Theory and Practice in Aircraft Financial Evaluation

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Introduction

The world's airlines are continually challenged to deal effectively with uncertainty in the transport sector and the inevitable downturns faced by any business. These cyclical swings are exaggerated by the periodic need to replace older equipment with more modern aircraft. Financial innovations provide a certain number of solutions to the problem of matching transport capacity to the fluctuations of demand.

Financial theory as implemented in companies around the world provides a clear method for estimating the financial cost of investing in equipment such aircraft, an average of the cost of borrowing, or debt, and cost of invested funds, or equity. The Weighted-Average Cost of Capital (WACC) has been used in investment appraisal for over twenty years, and more recently, has been applied to corporate financial management, in techniques such as Economic Value-added (EVA).

The techniques used to value the financial viability of investments - from basic profitability, to Return on Investment, Net Present Value and Internal Rate of Return - are taught to hundreds of thousands of business students around the world every year. Many books and software tools are available to assist companies in valuing investments. Clearly, financial valuation has reached a mature stage of balancing theoretical correctness with practical usability.

So, what is the state of practice? Clearly there are positive points (many managers are familiar with the techniques), but on the other hand a certain lack of clarity in definitions can be detrimental to their proper use. In our work in the aviation industry, we find that there is considerable frustration with the limits of the theoretical responses to practical issues surrounding implementation.

The objective of this paper is to stimulate discussion, research and debate about potential innovations for practitioners in the aviation field. The scope of the paper - like the airline industry itself - is global, which means that we attempt to point up solutions for airlines in developing as well as mature economies.

Sources of airline capital and corporate valuation

In many countries, airlines have historically been viewed at least partially as an infrastructure investment, required to promote economic development and growth. This implies that for many governments, airline financing can be viewed as part of the state's overall infrastructure financing. Further, because of the strategic and military background of aviation, many of the world's airlines were initially financed using state funds.

In this historical perspective, the cost of financing investment in aircraft is the government's own cost of financing.

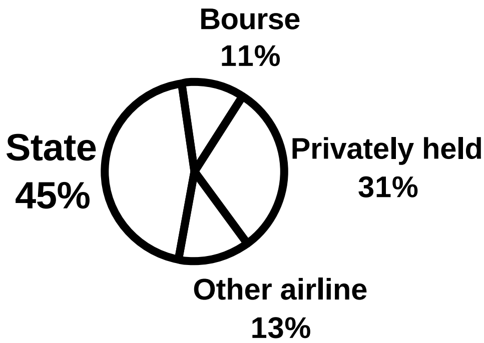
A government's cost of financing will depend on:

- the willingness (or obligation!) of taxpayers to provide interest-free financing
- the interest rate on public debt.

The latter will be determined by investors' assessment of the state's creditworthiness, often based on work by rating agencies such as Moody's Investor Service, Fitch, and Standard and Poor's.

The notion that aircraft investment is state-funded is of course heresy in the current view of airlines as generators of economic wealth. Financiers correctly point out that the relatively low cost of government financing can encourage dramatic over-investment, when the airline is competing against profit-oriented airlines in the international arena. However, the fact of the matter is that a huge amount of airline equity remains in the hands of governments around the world. The following graph shows that among the world's alliance members , the state is the largest shareholder in 45% of the airlines surveyed by Airline Business.

Airline ownership: Largest shareholder in the airline



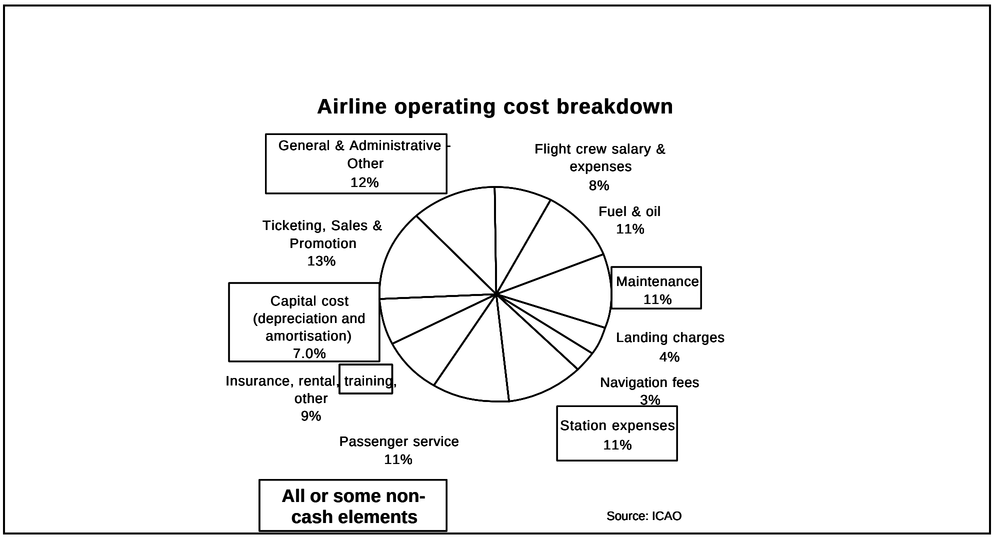
Source: Airline Business Alliance Survey, 2001, 163 Alliance members surveyed

On the other hand, most of the world's airlines today seek to make increased use of capital market financing. The wave of privatisation is reaching into every part of the globe. China Eastern and China Southern in Asia, and ACES and LAN Chile in South America are just a few examples of airlines partially or fully privatised in the last 20 years. The most dramatic wave of privatisation has been in Western Europe, where Air France, British Airways, Iberia and Lufthansa have raised large amounts of private equity, Of these four leading companies, only Air France remains majority state-owned. In addition, start-up airlines are finding private capital where no state funds are available. Notable examples are India's Sahara and Jet, not to mention such roaring newcomers as easyJet and Ryanair in Europe, and JetBlue in the United States.

This unmistakable trend toward the use of private capital points up clearly the need for financial valuation of the companies, as well as a solid and transparent financial justification for the large investments needed to support growth and profitability in the future.

Investment valuation tools for airlines

Analysts and academics agree that cash-based measures provide the soundest indicator of investment viability, if for no other reason than the fact that investors are putting up cash, and demand a cash return from the project. That said, the fundamental tool used to compare aircraft in terms of economic performance remains Direct Operating Cost (DOC), which reflects a P&L approach, including non-cash items such as aircraft depreciation.



Airlines and aircraft manufacturers use absolute and relative DOC figures to compare aircraft in economic terms. While extremely useful for comparing the characteristics of today's aircraft, DOC must be complemented by time-sensitive measures of economic viability for managers:

- it is a static measure, ignoring the risky evolution of economic conditions as well as the time value of money.
- it combines cash and non-cash items, making valuation difficult
- it assumes that the aircraft investment is fixed from order to retirement of the aircraft, ignoring the flexibility offered by conversion options and operating leases
- it places the emphasis on cost rather than focussing on the revenue-generating potential of a given unit (seat-kilometre or trip)

Using NPV for investment valuation

To correctly value a long-term investment, firms must first estimate cash flows in three clearly defined categories, consistent with cash-flow statements and corporate finance theory.

The three commonly accepted cash-flow categories are

- **Operating** cash flows arising from the use of the equipment
- **Investing** cash flows, the purchase and eventual disposal of the equipment
- **Financing** cash flows directly related to acquiring the equipment

The publication of cash-flow statements in this format by airlines is relatively recent. For example, British Airways first began publishing a complete cash-flow statement in the mid-nineties, but by now, analysts are familiar with these categories.

The financial theory taught in business schools and presented in corporate finance texts requires that the Operating and Investing cash flows be discounted at the company's overall cost of financing - usually defined as the Weighted-Average Cost of Capital (WACC) - to calculate the Net Present Value (NPV).

The financing cash-flows must be left out of the discount calculation for very good reasons:

- WACC already includes a charge to the project for the debt financing
- discounting financing cash flows at WACC would incorrectly show value creation by borrowing at the lower debt rate and "lending" the proceeds to the project at the higher WACC rate
- management is forced to focus on the investment and operation, rather than the way the aircraft are financed

This method, widely taught and at least partially understood in industry, poses serious problems for analysis of aircraft investments where increasingly, there are critical interactions between investment and financing decisions.

Practical Problem 1: Estimating the cost of capital (WACC)

WACC is as its name suggests, the average cost of debt and equity capital financing, weighted by the relative market values of debt and equity in the firm's target capital structure.

The cost of debt is more or less transparent thanks to the financial press. For private carriers, credit ratings or shadow ratings and information published in financial journals provide at least rough guidelines to borrowing costs. For state-owned airlines, the government borrowing rate plus a margin for the specific credit risk of the airline can be used as a proxy.

Cost of equity is another matter. Many state-owned airlines are simply unaware that there is a cost to equity, considering that their "company" is a public service, funded by tax revenue and general government borrowing. Closely held private airlines also demonstrate a lack of transparency regarding the cost of equity, though presumably the airline's management is quite well aware of the returns their shareholders expect.

Even in more mature markets such as Western Europe, Japan and the U.S., estimating cost of equity is difficult. Turner and Morrell (2002) clearly show that estimates of systematic risk and cost of equity vary among different sources, and in any case are volatile over time.

Practical Problem 2: operating lease vs. purchase analysis

Lease rentals include a charge for the aircraft depreciation, another reflecting the cost of financing the aircraft, and a profit margin for the lessor. If the rentals are *included* in the cash flow the rule of leaving out financing flows if violated, and if they are *excluded* the cost of the aircraft is ignored.

This problem complicates the necessary task of comparing leasing with purchasing. While there are many theoretical discussions of lease valuation, these are too often bound up with complex tax formulations and couched in language practitioners don't understand. There are surprisingly few practical solutions proposed by the literature.

Practical Problem 3: Pre-tax vs. after-tax analysis

Copeland et al. (2000) compare pre-tax and after-tax analysis, and conclude that "it is virtually impossible to perform a real-world discounted cash-flow analysis using the pre-tax approach." In leasing vs. purchasing analysis, tax considerations can be very important

After-tax analysis can be somewhat complex, due to the diversity and ambiguity of tax codes, and the fact that tax is often based on accrual accounting rather than cash-flow. In practice, financial managers often require that analysis be done pre-tax.

One notable effect is to *increase the project discount rate*, providing a practical sort of financial cushion against the risks of the project. The increase is due to the tax-deductibility of interest payments: the after-tax borrowing cost is the pre-tax interest rate times (1-Tc), where Tc is the effective tax rate on corporate profits.

Practical Problem 4: Bottom-line returns to investors

Airline management justifiably wants to know the net cash flows that will accrue to the shareholders, including the leverage benefits offered by debt financing. There is a strong tendency to discount ALL the cash flows.

Financial theoreticians have resisted this approach, ever since the classic Modigliani and Miller Propositions I & II, which postulate that returns on investments in companies are independent of the way the firm is financed, since shareholders can duplicate any debt financing for themselves. Proposition II softens this stance by recognising the benefit of interest tax deductions, but the bias against including financing cash-flow remains. Thus, classic NPV analysis ignores this measure, but in practice, the investment modelling done for project finance provides some insight.

Practical Problem 5: Dealing with uncertainty in the cash flows

This is the greatest problem of all, starkly illustrated by many airlines' current struggle to maintain profitability and cash reserves in the face of a dramatic downturn in air traffic following the terrorist attacks on New York and Washington, the subsequent wars in Afghanistan and Iraq, and most recently, the SARS epidemic. The current situation is the most dramatic example of the shocks – such as the Gulf War - and cyclical downturns – such as the 1970's oil shocks - that periodically turn the airline world upside-down.

A common "solution" is to artificially raise the discount rate to compensate for the risks of the project. This is modelling equivalent of attempting to "insure away the problem." It begs the question of the key management responsibility to manage risk, and ignores the potential upside if market conditions are good.

In the rest of this paper, we will propose a comprehensive set of solutions to problems 2 & 4, and especially this critical problem of uncertainty in investment analysis, both within the NPV framework, and using Real Options valuation.

Solutions within the NPV Framework

To clearly and comprehensively approach these issues, it is critical to have a sharp understanding of the elements under analysis. On the financial side, managers must estimate cost of debt and cost of equity using the tools available, however imperfect they may be.

Second, it is critical to clearly distinguish between, operating, investing, and financing cash flows. Recent advances in financial reporting requirements (yes, there have been some advances!) help to clarify these distinctions. Once a company has clarified these definitions, a comprehensive approach is possible.

Finally, it is important to see that the results are significant! In this section we will discuss the alternative methods proposed, and provide a mathematical example of the results. Throughout the paper, we will be looking at operating an A320 family aircraft over a densely travelled 600 nm sector. Revenue and costs used are those costs typically encountered in the European travel environment, which couples a dense and competitive transport network with high operating costs, notably labour and navigation/landing/ handling fees. The example is stylised, and not intended to represent any particular aircraft operation.

Estimating the cost of capital

If we look broadly at the global airline industry, airlines in Europe, the U.S., Japan, with their extensive access to stock market financing, are the exception rather than the rule. Their listed shares provide highly transparent historic returns, which can be used to estimate cost of equity with the Capital Asset Pricing Model (CAPM) or other techniques.

An excellent recent example of financial transparency and discipline in applying the concepts to airlines is Lufthansa. The airline has published its estimated WACC, which is used to complement the traditional DOC analysis, which of course it continues to perform in evaluating aircraft.

Value-oriented management of the business segments
Basis for calculating the cost of capital

	2001
Risk-free interest rate	5.1%
Market risk premium	5.7%
Beta factor	1.05
➔ Cost of equity after taxes	11.1%
Cost of debt	6.3%
Equity share (market value, target capital structure)	55.0%
Debt share (target capital structure)	45.0%
➔ WACC after taxes	8.9%

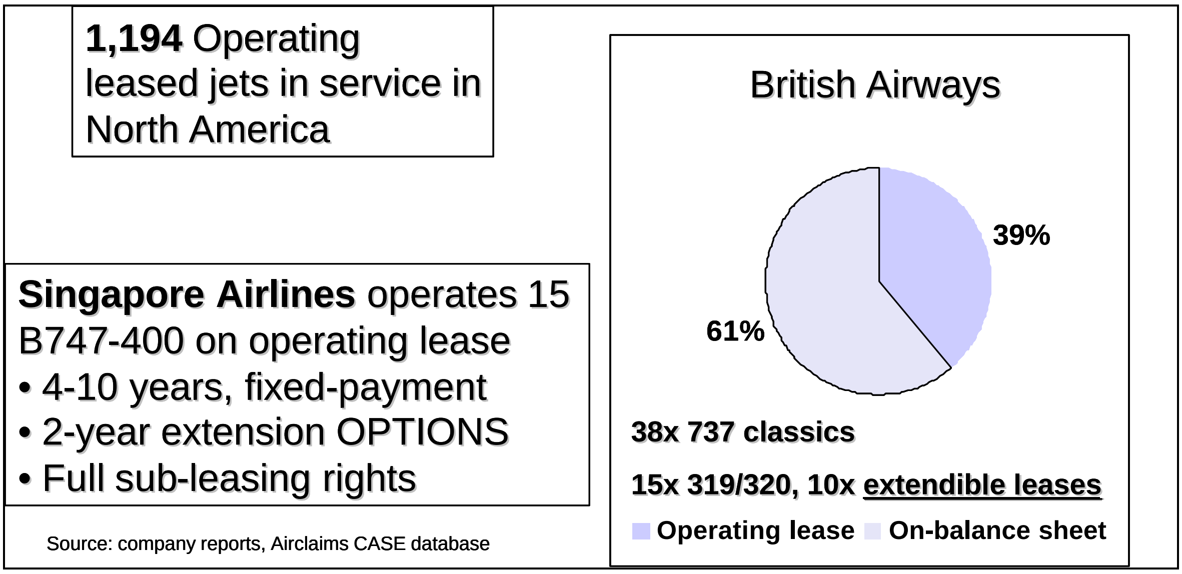
Source: Lufthansa Annual report, 2001

Because of the volatility of both borrowing and equity costs, there is a strong temptation to compensate for risk by artificially increasing the discount rate used in the analysis, thus making the project more difficult to justify. This approach has the serious disadvantage of “funnelling” all the risk through the discount rate, and also reduces the value of the analysis itself: a fundamental task of management is to deal with risk effectively rather than “insuring it away” by using an artificially high cost of capital.

We suggest that a better approach to uncertainty is use a moderate cost of capital, either using market measures such as Lufthansa has done, or alternatively, using broad, long-term regional benchmarks such as those identified in Dimson, Marsh and Staunton (2002). We then can capture cash-flow volatility using Monte Carlo simulation, calculate *Expected* NPV and the probability of success, and extend the investment analysis using

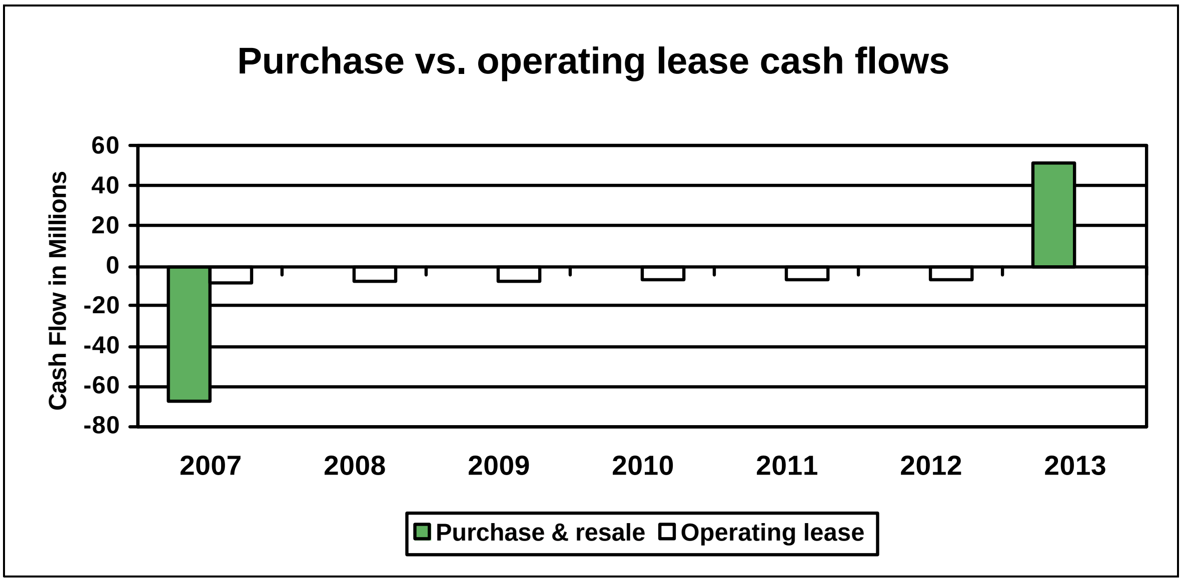
Operating lease vs. Purchase analysis

Operating leasing has undeniable benefits for operators of aircraft, offering a level of fleet flexibility and residual value risk reduction unobtainable when purchasing. Growing far beyond their origins as a "cheap" – or more accurately, low cash-out - solution to aircraft finance, operating leases are the financing vehicle of choice for around one quarter of all new large civil aircraft delivered today, extensively used today by the world's largest airlines. Companies use operating leases for flexibility, when adopting a new aircraft type, or as part of an aircraft type exit strategy, as shown below..



A correct discounted cash flow (DCF or NPV) analysis of leasing vs. purchasing should at lease estimate and include the COST of the flexibility benefits, when compared to debt financing. The classic pitfall in NPV is including and comparing the operating lease cash flows, and comparing the result against the purchase cash flows. This problem is discussed from a theoretical standpoint in Myers (1974), Myers, Dill, Bautista (1976), Copeland and Weston (1982), and applied to aviation in Stonier (1998).

Viewed graphically, the differences are apparent.



When the cash flows are discounted at the WACC, the result is inevitably favourable to leasing, and places undue emphasis on residual values.

This is conceptually incorrect for two reasons:

- The cost of purchasing or leasing an aircraft should be compared to the benefits of operating the aircraft, not to one another
- Lease payments include both investing and financing cash flows, as well as a risk premium for the lessor.

Leasing is fundamentally a financing vehicle, and should be compared with the costs of borrowing or taking on a finance lease (also known as a capital lease).

To correctly estimate the cost of leasing, we recommend using a variant of the well-documented Adjusted Present Value concept. Under APV, cash flows of different risk classes are discounted at the discount rates that reflect the risk class of the cash flows. This method is discussed from a theoretical standpoint in Myers (1974), Myers, Dill, Bautista (1976), Copeland and Weston (1982), Copeland et al., 2000. Our experience suggests that it has yet to be fully understood and adopted in industry practice.

Implementing the method is straightforward, as summarised in the following table.

Discount rate	**Purchase** scenario	**Operating lease** scenario
Cost of debt	Financing cash flows: loan/finance lease advances and repayments of interest and principle	Leasing cash flows
Cost of equity	Operating cash flows Purchase and re-sale of the aircraft	Operating cash flows

This approach has two major advantages:

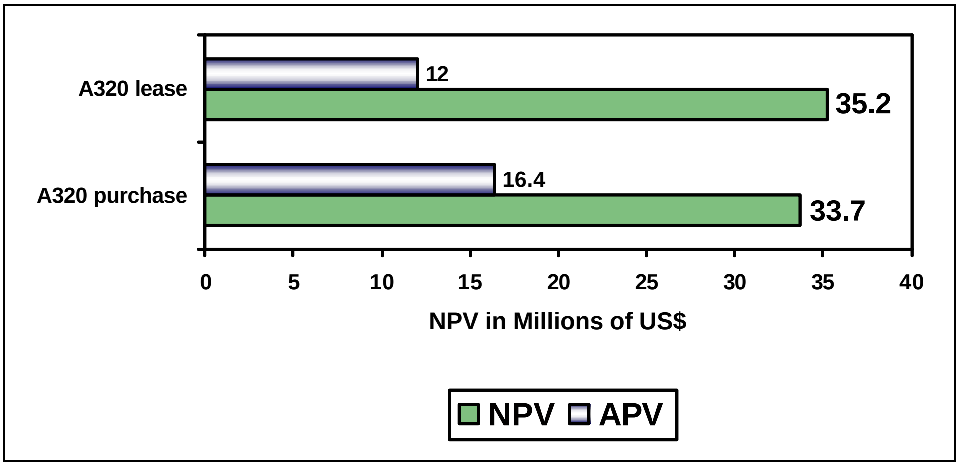
- clarifying that the risks of owning & operating aircraft are borne by the equity investors
- directly comparing the financing alternatives, and showing the cost of the flexibility inherent in leasing

This is a major step beyond classic APV, where only the tax deductions on interest payments are discounted at the cost of debt, capturing leverage benefits. We suggest that just as WACC has been thoroughly accepted in spite of its theoretical pitfalls and the difficulty in estimating cost of equity, this variant of APV should be examined and adopted to compare leasing versus purchasing in an NPV framework.

When it comes time to finance deliveries, aircraft finance specialists recommend that operators discount the term sheets offered by different financiers to determine the best offer. Our approach to investment analysis using APV simply extends this tactical approach to long-term strategic investment analysis.

A final practical problem in comparing leasing and purchasing concerns the investment horizon. Operating leases are generally less than ten years in length, and are often three, five, or seven years, with or without options to extend. To properly compare leasing and purchasing over a longer term, it is necessary to assume that a lease is renewed over the investment horizons. Methods used to re-price the lease after the primary period range from simply assuming that the lease rate will remain fixed, to modelling the variation in lease rates as a function of aircraft values.

As the graph below illustrates, the differences in valuation are clearly significant. First, APV results in a lower overall evaluation because the operating cash flows are discounted using the higher equity rate. Second, the purchase scenario APV is $2.4m higher than operating lease, reflecting the cost of the residual value risk transfer to the lessor.



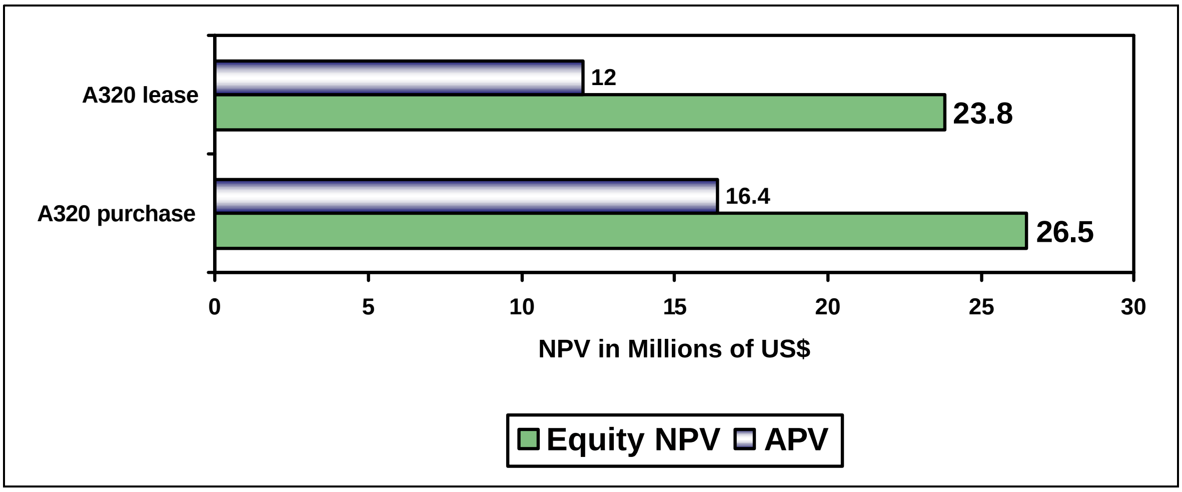
Bottom-line returns to investors

In the classic theoretical and management literature, the investment and financing decisions are kept strictly separate. On the other hand, airline stakeholders need to understand the overall costs and benefits of investing.

For this purpose, the Equity NPV concept commonly used in project finance builds on the notion of clearly distinguishing the cost of debt, and the cost of equity. All project cash flows – investing, operating, and financing – are discounted at the cost of equity.

The resulting value shows the result of the investment from the shareholders' point of view, including the leverage benefits from debt financing, and obviating the distinction between leasing and purchasing.

Since tax is a very important consideration for investors, this analysis requires an after-tax approach. As with APV, the differences in valuation are substantial, and the underlying assumptions and implications need to be clearly understood by managers.



Comparing the methods

Each method answers a different, critical question.

- *NPV* measures the fundamental return on the investment, assuming the project is financed using the firm's overall capital resources at a target debt and equity mix.
- *APV* clearly separates cash flows into different risk classes, and measures the cost of residual value risk transfer to the operating lessor.
- *Equity NPV* shows the bottom-line returns to the investors, including the leverage benefits of the financing.

Investment Planning and Uncertainty

Now we come to the greatest challenge for airlines today, which can make the difference between success, and failure: dealing with unexpected shocks in the environment, large or small. Two of the most prominent trends over the last 15 years in aircraft investment planning have been reductions in manufacture lead-times which increase airline flexibility to convert from one aircraft type to another before delivery, and the increased use of operating leasing by airlines of all sizes and locations.

Both innovations help airlines cope with the uncertainties they face in operating aircraft. Financial theory provides new means to value these benefits, which can then be incorporated directly into the cost of the financing overall on a strategic basis, rather than deal-by-deal or delivery-by-delivery.

As we have seen, simple NPV analysis fails to take into account both the highly uncertain economic environment airlines face, and the flexibility offered by conversion options and operating leasing. The APV concept discussed above is really a measure of the *cost* of leasing – and hence the transfer of value to the lessor – rather than an estimate of the flexibility benefits to the operator of the aircraft.

We propose two complementary approaches that take advantage of the potential flexibility of the NPV approach to better understand investment dynamics on the one hand, and the application of Real Options Analysis (ROA) to better understand the value of flexibility to aircraft operators on the other.

Dealing with uncertainty in the cash flows: the Expected NPV concept

As we have seen, the NPV methodology can be adapted to address many difficult questions in airline investment planning. It is well documented and widely taught, and has the advantage of being relatively easy to explain and intuitive. On the other hand, practitioners suffer from a tendency to inflate the discount rate artificially, to "insure" against risk. We propose to capture the risk of airline cash flows in a different way, by extending the concept to an *Expected NP",* similar to the familiar statistical concept of Expected Value, where outcomes are weighted by probabilities.

To do this we use Monte Carlo analysis, a well-proven statistical technique which has earned a key place in airline investment planning.

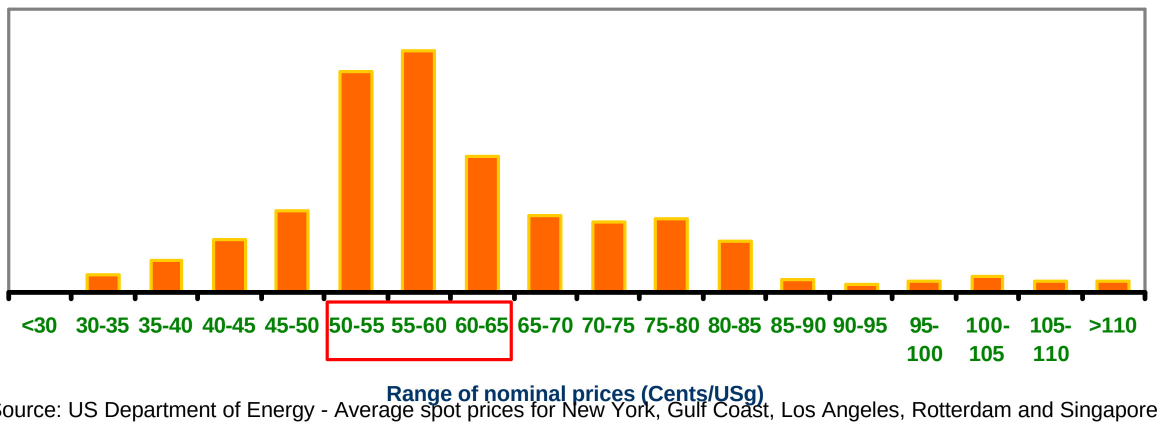
The Monte Carlo simulation is built on a cash flow model, which calculates NPV. Uncertainties in the operating environment are estimated using probability distributions. Good examples in aviation include fuel prices, traffic growth & yields, and cash operating costs. These estimates may be derived from historical data, management judgement, or a combination of the two.

The NPV model is then run hundreds or thousands of times. For each trial, a discrete value is assigned to each input variable according to the assigned probability distribution. An outcome (NPV) is generated, and added to the data set.

The output of the analysis is a range of possible NPVs, including an *Expected NPV* (the mean outcome). In addition, standard measures of dispersion around the mean are calculated. A probability of a positive NPV can then be readily calculated, changing the focus of the analysis and management discussion.

Taking a very well known – and volatile – example from aviation, the histogram below shows the pattern of fuel prices in the 1990s.

Distribution of fuel prices - 1990-2002



Source: US Department of Energy - Average spot prices for New York, Gulf Coast, Los Angeles, Rotterdam and Singapore
Analysis courtesy of Claude Pluzanski, Airbus

In classic NPV, we assume that input prices will be reliably predictable, which is more comfortable. In *Expected NPV*, we recognise that there is significant uncertainty in prediction.

There are at least two major benefits to using Monte Carlo analysis to complement DCF in investment analysis:

- It forces management to estimate and manage input risks, rather than insure them away.
- One of the key outputs is an estimate of the probability of success, given the results of the trials

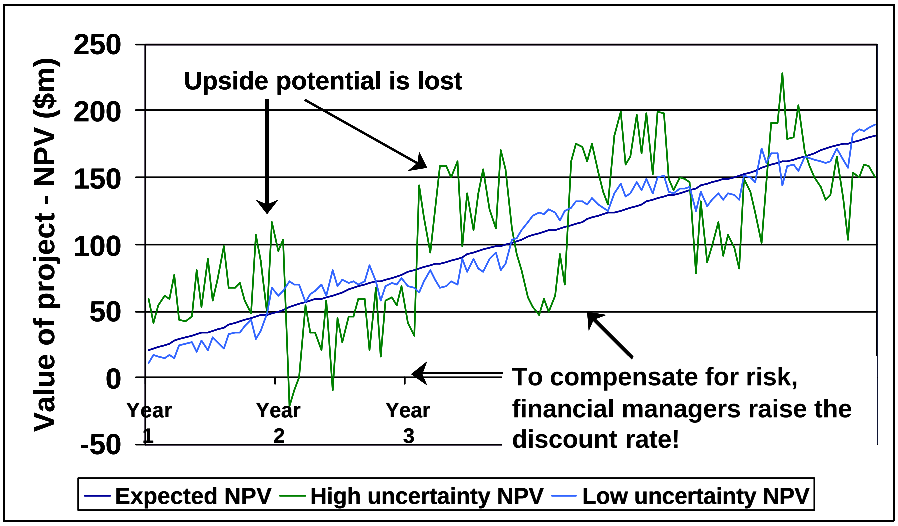
Not surprisingly, these benefits create corollary challenges: management is indeed directly confronted with the need to quantify and manage uncertainty, and to accept that the decision to invest is made knowing that there is a readily calculable uncertainty of success.

This is particularly uncomfortable for management cultures that do not readily accept uncertainty. In fact, the framework of analysis is shifted to a risk management approach, which is inherently less comfortable than the "yes-or-no" outcome of NPV analysis.

Using Real Options to value flexibility

Clearly, the NPV approach to investment planning is useful as part of the analysis, but in many ways it fails to value the flexibility offered by lessors and manufacturers, and by extension, the cost of giving up flexibility when using constraining financing or ownership structures such as leveraged leases (tax leases).

As we have seen, one common practice in using NPV is to raise the discount rate in order to compensate for risk. The effect of this is illustrated in the following graph.



NPV taken alone will incorrectly estimate value creation in a volatile environment, which can be misleading on the upside as well as the downside. Real Options Analysis (ROA) builds on *Expected NPV*, providing new insights into the value of flexibility: APV measures the financial *cost* of flexibility, whereas Real Options measures the *value* of flexibility in investment planning.

Review of real options methodology

Options pricing theory was introduced by Fischer Black and Myron Scholes in 1973, and has been used since then to price financial options on shares, commodities, currencies, and interest rates. Real Options applies this basic framework to the pricing of options on real assets, such as aircraft. These can be Call options such as purchase options and aircraft family conversion options, or Put options such as extendible operating leases or residual value guarantees.

Options pricing is a curious blend of intuitively correct - even obvious - value drivers, rather abstruse mathematics, and very large assumptions about the similitude of real assets and financial assets.

Fundamentally, the value of an option *increases* with

- volatility in the economic cycle and demand for air transport
- uncertainty in competitor responses
- variability in input prices: fuel, labour, financing...
- time to expiry of the option, eg., delivery of the aircraft or end of the extendible lease
- the interest cost of borrowing

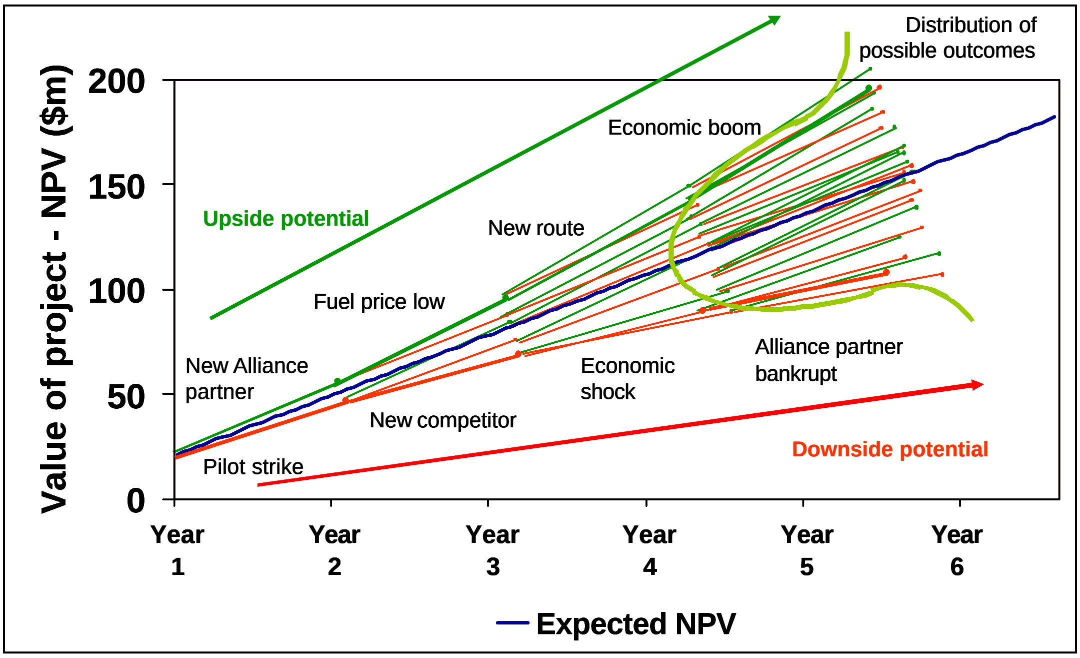
and *decreases* with...

- the price of the option
- the implementation cost of exercising the option

The theory and practice of real options valuation is extensively discussed in Copeland (2001), Mun (2002). Stonier (1999, 2001) goes the furthest in applying the concept to aircraft option valuation.

The basic methodological tool is the binomial lattice, which builds a set of potential outcomes to the project using the output from our *Expected NPV* under Monte Carlo. Key inputs to build the lattice are the standard deviation of returns given uncertainty, and the number of "steps" or branches in the binomial lattice. Hence, Real Options can be viewed as an extension and improvement on *Expected NPV*, itself a great advance beyond simple, deterministic NPV.

The binomial lattice is a convenient way to represent the uncertainty present in a dynamic market like air transport, as the graphic below demonstrates. Around the straight line Expected NPV, upside and downside potential are present in this more realistic view of the potential for value creation.



Notwithstanding certain methodological barriers, Real Options provides insight into the costs and value of intangibles like aircraft family conversion options, and operating leases. It is a method that quantifies and prices the intuitive advantages of "looking before you leap."

Using ROA to value an aircraft family conversion option

To demonstrate the technique, we will use the example of a family conversion option, known in the options jargon as a "switching option." Manufacturers of aircraft offer airlines the possibility to convert between members of an aircraft family before delivery, given a firm order. In our example we will value the option to switch from and A320 with 150 seats, to an A321 with 175 seats.

Intuitively, we realise that the A321 investment acquires value if airline traffic and yield conditions are favourable. Since these two variables are highly unpredictable, options pricing takes us beyond the intuition to the understanding that the option to choose *itself* has considerable value for airlines, whether traffic and yields increase *or* decrease.

To value the option, we set up a cash-flow model, with one scenario for the A320, and another for the A321. Each aircraft has its particular capacity for passengers and cargo, and its trip cost structure as a basic input. In the model, we simulate the operating environment: traffic demand, spill factor, revenue yields, and fuel costs are among the key inputs.

Next, we associate probability distributions with the key uncertain inputs to the model. In our stylised example, we will simulate uncertainty in basic demand for seats, and fuel prices. Seat demand is set using a most likely demand for 150 seats, with downside potential of demand for only 110 and upside up to165: zero overall traffic growth is assumed in our simplified example. Fuel price uncertainty is simulated using the historical analysis presented above.

Running the Monte Carlo simulation, we discover that the A320 returns carry (for example) a 6% standard deviation, and A321 returns carry a 7% standard deviation. This is intuitively correct, since a larger shell size will carry more upside potential, but more risk as well.

The standard deviations are used to build a binomial lattice of possible NPVs. At each node of the lattice, the model compares the NPV of acquiring and operating the A320 with that of the A321. If we choose to exercise the A321 option, an assumed switching cost of $500,000 is incurred for spares, training and other Entry into Service (EIS) costs for the new type. The NPV of the A321 must therefore exceed the A320 NPV by more than this $.5m cost, or we will stay with our original order of the A320. In our five-step example with sigmas of 6%/7%, the lattice of decisions based on our assumptions is represented below.

A320	**A321**	**A321**	**A321**	**A321**	**A321**
	A320	**A320**	**A321**	**A321**	**A321**
		A320	**A320**	**A320**	**A321**
			A320	**A320**	**A320**
				A320	**A320**
					A320

In nine of the simulated potential states of nature in which conditions in the air transport market are relatively good, we will exercise the option to convert to the A321. If conditions are consistently bad over the period the option remains open, there are 12 outcomes under which we will stay with the A320.

To value the option at contract signature, we must reason *backward* from the deadline to exercise the option in the future, to today. At deadline, we will maximise our benefit (NPV) by choosing the A320 or the A321. At each *preceding* node in the lattice, we will either exercise the option to convert to the A321, or we will keep the option open. The option value at each node as we move backward to today is thus the maximum of the A321 NPV less the switching cost and the expected value of the subsequent nodes, discounted back at the risk-free rate to compensate for the time value of money.

The value of the flexibility during the option period (the option price) is the single value at the root of the lattice, minus the NPV that we expect from the aircraft. In our example, the value is nearly $125,000. This is a measure of the value inherent in flexibility offered to the airline, consistent with valuation methods used throughout the world, and built on well-established statistical and mathematical theory.

Methodological challenges of Expected NPV and Real Options Analysis

Mean reversion and autocorrelations in cash flows can create erroneous results in both Expected NPV and ROA valuations. In a cyclical industry, many inputs tend to correct themselves over the cycle, reverting to a long-term trend or average. Mean reversion in aviation markets is discussed in Stonier (1999). Further, there may be correlations between the behaviour of input variables. A notable example is the relationship between aircraft market values and operating lease rates. The validity of postulating correlations between input variables needs to be further examined, and clear limits determined.

Estimating the project volatility is another question mark for practitioners. In one method, managers are asked to accept the postulate that real asset values can be approximated by comparing them with listed firms, a rather tenuous proposition, and it is unusable in less open securities markets, where share prices are not readily available. In another, the volatility of projects with significant negative cash flows in extended periods cannot be calculated accurately, due to the impossibility of calculating a natural logarithm of a negative number. Five potential methods are dissected in Mun (2002). We use the logarithmic present value approach in our modelling, and have found no significant practical difficulties.

Both NPV and ROA are subject to the assumption of a *constant discount rate throughout the project.* Turner and Morrell (2002) and others have pointed out that discount rate estimates are variable, and clearly, companies' costs of capital vary over time. This is an excellent example of volatility in the market, and yet, the value is left constant in NPV. In ROA, a constant rate is used to calculate project volatility in the logarithmic present value method. No completely satisfactory solution to this problem is available.

Time vs. steps in the binomial lattice is another practical challenge. The outcome of the lattice is a set of states of nature, all expressed in NPV. The number of terminal nodes in the lattice depends on the number of steps used in the analysis, which is not the same as the time to expiry of the option. On the other hand, the nodes of the lattice are discounted back to determine the option value, implying that the potential NPVs become known in the future. Understanding the relationship between the steps and nodes on the one hand, and the time and decision points between contract and expiry on the other, is rather arduous for practitioners. Unlike the fundamental options value drivers, it is not at all intuitive.

Financial evaluation is an important part of airline fleet planning, but it is just one part of a very complex strategic process. Airline managers do not have infinite time to dedicate to learning how to value options. Mastery of the *advanced stochastic methods* used is rare enough outside Operations Research departments of universities. Additionally, the ability to explain the concepts in an efficient, intuitive way is not given to all the mathematical experts. We believe that this "knowledge gap," between expertise and explanatory ability needs to be closed, through co-operative research between learning institutions and airlines.

There are large imperfections in any valuation method, but we suggest that in managing large risks in investment decisions, an imperfect answer to management and shareholders is better than no answer.

Conclusion

We propose in this paper the notion that the NPV technique offers the potential for flexibility beyond its classic interpretation. Our proposed extension of Adjusted Present Value (APV) provides insight into lease vs. purchase decisions unavailable through classic NPV analysis. Equity NPV demonstrates the overall returns of the project from a shareholder perspective.

In order to benefit from these techniques, managers need very clear definitions of the elements of analysis – costs of debt and equity, cash-flow categories – in order to exploit the potential of the method.

APV is very useful in today's environment, as it measures the *cost* of flexibility in a concrete and consistent way. Real Options Analysis complements this analysis, by measuring the potential *value* of options. Practitioner can reason in terms of uncertain outcomes, in addition to measuring financial costs, yielding a complete picture of the investment dynamics.

The methods – in particular ROA - require further research & elucidation before they will be widely applied in practice. Financial theoreticians must also keep in mind that financial evaluation is only part of the extraordinarily complex evaluation of today's aircraft by airlines around the world.

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