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Capital budgeting under uncertainty : an operational management approach.

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CAPITAL BUDGETING UNDER UNCERTAINTY: AN OPERATIONAL MANAGEMENT APPROACH

A Dissertation Presented

By

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The completion of this work could not have been accomplished without the herculean effort of my friend and wife Judy. For her dedication, determination and devotion I will be ever greatful, as will I for the consideration of the many others that have lent me invaluable assistance.

For the inevitable errors that remain, I am completely responsible.

ABSTRACT

Capital Budgeting Under Uncertainty:
An Operational Management Approach

(February 1985)

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For many firms, especially those with a high degree of operating or financial leverage, standard capital budgeting techniques do not allow for the incorporation of enough important economic or firm specific information. Nor do most techniques allow for the conduct of sensitivity analysis as it pertains to the capital budgeting decision.

This thesis presents a capital budgeting model, a simulation model, which ties anticipated cash flows to standard economic factors and derives a distribution of net present values for each project under consideration. Stochastic dominance is then utilized to provide the decision criterion to choose from among these distributions of net present values.

Developed, also, is an application of this model to aircraft procurement decisions in the commercial airline industry. Economic variable sensitivity analysis is performed within several of the project comparisons utilized.

Further applications of this model are discussed as logical extensions of the work presented here. Among these extensions is the development of hedging strategies, to include the use of options and futures, to reduce project risk. Use of this model within a decisions support framework is cited as its most likely future means of implementation.

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INTRODUCTION

> "The problems of capital budgeting seems to be, figuratively speaking, everyone's concern. Industrial engineers, economists, operations research analysts and finance specialists claim the subject matter as their domain. Each has a unique perspective and point of view: each tends to concentrate attention on a different type of problem because of slightly different goals: each tends to use a different set of tools and techniques: and each tends to talk among themselves."
>
> – Howard E. Thompson [1976]

One of the more striking features of the literature on capital budgeting is that while various subfacets of the issue have been analyzed, the process relating capital budgeting across business specialties is largely undeveloped. Bower and Lessard [1973] and Pinches [1982], for instance, have commented on the lack of a truly integrated approach to capital budgeting. Scholars in the area of management science have been primarily concerned with deterministic methods (eg. linear programming) capturing the essence of project risk and displaying it in a form useable to the decision maker. This risk has been largely associated with the cash flows stemming from a project. Finance theorists have turned their concerns largely to the establishment of a proper discount rate to be applied to future and uncertain cash flows. Economists have been most concerned with the utility theory aspect of the investment decision and the establishment and implementation of a means by which investor preferences may be reflected.

Need for the Study

In an attempt to encourage academic area integration, Beranek [1981] raises several issues that are still to be addressed. Among them are: (1) What is the role of diversification in reducing risk in a firm's capital budgeting portfolio?, (2) How can simulation better be employed?, (3) How can sensitivity analysis better be integrated? At present, these issues still remain largely unexplored. This study is intended to fill these voids in the literature.

The goal here is the development of a more complete multi-period capital budgeting model wherein factors leading to the inherent uncertainty of the decision environment are identified and modeled, and where inherent inter-relationships among variables are accounted for. The model is intended for use in evaluating projects across many possible scenarios and for the conduct of sensitivity analysis, where the impact of specific scenarios can be evaluated. An operational variable approach, as opposed to an accounting variable approach, is the focus of this thesis.

Makridakis and Wheelwright [1980] have identified six factors that should be considered in choosing a forecasting model:

1. patterns in the data (cycles and trends)

2. type of model desired (time-series vs. causal)

3. time horizon (timely input for planning)

4. cost of obtaining perdictions (developmental, storage and operating costs)

5. accuracy sought (indicated by root-mean-squared error)

6. applicability (suitability for a given application)

It is with these factors in mind that the model in this thesis will be developed.

To aid the presentation of this methodological refinement we will develop a specific application. The application chosen is the capital budgeting decision for the airline industry. This is selected because it reflects many of the realities inherent to other capital budgeting problems. Specifically, there is a good deal of historical information on some key variables, while other variables require subjective assessments to determine their distributions. The simulation model, as developed in this thesis, can be used primarily for two types of capital budgeting decisions. The first type concerns the decision of an airline considering expansion to a route not currently serviced by the deciding airline but which is serviced by competitors. The second type of capital budgeting problem centers on which aircraft a given airline should procure for service on a given route. In addition sensitivity analysis is judged by the industry to be of critical importance. This sensitivity analysis can be done either within the framework of capital budgeting decisions or conducted independently without weighing any given new project. The means by which this analysis will be carried out will be by utilizing a simulation model that will incorporate historical data as well as subjective judgements and will be readily adaptable for future use in the exploration of diversification strategies involving portfolios of risky projects coupled with options and futures.

Organizational Plan

As stated, the goal of this study is to derive an operational approach to capital budgeting. To this end, Chapter II will achieve a review of literature related to capital budgeting. The simulation model itself will be developed in Chapter III. Here variables will be identified and inter-relationships explored. Chapter IV will concern itself with the simulations themselves as well as with the application of the proper decision criterion. Chapter V will be devoted to the explanation of results derived from this model and discussion of the conclusions and implications stemming from its use.

CHAPTER II

SURVEY OF RELATED STUDIES

There exist three major decisions confronting virtually every firm: (1) the investment decision, (2) the financing decision and (3) the dividend decision. This thesis addresses the first of these three concerns. Capital budgeting techniques has long been at the core of the presentations contained in financial texts. (eg. Van Horne) [1980]. It is only very recently that significant evidence (Gitman and Forrester) [1977] has been produced to demonstrate that any theoretically based capital budgeting techniques has been favored by industry.[1] Yet while evidence exists of firms adopting more sophisticated tools of analysis (McKeon and Hassan) [1982], (e.g. general equilibrium models, mathematical programming models and risk analysis models), most capital budgetting systems rely on simple accounting and

[1] In a study of 268 major firms, they found a strong preference (72% of sampled firms) for capital budgeting techniques which explicitly consider the time value of money (eg. IRR, NPV, etc.). This is significantly greater than Klammer's earlier findings (1972). In addition, cash flow estimation was cited as the single most difficult and important stage in the capital budgeting process by 65% of all firms.

subjective methods (McKeon and Hassan) [1982].

One major criticism of the more sophisticated capital budgeting approaches is that they fail to relate to the real capital budgeting decision process of the firm (Hastie) [1974]. He identifies nine steps in the actual capital budgeting decision:

1. determine alternative investments

2. weigh strategic aspects of the alternatives

3. collect data and information on the viable alternatives

4. develop assumptions and calculate the incremental income and cash flow benefits

5. measure net benefits

6. assess the effect that different assumptions have on the project's measured results

7. analyze the risks of the project

8. weigh the benefits and strategic purpose of that project against its risk and the constraints of the corporation

9. communicate the relevant information to top management in a manner that facilitates effective decision making

He observes that the overwhelming preponderance of academic endeavor has been concentrated at step five.

Any capital budgeting technique, for it to be of significant value to the decision maker, must deal with the decision in the environment in which it exists. In virtually all situations this environment is characterized by uncertainty. In the decision environment there are several sources of uncertainty. Haugen and Wichern [1974] have investigated the impact of stochastic interest rates. Findley [1976] has investigated the influence of inflation on the capital budgeting decision. These influences have also been investigated by Cooley, Roenfeldt and Chew [1977]. For the most part, however, it is directly the risk of cash flows from the project or projects under consideration that is the object of analysis.

In reviewing the literature pertaining to capital budgeting the three main directions of the literature have been: (1) general equilibrium models based on historical data, (2) risk analysis models based on subjective evaluations of probabilities and generally allowing for sensitivity analysis and (3) mathematical programming approaches generally based on utility maximization. Some decision models include variables for which we have relevant historical data, some include variables whose future values must be subjectively assessed and others include policy variables which are nondistributional in nature. No one approach has been developed whereby the impact of all three variables on uncertain cash flows has been brought to bear.

General Equilibrium Models

The process of decision making in an uncertain environment is a two step process. First, uncertainty must be reduced to a form in which it can be compared to other projects, in a risk context, having either uncertain or known outcomes. Secondly, some means must be utilized to account for investor preferences. A very large segment of literature addresses these issues simultaneously via a general equilibrium model. One common such model is the Capital Asset Pricing Model (CAPM). A CAPM in this context, as in many others, is used to assign a market value for the assumption of risk.

The major contribution of the general equilibrium approach (e.g. CAPM) is that projects can be evaluated at the market set price of risk. This discount rate allows for the distinction between diversifiable risk and non-diversifiable risk. No added benefit is allowed for the assumption of diversifiable risk.

Rubenstein [1973] was among the first to apply the CAPM to the capital budgeting problem. In his development he contrasted the CAPM approach to that of the use of the traditional weighted average cost of capital (WACC). He demonstrated that for high risk projects the WACC required return often under-estimated CAPM based required return whereas, for low risk projects the WACC required return often over-estimated the CAPM based required rate of return. The only instance where the WACC criterion and the CAPM yielded an equivalent cut off rate was for projects in the same "risk class" as the firm. This is due to the fact the the WACC makes no allowance for individual project risk. Weston [1973] too has written on the inadequacy of the WACC as a risk adjusted discount rate. He, however, admits that the WACC is generally offered to apply only within a given risk class. It is the definition of the risk class of the given projects that he sees as the prime concern in this approach. He favors the market price of risk (MPR) criterion because all but one of its statistical factors are market constants applicable to all firms and to all projects. Myers [1974] develops an Adjusted Present Value (APV) as an alternative to the WACC for practical applications. This alternative discount rate is necessitated in instances where one or more of the underlying assumptions of the WACC are violated.

Fama [1977] demonstrated that the current market value of any future net cash flow is equivalent to the current expected value of the flow discounted at risk adjusted discount rates in each period.

Further advances in the use of the CAPM in capital budgeting were made by Myers and Turnbull [1977]. They assumed a random walk stochastic cash flow process. This approach is also taken by Treynor and Black [1976]. Unlike Myers and Turnbull who used a discrete time CAPM model, Bhattacharya [1978] modified the random walk assumptions of these previous studies and adopted a mean-reverting stochastic process for future cash flows. Cox and Ross [1976] introduced several other stochastic processes that might be considered in the capital budgeting problem. Predominant among their offered processes is the Markov jump process, a diffusion process that models a reaction to information flows. Ben-Shahar and Werner [1977] draw from these theoretical works to derive a practical application of the CAPM to the capital budgeting decision. Broyles and Franks [1976] use market model derived betas to group projects into risk classifications on the basis of non-diversifiable risks.

Each of these studies has a common feature. Uncertainty is reduced to cash flow risk for which distribution and stochastic processes are assumed. In order to determine a cost (require rate of return) on this risk estimate, the CAPM relies heavily on historical data, distributional inferences that may be drawn from these data are limited by the extent to which the historical period reflects the attributes of the future period of interest. Unfortunately, distributions of future cash flows will be hard to derive since it is not possible to sample from the true population. Fortunately, Bogue and Roll [1974] assert that if errors in the assessment of probability distributions are not systematically biased stockholders of the capital budgeting corporation can protect themselves from the adverse effects of these misassessments by diversifying away many of these errors.

Others have also used the CAPM but have incorporated additional aspects of risk. Dothan and Williams [1980] have dealt with stochastic interest rates. This element of risk is critical for a multi-period model which claims relevance to the current capital budgeting decisions. Hagerman and Kim [1976] have developed a CAPM model under the conditions of changing price levels. The impact found was minimal under most conditions. Chen and Boness [1975] have also studied the effects of inflation on investment decisions utilizing the CAPM framework. They found uncertain inflation to affect the cost of capital of a specific project through the market price of risk and the systematic risk of the project. Kim [1979] has investigated the effect of inflation via the over statement of net operating income (NOI) before taxes. His empirical analysis indicated a strong inflation sensitivity on NOI. This implies a need for capital rationing such that investment rates vary inversely with rates of inflation. Cooley, Roenfeldt and Chew [1977] have expanded on the traditional net present value model to incorporate anticipated inflation and allow for uncertainties in real cash flow. Kalymon [1981] incorporates uncertain oil pricing in the capital budgeting decision involving large projects which have considerable oil dependence. Both of these studies can be considered as attempts to include some determinants of uncertain cash flows while remaining in the CAPM framework.

In an alternative development within a general equilibrium framework Brennan [1973] derives a differential equation approach to the valuation of uncertain cash flows. This paper, however, leaves open the questions of both project assessment and the determinants of the risk effect. In a related study Schmalensee [1981] utilizes a partial equilibrium model to develop an alternative measure of risk based on market valuation of stochastic cash flow streams. This is utilized for both capital budgeting and for accounting measures of risk. Ang and Lewellen [1982] have pointed out, a project will be worth acceptance to a firm only if its periodic cash flows contain an element of riskless disequilibrium. Their approach has been to attempt to separate these two components. This is not inconsistent with the CAPM, which requires efficiency in the financial market and not necessarily real asset market efficiency.

Ross [1978], has used the assumption of market equilibrium to show how arbitrage pricing theory can be used to value cash streams generated by risky assets using only information available in the market. Gehr [1981] has extended Ross's method to a two-state option pricing technique used to find a portfolio of marketed assets with identical cash flows to those of the investment. A risk adjusted net present value is utilized.

The major problems with the use of such an approach are best summarized in (Gentry) [1973]. Among the most important problems cited is the necessity of identifying a <u>firm</u> whose similarity to the considered <u>project</u> is sufficient to justify using the former as a proxy for the latter in the application of the CAPM. The use of the capital asset pricing model in capital budgeting decisions is prone to the same difficulties that plague the CAPM in other applications. Among the most serious problems for this application are those relating to non-stationary of betas and the assumption of market efficiency in capital investments. However, Bogue and

Roll [1974] contend that to the extent that the CAPM is valid it should be used if shareholder wealth is to be maximized. The general equilibrium approach will yield a single required rate of return appropriate for a determined level of systematic risk. Rendleman [1978] however points out that if this systematic risk is based on market measures, as opposed to project cost measures, inappropriate project rankings could result. In addition, the previously stated problems of beta stability over time and the assumption of market efficiency in capital investments also loom greatly as difficulties in the applicability of the CAPM to capital budgeting problems.

Mathematical Programming

Another approach to handling risk and investor preferences simultaneously has been constrained utility maximization. Lockett and Gear [1975] formulated the capital budgeting problem utilizing a multi-stage integer programming approach. Stochastic decision tree analysis was used as a branching criterion within the stages. Keown and Taylor [1980] accounted for uncertainties in demand for capital budgeting in the production environment. This they did through an integer goal programming model. Lee and Olson [1981] evaluated several integer goal programming models utilizing dummy variables to implement chance constraints. In a similar approach Spahr [1982] developed a model to account for risk in reinvestment rates of future cash flows. Thompson [1976] uses a mathematical programming approach to assist in accounting for mutually exclusive, contingent, competitive or complementary projects. He, however, defers to the capital asset pricing model to set the market price of risk and, hence, determine the appropriate discount rate for future expected cash flows.

The major limitation of a mathematical programming approach to capital budgeting is the efficacy with which information available concerning the uncertainties can be incorporated into the model. Stochastic variables are not easily handled by such an approach. In addition, there is no theoretically supportable acceptance criterion that is eminently compatible with this approach. Its strength, however, lies in the fact that the assumptions inherent in the general equilibrium approach are greatly reduced and projects may be selected without deference to like firms or projects.

Risk Analysis

In addition to CAPM and MS approaches a third approach, which I will name Risk Analysis, shares a common feature in that it addresses the uncertainty aspect and the utility aspect of risk separately. These approaches attempt to incorporate more known information concerning the uncertainties than do the approaches previously mentioned. They generally attempt to derive, by various means, a present value certainty equivalent value for the risky future cash flows. These approaches differ largely in the manner in which they treat subjective evaluations of probabilities and probability distributions derived from available data.

In Hertz's [1964] framework subjective evaluations of probability distributions of key macro determinants of uncertain cash flows are utilized to derive a "risk profile" for the project in question. Multiple projects are evaluated using a mean-variance criterion. Barnes, Zinn and Eldred [1978] have extended this work by deriving a mathematical formulation of the probability density function of this probabilistic cash flow profile. Demonstratively this is to aid in the selection process when preferences are evaluated. Cozzolino [1979] extended the utility aspect of risk analysis by abandoning previous definitions of risk aversion and deriving a new "risk preference curve." His analysis, like Hertz and others, was to use exclusively subjective evaluations to derive probability estimates of the macro determinants of uncertain cash flows. In a similar attempt to further define risk preference, Blatt [1979] rejected the entire notion of a utility functions and adopted a preference ordering approach designed to yield a less restrictive means of expressing attitude towards risk.

Each of these approaches shares a common attribute, each has no formalized means to weigh historical data and each has generally failed to handle both inter-temporal and intra-temporal correlations among variables. This was among the issues addressed by Lewellen and Long [1972] in perhaps the most critical review of this methodology. They also take exception to the concentration on a projects "own risk" as opposed to the allowances made for diversifiable risk by the general equilibrium approach. Fuller and Kim [1980] have also commented on the need for the incorporation of inter-temporal correlations among variables.

Bower and Lessard [1973] have commented on the matching of risk measurement to proper selection criteria. Operating under the assumption that the result of a risk analysis model is a distribution of probabilistic cash flows they argue, quite correctly, that standard criterion ratios are not proper for this application. Porter and

Carey [1974] offer stochastic dominance as the proper alternative selection criterion in such a situation. Bawa, Lindenberg and Rafsky [1975] have developed an algorithm to apply stochastic dominance that is adaptable to the risk analysis framework. Park and Thuesen [1979] have also offered an alternative criterion. They advocate a system which matches their approach with a decision tree analysis framework that yields a project balance criterion (PBC). This PBC is a time dependent measure of an investments worth. In their paper they empirically test the PBC against the traditional mean-variance criterion.

Risk analysis has made several important contributions to the area of capital budgeting. Most important among these has been the focusing on, at least in the macro sense, the determinants of uncertain cash flows and the establishment of a framework wherein more than just the means of these determinants can be considered in the decision making process. The main shortcoming of this risk analysis is that inter-relationships among variables have been largely ignored. Emphasis has been almost entirely on subjective evaluations of probability distributions and the issue of diversification has been totally ignored.

Other Approaches

Up to this point the approaches mentioned have been developed within familiar frameworks. Vickers [1981], based on the work of Shackle [1969], has derived a different approach. He has rejected the use of historical data in deriving distributions and also rejects subjective evaluations of probabilities. Vickers adopts a totally nondistributional variable approach whereby anticipated surprise at a possible outcome replaces the probability of such outcomes. While his analysis is interesting, its applicability or relevance to actual capital budgeting has not yet been demonstrated.

While differing considerably from the simulation model proposed in this thesis several authors have incorporated computer simulations in their work in capital budgeting. Fielitz and Muller [1983] have reported the use of a simulation program, SIMR, that allows the investor to isolate the effects of four factors: risk, return, time horizon and utility preference. These factors can be varied to perform sensitivity analysis as part of the investment decision. Fourcans and Hindelang [1975] have used a "Hertz-type" simulation model to evaluate capital budgeting plans for multinational firms. Bonini [1977] based on the work of Forrester [1968], offered a dynamic programming model that incorporated allowances for abandonment options. Sundem [1975] has used simulation as a means of generating extant investment environments wherein alternative capital budgeting models may be evaluated. As an adjunct to the simulation approach several authors have advocated the use of sensitivity analysis in capital budgeting. House [1968] advocated such an approach as did Hastie [1974] who accepts that as one of the few sophisticated techniques of practical relevance to the actual decision maker.

Whereas most of the studies mentioned so far imply that investor preferences, or corporate disposition toward risk, can be captured by the mean and variance of the distribution of returns, some authors have brought this aspect into question. Cozzolino [1980] has offered utility risk preference theory as a means to fully incorporate disposition towards risk. This he applies in a specific application to petroleum exploration risk. Porter and Bey [1975] cite evidence that indicates that a business executive's actual concept of risk can best be captured, not by the variance, as is customarily used, but by the semivariance. Their model is, therefore, based on a mean-semivariance approach. Norgaard and Killeen [1980] have varied the assumptions in the opposite direction.

They note that if preferences can be correctly represented by a mean-variance criteria the usually assumed normal distribution is not necessitated. Rather, because the two moment approach disregards the tails of the distribution only a truncated normal distribution need be estimated for use in an analysis.

In an extension of simple cash equivalents Perrakis [1975] has presented a certainty equivalent capital budgeting approach. In an extension of this Constantinides [1978] offered a rule which would reduce the problem of valuation under the conditions of market risk to the problem of valuation where the market price of risk is zero. This is done by the replacement of model parameters by "effective values" in discounting all expected cash flows at the riskless rate of return.

Rubinstein [1976] has developed a novel approach to the valuation of uncertain income streams that is consistent with rational risk averse investor behavior and equilibrium in financial markets. The formula assumes no specific stochastic process for income streams and can be used to value capital budgeting projects with serially correlated cash flows or rates of return. When applied to option pricing his valuation approach is found to be identical to the Black-Scholes option pricing formula.

Finally, Smidt [1979] has focused his attention on the potential disparities between forecast net present values and actual results. He develops a model and applies Bayesian analysis to correct for biases in initial forecasts.

Summary

Clearly the literature surrounding capital budgeting is both voluminous and diverse. What it, for the most part, is not, is integrative. Pinches [1982] also has commented on the isolationist developments of portions of the capital budgeting problem. While there are several lines of development in the literature that offer many important insights to the problem, there is not, as yet, any one approach that adaquately accounts for inter-relationships among cash flow determinants, of all three types (historical, subjectively derived and policy) in a multi-period framework. Nor is there a model which lends itself easily to sensitivity analysis or investigation of diversification strategies. This thesis is intended to develop a multi-period capital budgeting model which incorporates historical, subjective and policy variables and their determinants and could be adapted for use in diversification strategies involving options and futures.

CHAPTER III

DEVELOPMENT OF THE MODEL

As discussed in the previous chapter, the literature has reported few approaches to capital budgeting that allow for the consideration of information that is both historically derived (CAPM) as well as information stemming from subjective evaluation (Hertz). Also lacking in previous studies is an approach that adaquately deals with both inter-temporal and intra-temporal correlations. The approach proposed herein utilizes a simulation model that will allow for the inclusion of various forms of available information, as well as allow sensitivity analysis for scenarios which are imposed upon the model.

Two phases to the methodology are proposed in this thesis. In the first phase the structural development of the simulation model using historical time series data to derive and model inter-relationships among variables. In the second phase, the simulation phase, sample distributions are derived, in part, by use of the same data in a cross-sectional mode. This chapter concerns the first phase of the methodology.

Model development is accomplished in three stages. In the first stage determinants of cash flows resulting from a proposed project are identified. In the second stage the structural relationship among these variables is explored utilizing historical data. In the final stage sample frequency distributions for each exogenous factor are developed utilizing cross-sectional historical data and subjective evaluations.

The process for this methodology is depicted in Figure 1.

Identifying Factors

In any actual capital budgeting decision it must be considered implausible that those making the decision would not have considerable insight concerning those factors that contribute to a project's cash flows. Factor identification, therefore, starts with industry input. For those projects that are similar to other projects that the firm has adopted, much of this task may already be institutionalized. Although the firm has usually identified the pertinent factors, these factors must be analyzed to determine if they can further be disaggregated into their determinants.

The critical issue for determining the proper level

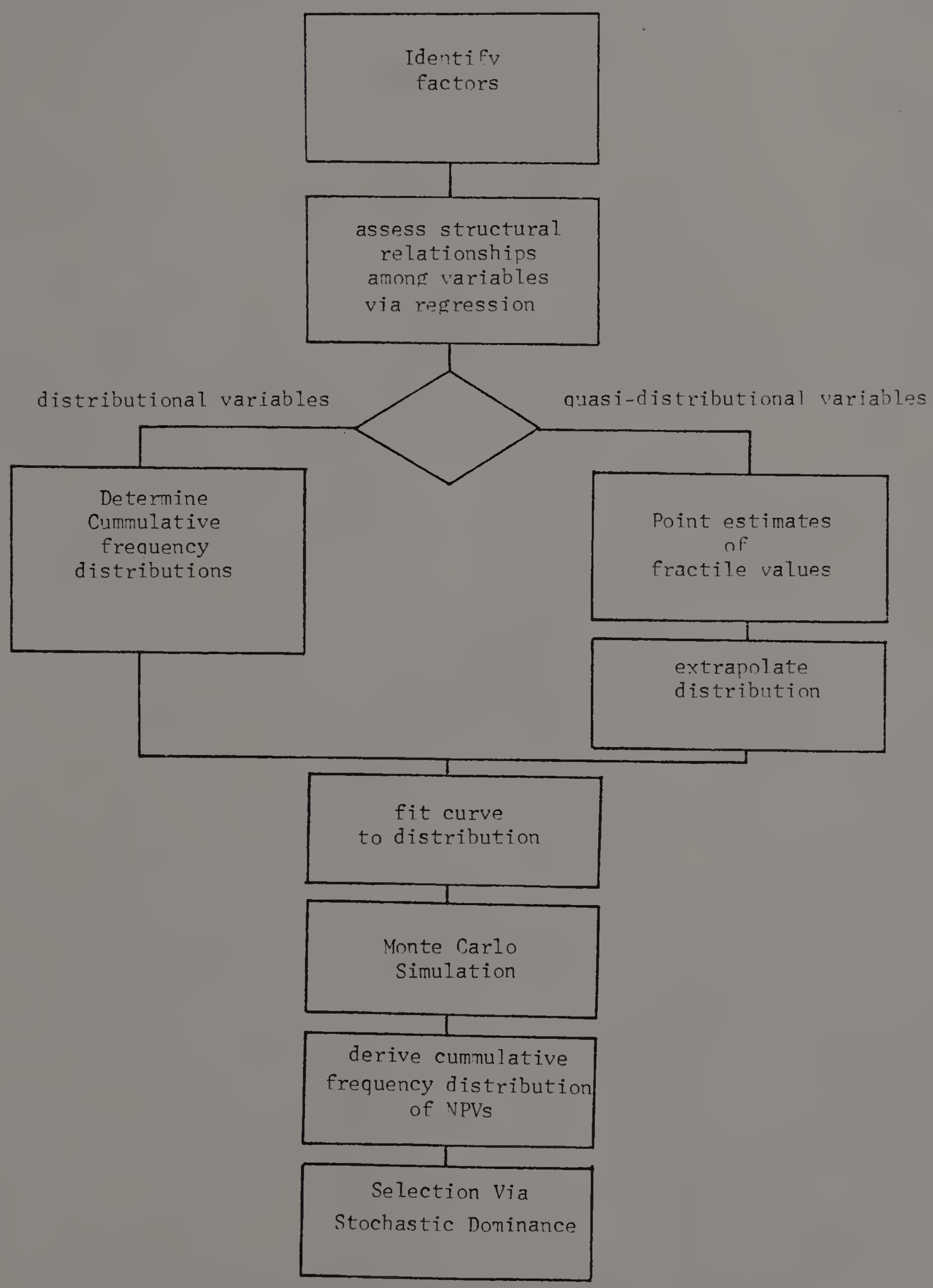

Identify factors
assess structural relationships among variables via regression
distributional variables
quasi-distributional variables
Determine Cummulative frequency distributions
Point estimates of fractile values
extrapolate distribution
fit curve to distribution
Monte Carlo Simulation
derive cummulative frequency distribution of NPVs
Selection Via Stochastic Dominance

Figure 1

of disaggregation to pursue is the availability of recorded data for past periods. As many underlying factors will be standard economic variables, data is available. The availability of data for other determinants will be largely dependent upon the industry and the level of sophistication of the firm. For the firm which historically has not gathered the required data, or for new entries into the industry, data are often available through an industry leader.

For the aircraft procurement application of this thesis two industry sources, Eastern Airlines Inc. and Boeing Commercial Airplane Company, were available to aid in the identification of critical factors. The most important factors for the capital budgeting decision pertain to costs and revenues.

Costs can be said to have three components; direct operating costs, maintenance costs and ownership costs. The most important components of direct operating costs for airlines are: fuel costs and crew costs. Ownership costs are largely determined by the capital investment for the aircraft, interest rates, depreciation and insurance costs. Each of these costs can further be tied to general economic factors which in the end will determine the actual cost situation faced by the airline. Since the same micro-economic factors are determinants of several micro variables in the model the inter-relationships among these variables are evident.

For this model, revenues can be said to be related only to the number of passengers and the average ticket price. Passenger loads too will be dependent upon variations in key economic variables, some of which will be the same factors that impact on cost.

While the essence of the first stage of this methodology is the assessing of structural relationships among cost and revenue variables and their determinants, a necessary precursor to this is the collection of data for a likely set of economic determinant variables. For the aircraft procurement application of this proposed methodology, factors can be broken into two categories: micro factors, specific to this study and macro factors that originate from a macro econometric model derived from a model developed by Pindyck and Rubinfeld [1981]. A macro model we shall use to drive our micro capital budgeting simulation model. Micro factors are to be found in Table 1 while macro factors are contained in Table 2.

The Data

Since the market conditions of importance to this study have truely only existed since airline deregulation

Table 1

MICRO FACTORS

endogenous

total passenger miles	(PM)
passenger loads	(PLF)
fuel consumption	(FLCON)
fuel prices	(FLPC)
residual value	(RESVAL)
ownership costs	(OWNCT)
economic life	(ECOLF)
maintenance costs	(MNTCT)
operating costs	(OPCT)

exogenous

flight miles	(FM)
fuel performance	(FP)
ticket prices	(TKPC)

Table 2

MACRO FACTORS

<u>endogenous</u>

Consumption	(C)
Inventory investment	(IIN)
Nonresidential investment	(INR)
Stock of inventories	(INV)
Residential investment	(IR)
Price level	(P)
Long-term interest rate	(RL)
Short term interest rate	(RS)
Nominal wage rate	(W)
Disposable income	(YD)

<u>exogenous</u>

Government spending	(G)
Money supply	(M)
Transfer payment	(TR)
Wealth	(WLTH)

in October 1978 all pertinent data will pertain to the period from that time to the present. A monthly model has been chosen for this study. Data required for this study have come from three general sources; US Department of Commerce, Civil Aeronautics Board and private industry. Monthly observations on all macro econometric variables were available in a single series of publications entitled Survey of Current Business, published by the Department of Commerce. The following is a description of the data for each of these variables:

Consumption (CON) - Personal consumption expenditures in in constant (1972) dollars (in billions) as an instrumental variable for actual consumption.

Nonresidential Investment (INR) - Nonresidential buildings, except farm and public utilities, total (in millions).

Stock of Inventories (INV) - Manufacturing and trade inventories, book value, end of month (seasonally adjusted, in millions).

Residential Investment (IR) - Total, private, new residential construction (in millions).

Price Level (P) - Consumer prices (US Departmentof Labor Indexes). All items, all urban consumers indexed to 1967 equals 100.

Long-term Interest Rate (LR) - US Treasury Securities (taxable) three year yield (percent), (<u>Economic Indicators</u>, US Government printing office).

Short-term Interest Rate (RS) - Yield on US Government Securities (taxable) three month bills (rate on new issue, percent).

Nominal Wage Rate (W) - Average weekly earnings per worker, private non-farm current dollars, seasonally adjusted.

Disposable Income (YD) - Disposable personal income, seasonally adjusted (in billions).

Government Spending (G) - Total Federal Government monthly outlays (in millions).

Transfer Payments (TR) - Total Personal Income from transfer payments (in billions) is used as an instrumental variable for total government transfers.

Money Supply (M) - M1 stock (seasonally adjusted, in billions).

Wealth (WLTH) - Total demand deposits, individuals, partnerships and corporations (in millions). This is an instrumental variable.

Total Passenger Miles (PM) - Certified Route Carriers: Passenger-Miles (Revenue), in billions. This variable is used as a proxy for the volatility of the airline industry.

The Civil Aeronautics Board is the principal source for micro variables. CAB provided data are:

Passenger Load Factors (PLF) - Average percentage of seats occupied per aircraft per route.[2]

[2] The three routes chosen for this study are Atlanta-Chicago (Eastern and Delta Airlines), Boston-Dallas/Ft. Worth (American) and Los Angeles-New York (American).

Number of Passengers (PNO) - Total number of passengers per airline per route per month.

Jet Fuel Prices (FLPC) - Average cost per gallon of jet fuel as paid by large commercial carriers in each month.

In addition to the variables mentioned, information collected from private industry includes:

Ticket Prices (TKPC) - Standard Y-fare per passenger (sources: American Airlines, Delta Airlines, Eastern Airlines).

Residual Value (RESVAL) - Percentage retained market value per aircraft per year of age (source: Boeing Commercial Airplane Company).

Assessing Structural Relationships

The principal objective at this stage is to determine the relative impact of variables on each other, and ultimately on the cash flows themselves. Some of these relationships will be deterministic and known. Others will be determined through regression analysis of historical time series data. It is important to observe at this point that the data collected for this study can be looked at from both a time series perspective (data pertains to consecutive discrete time periods) and a cross-sectional perspective (emphasis on the distribution of values without regard to time period). Data is used in a time series sense for the assessment of structural relationships and the same data is used cross-sectionally in the simulation itself.

At this stage of the model development we become concerned with, initially, intra-temporal correlations among the variables. On the surface this task may not appear difficult but we must determine not only pairwise correlations between variables, but also multiple correlations among variables. These may be determined by performing regressions for all hypothesized relationships among variables and analyzing both the R^2 as an indicator of degree of correlation and the betas as indicators of the direction and magnitude of these relationships. These regressions will be utilized to develop the most simple scheme that properly captures the true inter-relationships amongst variables. For most models of this nature there are two separate and distinct steps required in assessing structural relationships. The first is the identification of factor determinants and fitting individual equations.

The second step entails estimation of the complete simultaneous equation model. Usually the simultaneous estimation of the model would involve an estimation technique that would account for the covariances across equations. One such commonly used technique is three-stage least squares. The model developed in this thesis, however, is a special case. As it happens, this model is diagonally recursive.[3] In this case, it has been shown that the application of OLS to each of the separate equations yields parameter estimates which are consistent and asymptotically efficient.

We now turn our attention to the estimation of the individual equations.

Equation estimation

Before a simultaneous equation model can be fit one must first assure that the proper explanatory variables are identified in each equation of that model. Here we will address each individual equation and discuss the explanatory variables. Specific regression results from the individual equations are found at Table 4.

We begin the estimation of the model with the estimation of the underlying economic determinants.

[3]For a further explanation of recursive models see Kmenta, p. 585.

Consumption needs to be expressed as a function of an explanatory variable. Here we simply regress it on transfer payments and its own lag value (LCON). This equation is given as:

$$CON= \beta_0+ \beta_1 TR+ \beta_2 LCON+ e \qquad (1)$$

The price level is seen largely as a variable that is characterized by a "random walk." We regress the price level change on disposable income (DELYD) and its own value with a one period lag or:

$$P= \beta_0+ \beta_1 LP+ \beta_2 DELYD+ e \qquad (2)$$

Short-term interest rates, an explanatory variable in several equations to come, should best be explained by the most recent change in money supply ($DELM=M_t-M_{t-1}$), it's own value with a one period lag (LRS) and the one period percent change in the price level (PRAT). The next equation will therefore be:

$$RS= \beta_0 + \beta_1 DELM+ \beta_2 PRAT+ \beta_3 LRS+ e \qquad (3)$$

Long-term interest rates are a function, as we might expect, the change in short-term interest (DELRS) and its own lag value.

$$RL= \beta_0 + \beta_1 DELRS+ \beta_2 LRL+ e \qquad (4)$$

Before discussing the remainder of the equations in the model, a brief but important secondary issue must be discussed. As in many US Industries, the Airline industry has been greatly affected by the turbulence of fuel prices in the last decade. As important to this capital budgeting decision as oil prices may be, it would not be correct to include FLPC as an endogenous variables since clearly it is not our economy which determines what fuel prices will be. As an alternative to including FLPC as an endogenous variable we might, and have, assessed the impact of FLPC on other macro variables and treat FLPC as an exogenous variable. Consequently; several of the remaining equations, while customarily not thought to include fuel prices, do include fuel prices and in every case FLPC adds significant explanatory power.

Disposable income similarly incorporates FLPC in addition to the traditional consumption and wealth.

$$YD = \beta_0 + \beta_1 CON + \beta_2 FLPC + \beta_3 WLTH + e \qquad (5)$$

The determination of the factors contributing to inventory investment is one such situation where FLPC can be added to contribute its influence. In addition to FLPC inventory investment is seen as a function of the expected long-term interest rates, wealth and price level. The regression equation for INV is:

$$INV = \beta_0 + \beta_1 P + \beta_2 WLTH + \beta_3 FLPC + \beta_4 RL + e \qquad (6)$$

Both residential and nonresidential are explanatory variables for passenger miles, a key determinant of our cash flows. We must next express them in terms of exogenous variables. Residential investment is expressed simply as a function of disposable income and its own lag value or:

$$IR = \beta_0 + \beta_1 YD + \beta_2 LIR + e \qquad (7)$$

Nonresidential investment is determined to be a function of both inventory investment and residential investment or:

$$INR = \beta_0 + \beta_1 INV + \beta_2 IR + e \qquad (8)$$

The nominal wage rate is given by the standard econometric relationship:

$$W = \beta_0 + \beta_1 P + \beta_2 YD + \beta_3 LW + e$$

where LW is the nominal wage rate with a one period lag.

Necessarily, the most important equations in the model will be those that relate directly to either costs or revenues. On the revenue side, <u>the key</u> variable whose determinants must be found is the number of passengers that the airline might expect to carry (PNO). While there is no strong theory that would indicate what the determinants of passenger loads should be, there are some factors that we might hypothesize. Most obviously, the number of passengers traveling on a given route should be strongly related to the total industry wide number of passenger miles (PM). Beyond this, it might be that factors that determine passenger loads will be largely dependent upon the specific route and airline under consideration. To test this we derived, with the aid of a step-wise regression routine, the determinants applicable

	Delta	American	Eastern
Atl-Chi	I		II
Bst-DFW		III	
LA-NY		IV	

We then applied that specification to the situations in each of the other cells of the diagram and test for equivalence of regression equations. The specification utilized for this is:

$$PNO(I) = \beta_0 + \beta_1 PM + \beta_2 RS + \beta_3 CON + \beta_4 G + e \qquad (10)$$

The hypotheses tested are:

I) $H_0: \beta_{0I} = \beta_{0II}, \beta_{1I} = \beta_{1II}, \ldots, \beta_{4I} = \beta_{4II}$

II) $H_0: \beta_{0I} = \beta_{0III}, \beta_{1I} = \beta_{1III}, \ldots, \beta_{4I} = \beta_{4III}$

III) $H_0: \beta_{0I} = \beta_{0IV}, \beta_{1I} = \beta_{1IV}, \ldots, \beta_{4I} = \beta_{4IV}$

IV) $H_0: \beta_{0III} = \beta_{0IV}, \beta_{1III} = \beta_{1IV}, \ldots, \beta_{4III} = \beta_{4IV}$

The procedure utilized to test these hypotheses is as follows:

1) Data from each of the tested pairs are pooled and regressions are run utilizing the above specification.

2) Regressions are performed using the above specification are preformed within each separate cell.

3) A Chow test is then performed using:

$$\frac{(SSE_c - SSE_1 - SSE_2)/K}{(SSE_1 + SSE_2)/(n+m-2K)} \quad F_{K,n+m-2K}$$

where: SSE_c = error sum of squares, pooled regression
SSE_1 = error sum of squares, partition 1
SSE_2 = error sum of squares, partition 2
n = number of observations in partition 1
m = number of observations in partition 2
K = number of explanatory variables

The results of this test can be found at Table 3. The results, on the surface, appear somewhat perplexing. As expected, the model seems to hold for different routes on the same airline (cell III vs. cell IV). But it does not hold for the same route on different airline (cell I vs. cell II). This is only mildly surprising, except that it does seem to hold between cells I and III, different routes different airline. A fact which is not obvious can explain this situation. Cell I pertains to Delta airline's Atlanta to Chicago traffic, and cell III pertains to American Airline's Boston to Dallas/Ft. Worth traffic. Both airlines operate under a "hub" system around an airport central to their operation. The center of Delta's operation is Atlanta, while American's hub is Dallas/Ft. Worth. The impact of this configuration appears stronger than similarites by route.

Recognizing now that differences in the proper specification of this equation do exist, alternative specifications were then developed. We, therefore, again utilized a stepwise regression routine to assist in the specification of the other three required equations. It should be noted that the potential hazard of prediction bias, basing a model on unique data, stemming from use of stepwise regression has been seriously considered. However, we have avoided total reliance on the procedure and have coupled its evidence with sound judgement to derive the following specifications:

$$PNO(II) = \beta_0 + \beta_1 PM + \beta_2 P + \beta_3 RL + \beta_4 RS + \beta_5 INV + e \quad (11)$$

$$PNO(III) = \beta_0 + \beta_1 PM + \beta_2 P + \beta_3 INV + \beta_4 M + \beta_5 INR + e \quad (12)$$

$$PNO(IV) = \beta_0 + \beta_1 PM + \beta_2 RS + \beta_3 CON + \beta_4 G + e \quad (13)$$

For these equations to be of significant value we must now link these explanatory variables to the models exogenous variables. Passenger miles, as an indicator for the airline industry in general, will be very closely tied to macro economic variables itself. It, too, should be a function of the short-term interest rate and of consumption. In addition, one would expect it to be correlated with both residential and nonresidential investment. In addition, it would seem likely that our proxy for wealth (WLTH) would be related to non-business air travel. This equation, therefore, becomes:

$$PM = \beta_0 + \beta_1 IR + \beta_2 INR + \beta_3 RS + \beta_4 WLTH + \beta_5 CON + e \quad (14)$$

Table 3

Comparison	SSE_c	SSE_1	SSE_2	K	F	$F_{(0.95)}$
Cell I vs. cell II	2.31756E+10	1.03543E+10	5.26377E+08	5	2.7162	2.29
Cell I vs. cell III	1.75633E+10	1.03543E+10	5.07240E+08	5	1.6334	2.29
Cell I vs. cell IV	7.41796E+10	5.07240E+10	1.45916E+10	5	35.999	2.29
Cell III vs. cell IV	2.92723E+10	1.03543E+10	1.45916E+10	5	.41623	2.29

The result of each of these regressions can be found in Table 4.

What we now find we have is a system of eleven recursive equations. Upon linking with cost and revenue identities we will have the structure for the simulation model.

Testing Inter-temporal Stability

With all estimated relationships having been now derived, the issue of the degree of stability in these relationships over time becomes important. Inter-temporal stability is an important issue to model validity. Each of the econometric relationships derived in the last section will now be subjected to this test of stability and while we do not expect every equation to be stable, we do expect at least the key relationships to have this characteristic. In this test we use the following procedure:

1) Using the specifications derived earlier each equation is regressed using the full data set (56 observations).

2) The data set is partitioned into two even groupings (26 observations each) and the same regressions are performed.

3) A chow test (see previous section) is then

Table 4

equation 1

Dependent variable; Consumption R^2 = .937763

exlpanatory variable	Coefficient	t-statistic
Constant	97,8999	1.83613
transfers	.07425085	2.32859
lagged consumption	.873403	13.4611

equation 2

Dependent variable:Price level R^2 = .999159

explanatory variables	Coefficient	t-statistic
Constant	6.98849	6.77735
Lagged price level	.980002	250.263
Change in disposable income	-.00658263	-.473646

equation 3

Dependent variable:Short-term interest rate R^2=.775276

explanatory variable	Coefficient	t-statistic
Constant	1.44290	1.88933
Change in money supply	-.0196746	-.0949604
% change in price level	52.1130	1.21681
lagged ST interest rate	.842973	12.1321

equation 4

Dependent variable:Longterm interest rate R^2=.948331

explanatory variables	Coefficient	t-Statistic
Constant	.278259	.729321
Change in ST Interest rate	.546372	10.2550
Lagged LT interest rate	.979170	30.9523

equation 5

Dependent variable:Disposable Income R^2=.897426

explanatory variables	Coefficient	t-Statistic
Constant	170.091	3.17132
Consumption	.930759	16.8173
Fuel price	.409355	4.53265
Wealth	-.00419327	-2.48660

equation 6

Dependent Variable:Investment R^2=.985392

explanatory variable	Coefficient	t-Statistic
Constant	156683	10.1655
Price level	1158.40	28.3399

Wealth	-.308621	-3.42580
Fuel price	349.037	3.83803
LT interest rate	1959.34	4.12436

equation 7

Dependent variable=Residential Investment R^2=.851418

explanatory variable	Coefficient	t-Statistic
Constant	-2512.24	-.986220
Disposable income	2.68421	1.10320
Lagged Residential Investment	.975228	17.3543

equation 8

Dependent variable = wage rate R^2=.980135

explanatory variable	Coefficient	t-Statistic
Constant	-57.3968	-1.86916
Price level	.398419	4.71689
Disposable income	.123912	2.85205
Lagged wage rate	.296008	2.21130

equation 9

Dependent variable:Non-residential Investment R^2=.774569

explanatory variable	Coefficient	t-Statistic
Constant	-3244.31	-5.25317
Investment	.0148956	13.4339
Residential Investment	.119173	3.73672

equation 10

Dependent variable=number of passengers (RouteI) R^2=.48237

explanatory variable	Coefficient	t-Statistic
Constant	129.155	3.35058
Passenger miles	1315.54	3.75491
Short term interest rate	-1408.15	-4.09214
Consumption	-91.0419	-2.03064
Government spending	-.110663	-.878538

equation 11

Dependent variable=number of passengers (RouteII) R^2=.799673

explanatory variable	Coefficient	t-Statistic
Constant	34596.3	2.82540
Passenger miles	1055.22	5.75132
Price level	-343.056	-3.35504
Long-term interest rate	-2780.46	-3.62528
Investment	.168179	2.02839
Short-term interest rate	1509.84	2.99866

equation 12

Dependent variable=number of passengers (RouteIII) R^2=.815211

explanatory variable	Coefficient	t-Statistic
Constant	-34943.9	-4.56331
Price level	-8.85494	.0907648
Inventory	.0107738	.196952
Money Supply	58.3722	2.39972
Non-residential investment	4.90516	4.15900

equation 13

Dependent variable=number of passengers (RouteIV) R^2=.656371

explanatory variable	Coefficient	t-Statistic
Constant	203357	3.19775
Passenger miles	4556.19	7.88262
Short term interest rate	-1716.15	-3.02296
Consumption	-216.194	-2.92287
Government spending	-.160468	-.772187

equation 14

Dependent variable:Passenger miles R^2=.386762

explanatory variable	Coefficient	t-Statistic
Constant	27.8100	2.30727
Residential Investment	.0012079	2.35291
Short term Interest rate	-.182399	-1.59330
Wealth	-.465759E-04	-1.32243
Consumption	-.0109653	-.825639

preformed utilizing the error sum of squares from the first two regressions, the derived F statistic is compared to the applicable critical value.

The results of the application of this test to the structural equations have shown nine of the fourteen structural equations to be unstable overtime. The five equations that are stable over time are consumption, interest rates short- and long-term, wage rate and total passenger miles.

While stability of all equations would be desireable it is important to note that the total passenger number equation, which is the key determinant of revenues (see next section) is stable over time. Complete results of this test are found at Table 5.

Cost and Revenue Equations

At this point we have developed the underlying structure of the economic determinant variables. For these to be of importance to our capital budgeting model we must relate them to cash flows, through cost and revenue equations.

We begin with costs. There are two critical components to cost, operating costs and ownership costs. Operating costs can be broken down primarily into crew

Table 5

Equation	SSE (0)	SSE (1)	SSE(2)	k	F	$F_{(0.95)}$
Con	2601.06	1228.21	1111.65	3	1.86051	2.788
P	39.1175	8.94621	21.7932	3	4.54254	2.788
RS	83.4021	58.664	18.8335	4	.91429	2.566
RL	13.5467	6.93877	6.03712	3	.733167	2.788
YD	5353.28	2410.37	390.435	4	10.9363	2.566
INV	1.33088E+9	3.60122E+8	3.09718E+8	5	7.07913	2.414
IR	1.63621E+7	6.35625E+6	5.77798E+6	3	5.80708	2.788
W	520.054	417.883	55.0147	4	1.19661	2.566
INR	5.73402E+6	1.16317E+6	3.54252E-6	3	3.64215	2.788
PM	226.362	99.7324	102.668	6	.866172	2.308
PNO1	2.03543E+10	4.09988E+8	7.50007E+8	5	16.1431	2.414
PNO2	.357165E+09	.126796E+09	.123990E+09	6	4.2426	2.308
PNO3	.861806E+09	.106911E+09	.185818E+09	5	118.7526	2.414
PNO4	.553994E+10	.177872E+10	.229725E+10	6	3.59177	2.308

costs and fuel costs. For this model crew costs is given by:

2 Man Flight Crew	\$333+\$36 X TOGW/100,000 (per Block Hour)
	where: TOGW=Take off gross weight
	(Based on CAB data escalated to 1981)
Cabin Crew	\$1.55 per Seat (per Block Hour)
Total Crew Costs	Flight crew + Cabin crew x W_t/W_0
	where: W_t/W_0 adjusts crew costs by the prevailing wage rate.

Fuel costs are a somewhat easier issue. For this model fuel costs is given by:

Fuel Costs $\quad$ $PERF \times BT \times N \times FLPC_T$

where: PERF = aircraft fuel economy (gallons/Block Hour)

BT = Block Time (hours)

N = Number of flights per month

FLPC = Fuel price

Ownership cost has two principal components; debt cost and depreciation/insurance. Depreciation/insurance is given by:

Depreciation/Insurance

$$(P/U) \times \frac{(1-R/100)}{D} + (i/100) \times (1-S/100)$$

where P = Airlplane investment

i = insurance premium (2%)

U = utilization (months)

D = depreciation period

R = % Redisual Value

Debt cost is given by a standard annuity[4]:

$$\text{debt cost} \quad \frac{1-(1+i)-N}{i} \quad / \text{PV}$$

Finally, revenue is given by the very simple expression:

revenue PNOn X TKPC

where: PNOn is the number of passengers traveling on route n per month

TKPC = standard Y fare on route n

The cash flow for period t is now simply the total revenue for the period minus the total costs for the period. The complete model is shown in Figure 2.

Discounting Procedures

Each simulation run, wherein values for the distributional and quasi-distributional variables are

[4]The appropriate interest rate here can either be fixed or variable. Both are common in aircraft financing.

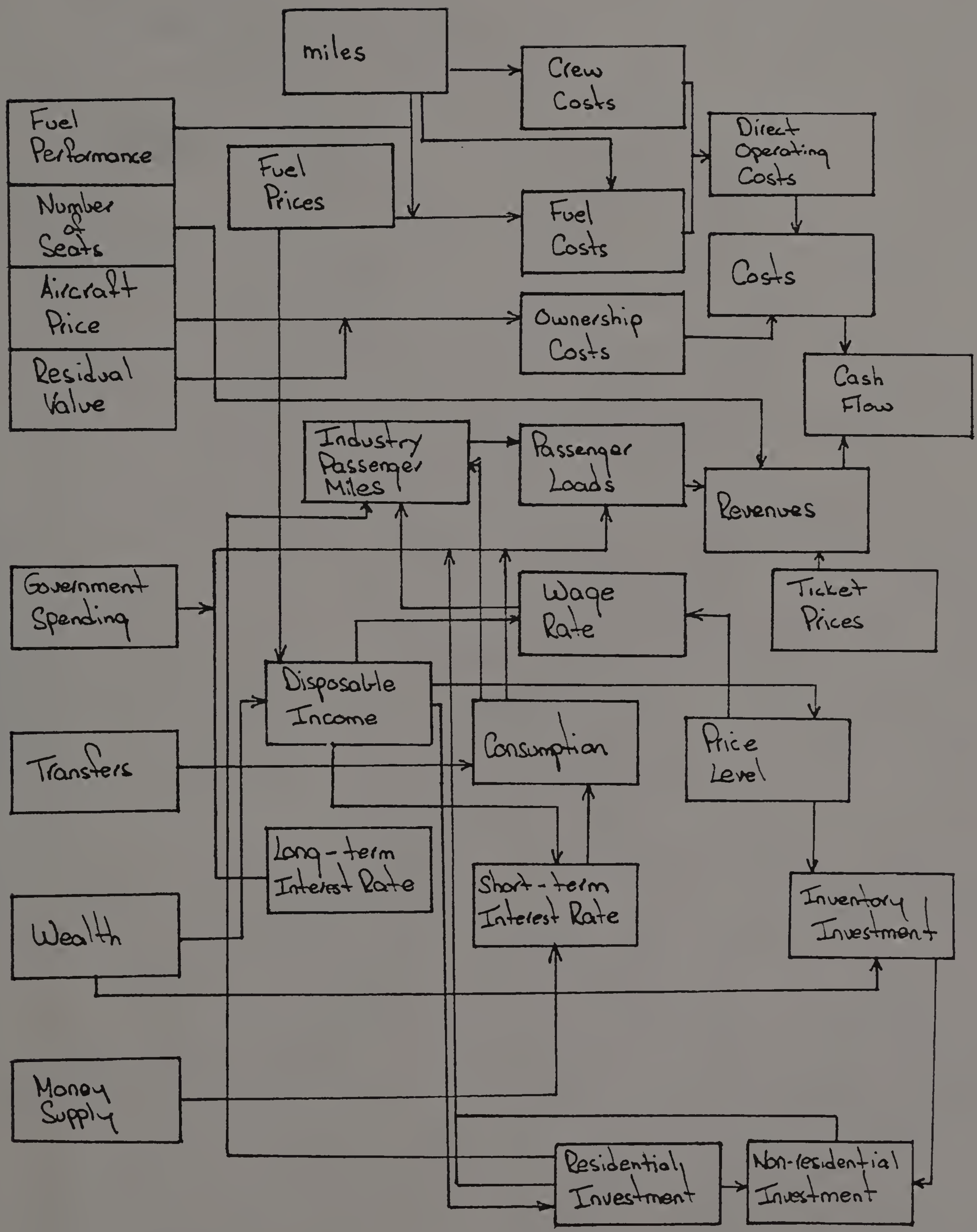

miles
Crew Costs
Fuel Performance
Direct Operating Costs
Fuel Prices
Number of Seats
Fuel Costs
Costs
Aircraft Price
Ownership Costs
Residual Value
Cash Flow
Industry Passenger Miles
Passenger Loads
Revenues
Government Spending
Wage Rate
Ticket Prices
Disposable Income
Consumption
Price Level
Transfers
Long-term Interest Rate
Short-term Interest Rate
Inventory Investment
Wealth
Money Supply
Residential Investment
Non-residential Investment

Figure 2

selected, can be viewed as representing the life of single project under conditions of certainty. Each variable for a given simulation trial has a fixed known value. Cash flows are, in turn, known with certainty at each period in the simulation run. The choice of a discount rate to apply to these cash flows must be tempered with this fact in mind.

There are many candidates for use as the proper discount rate. A large portion of the finance literature centers around the weighted average cost of capital (WACC) as a discount rate for capital budgeting decisions. The WACC is given by :

$$r^* = r_d(1-T_c)\ D/V + r_E E/V$$

where: r^* = the adjusted cost of capital

r_d = the firm's current borrowing rate

r_E = the expected rate of returnon the firm's stock (a function of the firm's business risk and its debt ratio)

D,E = the market values of currently outstanding debt and equity

V = D+E = the total market value of the firm

The use of the WACC for our application suffers the same difficulties confronting the CAPM. Each of the variables in the formulation pertain to the firm. It implicitly assumes that the risk of the project is identical to the risk of the firm. For this application, as we have said, there is no risk involved. Therefore, use of the WACC will introduce a negative bias to the distribution of net present values.

The simplest and most obvious alternative for discounting riskless cash flows is use of the risk free rate. This rate is proper in the sense that there is no allowance for differential risk, and hence, it eliminates that source of bias. Several authors, e.g. Meyers [1974], have recommended adjusting this discount rate to allow for the interaction of the financing and investment decisions. Since, in aircraft procurement decisions preferential financing schemes are commonly offered as inducements by aircraft manufacturers, this suggestion would appear to have merit. It is important to note that the risk free rate needed for the discounting of cash flows is already a variable in our model. The use of this simplified discount rate will be appropriate as long as the adoption of the project under review does not alter the capital structure of the firm.

The output of the simulation model for one trial is then a single net present value (NPV) for that project's cash flow. After several replications of the simulation we will derive a cumulative density function depicting the profile for that given project under all likely scenarios and subject to all attendant probabilities. This will look very much like a cumulative probability density function.

Determination of Cumulative Frequencies

As stated earlier, the simulation phase of this methodology requires that the available data be used in a cross-sectional sense. Specifically, we must determine the distributions from which simulated values of modeled variables will be drawn. The first important issue in this process is the differentiation amongst the three distinct types of variables with which we will deal: distributional, quasi-distributional and non-distributional. Distributional variables are those variables for which ex post data, representative of the entire population, are available from which to sample. Quasi-distributional variables we define as those variables for which such data do not exist, but about which subjective assessments can be made as to their distribution. Non-distributional variables we define as those for which we use neither ex post data nor subjective assessments. For these variables we choose values that are either of concern to us or implement policy variables which are under our control. Without exception we will assume these variables to be discrete, and most frequently to be dichotomous.

The distinction of the types of variables in this model is not an arbitrary one. The crux of the issue is the reliance of all probability theory on statistical sampling. For statistical inferences to be drawn from a sample of data several conditions must exist, most important of which, if we intend to infer characteristics about the population, is that the sample be representative of the population. Upon reflection it must be admitted that data from previous observations are infrequently precisely applicable to future occurrences. More often events of the past and present must be assumed to have an impact on occurrences of the future. For us to sample from the entire population in such cases we would have to sample from the future; a requirement that we cannot meet. Yet, for us to include a variable as a distributional variable this is what we would have to do. Consequently, the first analysis that must be done at this phase is the determination of whether or not we have reason to believe that the data we have for any variable are representative of the entire population, to include future periods. Distributional variables will be those for which we have adequate ex post data.

That we reject our ability to properly sample the population does not imply that a well behaved distribution for a variable does not exist. In reality we do not question that all variables might be considered distributional variables. However, in this model we now seek to apply an alternative terminology to those variables that have failed to meet this criterion.

The following are example variable differentiations for factors that will be included in the model:

<u>Distributional Variables</u>

industry growth	Consumption
passenger loads	Inventory investment
fuel consumption	Unemployment rate
crew costs	Residential investment

<u>Quasi-distributional Variable</u>

Government spending	Long-term interest rate
Money Supply	Short-term interest rate

<u>Non-distributional Variables</u>

Fuel prices	Ticket prices

The results from the previous analysis can help lead us to some conclusions concerning the nature of some of the variables in our model. For endogenous variables whose specifications are stable over time the assumption of being distributional seems a sound one. For these variables a distribution will emerge based on the distribution of:

1) a distribution of determinant variables.

2) the distribution of coefficients.

3) the distribution of random error terms.

In this model these variables will without exception be normally distributed. There are, as we have seen, some inter-temporal instabilities among the structural equations, for example in the interest rate equations. In these situations, based upon informations of external forecasts of future values, we can subject a distribution to Bayesian adjustment.

Most importantly, distributions for the exogenous variables must be derived. For these variables we initially start with the historical distribution. In some cases this yields very positive results. For example, wealth appears to be a strictly distributional variable. For it we may calculate the values exhibited within 10-percentile regions and sample directly from this distribution within the simulation model. Other variables, when tested, exhibit, in addition to distributional qualities, trends over time. In this model three variables exhibit such behavior; transfer payments, money supply and government spending. For these variables we calculate the distribution of the changes from one period to the next. For those variables increasing over time these distributions will have positive means.

Finally, there is at least one exogenous variable in the model that is non-distributional but changes through time, that is, fuel price. For this variable initially, we utilize an industry estimate of projected price behavior.[5] Such a subjective evaluation can be modified to reflect alternative assumptions.

The remainder of exogenous variables in the model are to have constant values through time in the simulation model, and across simulations. While this restriction simplifies the analysis at hand, its eventual relaxation, and the conduct of sensitivity analysis with <u>all</u> exogenous variables will be one of the more interesting extensions of this approach.

At this stage we now have a simulation model that is capable of generating a distribution of cash flows while taking into account both subjective and historical inputs

[5] "Boeing projections estimate that real fuel prices in constant 1980 dollars will go up another 50% by 1990 to approximately $1.50 per gallon and then remain relatively stable thereafter, in great measure due to the positive impact of synthetic fuels production. This means an average escalation rate of 2% to 4% per year above the general inflation rate through the 1980's and at the general inflation rate therafter." <u>Aircraft Economic Obsolescence</u>, Boeing Commercial Airplane Company, p. 9.

and accounting for inter- and intra-temperal correlations among variables. What remains, is the application of this model to capital budgeting.

CHAPTER IV

SIMULATION AND ANALYSIS

In the previous chapter we have derived, through regression analysis, the econometric equations of this simulation model and have, in turn, linked these factors to costs and revenues in the aircraft procurement capital budgeting decision. With the equations of the model fully specified, we then briefly discussed alterntive approaches to discounting these cash flows and the means by which the stochastic nature of both variables and betas can be reflected. In this chapter we begin by elaborating on these last two topics and then turn our attention to the demonstration of how this model is used for capital budgeting and how sensitivity analysis may be performed.

As developed earlier, the result of each simulation run of this model will be the single net present value for that project. The result of multiple simulation runs, or a simulation trial, utilizing the same values within the model will be a distribution of these net present values. As the result of each run is singular, it in no way can be considered itself to be stochastic in nature.

Consequently, the procedure that we shall use to discount the cash flows of each period within the model to its present value at t=0 will be a procedure appropriate where cash flows are known with certainty. It will be unnecessary to adjust this discount rate to either inflation or risk, since the model accounts for inflation and our treatment of the distribution of net present values accounts for risk. Since interest rates themselves are endogenous to the model we need only utilize the prevailing long-term interest rate in a given period to discount that period's cash flow.

In this thesis each simulation run consists of 120 consecutive monthly periods and we use 100 simulation runs in a simulation trial. The 100 separate net present values of the simulation are aggregated to derive a cumulative probability distribution with ten deciles. For each simulation trial there will be two distributions of net present values of importance, one for each project under consideration. The distributions for net present values will then be compared utilizing stochastic dominance.

Stochastic Dominance

Thus far in this discussion we have made no attempt to incorporate either investor or corporate disposition toward risk. While in most cases, there are several ways that such preferences might be brought to bear this particular case calls for some very specialized requirements. Namely, the decision criterion must be able to take a cumulative density function of an unknown and probably unfamiliar or irregular distribution and weigh it against the density function of another project with an equally strange shape. Many approaches must be ruled out due to our inability to properly specify the distribution. There remains a valuable and effective tool in stochastic dominance. This technique allows for contrasting any two cumulative density functions without regard to the mathematical function.

Stochastic Dominance is applied in escalating degrees, each with increasingly restrictive assumptions concerning the utility function.

First Degree Stochastic Dominance (SFD) assumes the the utility function, $U(x)$ to be finite, continuously differentiable, and strictly increasing over x. In behavioral terms this amounts to nothing more than the assumption of greed, that more is better than less. Given that $F1(x)$, $F2(x)$ are the distribution functions of two projects, then if:

$$F1 < F2$$

project 1 is said to dominate project 2.

This is equivalent, graphically, to saying, with P on the x axis that any project whose cumulative density function lies entirely to the left of another project dominates that project by FSD.

Second Degree Stochastic Dominance (SSD) assumes, in addition to the assumptions of FSD, that U(x) is strictly quasi-concave. Again, in behavioral terms this is the same as the assumption of risk aversion. If:

$$\int_{-\infty}^{z} (F2(x) - F1(x))\, dx > 0 \text{ for all } z$$

then project 1 dominates project 2.

This is equivalent to saying that if the total area under project 1's cumulative density function, where this function lies above that of project 2's, is greater than that under project 2's, where project 2's function lies above that of project 1, then project 1 dominates project 2 by SSD.

While there are further degrees of stochastic dominance, it is only through the second degree that the behavioral assumptions can be easily defended. If no project dominates another then it can be said that the investor would be indifferent between the two projects.

Since, any simulation of this type produces a net present value distribution of discrete values rather than a continuous function we must modify, slightly, the decision rules mentioned above. For first order of stochastic dominance we will say that if:

$$NPV_1(P)>NPV_2(P) \quad \text{for } P=1,10$$

where P represents each successive probability dectile

then project 1 dominates project 2 by FSD. Similarly if:

$$\sum_{P=1} NPV_1(P)-NPV_2(P)>0$$

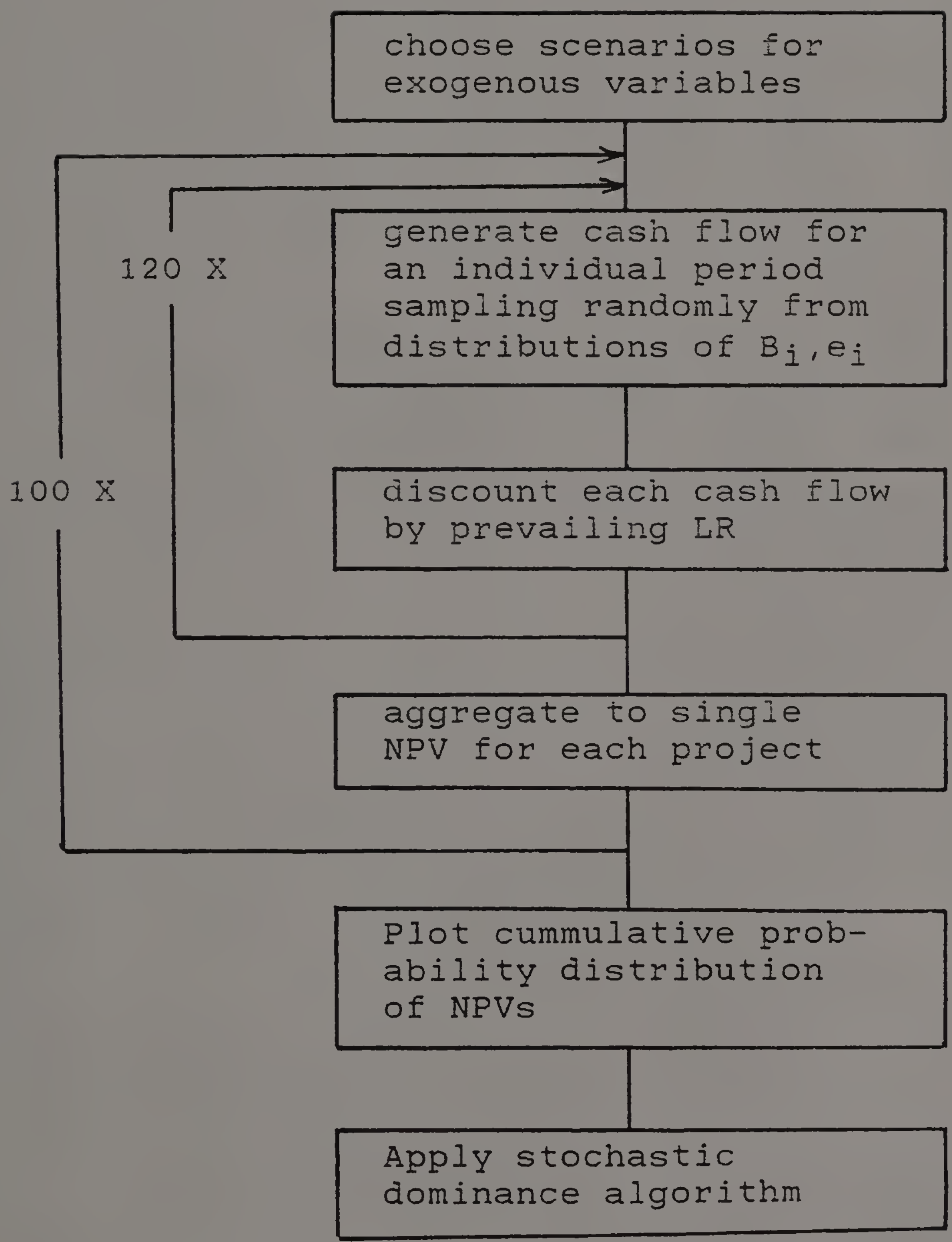
then project 1 dominates project 2 by SSD. While in most cases in this thesis the dominance relationships are obvious by visual inspection, a simple BASIC program has been written and utilized to formally determine these relationships.

With the development, explanation, and justification of this approach complete (a flow chart of the simulation process is at Figure 3), the time is at hand to turn our attention to the actual conduct of simulations and the performance of sensitivity analysis.

Implementation of the Model

The development up to this point has addressed everything but the actual application of the model to capital budgeting. The tool of implementation most appropriate for this application is a computer program.

Figure 3


choose scenarios for exogenous variables
120 X
generate cash flow for an individual period sampling randomly from distributions of Bi, ei
100 X
discount each cash flow by prevailing LR
aggregate to single NPV for each project
Plot cummulative probability distribution of NPVs
Apply stochastic dominance algorithm

More specifically, we have utilized a BASIC program which randomly generates stochastic coefficient from their distributions and generates equation residual terms from their distribution. Through this process, and the initialization of exogenous variables, each equation in the model is solved, and in turn, cost and revenue values are derived within each period. The program then discounts each cash flow by the interest rate derived for that period. The program further aggregates these discounted cash flows to derive a single net present value for the project. This process is accomplished 100 times and the ten percentile values (value at which 10% of all results fall under, value at which 20%........) are derived. The program then, for the two projects under consideration, applies the tests for stochastic dominance, discussed in the previous section, to these results. A separate program then generates a plot of the two cumulative probability distributions.

What follows is the application of this model to several hypothetical project selections. Projects proposed for adoption as well as economic scenarios under which they are evaluated are exclusively representative and in no way exhaustive.

Interest Rate Scenarios

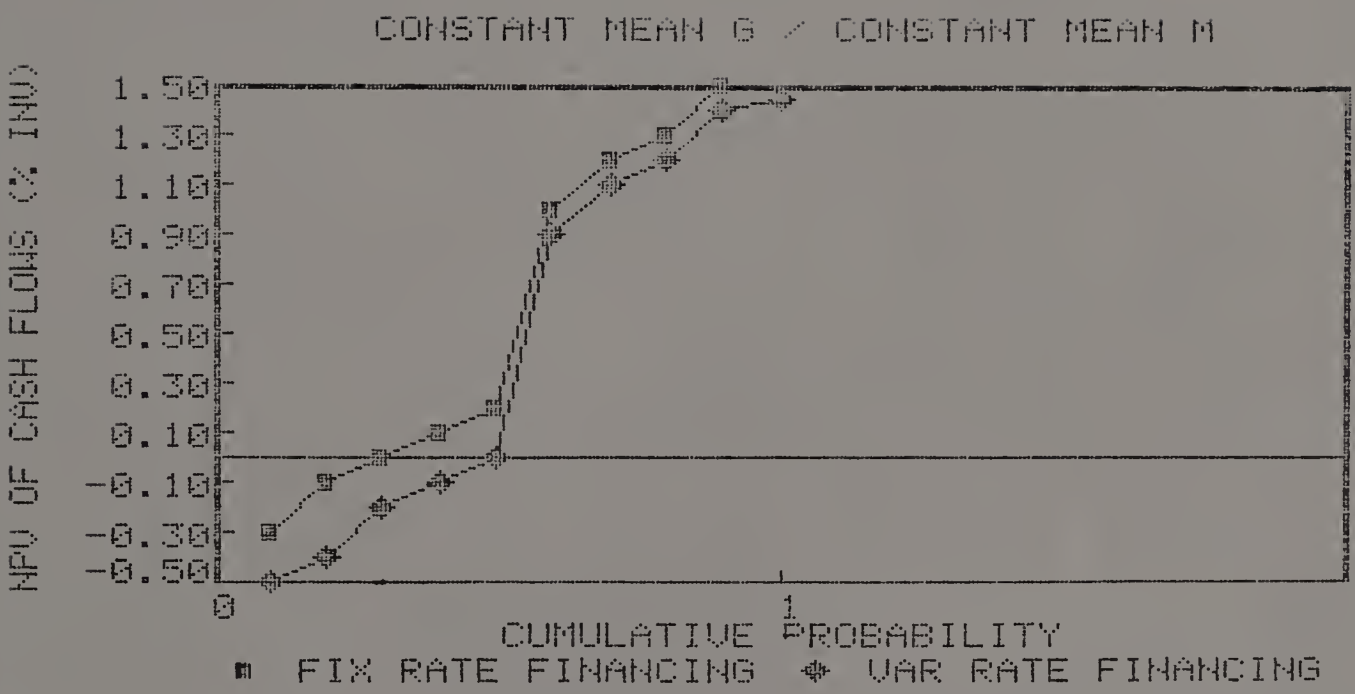
A capital project as large as an aircraft procurement, especially one employing significant financial leverage, is characterized by considerable sensitivity to interest rate fluctuations. The cash flows forecasted to accrue to a project are greatly influenced by the expected interest rate scenario. In the financing of an aircraft procurement there are, at times, two alternatives available to an airline. The first and more conventional is to seek variable rate financing for an aircraft from either the manufacturer or another source. The second is to accept fixed rate financing, at a rate that incorporates expectations of future interest rates, from either source. We now use the model to evaluate these alternatives across two economic scenarios.

In our model, interest rates are endogenous variables and as such should be manipulated through changes in exogenous policy variables. The two policy variables that most closely control interest rate fluctuations are government spending and money supply.

In our first simulation trial we adopt a scenario of a constant mean government spending coupled with a constant mean money supply. We evaluate the alternative result of the two mentioned financing schemes for a 6.5

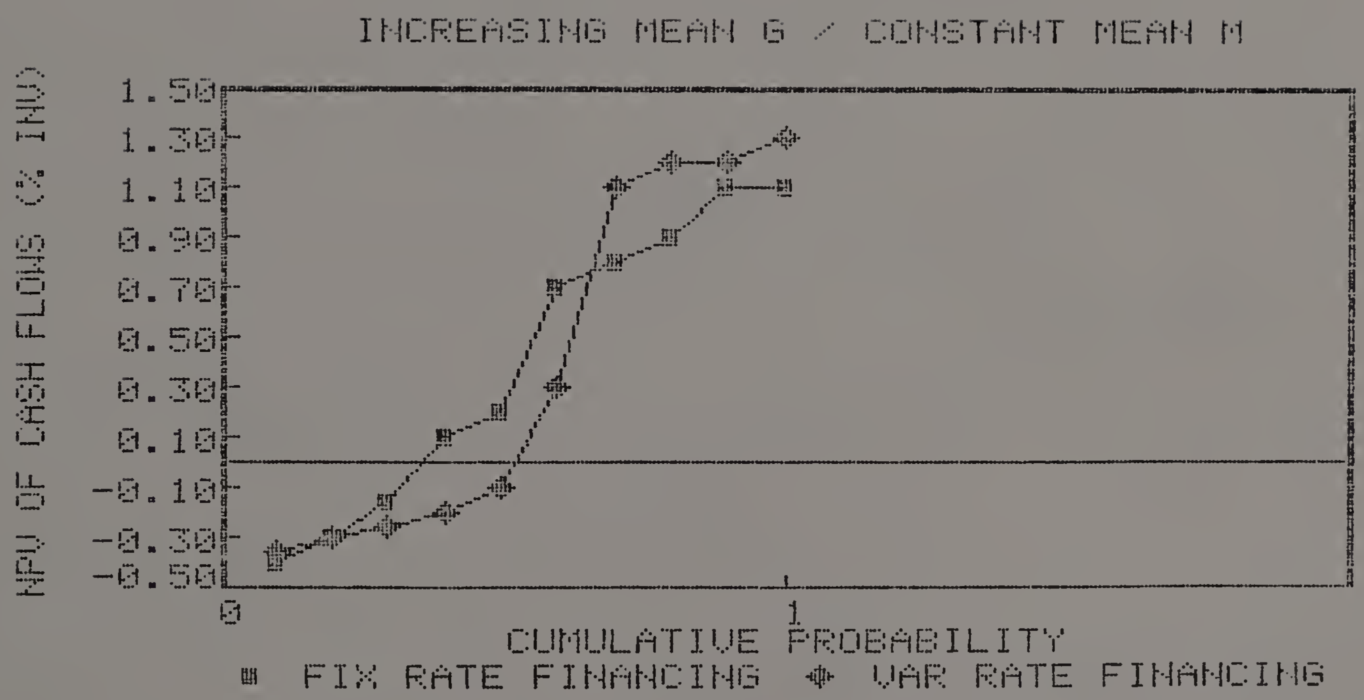
million dollar investment (fully leveraged) in a Boeing 727-200 on the Los Angeles to New York route. Specific performance data for this aircraft (such as fuel consumption rate and speed and seating capacities) are initialized in the model. The results of this simulation can be found at Figure 4. Given this scenario we find the fixed rate financing alternative to dominate the variable rate alternative by second degree stochastic dominance. Also note in Figure 4 that both alternatives have a positive and roughly equivalent mean net present value but significantly different distributions.

In the second simulation trial the economic scenario is modified. In this scenario we assume a restrictive federal reserve policy as represented by a constant mean money supply but coupled this time with increasing mean government spending. The expected result of this policy is a squeeze on investment capital and a representative increase in interest rates. As can be seen in Figure 5 this scenario has, in fact, yielded different results. Again, the mean net present values of the two alternatives are very similar but this time fixed rate financing dominants variable rate financing by first degree stochastic dominance.



Note: The reader accustomed to viewing probability distributions with probability on the vertical axis can achieve the same effect by rotating the graph 90^0 counter-clockwise.

Figure 4



INCREASING MEAN G / CONSTANT MEAN M
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
FIX RATE FINANCING
VAR RATE FINANCING

Figure 5

Effects of Industry Growth

Growth within any industry is among the principal concerns and hopes of any firm. It is often an explicit objective of a capital budgeting decision to put the firm in a position where they can best take advantage of growth when and if it comes. In this model, growth is accounted for through the variable "total industry passenger miles", PM. While this variable is endogenous to the model, various growth scenarios can be forced upon the model through either the regression coefficients which determine the number of passengers industry wide, or through the stochastic residual which accounts for all other factors beyond those included in the equation.

In examining the effects of alternative assumptions concerning industry growth, the two projects that we will consider will be the acquisition of either Boeing's 727-200 aircraft or Airbus Industries' A-300-B2. While they compete for the same market, the characteristics of these aircraft are quite diverse. The Boeing 727-200 as its name implies is a nominal 200 passenger aircraft. It is a 3-engine, turbofan, regular-bodied jet. This aircraft has less than impressive fuel consumption rate, .019 gallons/seat-miles, and travels at an average speed of 464 mph. The Boeing 727 series has been in production for over twenty years, and as such has a relatively low acquisition cost of $6.5 million.

Airbus Industries' A-300-B2 is a much more modern aircraft. It is a two-engine, turbofan, wide-bodied jet. It's more efficient airframe and its use of only two engines, while maintaining an average speed of 441 mph, allows for a 26% reduction in fuel consumption from that of the Boeing 727 (.014 gallons/seat-miles). Because this aircraft is both newer to the market and produced by a British company the acquisition cost greatly exceeds that of the Boeing 727. The representative acquisition price which we shall use in the comparison will be $10 million per aircraft.

In testing the sensitivity of the decision criteria to alternative industry growth assumptions, we therefore compare an aircraft with low acquisition cost, moderate performance and moderate capacity (the Boeing 727-200) with an aircraft of higher acquisition cost, better performance and greater capacity.

In our first simulation trial (results at Figure 6), which pertains to the Atlanta-Chicago route, we will assume that industry growth continues as it has in the past and will make no adjustments to the total passenger mile equation of our model. The results of the simulation are not greatly surprising. Procurement of the lower acquisition cost, Boeing 727, dominates that of the better performing higher acquisition cost Airbus. This is largely due to the fact that in most periods the Airbus operated at low capacity.

In the second scenario, reported in Figure 7 we assume the mean growth in passenger miles to be the same as in the previous example but here we cause a greater variance in passenger miles. This we force through manipulation of the residual term of the equation. As might be expected, the difference in the performance of the two projects has largely dissipated with this assumption and neither project is dominant. This is due to the fact that here the Airbus is able to fly at its profitable capacity in many periods but seems to be less affected by the down side of the variance increased total passenger miles.

In a third scenario we caused the passenger mile equation to have a greater mean growth than that historically derived (150% historical growth). This we caused through Bayesian adjustment of the equations coefficient. As expected, in this scenario the Airbus aircraft far surpasses the Boeing aircraft and dominates it by first degree stochastic dominance.

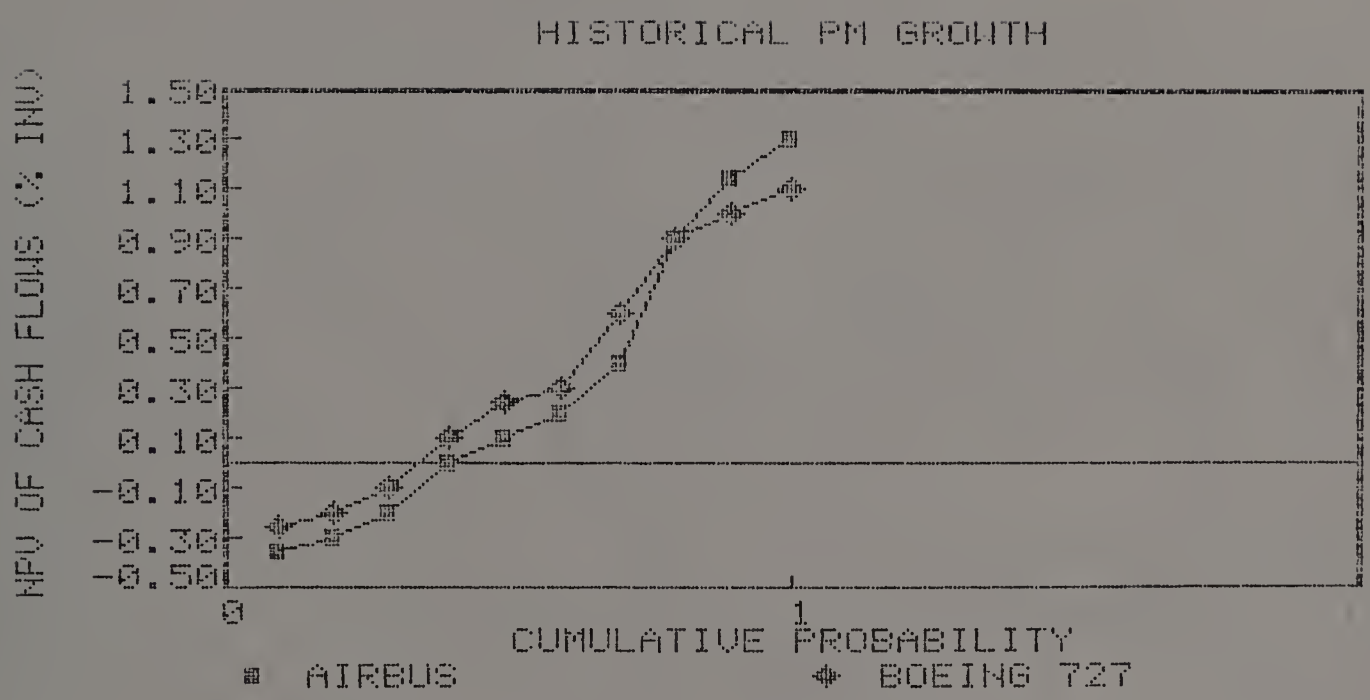

HISTORICAL PM GROWTH
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
AIRBUS
BOEING 727

Figure 6

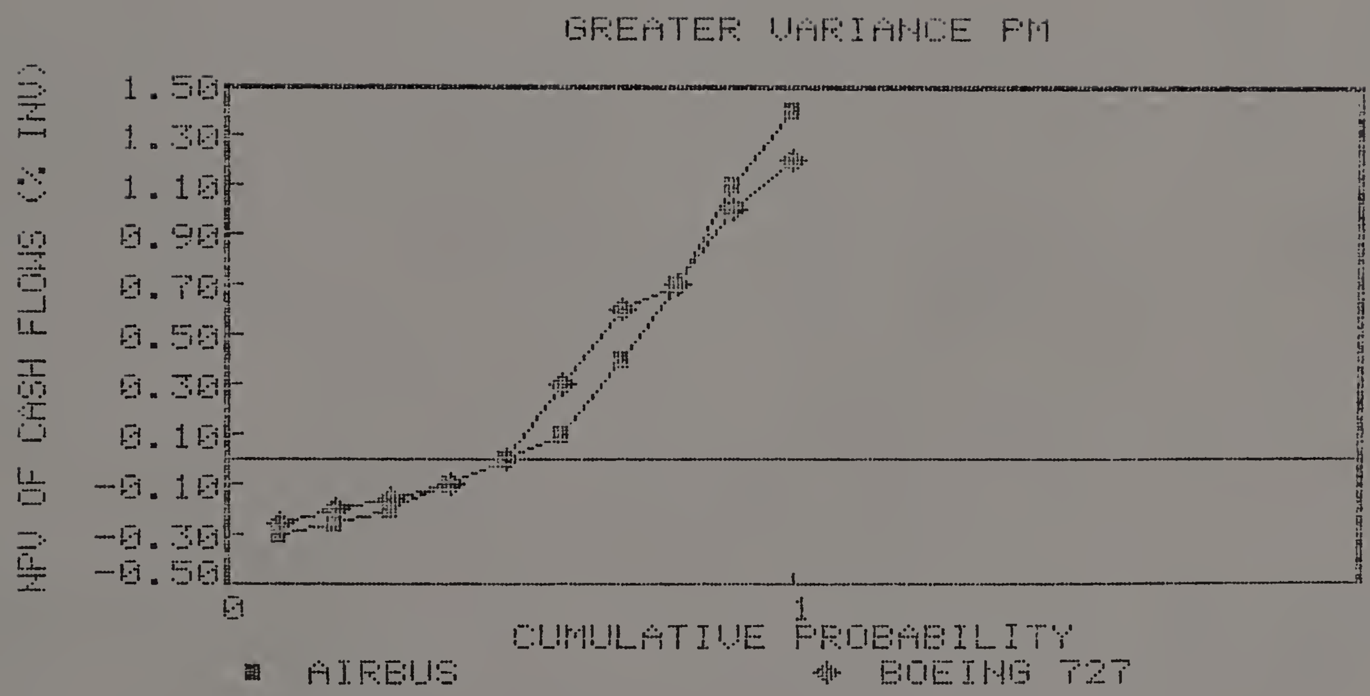

GREATER VARIANCE PM
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
AIRBUS
BOEING 727

Figure 7

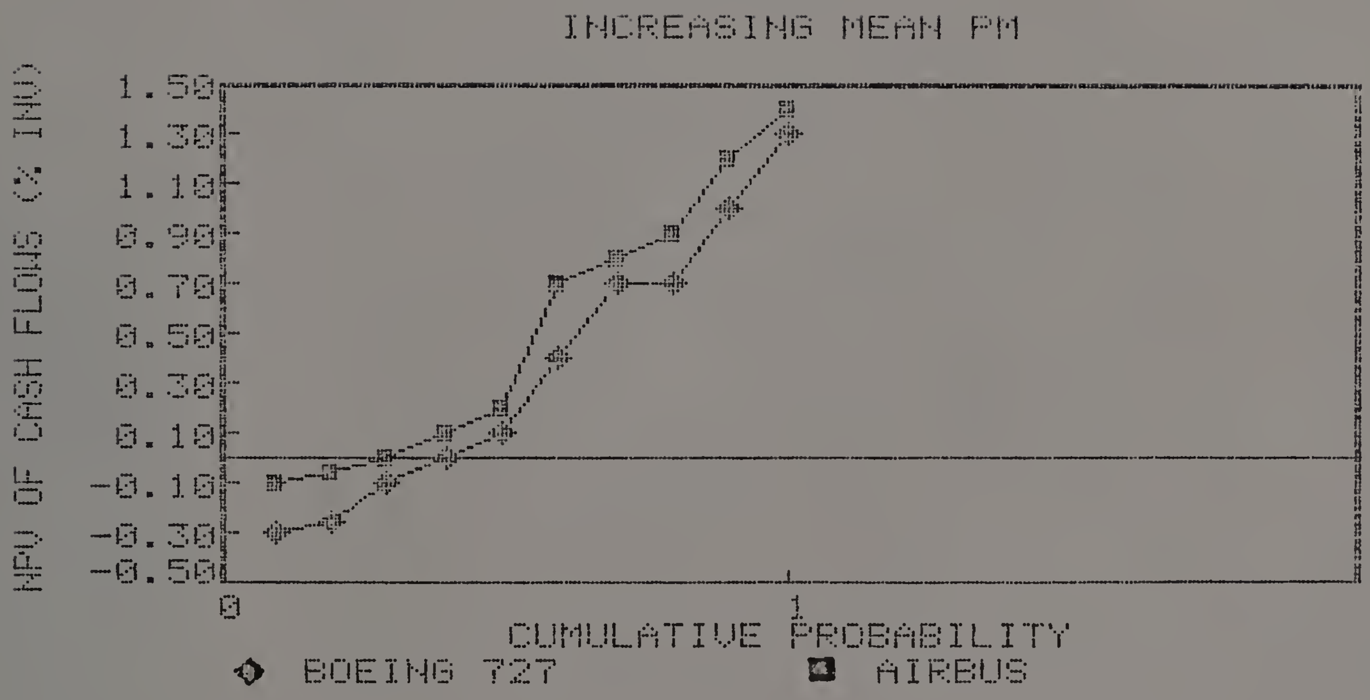

INCREASING MEAN PM
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
BOEING 727
AIRBUS

Figure 8

Effects of Oil Prices

Perhaps more interesting due to its deep felt and unpredictable volatility are the effects of changing oil prices. To an extent greater than that of most industries, the airline industry is very susceptible to fluctuations in oil prices. This can clearly be seen by observing the impact of the variable FLPC in our model. During the time of the great oil crisis of the mid 1970's airlines found themselves in a significant price squeeze. Aircraft manufacturers began accelerated development of newer and more efficient passenger carriers. Conditions have significantly improved for the airlines and the choice between these more efficient aircraft and the less expensive and less efficient older versions are less obvious.

The two aircraft contrasted in the previous sensitivity analysis are a classic case of the newer more efficient airplane versus the cheeper less efficient one. In our first simulation trial, utilizing the Boston-Dallas/Ft. Worth route, we will develop the baseline comparison by causing aircraft fuel prices to be distributed around its current mean of $.89 per gallon as FLPC is an exogenous variable this can be done directly. The results of this simulation can be found at Figure 9.

As can be seen in this graph the two projects are very closely comparable but with procurement of the 727 dominating by second degree stochastic dominance. Clearly, the reason for the excellent performance the Boeing aircraft is the maintenance of the currently low fuel price, continued high economic activity (as a partial result of low fuel prices) and low acquisition cost.

In the second scenario, reported in Figure 10, we allow for increases in fuel costs as hypothesized in the Boeing document cited in Chapter 3. This allows for a 11% annual increase through the end of the simulation period (1990) where FLPC will equal $1.50 a gallon. We would expect such a pessimistic scenario to greatly favor a more efficient aircraft and, in fact, reference to Figure 10 confirms our suspicions. Procurement of the Airbus A-300-B2 dominates by first degree stochastic dominance.

While the previous scenario is Boeing's forecast of future fuel prices made in 1982, current conditions cause us to suspect that such a scenario may be far too pessimistic. As an alternative to this scenario in the third simulation trial we will assume that the present world oil glut will continue for two more years and that oil prices will continue to fall by 2% per year. After this two year period we will assume that oil prices regain their strength and grow at an estimated 5% per year. The

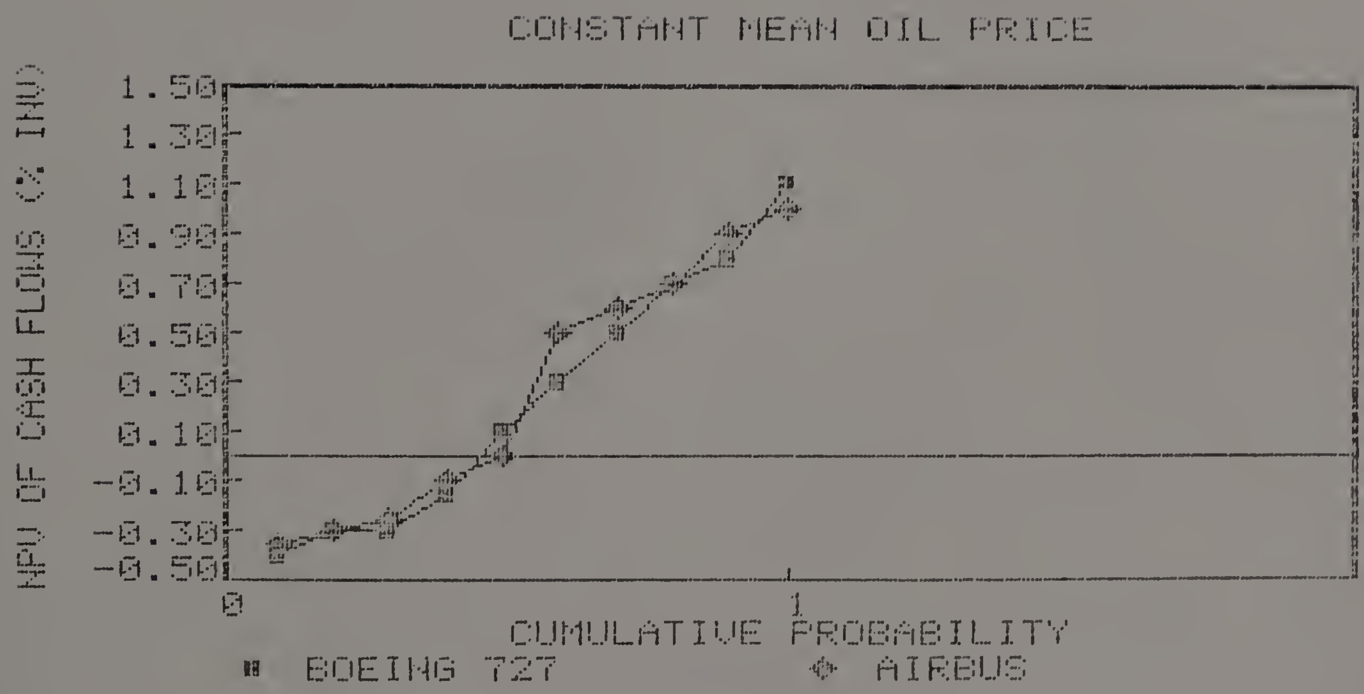

CONSTANT MEAN OIL PRICE
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
BOEING 727
AIRBUS

Figure 9

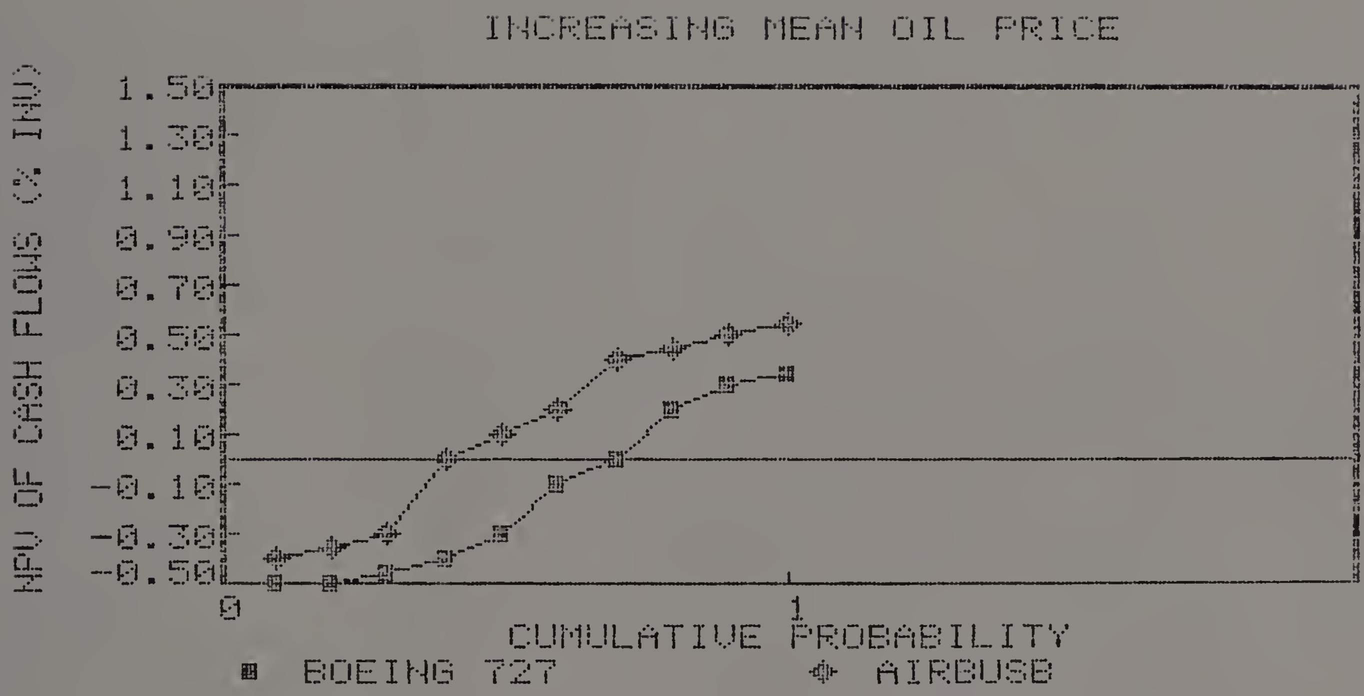

INCREASING MEAN OIL PRICE
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
BOEING 727
AIRBUSB

Figure 10

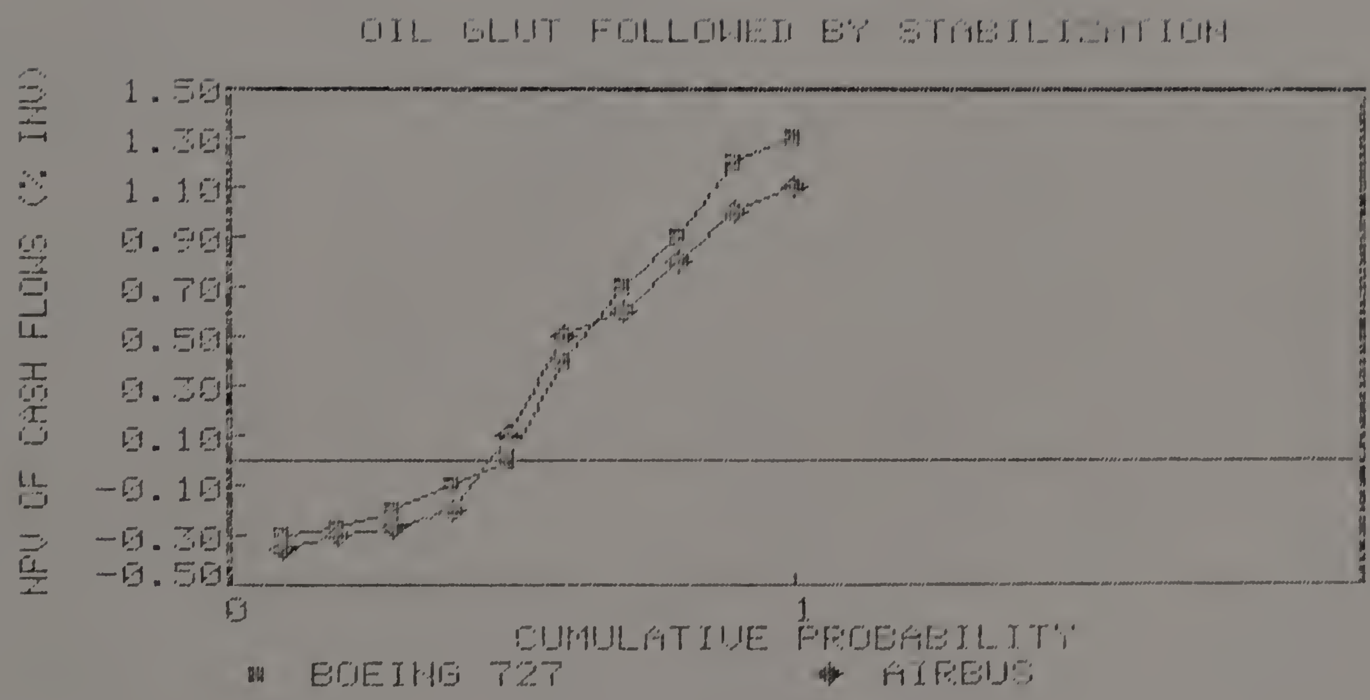

OIL GLUT FOLLOWED BY STABILIZATION
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
BOEING 727
AIRBUS

Figure 11

results of such a scenario can be seen at Figure 11. Here the favorable initial oil price scenario has tipped the scale in favor of the Boeing 727 even though oil prices do rise after the second year.

A financial analyst in any industry as sensitive to oil prices as is the airline industry would certainly need, and desire, to test the effects of their own expectations of future oil prices on projects considered for adoption. As can be seen, this capital budgeting approach greatly facilitates this need.

Advent of New Technology

It is not totally unfair to characterize the 727 as the aircraft of yesterday and Airbus Industries' A-300-B2 as the aircraft of today. However, as we have seen, there are conditions under which the procurement of yesterday's aircraft, can be more rewarding to the firm than the procurement of the aircraft of today. Since the currently available modern aircraft under some conditions does not offer a significant advantage over the older aircraft a firm might opt to decide in favor of an older design less expensive aircraft with the intention to replace it with an aircraft of significant improvement at some point in the future.

In this simulation trial we contrast just such a strategy with the procurement of the Airbus A-300-B2. For this illustration we assume that there is currently under development an aircraft that will provide a 40% fuel reduction over the Boeing 727, carry 300 passengers and cost $12 million. We further assume that this aircraft will be available for adoption in two years, but that <u>some</u> aircraft must be adopted at this time. We also assume that the Boeing 727's procured today will retain their historical 92% mean resale value after two years. The alternative project under consideration then will be the current adoption of the Boeing 727, it's subsequent resale in two years and the adoption of the more sophisticated aircraft for the remaining three years of the simulation.

We assess the impact of these two alternatives across two economic scenarios, utilizing the Atlanta-Chicago route. In the first of these scenarios, shown in Figure 12, we assume a constant mean oil price over the duration of the simulation. As we can see the Boeing/substitute aircraft option dominates the Airbus by second degree stochastic dominance. For this study we have chosen to employ a further capacity of our model. In analysing the distribution of cash flows for each project in each period we find that contrary to our initial expectations that the Airbus aircraft would be dominant in early periods, we

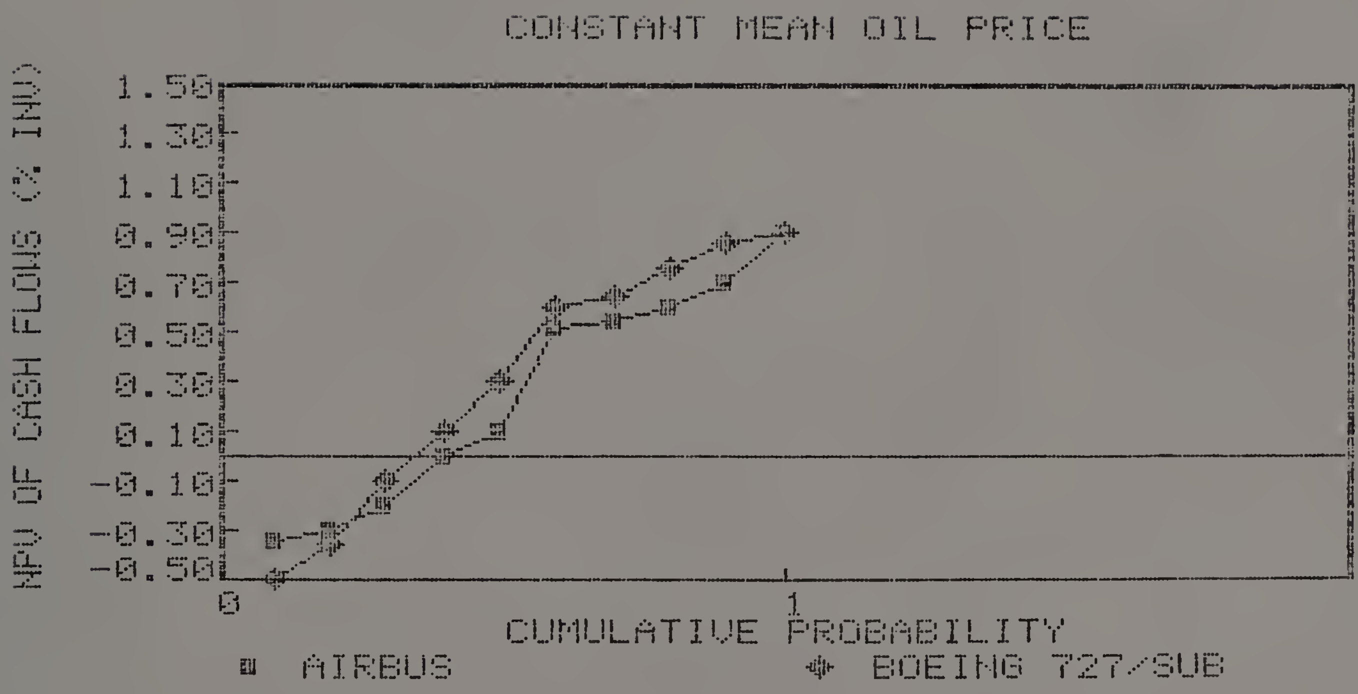
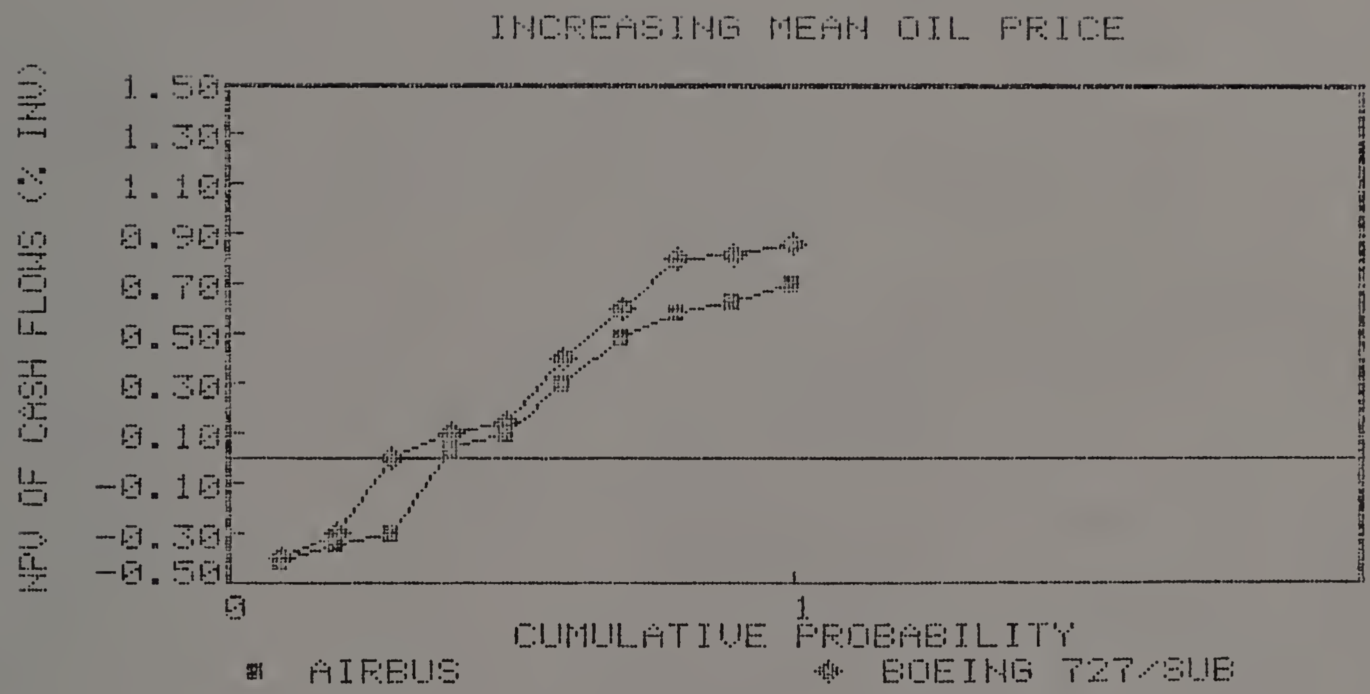

CONSTANT MEAN OIL PRICE
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
AIRBUS
BOEING 727/SUB

Figure 12



INCREASING MEAN OIL PRICE
NPV OF CASH FLOWS (% INV)
1.50
1.30
1.10
0.90
0.70
0.50
0.30
0.10
-0.10
-0.30
-0.50
0
1
CUMULATIVE PROBABILITY
AIRBUS
BOEING 727/SUB

Figure 13

find rather that the Boeing aircraft performs nearly as well as the Airbus and neither dominates, but as we suspected, the new technology airplane that we adopt in year three does dominate the Airbus aircraft by first degree stochastic dominance.

In the second scenario, under the assumption of increasing mean oil prices, the situation is very similar to that of the first scenario but here the net result is that the Boeing/substitute alternative dominates by first degree stochastic dominance. This is reported in Figure 13.

Summary

This chapter has been devoted to the demonstration of this capital budgeting model in action. We have shown how it can be used to perform sensitivity analysis and aid in project selection. Both the hypothetical projects and economic scenarios are representative of those likely to be of interest to a decision maker in this industry but, as we have said before, can hardly be considered exhaustive.

While each application in this chapter has revolved strictly around the investment decision, we will in the next chapter briefly identify some additional applications.

CHAPTER V

CONCLUSIONS AND EXTENSIONS

In the previous chapters we have surveyed the literature pertaining to capital budgeting, identified the need for the development of the approach offered here, developed a capital budgeting simulation model for aircraft procurement, and used this model to perform sensitivity analysis across several economic scenarios in hypothetical capital budgeting applications. In this chapter we will discuss the relevance of what we have done, limitations and advantages of this approach and what direction future endeavor in this area should take.

Capital Budgeting and Strategic Planning

The approach proposed within this thesis, it is clear, requires considerable resources to utilize. The justification for such detailed approach begins with the role of capital budgeting in strategic planning.

Lyneis provides us with a definition of strategic planning which is germane to the development in this thesis:

> "Strategic planning is the process of translating corporate objectives into the policies and resource allocations that will achieve those objectives. The process usually entails (1) establishing corporate goals and objectives, (2) assessing likely trends in the economic, political, technical, and competitive environment, (3) identifying potential opportunities and threats, and (4) developing strategies, policies, and resource allocations to cope with the threats and take advantage of opportunities."

The connection between this definition of strategic planning and capital budgeting should be obvious. Capital budgeting is one of the firm's principal means of resource allocation. It deals with the most important of all corporate decisions, the investment decision. Capital budgeting is, therefore, a principal implementation tool of strategic planning. Capital budgeting embodies strategic planning for the investment decision.

For capital budgeting to be an effective device of strategic planning it must relate to the elements of strategic planning. Given the elements as outlined by Lyneis above, we will now contrast the approach presented in this thesis with standard capital budgeting approaches to demonstrate that this approach is more consistent with true corporate strategic planning.

The first element deals with the establishment of corporate goals and objectives. Capital budgeting, as an effective tool of strategic planning, must be able to evaluate alternative investment opportunities in light of these goals and objectives. Standard capital budgeting procedures generally, and almost exclusively, will allow for the consideration of a project on its merits alone. As long as corporate objectives are expressed in terms of individual project performance this should not present a problem. If, however, as is more likely, corporate objectives are expressed in terms of aggregate performance of all or many projects it is necessary that we be able to compare projects in a portfolio context. The distributional approach for project assessment, as proposed here, is eminently adaptable to this project portfolio evaluation. The probability distribution of cash flows for each project within a firm can and should be aggregated to form a lower variance cash flow profile that more accurately portrays the net result of several corporate projects. As will be discussed later, this is a principal extension of this approach.

The second element of strategic planning as outlined by Lyneis involves the identification of economic and other trends that impact on corporate performance. It is here that this approach provides a significant improvement over all other approaches to capital budgeting. Other approaches, most notably those utilizing the CAPM, rely strictly on ex post data concerning the cash flows themselves. There is no means by which the sensitivity of the cash flow estimates to changes in exogenous economic factors can be assessed. This approach centers on the inclusion of these economic factors into the model and can, therefore, be effectively used to perform sensitivity analysis utilizing expected or potential trends in these factors as well as determining the impact of possible or likely economic scenarios.

Akin to the first two elements a third element entails the identification of possible threats or pitfalls and possible opportunities. In the capital budgeting approach here, these pitfalls or opportunities will surface through the implementation of sensitivity analysis, and as dictated by element five, strategies can be developed to avoid threats and take advantage of opportunities. In the capital budgeting context, taking advantage of opportunities is synonymous with project adoption whereas avoiding threats or pitfalls can either be accomplished through project rejection or development of a hedging strategy to negate the effects of the potential threats.

The methodology presented in this thesis, therefore, renders capital budgeting as an effective tool of strategic planning.

Other Capital Budgeting Applications

We have limited the demonstration of this methodology to capital budgeting applications in the commercial airline industry. This has been done both due to the complexity of this particular decision as well as the availablity of pertinent data. More importantly, the airline industry today, is an industry "under the gun." That is, increased competition, especially since airline deregulation in the fourth quarter of 1978, and extreme sensitivity of profits to economic variables (eg. fuel prices) have caused the industry to begin to employ a greater degree of analysis in areas such as capital budgeting.

Applications of this methodology in other industries are certainly appropriate, and in many cases would require only a minor adjustment to the approach derived here. At this point, we will discuss under what conditions such a capital budgeting approach is beneficial and/or appropriate.

As we have seen, the essence of this approach has been to link cash flow estimates to underlying econometric factors. This is required data, and in some cases, projections relevant to these factors. The inclusion of these macro econometric variables facilitated two needs. First, it allowed for the determination and modeling of the interdependencies of cash flow micro factors. Second, it allowed for the use of sensitivity analysis involving alternative assumptions concerning these economic factors. The desirability of this approach is greatly enhanced by the need to conduct such sensitivity analysis.

The key to choosing this methodology over others then, lies in the existence of a dynamic interplay of underlying cash flow determinants. In situations where the net present value of a proposed project is highly dependent upon such a dynamic interplay this approach presents the only means by which the true project risk exposure can be measured and compared.

Applications Beyond Capital Budgeting

The thesis at hand deals exclusively with a simulation approach to capital budgeting and reference has been made to the importance of the investment decision. While not to be developed here there are very similar simulation applications to corporate decision making beyond the capital budgeting process.

The first of these additional applications pertains to strategic planning in a more general sense than we have addressed. Specifically, a simulation approach can be instrumental in the process of policy design. That is, rather than being used to aid in the making of an individual decision, such as a capital budgeting decision. This simulation approach could be expanded to aid in the development of the general rules of how decisions will be made. For example, capital budgeting policy may state that only projects representing a net present value in excess of a given amount will be considered for possible budgeting. A simulation model may be utilized to derive the net effect of such a policy on corporate performance. Based upon the evaluation of the results of many possible policies, that policy which consistantly achieves the goals of the organization can be adopted and will institutionaly facilitate future capital budgeting decisions.

Another potential application, in an approach similar to the one presented here, is the modeling of labor policies. By this I mean that alternative labor implementation strategies may be applied to virtually any production process. Most production cycles are examples of Markov processes. As such, they lead themselves to a simultaneous simulation approach as presented here.

Deriving the proper mix of labor to equipment at each stage in the production process while maintaining consistency with the requirements of modern labor practices (such as limits on hours per worker, per day and skilled mismatch) could be nearly as complex an issue as the one derived here. A simulation model could allow for capturing the stochastic nature of this human element as well as allow for sensitivity analysis of the entire complex system. As a further extension of this application attention could be turned to the substitution of robotic devices for labor at various points and the net result of these decisions could be modeled.

Areas For Further Development

This thesis has broached the periphery of an area that is ripe for further development. The interesting issues that follow can only be developed given a previously derived simulation model such as the one presented here. This thesis then provides the basis for what I consider to be an exciting and innovative advance in the financial management of the firm. The areas for development that follow should be considered illustrative rather than exhaustive.

Diversification Strategies

Reference has been made to the opportunities that this approach provide for viewing capital budgeting projects in a portfolio context through project diversification strategies. The need for such strategies has been from time to time brought into question. The argument has been made that shareholder wealth can better be achieved through diversification of the shareholder's portfolio rather than through the diversification of corporate capital projects. The fallacy of such an argument lies with the assumption, though a standard one, that managers seek exclusively to maximize shareholder wealth. A manager who adopts a "boom or bust" capital budgeting approach is not likely to remain in the favor of the shareholders for whom he works.

There are developments in this area that when explored would provide insights not previously attained. The first of these, which has been previously mentioned deals with the ability, through this distributional approach, to view a newly adopted or proposed project in the context of how it alters the portfolio of all corporate projects. Gained from this vantage point, would be recognition of the impact of alternative risk exposure. That is, a project which viewed separately might carry a seemingly high risk exposure but when viewed in a portfolio context offer diversification to total project risk and a higher net contribution to the firm than a project with seemingly better individual risk exposure.

Hedging Strategies

Perhaps more interestingly, this thesis can easily be expanded to incorporate the possible impact of both futures and options on the distribution of project cash flows.[8] In many situations, the one presented here for example, the risk associated with future cash flows can be very closely linked to the risk of phenomenon for which there are available, in the security markets, hedging instruments. Such elements that we have dealt with in this thesis are oil prices and interest rates. A simulation model is a most appropriate device to allow for the study of the impact of such hedging strategies on the capital budgeting process.

While generally considered to be a short-term strategy (while diversification is considered long-term), hedging does have some applications in long-term risk

[8]Bookstaber has developed a simulation model for deriving the impact of alternative hedging strategies utilizing options and futures. His approach is compatible with the one here.

structuring. Both offer fertile ground for future endeavor.

Decision Support Systems

The methodology offered here has entailed the retrieval of ex post data on economic and industry variables, the development and subsequent application of an economic model, the Bayesian adjustment of economic trends and the simulation of project cash flows. The approach might well appear to require resources and time beyond that which would likely be dedicated to a capital budgeting decision. The true efficacy of this approach lies in the potential to adopt it to a computer decision support system.

The term decision support system is a relatively newly coined phrase in computer applications. The concept is currently the object of much interest in many business circles, with finance slowly emerging as one of them. The concept entails the collection, in one package of required data, a data base management system (DBMS), models of analysis and ancillary input and output options (here, to conduct Bayesian adjustments and output risk profiles). The desired result is a software package which enables the manager to harness sophisticated simulation and modeling techniques to aid in analysis without the previously incumbent difficulties of retrieval and implementation.

A model such as the one developed here could be utilized within a decision support system which would draw, from a data base, data required for development of the structural model, determine the structural relationships among variables, allow for inputs of subjective estimation of economic scenarios from the decision maker and conduct simulations as conducted here. The ease by which this process could be carried out within a decision support system makes an analysis such as the one proposed here easily obtainable.

Currently, the major limitation to the implementation of a simulation model of this nature to a decision support system lies in the limited cycle time for existing microcomputers. This limitation is at the present time being nullified. Interesting new developments in both the decision support software and microcomputer hardware make this an exciting possibility. The next several years we will see many decision support systems emerge to assist in business decision making. Capital budgeting should soon be among this set.

Conclusion

For most firms today capital budgeting is among the most important decision facing the financial manager. The standard capital budgeting approaches offered by financial texts can provide a rational framework for such decisions. In many cases, however, a firm or an industry may be subject to such great cyclical variations or sensitivity to economic parameters that standard capital budgeting approaches do not allow for the incorporation of enough information pertinent to the decision. For such situations a capital budgeting approach is needed that will incorporate these economic parameters as well as allow for sensitivity analysis through these parameters. The simulation model presented in this thesis provides such an operational management tool. A tool needed but not currently available in industries such as the chosen commercial airline industry.

This model has been based on relationships derived through analysis of standard econometric data as well as industry specific data. It includes elements of both econometric modeling and Monte Carlo simulation and employs stochastic dominance as the decision criterion while using graphical output as an additional decision aid.

While under the proper conditions, this approach, as presented here, is useable and potentially important as a capital budgeting tool, this is not the primary importance of the innovation of this thesis. More important is the potential for these ideas to be carried further in two separate directions. First, this model, as it exhists, provides the framework in which to analysis diversification strategies offered by options and futures and project portfolios. Second, this approach offers an application for computer hardware and decision support system, software currently under development. As a decision support system, this approach could provide the manager with a superb tool of analysis in situations such as those described above.

As with any operational development in finance or other areas of business administration the importance of this innovation can only be measured when others choose to utilize it. It is my hope that the importance of this contribution will soon be measured.

SELECTED BIBLIOGRAPHY

1. Ang, J.S.and W.G. Lewellen, "Risk Adjustment in Capital Investment Project Evaluations," Financial Management, Summer, 1982, pp. 5-14.

2. Barnes, J.W., C.D. Zinn and B.S. Eldred, "A Methodology for Obtaining the Probability Density Function of the Present Worth of Probablistic Cash Flow Profiles," AIIE Transactions, Sept. 1978, pp. 226-236.

3. Bawa, V.S., E.B. Lindenberg and L.C. Rafsky, "An Efficient Algorithm to Determine Stochastic Dominance," Management Science, Vol. 25, No. 7, July 1979, pp. 609-622.

4. Ben-Shahar, H. and F.M. Werner, "Multiperiod Capital Budgeting Under Uncertainty: A Suggested Application," Journal of Financial and Quantitative Analysis, Vol. 12, No. 5, Dec. 1977, pp. 859-877.

5. Bhattacharya, S., "Project Valuation with Mean-Reverting Cash Flow Streams," Journal of Finance, December 1978, pp. 1317-1331.

6. Blatt, John M., "Investment Evaluation Under Uncertainty," Financial Management Association, Summer 1979, pp. 66-81.

7. Bogue M.C. and R. Roll, "Capital Budgeting of Risky Projects with `Imperfect' Markets for Physical Capital," Journal of Finance, May 1974, pp. 601-613.

8. Bonini, C.P., "Capital Investment Under Uncertainty with Abandonment Options," Journal of Financial and Quantitative Analysis, Vol. 12, No. 1, March 1977, pp. 39-54.

9. Bower, R. and D. Lessard, "An Opperational Approach to Risk Screening," Journal of Finance, May 1973, pp. 321-338.

10. Brennan, M.J., "An Approach to the Valuation of Uncertain Income Streams," Journal of Finance, Vol. 28, 1973, pp. 661-674.

11. Broyles, J. and J. Franks, "Capital Project Appraisal: A Modern Approach," Managerial Finance, Vol. 2, No. 2, 1976, pp. 85-96.

12. Chen, A.H.and A.J. Boness, "Effects of Uncertain Inflation on the Investment and Financing Decisions of a Firm," Journal of Finance, Vol. 30, 1975, pp. 18-27.

13. Constantinides, G.M., "Market Risk Adjustment in Project Valuation," Journal of Finance, Vol. 33, 1978, p. 603.

14. Cooley, P.L., R.L. Roenfeldt and It-Keong Chew, "Clarification of Three Capital Budgeting Criteria," The Financial Review, Spring 1977, pp. 20-27.

15. Cox, J.C. and S.A. Ross, "The Valuation of Options for Alternative Stochastic Processes," Journal of Financial Economics, January/March 1976, pp. 145-166.

16. Cozzolino, J.M., "Controlling Risk in Capital Budgeting: A Practical Use of Utility Theory for Measurement and Control of Petroleum Exploration Risk," Engineering Economist, Vol. 25, No. 3, Spring 1980, pp. 161-186.

17. ________________,"A New Method for Risk Analysis," Sloan Management Review, Spring 1979, pp. 53-65.

18. Dothan, U. and J. Williams, "Term-Risk Structures and the Valuation of Projects," Journal of Financial and Quantitative Analysis, November 1980, pp. 875-906.

19. Fama, E.F., "Risk-Adjusted Discount Rates and Capital Budgeting Under Uncertainty," Journal of Financial Economics, Vol. 5, No. 1, Aug. 1977.

20. Findlay, M. C. III, "Capital Budgeting Procedures

Under Inflation: Cooley Roenfeldt and Chew vs. Findlay and Frankle," Financial Management, Vol. 5, No. 3, Autumn 1976, pp. 83-90.

21. Fielitz, Bruce D. and Frederick L. Muller, "The Asset Allocation Decision," Financial Analysts Journal, July/August 1983.

22. Forrester, J.W., Principles of Systems, MIT Press Cambridge, Massachusetts, and London, England, 1968.

23. Fourcans, A and T. J. Hindelang, "Capital Investment Evaluation for the Multinational Firm," Omega, Vol. 3, No. 6, Dec. 1975, pp. 689-697.

24. Francis, J.C. and D.R. Rowell, "A Simultaneous Equation Model of the firm for Financial Analysis and Planning," Financial Management, Spring 1978, pp. 29-44.

25. Fuller, R.J. and S.H. Kim, "Inter-Temporal Correlation of Cash Flows and the Risk of Multi-Period Investment Projects," Financial Management, Vol. 6, No. 3, Fall 1977, pp. 66-71.

26. Gehr, A.K. Jr., "Risk-Adjusted Capital Budgeting Using Arbitrage," Financial Management, Vol. 10, No. 5, Winter 1981, pp. 14-19.

27. Gentry, J.A., "Simulation Revisited," Decision Sciences, Vol. 4, April 1973, pp. 572-574.

28. Gitman, L.J. and J.R. Forrester Jr., "A Survey of Capital Budgeting Techniques Used By Major U.S. Firms," Financial Management, Vol. 6, No. 3, Fall 1977, pp. 66-71.

29. Hagerman, R.L. and E.H. Kim, "Capital Asset Pricing with Price Level Changes," Journal of Financial and Quantitative Analysis, Vol. 11, No. 3, Sept. 1976. pp. 381-391.

30. Hastie, K.L., "One Businessman's View of Capital Budgeting," Financial Management, Winter, 1974, pp. 36-44.

31. Haugen, R.A. and D.W. Wichern, "The Elasticity of Financial Assets," Journal of Finance, Vol. 29, No. 4, Sept. 1974, pp. 1229-1240.

32. Hertz, David B. and Howard Thomas, Risk Analysis and Its Applications, 1983 and also 1964.

33. ________________, "Risk Analysis in Capital Investment," Harvard Business Review, January/February 1964, pp. 95-106.

34. House, W.C., "Sensitivity Analysis in Making Capital Budgeting Decisions," Research Managraph No. 3 (New York = National Association of Accountants), 1968.

35. Jane's All the World's Aircraft, Janes Publishing Company, London, England, 1983-84.

36. Kalymon, B.A., "Methods of Large Project Assessment Given Uncertainty in Future Energy Pricing," Management Science, Vol. 27, No. 4, April 1981, pp. 377-395.

37. Keown, A.J. and B.W. Taylor III, "A Chance-Constrained Integer Goal Programming Model for Capital Budgeting in the Production Area," Journal of the Operational Research Society, Vol. 31, No. 7, July 1980, pp. 579-589.

38. Kim, M.K., "Inflationary Effects in the Capital Investment Process: An Empirical Examination," Journal of Finance, Vol. 34, 1979, pp. 941-950.

39. Kmenta, Jan, Elements of Econometrics, Macmillan Company, New York, 1971.

40. Lee, C.F., Financial Analysis and Planning, New York: Addison-Wesley, 1983.

41. Lee, S.M. and P.L. Olson, "Consideration of Variance in Capital Budgeting Optimization Models with Multiple Objectives," AIIE Transactions, Fall 1981, pp. 281-287.

42. Lewellen, W.G. and M.S. Long, "Simulation Versus Single-Value Estimates in Capital Expenditure Analysis," Decision Sciences, Vol. 3, October 1972, pp. 19-32

43. Lockett, A.G. and A.E. Gear, "Multistage Capital Budgeting Under Uncertainty," Journal of Financial and Quantitative Analysis, Vol. 10, No. 1, March 1975, pp. 21-36.

44. Lyneis, James M., Corporate Planning and Policy Design: A System Dynamics Approach, MIT Press Cambridge, Massachusetts and London, England, 1980.

45. Makridakis, Spyros and Steven C. Wheelwright, "Forecasting and Organization's Futures," Handbook of Organizational Design, 1980, pp. 122-138.

46. McKeon, J.M. and N. Hassan, "Capital Budgeting Into the 1980's," Baylor Business Studies, Vol. 13, No. 1, February/March/April 1982, pp. 17-30.

47. Myers, S.C., "Interactions of Corporate Financing and Investment Decisions: Implications for Capital Budgeting," Journal of Finance, Vol. 29, 1974, pp. 1-25.

48. Myers, S.C. and S.M. Turnbull, "Capital Budgeting and the Capital Asset Pricing Model: Good News and Bad News," Journal of Finance, Vol. 32, No. 2, May 1977, p. 321.

49. Naylor, Thomas H., Joseph L. Balintfy, Donald S. Burdick and Kong Chu, Computer Simulation Techniques, 1966.

50. Norgaard, R. and T. Killeen, "Expected Utility and the Truncated Normal Distribution," Management Science, Vol. 26, No. 9, Sept. 1980, pp. 901-909.

51. Oakford, R.V., A. Salazar and J.R. Lohmann, "Mathematics, Computation and Practical Capital Budgeting Decisions," AIIE Proceedings, 1982 Conference, May 23-27, 1982, pp. 118-129.

52. Osteryoung, J.S. and R.L. Roenfeldt, "A Recon-

ciliation of the Capital Asset Pricing Model With Traditional Risk Measurement Techniques for Capital Budgeting Decisions," Annual Meeting of the Eastern Finance Association, April 1974, pp. 64-65.

53. Park,C.S. and G.J. Thuesen, "The Effectiveness of Using Uncertainty Resolution to Measure Investment Flexibility in Sequential Capital Rationing," AIIE Transactions, Vol. 11, No. 3, Sept. 1979, pp. 207-220.

54. Perrakis, S., "Certainty Equivalents and Timing Uncertainty," Journal of Financial and Quantitative Analysis, Vol. 10, No. 1, March 1975, pp. 109-118.

55. Petty, J.W. and O.D. Bowlin, "The Financial Manager and Quantitative Decision Models,"Financial Management, Winter 1976, pp. 32-41.

56. Pinches,G.E., "Myopia, Capital Budgeting and Decision Making," Financial Management, Vol. 11, No. 3, Autumn 1982, pp. 6-19.

57. Pindyck, R.S. and D.L. Rubinfeld, Econometric Models and Economic Forecasts, McGraw-Hill, Inc., 1981.

58. Porter,R.B. and R.P. Bey, "The Development of a Mean-semivariance Approach to Capital Budgeting," Journal of Financial and Quantitative Analysis, Vol. 10, No. 4, November 1975, pp. 639-649.

59. Porter, R.B. and K. Carey, "Stochastic Dominance as a Risk Analysis Criterion," Decision Sciences, 1974, pp. 10-21.

60. Rendlemen, R.J. Jr., "Ranking Errors in CAPM Capital Budgeting Applications," Financial Management, Vol. 7, No. 4, Winter 1978, pp. 40-44.

61. Ross, S.A., "A Simple Approach to the Valuation of Risky Streams," Journal of Business, Vol. 51, 1978, pp. 453-476.

62. Rubinstein, M., "Valuation of Uncertain Income Streams and the Pricing of Options," Bell Journal

of Economics, Autumn 1976, pp. 407-425.

63. Rubenstein, M., "A Mean Variance Synthesis of Corporate Financial Theory," *Journal of Finance*, March 1973, pp. 167-181.

64. Schmalensee, R., "Risk and Return on Long-Lived Tangible Assets," *Journal of Financial Economics*, Vol. 9, No. 2, June 1981, pp. 184-205.

65. Shackle,B.L.S., *Decision, Order and Time in Human Affairs*, Cambridge: Cambridge University Press, 1969.

66. Smidt,S., "A Bayesian Analysis of Project Selection an of Post Audit Evaluations," *Journal of Finance*, Vol.34, No. 3, June 1979, pp. 675-688.

67. Spahr,R.W., "Basic Uncertainty in Capital Budgeting: Stochastic Reinvestment Rates," *Engineering Economist*, Vol. 27, No. 4, Summer 1982, pp. 275-289.

68. Sundem,G.L., "Evaluating Capital Budgeting Models in Simulated Environments," *Journal of Finance*, September 1975, pp. 977-992.

69. Thompson, H.E., "Mathematical Programming, The Capital Asset Pricing Model and Capital Budgeting," *Journal of Finance*, March 1976, pp. 125-131.

70. Van Horne,J.C., *Financial Management and Policy*, Englewood Cliffs, New Jersey: Prentice-Hall, 1980.

71. Van Horne, J.C., "The Analysis of Uncertainty Resolution in Capital Budgeting for New Products," *Management Science*, Vol. 15, pp. B-376-386.

72. Treynar, J.L. and F. Black, "Corporate Investment Decisions," in *Modern Developments in Financial Management*, S.C. Myers (ed.), New York: Praeger Publishers (1976), pp. 310-327.

73. Vickers, Douglas, "Real Time and the Choice-Decision Point: A comment on Findlay and Williams' `Financial Theory'," *Journal of Post Keynesian*

Economics, Vol. III, No. 4, Summer 1981, pp. 545-551.

74. ________________, "Uncertainty, Choice and the Marginal Efficiencies," Journal of Post Keynesian Economics,

75. Watson,Hugh J., Computer Simulation in Business, New York: John Wiley & Sons, 1981.

76. Weston, F.J., "Investment Decisions Using the Capital Asset Pricing Model," Financial Management, Spring 1973, pp. 25-33.

77. Westerfield, R., "Uncertainty Resolution and Multi-Period Investment Decisions," Decision Sciences, April 1976, pp. 343-357.

78. Whitmore, G.A. and M. Findlay, (eds.) Stochastic Dominance: An Approach to Decision-Making Under Risk, D.C. Hearth, Lexington, MA., 1977.