5%; 6%	*70,786,590.16*	*51,367,213.18*
	8%, 11%	*63,441,201.62*	*43,954,374.45*
Passenger yield	**1.25%**	**97,221,004.19**	**70,506,204.00**
	1%	*93,079,311.47*	*67,273,860.22*
	1.5%	*101,500,158.25*	*73,845,828.17*
	2%	*110,493,836.74*	*80,864,857.05*
	3%	*130,398,834.51*	*96,399,518.92*
Block hours	**0.1%**	**79,723,589.47**	**56,894,051.88**
	0%	*77,781,963.66*	*55,335,193.94*
	0.05%	*78,749,725.69*	*56,112,173.62*
	0.5%	*87,740,075.10*	*63,330,173.93*
	0.75%	*92,961,748.92*	*67,522,442.45*

Note: Theoretical aircraft valuation trends are based on the assumption that all factors are kept constant but the factor studied. Figures in bold font are the base percentage changes used for theoretical aircraft valuation among additional factors introduced in Table 4 in the Appendix.

Table 9: Impact on Theoretical Aircraft Value of New Wide-body Aircrafts by changing One Factor, Holding all Others Constant

		Theoretical new aircraft value ($)	
Factor	**Applied growth rate**	**Airbus A330**	**Boeing 767-400ER**
Discount rate	**12%**	**187,074,341.29**	**183,604,118.45**
	9%	*238,596,282.72*	*234,170,329.31*
	10%	*218,931,529.78*	*214,870,356.99*
	11%	*201,905,443.30*	*198,160,103.94*
	13%	*174,079,755.17*	*170,850,581.52*
Fuel cost (price per gallon)	**2%**	**165,291,696.60**	**163,652,082.29**
	1%	*176,887,926.98*	*174,273,768.09*
	1.5%	*171,280,534.43*	*169,137,619.54*
	3%	*152,037,075.17*	*151,511,376.25*
	5%	*119,303,959.45*	*121,529,144.17*
Maintenance expenses A330; B767-400ER	**12.45%; 12.65%**	**172,828,517.29**	**166,081,472.10**
	9%, 9%	*179,712,746.51*	*174,875,370.35*
	11%, 11%	*177,187,438.70*	*171,881,076.81*
	14%; 14%	*168,191,602.05*	*161,214,584.77*
	15%, 15%	*164,479,368.77*	*156,812,936.74*
Passenger yield	**1.25%**	**239,254,569.70**	**231,418,713.14**
	1%	*228,137,021.40*	*221,231,309.18*
	1.5%	*250,741,105.58*	*241,944,233.53*
	2%	*274,882,842.28*	*264,066,163.44*
	3%	*328,313,840.01*	*313,026,882.45*
Block hours	**0.1%**	**191,659,861.54**	**188,102,033.42**
	0%	*187,074,341.29*	*183,604,118.45*
	0.05%	*189,359,896.19*	*185,846,008.36*
	0.5%	*210,592,323.70*	*206,672,795.38*
	0.75%	*222,924,303.92*	*218,769,176.03*

Note: Theoretical aircraft valuation trends are based on the assumption that all factors are kept constant but the factor studied. For factors other than the discount rate, the discount rate was estimated to be 12%. Bold numbers are the base percentage changes used for theoretical aircraft valuation among additional factors introduced in Table 5 in the Appendix.

Table 10: Selected Airline Decoding

Code	Airline Name	Code	Airline Name
AQ	Aloha Airlines	Ted	Ted (United Airlines)
AS	Alaska Airlines	U5	USA 3000
B6	Jetblue Airways	UA	United Airlines
CO	Continental Air Lines	US	US Airways
DL	Delta Air Lines	Virgin	Virgin America
FL	AirTran Airways	WN	Southwest Airlines
NW	Northwest Airlines		

Table 11: Examples of Data Set

Category	Sub Account	2005
Age in Years		1
Daily Aircraft Utilization		11.6263
Total Block Hours		4,252.01
Gallons per Block Hour		793.49
Gallons Consumed		3,373,938.75
Fuel Cost (Price per Gallon)		1.67
Revenues		
Pax Revenue	Total Revenue Passenger Miles	204,708,614.57
	Yield (Pax)	11.92
Pax Revenue		24,407,817.53
Cargo Revenue	Total Revenue Ton Miles	20,813,750.25
	Yield (Cargo)	70.18
Cargo Revenue		14,606,694.46
Total Revenue		*39,014,512.00*
Revenue per Block Hour		9,175.54

Category	Sub Account	2005
Expenses		
Personnel Expenses	and Copilots	1,310,448.22
	Other flight Personnel	(554.45)
	Trainees and Instructors	46,969.07
	Personnel Expenses	136,070.48
	Professional and Technical Fees and Expense	7,229.36
Total Personnel Expenses		1,500,162.68
Personnel Expenses per Block Hour		352.81
Fuel and Oils	Aircraft Charges	-
	Aircraft Fuels (P52)	5,636,839.47
	Aircraft Oils (P52)	3,584.23
Total Fuel and Oils		5,640,423.69
Fuel and Oils per Block Hour		1,326.53
Other Direct Expenses	Rentals	1,435,018.05
	Other Supplies	2,566.50
	Insurance Purchased - General	43,779.52
	Employee Benefits + Pensions	413,750.34
	Injuries Loss and Damage	433.79
	Taxes - Payroll	87,846.21
	Taxes - Other than Payroll	287,281.30
	Other Expenses	5,093.83
Total Other Expenses		2,275,769.54
Other Direct Expenses per Block Hour		535.22
Total Direct Costs (Flying Operations)		*9,416,355.92*
Total Direct Costs per Block Hour		2,214.56
Flight Equipment Maintenance	Labor - Airframes	228,139.96
	Labor - Aircraft Engines	7,987.51
	Airframe Repairs	555,521.58
	Aircraft Engine Repair	619,997.60
	Maintenance Materials - Airframes	137,167.92
	Maintenance Matertials - Aircraft Engines	94,483.31
	Airworth. Allow. Provs. - Airframes	15,127.57
	Airframe Overhauls Deferred	-
	Airworth. Allow. Provs. - Aircraft Engines	19,239.07
	Aircraft Engine Overhauls Deferred	-
	Total Direct Maintenance - Flight Equipment	1,677,664.51
	Ap. Maintenance Burden - Flight Equipment	561,104.46
Total Flight Equipment Maintenance		*2,238,768.97*
Flight Equipment Maintenance per Block Hour		526.52

Category	**Sub Account**	**2005**
Depreciation and Amortization	Net. Obsol. And Deterior'n - Exp. Parts	16,144.64
	Amort. - Developmental + Preop. Expense	-
	Amort. - Other Intangibles	-
	Depreciation - Airframes	386,691.31
	Depreciation - Aircraft Engines	104,450.60
	Depreciation - Airframe Parts	29,125.13
	Depreciation - Aircraft Eng. Parts	20,934.33
	Depreciation - Other Flight Equipment	31,496.84
	Depreciation - Maint. Equip. + Hangers	-
	Depreciation - General Ground Property	-
	Amortization Expense - Capital Leases - Flt	56,674.12
	Amortization - Capital Leases	-
	Flying Operations	-
	Maintenance	-
Total Depreciation and Amortization		*645,516.97*
Depreciation and Amortization per Block Hour		151.81
Total Aircraft Operating Expenses		**12,300,641.86**
Total Aircraft Operating Expenses per Block Hour		2,892.90
Servicing, Sales and General Ops Expenses	Total Passenger Service Expense	2,042,875.50
	Total Aircraft Servicing Expense	1,636,502.44
	Total Traffic Servicing Expense	2,990,293.82
	Total Reservation and Sales Expense	1,670,845.84
	Total Advertising and Publicity Expense	289,758.00
	General and Administrative Expense	1,822,001.61
	Total Maint. + Deprec. - Ground Property + Equip.	563,258.53
	Depreciation expense - Maintenance Equipment	42,646.86
	Amortization (Other than Flight Equipment)	82,131.79
Total Servicing, Sales and General Ops Expenses		**11,140,314.39**
Servicing, Sales and General Ops Expenses per Block Hour		2,620.01
Transport related Expenses		**5,923,910.84**
Transport related Expenses per Block Hour		1,393.20
Total Operating Expenses		***29,364,867.09***
Operating Expenses per Block Hour		6,906.11
Total Pre-Tax Profit		***9,649,644.91***
Pre-Tax Profit per Block Hour		2,269.43
Pre-Tax margin		24.73%