# A PROCESS TO ESTIMATE THE VALUE OF A COMPANY BASED ON OPERATIONAL PERFORMANCE METRICS

BY

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**B.S., Kansas State University, 1982**
**M.S., Kansas State University1985**

**AN ABSTRACT OF A DISSERTATION**

**submitted in partial fulfillment of the**

**requirements for the degree**

**DOCTOR OF PHILOSOPHY**

**Department of Industrial and Manufacturing Systems Engineering**
**College of Engineering**

**KANSAS STATE UNIVERSITY**
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**ABSTRACT**

This research shows that industry and company related performance indicators enhance the business valuation process by providing a broader, more encompassing view of overall corporate health and a better understanding of improvement opportunity areas within a company. To incorporate performance indicators in the business valuation process, new methodologies are required to integrate the non-financial and soft data with the typical financial information used in business valuation. This requires a "re-think" of the standard business valuation process and the exploration and application of other methods and analytical techniques.

The results of this research are the definition of a problem type and the development of a new business valuation process. The problem structure has as inputs industry specific performance metrics grouped into three primary areas Production Processes, Products/Services and Marketability and Management, a fuzzy logic model with fuzzy and approximate relationships between performance metrics and financial information and crisp financial information as output. The framework for a fuzzy logic model was developed and is used to approximate relationships and model a non-linear environment. The resulting crisp financial information is then input and integrated into the traditional business valuation process.

The process was demonstrated with an example production company and with data from two regional airlines. A step-by-step example of the process was provided using the production company example to demonstrate how the results are generated and integrated with DCF business valuation. Heuristics to identify areas to improve company performance were described. Two regional airlines, individually and combined, were tested with actual data using the original fuzzy logic model structure and then the original fuzzy logic model structure was revised and new results generated. Tuning the model showed an improvement in the business valuation process performance. The benefits from this research include the definition of a new class of problems and a process to solve

problems of this nature.  The insights gained from this research can be applied in major disciplines such as accounting, business and finance, engineering and decision theory.

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**Approved by:**

Major Professor
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# DEDICATION

*This research is dedicated to my children, Kasey, Kristina and Victor. They have always been and will always be my inspiration.*

# CHAPTER 1
# INTRODUCTION

## 1.1 Introduction

The basic premise of this study is that other industry, company and operating related performance indicators can be incorporated into the business valuation process to enhance the representation of business value and better understand opportunity areas, strengths and weaknesses of a business. Financial numbers alone may not be representative of the operating viability of a company. This can be seen in many of the recent events regarding WorldCom, Enron, etc. Because of this, a broader, more encompassing view of overall corporate health based on both its performance characteristics and financial health should be included in the business valuation process. Some other potential factors that should be assessed and included in the business valuation process are as follows:

- Management and leadership
- Marketing channels and positioning
- Customer service and satisfaction
- Production efficiencies and capacities
- Research and product development
- Product lines and product proliferation

To incorporate this additional information, new methodologies are required to address the non-financial and soft data used to measure these other performance indicators. This requires a "re-think" of the standard process and the exploration and application of other theories and analytical techniques to incorporate non-financial information into the overall business valuation process. Traditional methods have been researched and analyzed to determine their operational procedures, data, strengths and weaknesses. The financial measures used in traditional business valuation are integrated with the performance metrics to form the new valuation process described in this thesis. This additional information enhances the information and decision making capability of traditional business valuation.

The benefits from this research to the academic community include the definition of a new class of problems and a process to solve problems of this nature. The insights gained from this research can be applied in major disciplines such as accounting, business and finance, engineering and engineering management, operations research, engineering economy and decision theory. The process developed uses sound theoretical methodologies to solve practical business problems. This new business valuation process can be used to determine the dollar business value, areas of potential improvement to a company, analyze investment opportunities and to identify the key value drivers that help management understand what areas most impact overall business value.

Business valuation is traditionally based on the financial and monetary representation of a company using a number of financial, economic and accounting based methods. Business valuation processes do not directly measure the performance effects of business practices and operating methods in a company. It is expected that good performance and operating characteristics should lead to better financial performance. It is this belief that has motivated the research described herein.

The purpose of this research is to develop a process for a performance and financial based approach to business valuation. The result is the definition of a problem type and a process that can be used to solve these problems. Additionally, this process is demonstrated with data representing a production company and validated with actual data from the regional airline industry. This new process is used in conjunction with traditional business valuation methods to enhance the process with additional decision making information.

### 1.1.1 Need to Incorporate Financial and Non-Financial Performance Data

Different accounting procedures can lead to different representations of a company value. Although standards do exist, there is latitude regarding the representation of various types of account groupings, inclusions and exclusions, on the published financial statements. One example provided by Rosen [2000] showed that a pension expense of $5 million became a financial statement income of $14 million. The income led to a $9 million "earnings before income tax" which would have been a loss of $10 million. Only by closely reading and interpreting the financial statements did this income become evident. Many examples exist on a smaller and larger scale such as the WorldCom and Enron problems that have grabbed the news headlines [Paris 2004, McGill 2004].

Current methods involve computing a financial dollar value using a given set of financially based computational procedures. These standard procedures typically involve gathering the financial data, manipulating it in different ways, performing the required computations and then developing an overall representation of business value. The comparable companies and asset-based methods do not address forecasting the future to any great degree. If future forecasts are made, such as with the Discounted Cash Flow (DCF) method, these future forecasts are based primarily on historical data. DCF forecasts for the near and far term and can incorporate some adjustments to the cash flows based on the knowledge of such things as product introduction, machine replacements, etc. However, the method does not contain a comprehensive approach to view and incorporate overall operational and strategic performance metrics associated with the company. Financial forecasts based on historical financial data assume that the future will be the same as the past, which in the ever-changing business climate of today, may not be true.

Current financial valuation methods do not address all of the operational and strategic perspectives associated with running a business and valuing business activities. A more comprehensive view of overall value must be incorporated into the valuation process. "Accountants must now determine the true cost of a company's various business activities by establishing the value of a specific business capability-and that includes such things as quantifying the value of contracting out supply chain logistics or human resource management" [Goldman 2002]. New books and literature are being written that focus on value metrics and drivers that are used to determine the overall value of operational parameters in the corporate environment. Operational concepts and metrics are being embraced from a valuation perspective to enhance the representation of overall corporate worth. Said about the success of Wal-Mart and Dell, "Its superior business models, tied very closely to superior business processes, and these value drivers don't appear anywhere on the traditional financial statements" [Millman 2002].

Strategic direction and operational performance are the types of factors that can make the difference between a good company and a great company. Each of the traditionally used business valuation techniques generates a dollar business value. These methods do not incorporate a value for how well a company operates, the vision of the leadership and company strategic direction. To gain a full understanding of the value of a company, these operational and strategic issues need to be incorporated into the overall valuation and business analysis process along with the traditional financial methods. To do this, a process for identifying key issues, gathering data and translating this type of information into a performance driven value of a company is needed. A performance driven valuation process will provide a comprehensive view and understanding of the key business drivers, their cause and effect relationships and how they affect the bottom line value of a company.

### 1.1.2 Need to Use Better Approach to Incorporate Hard and Soft Data in Business Valuation Process

Value drivers are those business activities that impact the performance of a company. Performance metrics quantify the performance of a company in a specific area and can be used to measure those key value drivers identified for a company. Value related activities are not always easily recognized or measured. However, identifying the critical areas that drive company performance and determining means by which they can be measured provide information and insight in operating a company. This performance related information is useful in determining the current and future value of a company. For example, a corporation may have a heavy R&D budget for a number of years to promote new product development. The same company may be upgrading information systems to enhance supply chain integration with suppliers and customers. The company may have also instituted a quality program that will better enhance customer satisfaction in the future. The anticipated improvement in performance as well as the dollars invested in the improvements should be included in business valuation to gain an accurate, overall picture of the current and future value of a company.

The use of additional information in a performance based business valuation process requires the development of a new process that can handle these different types of information. The data may be developed from historical and current performance metrics, anticipated future performance and strategic focuses. Typically, this information must be transformed at some level to represent a financial impact so that it can be incorporated into the resulting dollar based business valuation. To do this, new methods and approaches must be explored and employed to provide the ability to use this valuable information to enhance the business valuation process. The exploration of how to accomplish this combination is a primary result of this research.

Hard and soft data can both be used to represent performance drivers. Benchmarking and performance metrics provide a framework for evaluating a company with hard data. Expert opinions, subjective information, fuzzy data and fuzzy rules can be used to fill in the gaps of information representing operating performance and strategic direction. Non-traditional methods are used to integrate both hard and soft data in the new business valuation process. This new process then provides a broader and enhanced representation of overall corporate value.

New methods employed in the business valuation process must be used so that they accurately represent the key aspects of a corporate operating environment. Understanding key corporate operating characteristics along with engineering economy, business, finance, decision theory, fuzzy logic and operations research tools provide the necessary combination knowledge and tools to formulate this new approach. Through the development of a new process, these business and operational concepts can be integrated together to enhance the field of business valuation.

## 1.2 Background

### 1.2.1 Why is Business Valuation Important?

The purpose of valuing a company is to determine a representation of the overall worth of a business entity. Typically, this representation of the business value is in terms of a dollar value of the business. In this process, an individual or entity assigns a price tag to a business concern using some set of computational procedures. The means by which these computations are made are based on the method selected for evaluating the business. The use of these methods can affect the dollar value computed for the business and the amount of information that is gained from the valuation process.

There are a variety of reasons that a company may be valued. A company may want to acquire a business and determine the price to pay for that business. A company may want to merge with another company to enhance their market position or growth in a given industry or industries. Mergers and acquisitions have grown significantly in the past decade, up from 11,300 mergers in 1990 to 26,200 mergers worldwide in 1998 [Gerchak 2002]. An accurate representation of the overall value of the company is key to ensuring a good, strategic decision was made in the acquisition process. A company may look at selling their business to someone else or liquidating a business and recovering the price of the assets within the business. On a smaller scale, a business valuation may be done to divide assets between individuals owning a business. Stock analysts may also perform a business valuation to determine the overall worth of a business based on the capitalization of stock of a business and the stock prices to determine if they should buy or sell shares of stock in the company. Management of a company may also be interested in valuing their own company as a means to identify key opportunity areas within their company to improve or enhance their operational value and value to the share holders.

### 1.2.2 Applied Business Valuation

Numerous organizations provide training courses and certification in the area of business valuation [Zunitch 2003]. These organizations provide training to enable individuals to receive various certifications to perform business valuations. There are many hundreds of companies that provide business valuation services. These organizations include:

- American Institute of Certified Public Accountants (AICPA)
- American Society of Appraisers (ASA)
- Institute of Business Appraisers (IBA)
- National Association of Certified Valuation Analysts (NACVA)
- Appraisal Foundation

Business literature addresses a wide and varied number of business valuation topics. A sample of these types of topics are listed below:

- The impact of new accounting laws on stock options [Balsam 2003]
- Synergies to look at when combining companies [Loomer 2003]
- Building value in companies and company worth [Jusko 2002, Thompson 2002]
- Industrial facility valuation [Ellsworth 2002]
- Valuing closely held manufacturers [Ellentuck 2002]
- Uniform standards for business valuation [Hutchison 2003]
- A firm's value and strategic competition [Chen 2002]
- Business analysis [Sinnet 2002]
- Brand valuation and valuation methods [Hopelain 2003, Seetharman 2001]
- Valuation measures and building company value [McKinsey 2000]
- Economic simulation of IT projects instead of using ROI [Colkin 2002]

Valuation – Measuring and Managing the Value of Companies [McKinsey and Company, Inc.2000] provided a very good background of both practical and theoretical application of valuation techniques and application as well as other books [Gabehart 2002, Hitchner 2003, Pratt 2000]. Along with traditional methods, new concepts including the importance of key "Value Drivers" and the need for performance driven valuation is discussed in McKinsey and Company [2000].

> "Management has no way to affect financial ratios directly; it can only do so by affecting operating factors… This level of operating detail allows managers to analyze concrete improvement actions."

> "Operational numbers are particularly useful as leading indicators. Financial ratios alone can fail to alert managers that there are problems ahead"

> "Value drivers should be directly linked to shareholder value creation and cascade down throughout the organization."

New methods including "Real Options" analysis was also highlighted in the book by McKinsey as a very promising approach to business valuation.

Valuing a Business [Pratt 2000] provides a comprehensive description of business valuation procedures. Pratt addresses the traditional approaches to business valuation, including highly detailed descriptions of computational procedures.

Business valuation can also be used to enhance stock investments. In essence, purchasing stock is like purchasing a piece of a company. Super Stocks [Fisher 1986] and What Works on Wall Street [O'Shaughnessy 1998] provide an overall perspective of important factors that measure stock value of companies. Both business valuation and stock valuation are interrelated, especially in public companies; therefore, this background provides a framework for understanding stock valuation in the market.

### 1.2.3 Business Valuation Research Issues Broken Down by Discipline

There are four primary areas associated with research in the area of business valuation. The following sections discuss key topics and approaches being used to analyze and develop further enhancements in the area of business valuation. The four primary areas researched included Accounting, Economics, Business and Finance, and Industrial Engineering related topics (Operations Research/Management Science/Engineering).

#### Accounting

In general, the field of accounting carries out the "nuts and bolts" of the business valuation process. Accountants have the knowledge and background to represent corporate value using traditional and well accepted accounting procedures. Typically, business valuators are accountants or Certified Public Accountants (CPAs). Their primary perspective is to represent business value in terms of dollars based on financial statements and other related company information.

Accounting research addresses numerous aspects of business valuation. This includes traditional business valuation methods and basic procedures associated with business valuation. [Paton 1963, Lengua 2003, Liberman 2003, Cercone 2002, Bhjraj 2002, Sloan 2002, Trugman 2002], stock valuation based on relationships between financial and market or industry variables [Engle 2002, Core 2002, Aboody 2002], accounting procedural changes associated e-commerce [Core 2003, Kothari 2002], valuation from a key value driver perspective [Goldman 2002] and the real options approach to business valuation [Anonymous 2002].

Research methods associated with business and stock valuation were based on surveys, analysis, interpretation of laws and procedures, regression analysis and econometric methods which constitute the majority of the research efforts in the field.

## Economics

Business valuation from an economic perspective typically involves identifying industry or economy wide factors that affect various aspects of business performance. Economic studies involve a wide variety of topics and aspects associated with a company and their interaction with the industry [Riley 2003, Dutta 2003, Rajgopal 2003], overall market [Core 2003, Kothari 2003] and market related factors. More detailed studies are also performed based on internal factors associated with a company and identifying relationships between these factors and an output performance variable [Ittner 2002, Balsam 2002, Narayanan 2003].

Traditional economic and econometric business valuation research address current frontiers in financial econometrics and financial engineering [Ghysels 2003]. Option pricing methods were discussed in another article [Bates 2003]. The analysis focused on econometric models and the interpretation of various financial and other variables associated with data. Econometric models were also found within the framework of accounting research.

## Business and Finance

Business and finance addresses business valuation from both a practical and theoretical perspective. These fields tend to use the business valuation information in management and investment decisions. Although theoretical studies are done, the practical use and application of business valuation information is important in these fields [Rosen 2002, Goldman 2002, Thompson 2002, Helman 2002, Lieberman 2003, Hopelain 2003, Loomer 2003].

A sample of topics covered include business valuation fundamentals [Harrison 2003], new rules defining business intangibles [Sinnet 2002], valuing products at the SKU level [Allen 2002], valuation essentials for CFOs were discussed in another article [Evans 2002], comparable company valuation techniques [Hall 2003], problems with current valuation methods and investment decisions [Vocino 2002] and the impact of value metrics vs financial metrics in the overall assessment of a company value [Millman 2002].

Industrial Engineering Related Topics (Operations Research/Management Science/Engineering)

There are a number of aspects of business valuation related to Industrial Engineering. These can be seen in the areas of strategic planning, decision making, fuzzy set theory, business process modeling and optimization, operations management and economic analysis. The unique combination of aspects of the industrial engineering discipline bring together these different components of business operation and business management which can provide a framework for business decision making and ultimately business valuation.

Fuzzy and crisp multiple criteria decision making [Baas 1997, Chen and Hwang 1992, Lee-Kwang 1999, Wang 2003, Yeh 2000, Yen 1994], fuzzy set theory [Bagis 2003, Bilalis 2002, Bojadziev 1997, Chen 1999, Esogbue 1998, Feng 2000, Klir 1995, Klir 1997, Krishnapuram 1993, Pedrycz 2002, Ramik 2002, Smith 2000, Smolikova 2002, Yager 1993, Yager 1995, Yager 1998, Yager 2001, Yager 2002], fuzzy linguistics [Delgado 1993, Delgado 1998, Herrera 1977, Herrera 1996, Herrera 1997, Herrera 2000], dynamic programming [Bellman 1970, Chemachema 2002, Esogbue 1999, Gatev 2002, Kacprzyk 1998, Kacprzyk 1998, Lee 2001, Syau 1999], fuzzy and crisp group decision making [Hwang 1987, Kwok 2003, Lee 2002, MacKinnon 1969, MacKinnon 1973, Marimin 2002], and their associated methods can be used in decision making, strategic planning and corporate management. Fuzzy financial methods have also been defined in areas such as fuzzy finance, fuzzy cost benefit ratios and fuzzy net present values [Buckley 1987, Kahraman 2000]. Tools such as those listed above can be very useful in solving actual business problems. These methods do not deal directly with business valuation, but enhance the decision making process used by management that have an effect on the value of a business and the representation of the business environment.

Operations Research/Management Science/Engineering researchers also address business and stock valuation research concepts. Little research on business valuation has been published in operations research journals. Management Science has addressed business valuation concepts in regards to mergers and acquisitions [Gupta 2002] and bidding strategies [Gerchak 1992]. Engineering Management and Operations Management addressed topics such as bootstrapping financial time series data [Norsworthy 2001], mapping corporate growth opportunities [Anonymous 2003], the effects on the Intranet on corporate value [Azzone 2000], modeling and analyzing the enterprise process for value added activities [Crestani 1998], the impact of human resource management on operation performance [Ahmad 2003], the stock market reaction to mergers and acquisitions [Schusterman 2000] and a study on whether performance is enhanced when general managers and manufacturing managers agree on corporate objectives [Joshi 2003].

Additionally, understanding business process modeling and supply chain analysis provides a framework for understanding the business components and performance aspects that effect overall business value. The essentials of business process modeling and supply chain analysis can lead to the identification of the value drivers in a company [Malone 1999, Koubarakis 1999, Yu 1993, Zxetie 2003, Hauser 1998Burgelman 1996, Georgakopoulous 1995, Ettlie 1998, Grover 2003, Joines 2000, Chan 2002]

A new approach to business valuation, called Real Options, is based on the application of option pricing to determining the value of companies. Real Options is a new concept associated with business and investment evaluation and incorporates uncertainty into the overall valuation process and investment making decision process. Engineering economists have addressed this concept as well as the business and engineering management related fields. Examples of topics addressed regarding Real Options include:

- New product development [Jagle 200 1999]
- CPA's using real options [Anonymous 2002]
- Financial profession use as a "cutting-edge" tool [Kautt 2003]
- Convergence of valuation techniques for dot-coms [Oliva 2000]
- Overview of real options techniques [Miller 2002]
- Technical and theoretical modeling using real options [Rhys 2002]
- Introduction and application to R & D [Benninga 2002]
- Real options for quality control charts [Nembhard 2002]
- Real options used in valuing a mining company [Anonymous 2003]
- Statistical physics and their application to real options theory [Voit 2003]
- Retaining value with mergers and acquisitions in mining [Davies 2003]

In summary, current business valuation research covers a variety of topic areas as well as a number of different disciplines. Many of the research areas deal with traditional valuation methods and analysis techniques. Currently, the newest process and model for business valuation is Real Options. In all disciplines, reference is made as to Real Options being the cutting edge and newest opportunity area in business valuation research. Engineers and engineering economists have embraced these concepts and are conducting research in this area to support the application of Real Options in research and practical applications.

## 1.3 Conventional Business Valuation Methodologies

Business valuation is currently performed using three methods or a combination of these three methods. Although other methods exist, these are the readily used approaches. These methods are asset-based valuation, comparable company method and discounted cash flow method. The asset-based valuation method involves estimating the fair value of the assets and liabilities of the company. The comparable company method involves finding publicly traded companies most like the one being appraised and assigning a similar price-to-earnings ratio derived from the comparable companies to the earnings of the companies being appraised. The discounted cash flow method involves estimating future earnings and calculating the present value of that future earnings stream. A new approach, as mentioned previously, using option pricing theory called "Real Options" is gaining popularity and will most likely be used in the future to a greater extent. Each of these methods will be discussed in more detail in the following sections.

### 1.3.1 Discounted Cash Flow Method

The Discounted Cash Flow (DCF) method is based on the idea that company value should be based on its anticipated future economic benefits. In essence, it involves projecting a future stream of income at a discrete time and then a terminal point (or continuing concern value) and then discounting the future stream of earnings back to a present value based on the economic risk associated with the earnings stream. The DCF method provides a net present value representation of the firm based on the projections. Depending on the type of valuation, the economic income could be represented by net cash flow after taxes, gross profits, net operating profits, dividends or other applicable measures from which value is to be assigned for the company.

Obviously, a key in this method is developing the projected future earnings. One must thoughtfully construct the projection of future earnings. These projections include more than historical performance. The economics of the company and the industry must be analyzed and accounted for in the analysis and projections for the future should be made based on a detailed analysis. The projected future cash flow should include factors such as new product development, product life cycles, competition and other value metrics associated with company operation. An assessment of historical performance is necessary. Short, intermediate and long term forecasts are also necessary to develop an adequate representation of the future economic benefits of the company.

The DCF method is heavily used in merger and acquisition situations because the future projections and the discount rate used in the analysis may be specific to the purposes of the merger and acquisition activity. It may be used in other valuation of controlling and non-controlling stock interests as well. Additionally, it may also be used in combination with other methods to determine a weighted average type of valuation. To many, the income approach is core to valuation theory [Pratt 2000].

Data required to use this method is in-depth and detailed. Therefore, in certain situations, such as a hostile takeover or the sale of a closely held firm, an accurate valuation using this method may be difficult.

### 1.3.2 Asset-based Valuation

Most balance sheets and financial statements are represented by cost accounting procedures. In general, cost accounting procedures represent the amount of assets, liabilities and owners equity based on historical data and depreciation. These amounts typically do not represent current fair market value of assets and liabilities if they were to be bought or sold on the open market. Depreciation of assets is used in cost accounting, in theory, to recover the costs of assets, but may understate the current overall value of the company assets. Additionally, in cost accounting, many of a company's most valuable assets may be intangible ones. For example, patents may not be included at all on the balance sheet. The goal of asset-based valuation is to generate a true picture of the accounting axiom "assets minus liabilities equals owners equity."

In this method, all company assets and liabilities are re-valued to a standard value such as fair market value, fair value, intrinsic value or other representations of standard value. Appraisals of all company assets such as machinery, real estate and intangibles are performed to the standard value. Appraisals are also made for the company liabilities. This can be done with analytical procedures for collective revaluation or by individually revaluing the assets of the company. The end result of this analysis is the "owners equity" that results from the standard accounting equation.

This method may be very cumbersome in a large company, revaluing the actual assets etc. Collective revaluation will require assumptions that may also be broad and variable.

### 1.3.3 Comparable Company Valuation

Using the comparable company valuation method, similar companies are used to develop a representation of the value of the company in question. Data are readily available pertaining to 12,000 operating companies and another 4,000 holding companies [Pratt 2000]. Stocks are re-priced daily in the open market to react to the stockholder s perspective associated with company value based on their perspectives of dividends, cash flows and earnings.

Key in this method is using the data available regarding similar companies to develop a ratio/factor/multiple that can then be applied to a financial measure of the company to determine its overall value. The value measure is usually a multiple computed by dividing the price of the guideline company's stock by some relevant economic variable of the company being valued [Pratt 2000]. Some of the economic variables might include net sales, net cash flow, dividends, net income before taxes or others. Different variations of this approach can also be used based on common stock or all invested capital from all stock. Typically this measure is developed on an operating basis, with non-operating items being treated separately. Different time periods can also be used in computing the multiples used for comparable companies.

One of the difficulties with the comparable companies method is that when the financial markets are up, companies may be overvalued and when the financial markets are down, companies may be undervalued. Stock values may not accurately represent the actual value of the company [Hall 2003]. This may result in underestimating actual value of the comparable company. The quality and type of other data available for valuations may drive the need to use this method even in down financial markets.

### 1.3.4 Real Options Business Valuation

Real Options business valuation is based on adapting financial option pricing techniques to the valuation of investment decisions. The Real Options procedure integrates flexibility into the investment model. Real Options analysis is a relatively new field that has been embraced by the four key disciplines studied in this report. From an engineering perspective, engineering economists are developing examples and publishing extensively in this area.

> "An option gives its owner the right (but not the obligation) to buy or sell an asset at a predetermined price (called the strike or exercise price) for a predetermined period of time (called the life of the option). The right to take action is flexibility. Call options give the right to buy, and put options the right to sell. Options can be found on both sides of the balance sheet. Option valuation allows the flexibility of making decisions in the future contingent on new information." [McKinsey 2000]

> "First coined by Myers in 1977, the real options framework views decision makers with the option to invest, grow or abandon a project contingent upon the arrival of new information. The seminal work of Black and Scholes and Merton in 1973 provided a method to properly value options. Their work led to an explosion of research in pricing all derivative products and to the wide acceptance and use of the Chicago Board Options Exchange (CBOE). Using Black, Scholes and Merton concepts, companies are able to utilize financial derivative products to hedge risks unique to their business operations." [Miller 2002]

DCF methods and Real Options can be viewed as complementary decision frameworks. When problems are relatively straightforward with minimal risk, DCF may be the most useful tool. When there is uncertainty or risk in the business valuation, Real Options may provide the best tool.

### 1.4 Goals of the Research Effort

The goal of this research effort is to develop a structured, analytical process that can use objective, subjective and/or fuzzy operational and financial metrics to measure the current value of a company. This new process includes important factors that drive success that are not presently incorporated into business valuation models. The process itself provides the ability to identify the condition of a company given the current state and actions of the company and identify key value enhancement areas to improve company operations. The new, improved process is intended for use on a single company or multiple companies within a specific industry.

The process developed in this research provides additional benefits beyond a dollar value representation provided by the current methodologies. These benefits include the following:

- A model driven by performance or value metrics.
- Understanding the key drivers of value in a company and how the improvement of such can impact the underlying corporate value.
- A better assessment and integration of the business operating environment in determining corporate value.

The basic hypothesis of the research is as follows:

> The development of a business valuation approach using operational and strategic metrics along with current business valuation methodology will result in an improved process to calculate corporate value and understand how operational and strategic activities can impact corporate value.
>
> Assumption: An improved process is a process, which is based on the appropriate use of theoretically sound methods and tools and provides additional information beyond the traditional methods to enhance decision-making.

The tests of success of the model will be in achieving the following:

- The ability to generate a financial representation of company value linked to the key value drivers and performance metrics.

- A reasonable estimate of business value related to estimates with other methods.
- Performance metrics that show management where operations, marketing, etc. can improve to increase the overall business value.
- A methodology to determine where additional resources can be invested to improve corporate value.

Methods to demonstrate that these objectives are met involve selecting a sample industry, developing performance assessment parameters for the industry and applying this process to a specific company. Historical information is used to determine whether using this process and model would have improved the decision-making process and value of the specific company. Other companies within the industry are also tested to develop a representative set of potential companies and business valuation and assessment results. The results are judged on both an objective (statistical, decision theory) basis and subjective basis to determine the model's overall benefit. The following sections highlight some of the key contributions of the research effort.

## 1.5 Thesis Contributions

This thesis presents a new and unique process for business valuation. The contributions of this research include the definition of a new type of problem, a process for solving these types of problems, extension of current methods to include this new process within the framework of traditional business valuation, enhanced information in the business valuation process and a structured approach to comparing businesses and business models. Data providing additional information and insight is used to translate performance metrics into financial data. The new information provided in the process provides additional insight into corporate decision-making.

### 1.5.1 New Problem Definition and Process for Solving Problem

A new type of problem has been defined as part of this research. This new problem consists of the definition of performance based metrics and the process by which they are translated to financial information. The problem definition has a new and unique structure which is driven by the type of problem being solved and the approach by which a solution is developed.

The problem structure is broken down into a number of components.

- Performance metrics and decision criteria for major criteria (Production Processes, Product/Services and Marketability, and Management)
- Performance scoring for major criteria using Multiple Criteria Decision Making
- Fuzzification of major criteria with membership functions and linguistic representation
- Aggregation of major criteria and linguistic variables using production rules
- Defuzzification of output into financial information

In this research, this new problem definition and process is being used to perform business valuation. This same problem structure and process could also be applied in a number of different areas. Situations where performance metrics are related to output profits or costs can be formulated into this type of problem and solved using the process described in this research.

### 1.5.2 Extends Current Methods to Utilize Performance Metrics to Determine Value

A primary result of this research effort is to provide a sound approach to using both performance metrics and financial information to expand the types of information used in the business valuation process. A new process was developed to integrate non-financial information with financial information and result in a dollar representation for a business that can be used in the decision making process. Furthermore, the proposed business valuation method is able to incorporate objective, subjective and fuzzy data all in one model. The business valuation process requires that new approaches and techniques be used to integrate these different types of information. Fuzzy set theory is used to support the use and integration of these different types of information into a single overall process. Both operational and financial information then form a complete representation of overall business value.

Because of the types of information gathered and the form in which it is used, decision makers are able to assess the overall impact of various operational and strategic changes on business value. The use of operational and business performance information in this process provides the ability to look at changes to company operations from a strategic perspective and to use this process as a tool to determine the impact of these changes on the value of the business. Overall, this research uses what exists in the current methods and extends and enhances those methods with additional performance information.

### 1.5.3 New Information for Enhanced Valuation Methodology

This business valuation process was developed to use operational performance information in the business valuation process. These business performance characteristics are linked to the dollar value of the company. This additional information provides a comprehensive picture of the performance and financial well being of a company. The additional information captured in this process expands the information used in the business valuation process, which then enhances the decision-making capabilities of the company or those using the valuation information.

Linking performance metrics to corporate value can facilitate identifying operational procedures that enhance the current and future value of a company. This type of functionality has been incorporated into the process to aid decision makers as well as business valuators. The process is structured to determine the impact on overall corporate value if enhancements to performance areas were made. Decision makers can then test strategic decisions, perform what-if analysis and determine the overall impact of these decisions on current and future corporate value.

### 1.5.4 Use of New Methods in Business Valuation Process

Soft data, either in the form of opinion or estimates, can enhance the information that is used in the decision making process. Many times decisions are based on gut feel or corporate experience. Providing a structured way to capture this type of soft data helps define the information used in the decision process and capture this information for future use and decisions. The process described in this dissertation uses fuzzy set theory as a foundation to capture and integrate this information into the overall business valuation process. Fuzzy set theory enables the use of information beyond traditional crisp information when analyzing a company and in the making management decisions to determine ways that a company can be improved.

To date, it is not apparent that fuzzy set theory has been used in the business valuation process. This is a new and unique application of this technology in an environment that has much vague information. Additionally, fuzzy set theory has not been used in the framework of this type of overall business model assessments. The use of fuzzy set theory and the combination of fuzzy set theory with other methodologies such as multiple attribute decision making enhances the real world representation of the company being valued.

### 1.5.5 Structured Approach to Compare Business Models

The performance metrics and assessment criteria used in the process are developed so that they are industry specific. A single company or multiple companies within a specific industry can be compared and evaluated. Since the performance metrics contain operational, strategic and financial information, the assessment framework provides a means to compare business models as defined by these terms also.

## 1.6 How This Research Fits Into Current Business Valuation Processes

The intent of this research is not to replace the traditional methods of business valuation, but to enhance the process by providing additional information to management and business valuators. Typically, financial information and financial forecasts are used to develop a representation of business value. A traditional approach to business valuation such as the Discounted Cash Flow business valuation method is integrated with the process developed in this research. The business valuation process begins with the traditional financial analysis. Then, the new performance based evaluation is conducted. This evaluation involves using the process developed in this research to predict financial outcomes and conduct corporate analysis based on performance information. The results from the initial financial analysis and the performance-based evaluation are combined using the process developed in this research. The traditional financial evaluation is then continued and completed.

## 1.7 Thesis Organization

Chapter 1 of the dissertation provides introductory, background, goals and contributions of the effort. Chapter 2 discusses the theory and methods used in this research effort. Chapter 3 provides a general description of the new problem definition and an overview of the process. Chapter 4 provides a detailed description of the process and a general example of the process applied to a sample production company. Chapter 5 applies the process to two individual regional airlines and then applies the process to the two regional airlines combined. Both the initial model structure and a revised model structure are used in these examples with actual data. Chapter 6 discusses the results, conclusions and the contributions of this research as well as future research that can be performed in this area.

# CHAPTER 2
# OVERVIEW OF METHODOLOGIES USED IN RESEARCH

## 2.1 Methodologies Used in Model

The framework and assessment process uses existing and emerging theories and techniques and integrates them together in a unique way to form the new business valuation process. Overviews of the methodologies are given here to provide a framework to understand the theories and concepts behind this research effort. Each topic discussed is used, in part, in the development of the results of this research effort. Sufficient but not extensive information is given under the various topics to address key aspects of the concepts. Methodologies discussed in this chapter include the use of decision criteria in multiple criteria decision making, key performance indicators (KPIs), benchmarking, Multiple Attribute Decision Making (MADM), the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), fuzzy set theory, definition and operations on fuzzy sets, fuzzy numbers, constructing fuzzy sets, fuzzy logic, defuzzification methods, Discounted Cash Flow (DCF) business valuation process and the company and industry selection process used in this research.

### 2.1.1 Decision Criteria, Key Performance Indicators and Benchmarking

The concepts behind the development of decision criteria and key performance indicators and use of benchmarking form the business evaluation framework used in this model. A concept called the value creation index is also reviewed for its applicability in this effort. The development of these measures is vital because they form the basis for business model evaluation for a specific industry and companies within an industry. These measures are based on the combination of these different concepts or bodies of work found in literature and practice. Each of these are briefly described in this section.

#### 2.1.1.1 Decision Criteria Used in Multiple Attribute Decision Making

Multiple Attribute Decision Making (MADM) refers to making decisions in the presence of multiple, usually conflicting, criteria or attributes. MADM problems are common in business decisions, academic research and every day life. "Although MADM can be applied in diverse situations, these problems share some common characteristics:

- Alternatives – There can be several to thousands of candidate solutions to consider in a problem.
- Multiple Attributes – Each problem has multiple attributes or criteria. (An attribute is the criteria upon which a decision is made e.g., reliability, cost, weight, etc.) The number of attributes can be from several to a very high (hundreds) number, which are used to evaluate the candidate alternatives. These can be major criteria or there can be a hierarchy of sub-criteria used in a tree structure for evaluation.
- Conflict among attributes – The multiple attributes usually conflict, where reducing one attribute may improve another attribute of an alternative.
- Incommensurable units – Each attribute has different units of measure that are not the same.
- Decision weights – Not all attributes are equally important and must be assigned a different priority.

The goal of the MADM problem is to identify the alternatives that perform or score best (or in some cases for eliminating alternatives, score worst) from the given set of alternatives." [Chen and Hwang 1992]

The hierarchical structure of a MADM problem will be used as a basic structure in this business modeling process. Major criteria and sub-criteria for evaluating the performance of a company or companies in a specific industry will be evaluated using a hierarchical structure (See Figure 2.1.1.1-1). The hierarchical structure provides a logical way to group similar operational areas and its performance indicators. Each industry is different and will have a different set of hierarchical evaluation criteria and the importance of these criteria may differ. A typical MADM problem results in a selection or scoring of an alternative or ranking of a group of alternatives based on the evaluation of the alternative across all of the decision criteria in the hierarchy. These decision criteria may not all be equal and can be weighted differently.

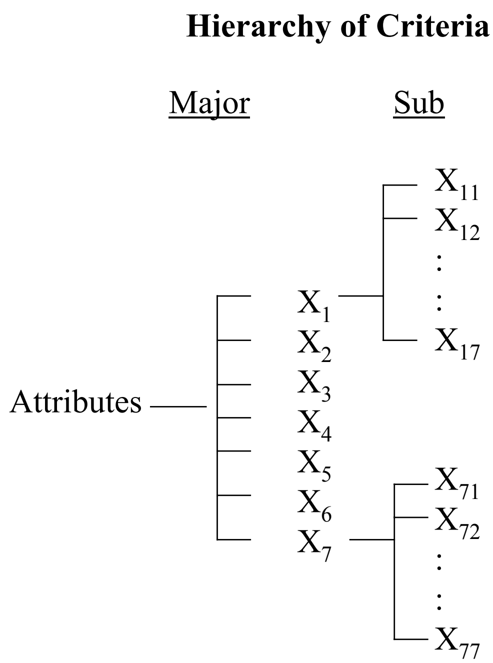



Figure 2.1.1.1-1. Example of Criteria Hierarchy

2.1.1.2 Key Performance Indicators

Large amounts of data are typically collected within a company or organization. Most organizations use less than 10 percent of all the data they collect. Typically, only five to seven percent of the people who could use this data have access to it (source Giga Information Group) [Joiynt 2002]. Industry is moving towards delivering this information to the individuals within the organization in the form of what is being called Key Performance Indicators, a balanced scorecard or a dashboard to provide to individuals data that measures and indicates the levels of performance in various areas of a company.  Approximately 50% of Fortune 1,000 companies in North America and about 40% in Europe use a version of the balanced score card, according to a recent survey by Bain & Co.  [Gumbus 2002].  Key performance indicators are the performance measures at various levels of a company and a balanced scorecard is used to provide detailed or rolled up information to various functions and individuals within a company. A dashboard provides a visual view of key performance indicators being monitored [Wyatt 2004].

These measures create a quantitative view of the business performance and business strategy.  Key performance indicators provide a comprehensive set of [objective and subjective] measures used to communicate and evaluate achievement of an organization's mission and strategy.  [Pineno 2003] Key Performance Indicators used by a company and within an industry, especially those currently being tracked and readily available, can be used as a starting point in the development of decision criteria used in the new business valuation process.

2.1.1.3 Benchmarking

Benchmarking and the use of key performance indicators, a balanced scorecard or a dashboard is similar.  All of these areas identify and quantify different performance characteristics of a company typically within an industry.  Benchmarking differs from the other two concepts because its primary focus is to compare internal performance with external benchmarked performance [Miller 1992].  Key performance indicators (KPIs) are the metrics deemed essential to understanding the operational health of a company. Measuring performance allows an organization to objectively determine what is working and what is not [Skogstad 2004].  The metrics or KPIs established for a benchmarking effort are compared to other companies to determine areas of potential improvement and to identify best business practices in an industry.

PricewaterhouseCoopers' (PWC) survey Trendsetter Barometer interviewed CEOs of 407 product and service companies that were identified in the media as the fastest growing

U.S. business over the last five years. The results suggest that companies who benchmark grow faster and are more productive than their peers. Benchmarking database users have achieved superior performance, with 69% faster growth and an average of 45% greater productivity. On average, these companies had fewer employees and larger annual gross revenues – hitting $160,000 in revenues per employee, versus $110,400 per employee in companies that didn't benchmark [Colman 2002].

The American Productivity and Quality Center (APQC) spent ten years developing a high-level, industry-neutral business model called the APQC Process Classification Framework℠ (PCF) that can be used in benchmarking efforts from a cross-industry perspective (http://www.apqc.org). APQC provides one source for performance criteria. Books, industry organizations, companies performing benchmarking services, government data and many other sources of information can be used to develop the hierarchy of criteria.

Those involved with benchmarking must avoid having a "one-size-fits-all" approach, which may not identify specific operating philosophies within a company. Not all types of "best practices" are "best practices" for all companies. Benchmarkers must be careful though, to analyze the best practices of others in light of their own culture and circumstances, or they may find that their efforts do more harm than good [Stauffer 2003]. Metrics should be tailored to capture data that is readily available across an industry.

Some sources for benchmarking are easily found while others may be difficult because some companies are not willing to share information. Benchmarking data are available to the public or can cost tens of thousands of dollars for access. Following are some potential sources for benchmarked data:

1. Industry trade associations
2. Malcolm Baldridge and other Quality Awards where the recipient is obliged to share practices

3. American Productivity and Quality Center of Excellence
4. Informal networks of companies that practice benchmarking
5. Companies providing services for benchmarking in various industries. Examples include PricewaterhouseCoopers, Industry Weekly, Performance Measurement Group, the Benchmarking Network, Manufacturing Performance Institute, Best Manufacturing Practices of the Department of Defense and many others (web site listings).

Decision criteria, key performance indicators, the balanced scorecard, dashboards and benchmarking have merit and can be used independently to achieve their specified intent.

#### 2.1.1.4 Value Creation Index

A comprehensive study performed by Cap Gemini Ernst & Young researchers, Wharton School of the University of Pennsylvania and Forbes ASAP developed a rigorous, comprehensive model of value creation for progressive companies, one that would enable them to measure the impact of key non-financial intangible assets. Through regression analysis and other statistical techniques, the researchers assessed the ability of each value-driver category to explain market values beyond what could be measured by traditional accounting of assets and liabilities [Low 2000, Low 2001]. The goal of the research in the Value Creation Index was to provide a means to capture and measure the non-tangible value of a company. Information was weighted and then used to create a Value Creation Index. The major categories used in this analysis were innovation, quality, customer relations, management capabilities, alliances, technology, brand value, employee relations and environmental and community issues.

Forbes ASAP research group then statistically tested and modified their representation of value using the following categories for intangible asset evaluation in the specific area of durable manufacturing in rank order [Baum 2000].

1. Innovation
2. Ability to attract talented employees
3. Alliances
4. Quality of major processes, products or services
5. Environmental Performance
6. Brand investment
7. Technology
8. Customer satisfaction

The Value Creation Index concept provides another view of non-financial criteria and their impact on a company's performance.

### 2.1.2 Multiple Attribute Decision Making - Technique for Order preference by Similarity to Ideal Solution (TOPSIS) [Hwang 1982]

Numerous Multiple Attribute Decision Making (MADM) methods exist which can be used to generate a score based on a number of attributes associated with alternatives. Some of these include methods such as Simple Additive Weighting (SAW), the Weighted Product Method, Technique for Order preference by Similarity to Ideal Solution (TOPSIS). Each of these methods has different computational procedures and merits. In this research, TOPSIS will be used to compute a relative score associated with company performance. The relative score computed by the TOPSIS model will represent the performance of a company, based on the performance level for the input decision criteria. The performance of one company can be compared to other companies or to its own performance over a number of different years.

The basic principle behind TOPSIS is that the chosen alternative should have the shortest distance from the ideal or best solution and the farthest distance from the worst or negative-ideal solution. Alternatives are measured relative to each other. TOPSIS defines an index called similarity or relative closeness to the positive-ideal solution and the remoteness from the negative-ideal solution. The positive-ideal solution is denoted as follows.

$$A^* = (x^*_1,\ldots, x^*_j,\ldots x^*_n)$$

where $x^*_j$ is the best value for the jth attribute among all available alternatives. The combination of all of the best attribute values for each attribute is called the positive-ideal solution. Conversely, the combination of all of the worst attribute values for each attribute is called the negative-ideal solution and is denoted as shown below.

$$A^- = (x^-_1,\ldots, x^-_j,\ldots x^-_n)$$

where $x^-_j$ is the worst value for the jth attribute among all of the alternatives.

The computational procedure is a series of steps based on finding the solution that is closest to the positive-ideal solution and farthest from the negative-ideal solution. These steps are as extracted from [Yoon and Hwang 1995] and are as follows:

*Step 1: Calculate Normalized Ratings for each Attribute.* The vector normalization is used for computing $r_{ij}$, which is given as

$$r_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1..m} x^2_{ij}}}$$

*Step 2. Calculate Weighted Normalized Ratings.* The weighted normalized value is calculated as

$$v_{ij} = w_j r_{ij},\ i = 1,\ldots,m;\ j=1,\ldots,n$$

where $w_j$ is the weight of the jth attribute

*Step 3. Identify Positive-Ideal and Negative-Ideal Solutions.* The $A^*$ and the $A^-$ are defined in terms of the weighted normalized values;

$$A^* = (v^*_1, v^*_2, \ldots, v^*_j, \ldots v^*_n)$$
$$= \{(\max_i v_{ij} \mid j \in J_1) (\min_i v_{ij} \mid j \in J_2) \mid i = 1, \ldots, m\}$$

$$A^- = (v^-_1, v^-_2, \ldots, v^-_j, \ldots v^-_n)$$
$$= \{(\min_i v_{ij} \mid j \in J_1) (\max_i v_{ij} \mid j \in J_2) \mid i = 1, \ldots, m\}$$

where $J_1$ is a set of benefit attributes and $J_2$ is a set of cost attributes.

*Step 4. Calculate the Separation Measures.* The separation or distances between alternatives can be measured by the n-dimensional Euclidean distance. A separation of each alternative from the positive-ideal solution, A*, is then given by

$$S_i^* = \sqrt{\sum j_{i=1..n} (v_{ij} - v^*_j)^2}, \quad I = 1, \ldots, m.$$

Similarly, the separation from the negative-ideal solution $A^-$, is given by

$$S_i^- = \sqrt{\sum j_{i=1..n} (v_{ij} - v^-_j)^2}, \quad i = 1, \ldots, m.$$

*Step 5. Calculated Similarities to Positive-Ideal Solution.*

$$C_i^* = S_i^- / (S_i^- + S_i^*)^2, \quad I = 1, \ldots, m.$$

Note that $0 \le C_i^* \le 1$, where $C_i^* = 0$ $A_i = A^-$, and $C_i^* = 1$ when $A_i = A^*$.

*Step 6. Rank Preference Order.* Choose and alternative with the maximum $C_i^*$ or rank alternative according to $C_i^*$ in descending order.

The TOPSIS approach has been used in this research because of some distinct benefits.

- Provides a preference order solution based on the best relative solution
- Uses non-dimensionalized criteria

- Establishes relative importance for each criteria through subjective weighting
- Classifies each criteria as a cost or a benefit
- Establishes positive and negative-ideal solution vectors
- Determines the Euclidean distance of each alternative relative to both the positive and negative-ideal solution
- Ranks alternatives based on the closeness to the positive-ideal solution and the distance from the negative-ideal solution.

Another aspect of TOPSIS that is beneficial in this research and the development of the business valuation process is that the positive and negative-ideal solutions provide bounds on the best and worst possible attribute values in the data set. Assuming that the data are actual and representative of the alternatives being assessed and measured, the TOPSIS procedure cannot generate an infeasible solution. The similarity measure or relative closeness will always be between 0 and 1 and the input values define the possible values that are used in the computations. The input values define the bounds and the output values are between 0 and 1, therefore, within the parameters of this method, there can be no infeasible solution.

### 2.1.3 Fuzzy Set Theory

Much of the information used in the business valuation process is soft or uncertain data. Although this information is vague or approximate, it provides value in the business assessment and valuation process. Because of the nature of this information, fuzzy set theory provides an excellent means to capture and utilize this additional information in the valuation process. Fuzzy set theory is a consistent body of mathematical tools that provides a means to utilize soft data in a decision process. Below is a very brief definition of fuzzy set theory. Entire bodies of research, journals, books, courses and conferences are dedicated to the study and application of fuzzy set theory.

2.1.3.1 Definition

Fuzzy set theory is not concerned with events or traditional probability theory and statistics, but with the definition of a “fuzzy” concept such as “tall” or “warm” and the degree to which the situation or the individual matches the meaning of the concept. Fuzzy set theory is useful when data are sparse, definitions are linguistic and measures of intervals are not well defined.

A fuzzy set F on a universe U is defined by a membership function $\mu_F$: U $\rightarrow$[0,1] and $\mu_F$ is the grade of membership of element u in F. At the mathematical level, the domain of the mapping of $\mu_F$ is $[0,1]^U$ which is not Boolean algebra. Fuzzy uncertainty is measured by partial membership of a point from the universe of discourse in an imprecisely defined region of space. The membership function describes the degree to which the element of universe corresponds to the property with which the fuzzy set is defined.

2.1.3.2 Basic Operations on Fuzzy Sets

To describe the basic operations on fuzzy sets [Bojadziev 1997], consider the fuzzy sets A and B in the universe U

$$A = \{(x, \mu_A(x)\}, \quad \mu_A(x) \in [0,1]$$
$$B = \{(x, \mu_B(x)\}, \quad \mu_B(x) \in [0,1].$$

The following operations on A and B are shown below:

*Equality*

The fuzzy sets A and B are equal, A = B, if and only if for every x $\in$ U,

$$\mu_A(x) = \mu_B(x).$$

*Inclusion*

The fuzzy set A is included in the fuzzy set B denoted by A $\subseteq$ if for every x $\in$ U,

$\mu_A(x) < \mu_B(x)$.

*Complementation*

The fuzzy sets A and A' are complementary if

$\mu_{A'}(x) = 1 - \mu_A(x)$ or $\mu_A(x) + \mu_{A'}(x) = 1$.

*Intersection*

The operation intersection of A and B denoted as $A \cap B$ is defined by

$\mu_{A\cap B}(x) = \text{Min}(\mu_A(x), \mu_B(x)), \qquad x \in U.$

*Union*

The operation union of A and B denoted as $A \cup B$ is defined by

$\mu_{A\cup B}(x) = \text{Max}(\mu_A(x), \mu_B(x)), \qquad x \in U.$

One property classical sets posseses and fuzzy sets do not possess is the law of the excluded middle. The law of the excluded middle is expressed by $A \cap A' = \phi$ and $A \cup A' = U$. For fuzzy sets, however, the law of the excluded middle is not valid since $A \cap A' \neq \phi$ and $A \cup A' \neq U$.

A fuzzy set X is always associated with a family of crisp subsets of X. Each of these subsets consists of all elements of X whose membership degrees in the fuzzy set are restricted to some given crisp subset of [0,1]. One way is to restrict membership degrees that are greater than or equal to some chosen value $\alpha$ in [0,1]. When this restriction is applied to a fuzzy set A we obtain a crisp subset ${}^{\alpha}A$ of the universal set X, which is called an $\alpha$-cut of A. Formally this is shown as:

${}^{\alpha}A = \{x \in X \mid A(x) \geq \alpha$ for any $\alpha \in [0,1]$.

This equation says that the $\alpha$-cut of a fuzzy set A is the crisp set ${}^{\alpha}A$ that contains all the elements of the universal set X whose membership degrees in A are greater than or equal to the specified value of $\alpha$.

#### 2.1.3.3 Fuzzy Numbers

A fuzzy number captures the concept of approximation or linguistic expression with crisp values. A linguistic expression such as approximately two represents the central value as being fully compatible with the concept and other values on either side of the central value as being compatible to a lesser degree. The degree of compatibility of each number with the concept should be dependent on the context, its proximity to the central value. The concept captured by a fuzzy set is defined on the set of real numbers. Its membership function should assign the degree of 1 to the central value and degrees to other numbers that reflect their proximity to the central value. Fuzzy sets of this kind are called fuzzy numbers [Klir 1997]. Fuzzy numbers play an important role in many applications of fuzzy set theory.

While every fuzzy number A is expressed by a membership function of the form

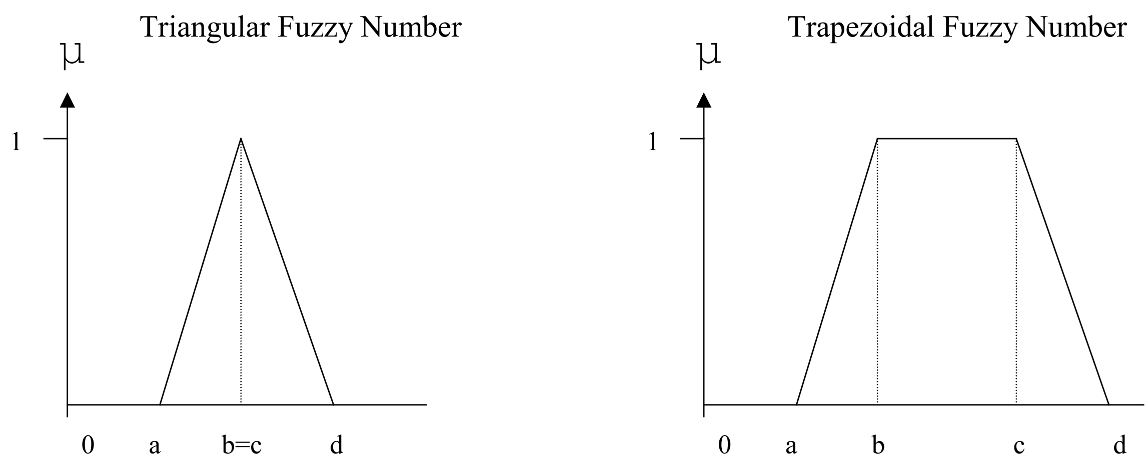
$$A: \Re \rightarrow [0,1],$$

not all membership functions of this form represent fuzzy numbers. To qualify as a fuzzy number, the membership function must capture the concept of a set of numbers that are around a real number of an interval of real numbers. Membership functions that conform to this concept must be expressed in the general form

$$A(x) = \begin{cases} f(x) & \text{for } x \in [a,b] \\ 1 & \text{for } x \in [b,c] \\ g(x) & \text{for } x \in [c,d] \\ 0 & \text{for } x < a \text{ and } x > d \end{cases}$$

where a ≤ b ≤ c ≤ d is a continuous function that increases to 1 at point b, and g is a continuous function that decreases from 1 at point c. Two membership functions that comply with this form are shown in the following diagrams. The most common fuzzy numbers are triangular and trapezoidal fuzzy numbers [Klir 1997]. These are easy to construct and manipulate.

## Examples of fuzzy numbers




Properties associated with fuzzy numbers include

a) Fuzzy numbers are normal fuzzy sets with one value equal to 1.
b) The $\alpha$-cuts of every fuzzy number are closed intervals of real numbers
c) The support of every real number is the open interval (a,d) of real numbers.
d) Fuzzy numbers are convex fuzzy sets.

Triangular and trapezoidal fuzzy numbers will be primarily used in this research.

2.1.3.4 Constructing Fuzzy Sets

Membership functions of fuzzy sets play a central roll in fuzzy set theory. In each application of fuzzy set theory, appropriately constructed fuzzy sets (i.e., their membership functions) insure that the intended meanings of relevant linguistic terms are adequately captured. These meanings are strongly dependent on the context that the terms are used [Klir 1997].

Many methods to construct fuzzy sets have been developed and will not be covered in this research. Justifiable mathematical formula will be used to develop a complete definition of the fuzzy set, if possible. If it is not feasible to define the membership function completely (mathematically), expert opinion will exemplify it for some representative individuals or sets of conditions. The result will be a set of pairs {x, A(x)} that exemplify the membership function under construction. This is then used for constructing the full membership function.

2.1.3.5 Fuzzy Variables

Fuzzy numbers play a fundamental role in formulating quantitative fuzzy variables. These are variables whose states are fuzzy numbers. When, in addition, the fuzzy numbers represent linguistic concepts, such as very small, small, medium, and so on, as interpreted in a particular context, the resulting constructs are usually called linguistic variables [Klir 1995].

Each linguistic variable the states of which are expressed by linguistic terms interpreted as specific fuzzy numbers is defined in terms of a base variable. A based variable is a variable exemplified by any physical variable as well as any other numerical variable. In a linguistic variable, appropriate fuzzy numbers captures linguistic terms representing approximate values of a base variable. An example of linguistic variable speed is shown in Figure 2.1.3.5-1.

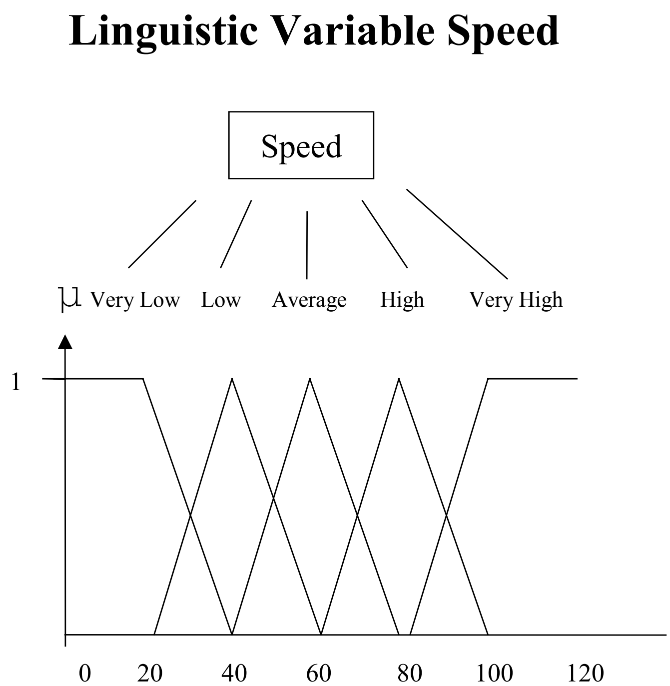



Figure 2.1.3.5-1. Linguistic Variable Speed

2.1.3.6 Basic Arithmetic Operations on Fuzzy Numbers

Basic arithmetic operations such as addition, subtraction, multiplication, and division operations for general fuzzy numbers are defined. In most cases, triangular fuzzy numbers will be used in the computational procedures. Triangular fuzzy numbers simplify computations using fuzzy numbers. Let $M_1 = [l_1, m_1, u_1]$ and $M_2 = [l_2, m_2, u_2]$ be two triangular fuzzy numbers with lower, most likely, and upper estimate. The sum is defined as

$$M_1 + M_2 = [l_1 + l_2, m_1 + m_2, u_1 + u_2]$$

and is associative and commutative. Subtraction is the addition operation on two fuzzy numbers when one has been multiplied by the scalar –1. Scalar multiplication for triangular fuzzy numbers (TFNs) is

$$aM_1 = \begin{cases} [al_1, am_1, au_1] & a >= 0 \\ [au_1, am_1, al_1] & a < 0 \end{cases}$$

The difference of two TFNs is then

$$M_1 - M_2 = [l_1 - u_2, m_1 - m_2, u_1 - l_2]$$

The multiplication of TFNs is only weakly distributive over addition, which means the solution process must either use the vertex method [110] or it may give a different outcome.

### 2.1.4 Fuzzy Logic [Klir 1995, 1997]

In a broad sense, fuzzy logic has been viewed as a system of concepts, principles and methods for handling problems that are approximate rather than exact. Fuzzy logic represents an application area of fuzzy set theory. The basic concepts and principles developed in fuzzy set theory are used to formulate sound approximate reasoning problem solutions. To use fuzzy logic, the degree of membership in a fuzzy set must be connected to the degree of truth in a proposition. Propositions, or statements, are declarative sentences that have a quality of truth or falsity between {0,1}. The relationship between the membership in a fuzzy set and the truth in a fuzzy proposition provide the framework for the use and evaluation of fuzzy concepts with fuzzy logic.

Membership in a fuzzy set has been described previously in this chapter. Given a fuzzy set A, the membership degree A(x) in the underlying universal set X may be interpreted as the degree of truth of the fuzzy proposition "x is a member of A." On the other hand, given a fuzzy proposition "x is F", where x is from the set X and F is a fuzzy linguistic expression (such as very low, low, medium, etc.), its degree of truth may be interpreted as the membership degree A(x) by which a fuzzy set A which is characterized by the linguistic expression F defined in a given context. With these concepts, operations of negation, conjunction, and disjunction on fuzzy propositions are defined in exactly the same way as the operations of complementation, intersection and union on fuzzy sets respectively. This is important for developing and utilizing additional concepts such as truth qualifiers, truth quantifiers, fuzzy probabilities, etc.

All propositions in classical logic are either completely true or completely false. Inferences, then, must fall into one of these two categories. However, in the real world environment, there are many cases where a proposition is neither completely true nor completely false. This may be seen, for example, in evaluating future events, because in that case, the outcome of the event is not known at this point. Alternative logics or multi-valued logics must be taken into account in representing this environment.

Multi-valued logics relax the traditional two-value logic into intermediate truth values. This may simply be three-value logic or can contain n-different or infinite levels of truth. The focus, however, is on reasoning with propositions involving imprecise concepts that are typical in natural language. Linguistic expressions involved may contain fuzzy linguistic terms of several types, including,

- Fuzzy predicates, such as tall, young, small, medium, etc.
- Fuzzy truth values, such as true, false, fairly true or very true
- Fuzzy probabilities, such as likely, unlikely, very likely or highly unlikely
- Fuzzy quantifiers, such as many, few, most or almost all.

All of these linguistic terms are represented in each context by approximate fuzzy sets.

#### 2.1.4.1 Fuzzy Propositions

The fundamental difference between classical propositions and fuzzy propositions is in the range of their truth values. Classical propositions are either true or false. True or false is a matter of degree with fuzzy propositions. [Klir 1997] There are a number of different types of fuzzy propositions and these propositions can be either qualified or unqualified. A general list of these types of propositions is shown below:

- Unconditional and unqualified propositions
- Unconditional and qualified propositions
- Conditional and unqualified propositions
- Conditional and qualified.

This research is primarily concerned with if-then production rules and truth qualifiers such as very low, low, medium, high and very high. These would be considered conditional and qualified propositions and are characterized by the form

p:'if X is A, then B is y' is S

where p, X, and A mean

p:'X is A' is true

but, S, a fuzzy truth qualifier, is a linguistic expression that adds a modifier to the claim of simple truth. These propositions are then considered truth qualified.

Each truth qualifier is characterized by an expression such as very low, fairly true, very false, and by a function from [0,1] to [0,1]. To determine the degree of truth $T_s(p_{x,y})$ of a particular proposition of this type, we first determine the degree of truth $T(p_{x,y})$ of the associated unqualified proposition and then apply the truth qualifier S to it. That is,

$$T_s(p_{x,y}) = S[T(p_{x,y})].$$

2.1.4.2 Fuzzy Logic Model

The key components of the type of fuzzy logic model that will be used in this research are input variables, linguistic variables described by fuzzy sets, if…then production rules, rule evaluation, aggregation of fuzzy output, defuzzification and the generation of a crisp output.

The major criteria scores generated by the selected scoring approach are the problem inputs. These crisp numbers are converted to linguistic variables based on the fuzzy sets developed for the model.

*If.. Then* rules are designed to produce a consequence from the input variables. *If.. Then* rules can be used to represent the interaction between certain areas in a company and capture information that may not be typically captured with numerical methods. The *If.. Then* rules or production rules are developed based on available data and/or expert opinion. These rules can then be refined as more information becomes available.

The input data are evaluated against the rules and this information is aggregated into a fuzzy output. The fuzzy output is then defuzzified to result in a crisp output or action.

The input and output variables are modeled by fuzzy sets $A_i$, $B_j$, $C_k$ and $S_l$ where each set contains a certain number of terms and are fuzzy sets defined as

$$A_i = \{(x, \mu_{Ai}(x)) \mid x \in A_i \subset U_1\},\ i = 1, \ldots, n,$$

$$B_j = \{(y, \mu_{Bj}(y)) \mid y \in B_j \subset U_2\},\ j = 1, \ldots, m,$$

$$C_k = \{(z, \mu_{Ck}(z) \mid z \in C_k \subset U_3\},\ k = 1, \ldots, p,$$

$$S_l = \{(w, \mu_{Sl}(w) \mid w \in S_l \subset U_4\},\ l = 1, \ldots, q,$$

The development of each fuzzy set involves the design of the following [Bojadziev 1997]:

1. The universal sets of the base variables x, y, z, and q for the linguistic variables described by A, B, C and S.
2. Selection of shapes of membership functions $A_i$, $B_j$, $C_k$, and $S_l$.
3. Specifying the number of terms
4. Specifying the support intervals.

The scores for the three different input criteria are used as inputs to the fuzzy logic model. Membership functions are developed for each of the three different major criteria. Initially, five levels {Very Low, Low, Medium, High, Very High} were used in this research (See Figure 2.1.4.2-1). These membership functions can then be modified to better fit the input and output variables in the model in the refinement process.

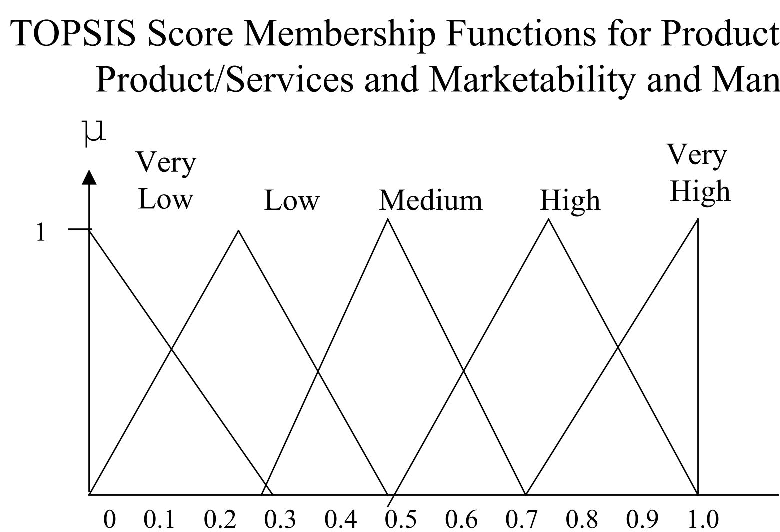



Figure 2.1.4.2-1. TOPSIS Score Membership Functions

Data analysis and expert opinion are used to develop the production rules used in the model. The production rules result is a series of *n* x *m* x *p* rules in the format

*If x is $A_i$ and y is $B_j$ and z is $C_k$ then w is $S_l$*

Decision tables can be used to present the fuzzy outputs labeled $S_{ijk}$ where i = 1,…,n, j = 1,…,m, k = 1,…,p, where $S_{ijk}$ is renamed as $S_l$.

Rules are typically represented in a decision table but represent the descriptive format above. Decision tables with three input variables are not easily represented and will only be shown in descriptive format.

The *and* part in the equation, called precondition,

*x is $A_i$* and *y is $B_j$* and *z is $C_k$*

is combined to be composition conjunction. It is a fuzzy relation in the A x B x C $\subseteq$ $U_1$ x $U_2$ x $U_3$ with membership function

$$\min(\mu_{Ai}(x), \mu_{Bj}(y), \mu_{Ck}(z)) \quad (x,y,z) \in A \times B \times C \subseteq U_1 \times U_2 \times U_3.$$

The *if … then* rule of inference is implication and expresses the truth of the precondition. The rule will be defined here as a conjunction-based rule expressed by operation $\wedge$(min) that will then include the consequence or conclusion and can be expressed as follows:

$$\min(\mu_{Ai}(x), \mu_{Bj}(y), \mu_{Ck}(z), \mu_{Sl}(w))$$

where i = 1,…, n, j = 1, …, m, k = 1,…,p, l = 1,…,q and (x,y,z,w) $\in$ A x B x C x S $\subseteq$ $U_1$ x $U_2$ x $U_3$ x $U_4$

This results in the truth value of the rule which is the result of the min operation on the membership functions of the fuzzy sets A, B, C, and S.

To evaluate the rules, the inputs into the fuzzy logic model $x = x_0$, $y = y_0$ and $z = z_0$ are used to find the corresponding output value w. The real numbers $x_0$, $y_0$, and $z_0$ are translated to the proper terms of the linguistic variables. These are matched to the appropriate membership functions because of the overlapping of terms. A straight line passing through $x_0$, for example, parallel to the μ axis intersects only the terms such as $A_i$ and $A_{i+1}$ which reduces the fuzzy terms to crisp values (singletons) denoted $\mu_{Ai}(x_0)$ and $\mu_{Ai+1}(x_0)$. Since the line $x = x_0$ does not intersect any other terms, we may say that the intersection is the empty set with membership function 0. This same type of exercise for $y_0$ and $z_0$ results in an induced decision table. Typically this table is populated with minimal non-zero terms.

The aggregation process involves determining which control action should be taken as a result of the firing of several rules. The active rules are used to determine the strength of the rule or the level of firing. This is denoted by, for example using the active rule,

Rule 1: If x is $A_i^{(0)}$ and y is $B_j^{(0)}$ and $C_k^{(0)}$ then w is $S_{ijk}$.

The strength of the rule or the level of firing is determined by

$$\alpha_{ijk} = \min(\mu_{Ai}(x_0), \mu_{Bj}(y_0), \mu_{Ck}(z_0)) \qquad \{2.4.2\text{-}1\}$$

This is done for all active rules to determine the rule strength table.

The output of each rule is defined by operation conjunction applied on its strength and conclusion as follows:

$$\text{Output of rule 1: } \alpha_{ijk} \wedge \mu_{Sijk}(w) = \min(\alpha_{ijk}, \mu_{Sijk}(w)) \qquad \{2.4.2\text{-}2\}$$

The outputs of the active rules must then be aggregated or combined in order to produce one control output. This is done with the max operation (Shown below with three "if" conditions, i.e., $2^3$ possible combinations).

$$\mu_{agg}(w) = (\alpha_{ijk} \wedge \mu_{Sijk}(w)) \vee (\alpha_{ij+1k} \wedge \mu_{Sij+1k}(w))$$
$$\vee (\alpha_{ij+1k+1} \wedge \mu_{Sij+1k+1}(w)) \vee (\alpha_{i+1jk} \wedge \mu_{Si+1jk}(w))$$
$$\vee (\alpha_{i+1j+1k} \wedge \mu_{Si+1j+1k}(w)) \vee (\alpha_{i+1j+1k+1} \wedge \mu_{Si+1j+1k+1}(w)) \qquad \{2.4.2\text{-}3\}$$
$$\vee (\alpha_{i+1jk+1} \wedge \mu_{Si+1jk+1}(w)) \vee (\alpha_{ijk+1} \wedge \mu_{Sijk+1}(w))$$

$$\mu_{agg}(w) = \max\ \{(\alpha_{ijk} \wedge \mu_{Sijk}(w)), (\alpha_{ij+1k} \wedge \mu_{Sij+1k}(w)), (\alpha_{ij+1k+1} \wedge \mu_{Sij+1k+1}(w)), (\alpha_{i+1jk} \wedge \mu_{Si+1jk}(w)), (\alpha_{i+1j+1k} \wedge \mu_{Si+1j+1k}(w)), (\alpha_{i+1j+1k+1} \wedge \mu_{Si+1j+1k+1}(w)), (\alpha_{i+1jk+1} \wedge \mu_{Si+1jk+1}(w)), (\alpha_{ijk+1} \wedge \mu_{Sijk+1}(w))\}$$

### 2.1.5 Defuzzification Methods

The next process is defuzzification. A number of different methods can be used to accomplish this. This includes the center of area method (CAM), the mean of maximum method (MMM), the height defuzzification method (HDM) or others. In this effort, the CAM method will be used.

To utilize fuzzy numbers as crisp numbers, the fuzzy numbers must be defuzzified. When using triangular or trapezoidal numbers, many times the crisp value is expressed corresponding to the average. As an example, to defuzzify the TFN $M_1 = [l_1, m_1, u_1]$, one may first look at $M_{Ave} = m_1$, which has the highest degree of membership (one) in the supporting interval $[l_1, u_1]$. Here $M_{Ave}$ attains its maximum at

$$x_{max} = m_1$$

which is called a maximizing value.

However, defuzzification cannot be uniquely defined. A number of methods exist, but three potential options for defuzzifying $M_{Ave}$ are shown below. These are essentially statistical average formulas:

(1) $x_{max} = \frac{l_1 + m_1 + u_1}{3}$

(2) $x_{max} = \frac{l_1 + 2m_1 + u_1}{4}$

(3) $x_{max} = \frac{l_1 + 4m_1 + u_1}{6}$

The center of area method (CAM) starts with aggregated rules from a fuzzy logic model which result in a membership function $\mu_{agg}$ (z), z ∈ [$z_0$, $z_q$]. The interval [$z_0$, $z_q$] is subdivided into q equal sub intervals by the points $z_1$, $z_2$, … , $z_{q-1}$.

The crisp value $z_c$ shown in this method is the weighted average of the numbers $z_k$ as shown in the formula below.

$$z_c = \frac{\sum_{k = 1,..q-1} z_k \mu_{agg} (z)}{\sum_{k = 1,..q-1} \mu_{agg} (z)}$$

The geometric interpretation of $z_c$ is that it is the center of the area under the curve $\mu_{agg}$ (z) bounded by the axis z. The physical interpretation is that this represents the center of gravity. This method is one of the most popular defuzzification methods because of its common sense nature.

## 2.2 Discounted Cash Flow Business Valuation Process

This research involves determining the overall business value of a firm in terms of its dollar value. Different methods exist to do this, however the Discounted Cash Flow (DCF) method will be used to demonstrate how the results from the new process can be integrated back into the business valuation process. Below is a general description of the computations involved in generating a discounted cash flow. Many variations of this method and the various components of this method exist. The intention is to demonstrate how the results of the process fit in the business valuation framework, not to provide a comprehensive view of the DCF method for business valuation.

The use of the Discounted Cash Flow method for computing business value begins with the computation of the Net Operating Profit Less Accumulated Taxes (NOPLAT). This is then used to compute the free cash flow, which must be projected and then discounted back to current dollars. NOPLAT represents the after tax profits of the company after adjusting the taxes to a cash basis. It is computed as shown below [McKinsey & Company 2000]:

**Computing NOPLAT**

Revenues
- Cost of Goods Sold
- Selling, general and administrative expenses
- Depreciation

= Operating earnings before interest, taxes and amortization (EBITA)
- Taxes on EBITA
- Changes in deferred taxes

= NOPLAT

In this research, the results from the fuzzy logic model are used to compute the NOPLAT, which is then used to further compute the Discounted Cash Flow. The Net Operating Profit prediction from the fuzzy logic model is used to compute the Operating Earnings before interest, taxes and amortization (EBITA). The Net Operating Profit projection made from the model includes operating revenues, operating expenses, depreciation and amortization. However, EBITA does not include amortization and must be estimated and removed from the projection. The taxes on EBITA and changes in deferred taxes are subtracted from EBITA to generate the NOPLAT.

**Computing Free Cash Flow**

The Free Cash Flow (FCF) is computed and then discounted to the present to compute the discounted cash flow, excluding the continuing value. Two formulas for computing Free Cash Flows are shown below:

Free Cash Flow = NOPLAT – Net Investment

Where Net Investment = Increase/Decrease in working capital + Capital Expenditures + (Increase) in other assets, net of liabilities + foreign currency translation effect

Or

Free Cash Flow = Gross Cash Flow [NOPLAT + Depreciation] – Gross Investment [Net Investment + Depreciation]

Computing the Weighted Average Cost of Capital (WACC)

To discount the FCF streams, it is necessary to compute the Weighted Average Cost of Capital (WACC). The general formula for estimating the after-tax WACC is the weighted average of the marginal after-tax cost of each source of capital:

$$WACC = k_b(1-T_c)(B/V) + k_p(P/V) + k_s(S/V)$$

Where

$k_b$ = The pretax market expected yield to maturity on noncallable, nonconvertible debt

$T_c$ = The marginal tax rate for the entity being valued.

B = The market value of interest bearing debt

V = The market value of the enterprise being valued (V = B + P + S)

$k_p$ = The after-tax cost of capital for noncallable, nonconvertible preferred stock (which equals the pretax cost of preferred stock when no deduction is made from corporate taxes for preferred dividends)

P = The market value of the preferred stock

$k_s$ = The market-determined opportunity cost of equity capital

S = The market value of equity

**Computing the Firm Value Excluding the Continuing Value**

The forecast period determining the discounted cash flow can be divided into a number of types for forecast periods. Detailed forecasts can be developed for the very near term such as one to three or five years. Average projections can then be developed for six to ten years. Beyond ten years (or the time frame determined by the valuator), the continuing value of the firm is computed.

With the new business valuation process described in this dissertation, the fuzzy logic model is used to project Net Operating Profit for the firm, based on changes to the input performance metrics. This, in turn, is used to compute the NOPLAT and FCF for each year in the forecast period (excluding the Continuing Value). The FCF is then discounted to the present using the WACC. This, in combination with the continuing value of a firm, generates the operating value of a firm.

**Computing the Continuing Value of a Firm**

Both the firm value and the continuing value of a firm are required to compute the overall business value using the WACC Discounted Cash Flow approach. To compute the continuing value of a firm, it is necessary to compute the Return on Invested Capital.

Return on Invested Capital (ROIC)

$$ROIC = \frac{\text{Net Operating Profit Less Adjusted Taxes}}{\text{Invested Capital}}$$

One recommended formula for computing the continuing value is shown below:

$$\text{Continuing value} = \frac{NOPLAT_{t+1}(1 - g/ROIC_i)}{WACC - g}$$

Where

$NOPLAT_{t+1}$ = The normalized level of NOPLAT in the first year after the explicit forecast period.

$g$ = The expected growth rate in NOPLAT in perpetuity

$ROIC_i$ = The expected rate of return on net new investment.

WACC = The weighted average cost of capital.

The firms total value is the Firm Value + the Continuing Value. The Firm Value is typically determined from forecasts in a short-term horizon. The Continuing Value is based on determining the firm's value from the perspective of a long-term, ongoing operating concern..

To compute the present value of the continuing value of the firm, the continuing value must be discounted to the present. This can be done with the following formula:

$$\text{Continuing value} = \frac{NOPLAT_{t+1}(1 - g/ROIC_i)}{WACC - g}[1/(1+WACC)]^n$$

Where n = the short/medium term planning horizon.

The result of these computations provides the operating value of a firm. To further use this information, the equity value of a firm may be computed. This information can be used to determine the stock prices of a firm based on the valuation and then compared to the current stock prices and used for decision-making purposes. To compute the equity value of a firm, the market value of non-operating assets such as excess cash, marketable securities, and investments in unconsolidated subsidiaries are added to the value of operations to obtain the enterprise value. Then debt, minority interest and other non-equity sources of financing are subtracted to obtain the equity value. The equity value of the firm can then be divided by the number of outstanding shares of stock and compared to current stock prices for decision making.

## 2.3 Company and Industry Selection

For this research, one actual industry and several companies were selected to demonstrate the new business valuation process. Selection parameters were used to narrow down the field of potential industries and companies that could be used to demonstrate the results of this research. This section describes some of the key factors used in the selection process.

### 2.3.1 Selection Parameters

The potential companies and industries needed to test this new business valuation process were vast. This made the selection process difficult. A number of selection parameters were established to choose an industry and then companies to use in the new business valuation process. A list of these parameters is given below with a brief description of their importance in the selection process.

1. *Uniformity of business, services and products* – Many companies produce, manufacture or provide services across a number of different industries and markets. To narrow the analysis field and develop a set of performance metrics (decision criteria) that were relatively standard required that the industry was fairly singular in its manufacturing or service area. Examples of this include manufacturing nuts and bolts for machinery, making candy and confections, printing companies, airline industry, etc.

2. *Established industry* – Each industry changes and evolves over time. However, some industries, such as the high-tech industry, can change on a daily basis with the introduction of new products and technologies. For this research, it was determined that an industry with relatively established

operating characteristics would be beneficial for testing this new process. The market, operating procedures, analysis, data and information may tend to be more readily available with an industry that has a track record and established history.

3. *Company with a new, interesting or successful approach to business* – This parameter provided an "interest level" for the research effort. Instead of studying a sedentary company with business "as usual," the thought was to find a company trying something newer or innovative within its industry and look at its business model in comparison to others operating in the same industry. The analysis of the new operating concept may then provide information regarding investment decisions regarding the specific company.

4. *Accessibility to data and information* – Since this research would be performed as an outsider without access to internal reports and financial information, it was necessary to select a company or industry that had accessible data and information. From an industry perspective, this would mean that performance information for various companies would be available to the general public in various forms such as that from private, public and government sources. Without accessibility to data, various assessments and comparisons to other companies could not readily be performed.

5. *Knowledge and/or experience with industry* – Having first hand knowledge provides additional insight regarding operations within an industry or company. This provides an additional point of reference for assessing a company within a given industry and can enhance the information extracted and developed as part of the analysis.

These preceding five factors are used to select an industry and companies used in this research.

## 2.4 Chapter Summary

This chapter provides an overview of the different methods that will be integrated into the new business valuation framework and assessment process. Primarily, multiple attribute decision making and fuzzy logic are used as a theoretical foundation for the unique integration of these methods. The resulting process provides a new and novel approach to business valuation.

# CHAPTER 3
# NEW BUSINESS VALUE MODEL CONCEPT

## 3.1 Overview of Model

This chapter provides a general overview of the new business valuation model framework and the analysis process developed in this research. The motivation for the research is reiterated to provide a basis for defining the problem. The problem is defined and discussion of some of the situations where this problem can be applied is provided. The structure of the problem solution is explained and an overview of the new process generated from this research is given. This chapter is intended to provide a framework for the detailed discussion and application of the process to an example production company shown in Chapter 4 and regional airlines discussed in Chapter 5.

Typically, financial economic analyses alone are used to evaluate companies with balance sheet and income statement information. Using the current approach, all available information is not integrated into the decision process. Factors such as production processes, products/services and marketability and management are important to establish future corporate value. By integrating various decision methodologies, a new business evaluation process is developed that incorporates both objective (historical) data and subjective (future) data.

Figure 3.1-1 shows a comparison of the differences between the approach proposed in this research and traditional business valuation methods. The key difference and the contribution of this research is the development of a process that measures the potential future value of a company based on 1.) Production Efficiency, 2.) Product Value and Marketing and 3.) Management Effectiveness.

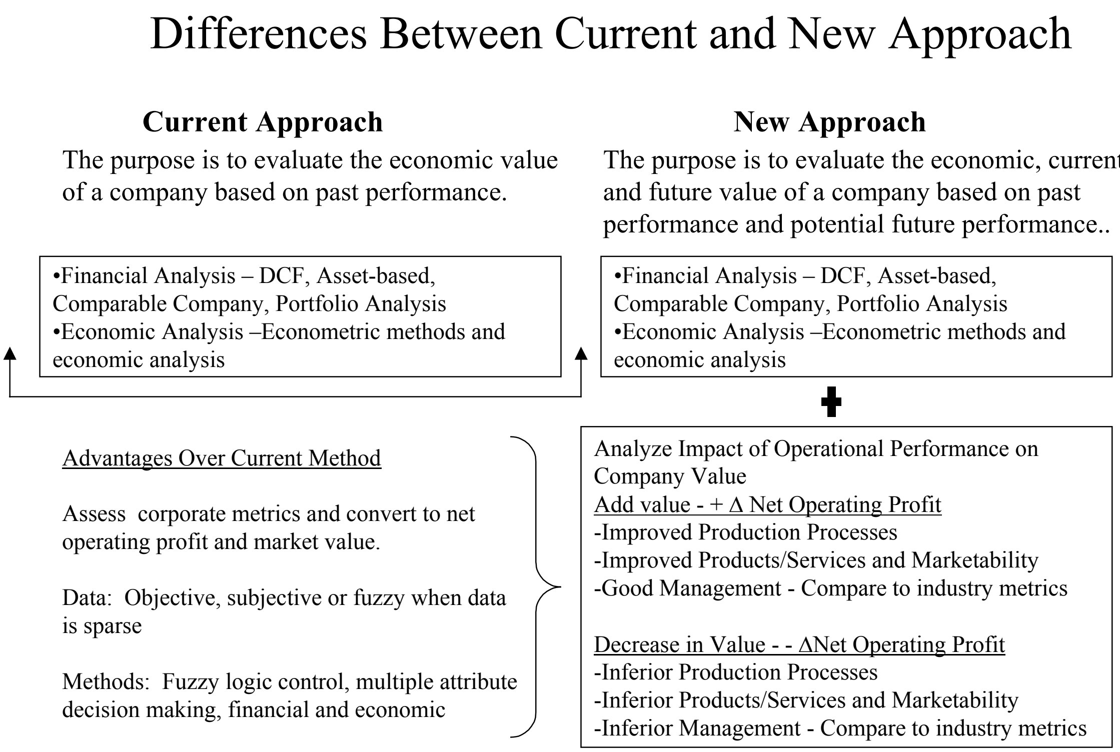



Figure 3.1-1. Differences Between Current and New Approach.

The motivation for the development of the new process is to facilitate the assessment of new and existing businesses and determine ways that these companies can invest resources to improve the overall corporate value. The new business model assessment framework provides a means to compare business models within an industry. This can be done for a single company or multiple companies within an industry.

The problem is given based on a high-level management understanding of various aspects of the operating environment. Performance metrics within functional or operational areas are identified for performance measurement. Vague or imprecise relationships between performance metrics, overall functional or operational areas and financial estimates are captured. The company is represented by complex relationships between areas within the company. Human knowledge or experience is necessary to provide a realistic representation of relationships within the company. The intended results are a sound and defensible estimate of financial value based on the company’s non-financial (operational) performance, financial performance and its ability to position itself in the future using all available information (financial and non-financial). Additionally, the results should include the ability to perform what-if and sensitivity analysis.

Company management or investment analysts within an industry can define their environment in terms of this problem structure and use this process to gain insights into a number of areas. Management may analyze their individual company performance to look at ways to improve overall corporate value. They could also use the new business valuation approach to benchmark themselves against others in the industry and use the resulting information to improve operational performance and value. An investment analyst may use the new business valuation process to look at a company for stock purchases, mergers, leveraged buy-outs, etc.

Powerful methodologies are integrated into this process to solve the various aspects of the problem. Concepts associated with benchmarking, key performance indicators or balanced scorecards are used to focus management in developing performance metrics. These performance metrics are grouped based on functional or operational areas and become decision criteria in a multiple attribute decision making problem. The performance assessments for the key functional areas are defined in terms of fuzzy sets and linguistic variables which are assessed and used in a fuzzy logic model. The output variables are defuzzified to generate the financial estimates.

A step-by-step process is described for applying the process developed in this research to solve the problem. This involves identifying the performance metrics and gathering data to support the metrics. The performance metrics are grouped under key functional areas and a multiple attribute decision making tool is used to generate an overall performance assessment of in the functional area. A fuzzy logic model, based on a standardized structure, is generated and then modified or tuned as necessary. The fuzzy sets, linguistic variables, membership functions and production rules are developed to support the fuzzy logic model. The output is generated from the model and the results defuzzified into financial terms.  This information is then input into a traditional discounted cash flow business valuation model.

The process is structured such that the data used in it may change, but the overall approach is applicable across numerous industries.  Pertinent operating information for a company is typically shown on the SEC filings 10-K report or in the annual report.  This is useful information that can now be integrated into the business valuation process using a structured and analytical approach.  Although the techniques used in the research existed previously, the combination and use of these methodologies in the business evaluation process has not been done before or documented in the literature.

3.2 Problem Definition

Assume that there exists a high-level knowledge regarding the operational and financial performance of a company.  Also assume that the company can be defined and represented by the following characteristics:

- Functional or operational areas that define the success of the company.

  The functional or operational areas of the company typically have different relationships and interactions that contribute to the overall financial performance of a company.  At this time, the overall functional or operational areas have been defined as Production Processes, Product/Services and Marketability and Management.  These three areas provide a high level representation of key areas within a company.  They are designed to encompass all of the key operational areas in a company.  Functional or operational areas are also used to group performance metrics.

  Production Processes performance metrics are those metrics that represent how well a company is able to produce their product.  These metrics may include machine utilizations, production efficiencies, etc.

Product/Services and Marketability performance metrics represent the development, sales and marketing aspects of company operations. Service levels, product lines needs, markets addressed, etc. may be represented in these performance metrics.

Management performance metrics are those that represent how well management is doing their job. These may be higher-level metrics that affect the company overall and may also be subjective metrics based on an assessor's perspective. These metrics may include overhead, growth, etc.

- Quantifiable (objective or subjective) metrics representing company performance at an operating level.

  These are performance metrics that exist at the operating level of a company. The metrics will differ from industry to industry but represent important operational characteristics of the company that are believed to contribute to the overall success or failure of the company. These metrics may be in the form of objective or statistical data or may be expert opinion.

- Ability to differentiate between the importance of performance metrics within the overall functional or operational area.

  Not all performance metrics may have the same impact in determining performance in an overall functional area. The ability to differentiate between the contribution of these metrics to overall importance is necessary.

- Vague or imprecise relationships between performance metrics and overall functional or operational performance.

It is difficult to develop a precise representation of how well each of the key value drivers contributes to the overall performance of a company in a functional area. Estimates, management knowledge, expert opinion or decision tools may be necessary to represent performance in a given functional area.

- Complex (non-linear) and imprecise relationships between overall functional or operational performance and financial estimates.

  The performance levels in the various functional areas may impact the financial estimates differently. A company performing poorly in one functional area may have a greater financial impact than performing poorly in another functional area.

- Human knowledge beyond historical data needed to represent the relationships between performance metrics, functional area performance and financial estimates.

  Management experience and/or expert opinion provides a body of knowledge that is not easily captured with traditional processes and means. Capturing this knowledge provides insight into the decision making process.

This problem has a nearly universal application in the corporate environment. Most companies can define performance metrics, but have no way to understand how those metrics affect the bottom line. There are many complex and vague relationships between areas of the company and in turn, representations of how these areas affect the overall performance of a company.

This same problem structure and process could also be applied in a number of different areas. This process is not limited to performance inputs and financial outputs only. For example, inputs used in this process could be the manpower needs for production, services, marketing, management, etc. for a company. The fuzzy logic model would then model the relationships between the three major criteria areas, Production Processes, Product/Services and Marketability and Management. The output from the process could then be the total amount of manpower required for a company. Although the nature of the inputs and outputs may differ, the problem structure supports other model types. Some examples of these different areas are shown in Table 3.2-1.

Table 3.2-1. Examples of Different Problem Areas to Apply Solution Approach.

| Type of Problem | Problem Components | Results | Difference Between Traditional And New Approach |
|---|---|---|---|
| Production facility equipment | Type of machinery to purchase based the impact of production operations, interactions with other departments within the facility, management capability to install, operate and maintain equipment. | Results are estimate of impact on financial performance of plant | Uses additional information such as production operations, interactions with other departments and management to approximate financial cost and/or financial impact on plant bottom line. |
| Manpower planning | Manpower needs for production operations, services and marketability and management and their interactions between each area on required work. | Results are an estimate of the number of individuals. | Uses additional information such as production, service and marketing and management interactions on required work and manpower necessary to complete work. |
| Capital budgeting | Funding needs assessment based on functional areas and the balance and interactions between the areas in terms of dollars spent. | Result is functional areas that have the greatest impact when contributing to the "bottom line." | Uses additional information such as the interactions between functional areas and management on the contribution of funding to the bottom line. |
| New product introductions | New product introductions and their effect on production operations, sales and marketing and management's past success with introductions. | Results will be estimate of product line profitability. | Uses additional information which integrates overall impact of new product introductions on company and management and its impact on profitability. |

Situations where performance metrics are related to output profits or costs can be formulated into this type of problem and solved using the process described in this thesis.

As discussed above, the new process described in this thesis can be used to solve problems with differing inputs and outputs. The focus of this dissertation has been to develop and apply the new business valuation process in a fairly restricted sense. The new business valuation process has been applied to a single or multiple company business analysis effort for a company or companies within the same industry. The analysis process described in this dissertation could be used for the following types of analysis.

1. One company analysis
   - Management analyzes how performance impacts financial value on a yearly basis
   - Management identifies the areas with the greatest potential impact on improving corporate value
   - Investment analyst uses this tool to analyze current and future value for investment purposes
   - Management uses to determine areas to invest resources within company to improve overall corporate value.

2. Multiple company analysis
   - Management develops understanding of relationships between industry performance metrics to financial performance
   - Management identifies opportunity areas for improvement by adopting other processes/procedures used in industry
   - Investment analyst performs comparative assessment of companies within industry

3.3 Problem Solution Structure

A new type of problem has been defined as part of this research. This new problem consists of the definition of performance-based metrics and the process by which they are translated to financial information. The solution structure is specifically adapted to the problem being solved and does so with a new and unique approach. A schematic of the new problem definition is shown in Figure 3.3-1.

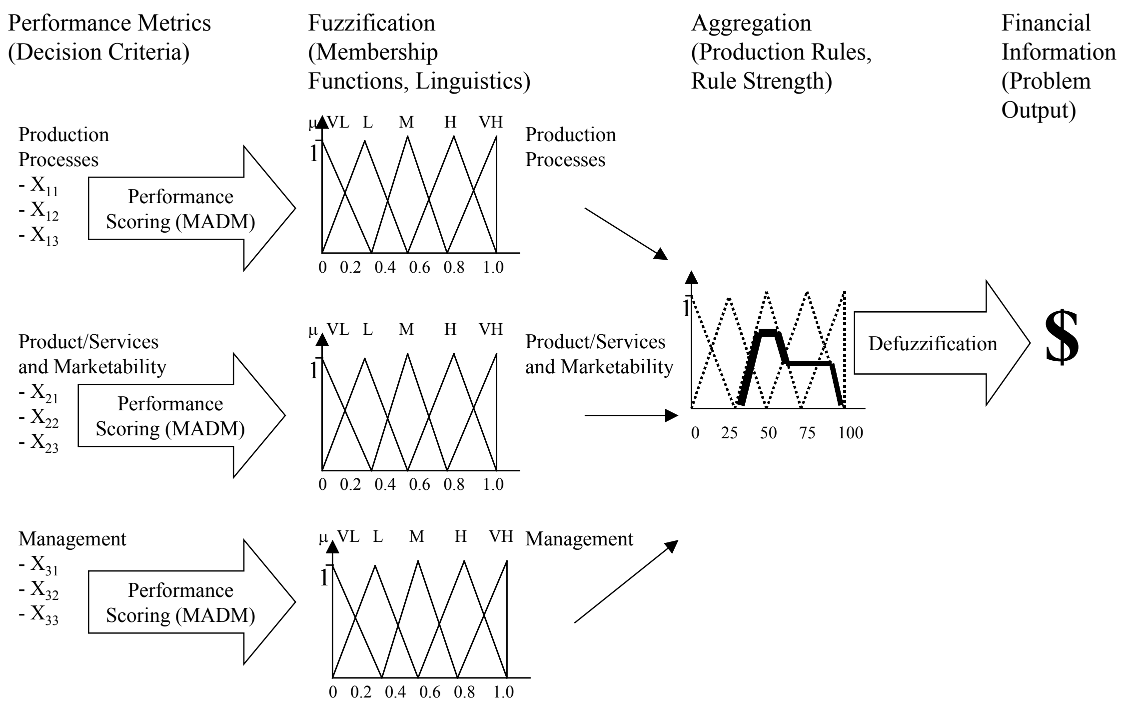


Figure 3.3-1. Solution Structure of Problem.

The problem solution structure is broken down into a number of components.

- Major decision criteria are chosen and performance metrics established and collected
- Performance scoring for major criteria using Multiple Attribute Decision Making
- Fuzzification of major criteria with membership functions and linguistic representation
- Aggregation of major criteria and linguistic variables using production rules

- Defuzzification of output into financial information

Performance metrics for the three major operational areas of a company are defined in terms of Production Processes, Product/Services and Marketability and Management. The performance metrics established are used as the decision criteria in a Multiple Attribute Decision Making method to score a company in a given operational area of performance. The decision criteria can be hierarchical with sub-criteria and can also be weighted according to their importance to the three major criteria.

Performance scoring is performed by a Multiple Attribute Decision Making method. Although methods that generate only a rank order (ordinal score) can score the performance of a company in a given operational area, a method that differentiates the performance between zero and one (a cardinal score) provides information regarding how much better performance is between alternatives. Methods such as TOPSIS and SAW provide this ability.

Fuzzification of the performance scoring is performed based on the development of membership functions associated with the performance levels generated from the performance scoring. The performance scores are associated with a degree of membership to the various fuzzy sets and linguistic variables. In the case of TOPSIS, all performance scores will be between zero and one. Using TOPSIS provides a standardized approach to developing performance based membership functions.

The three major criteria areas are aggregated with a fuzzy logic model based on a set of production rules and the rule strength is determined based on their evaluation in the membership functions. Production rules allow the decision maker to model the operating environment with flexibility (as a note, this can also be done with the membership functions). The production rules are a series of conditional propositions that are evaluated using the results from the fuzzification process. The fuzzy logic model provides the aggregated performance for a company based on the performance in various operational areas within the company.

Membership functions are developed for the output variable or variables. A number of methods, i.e., Center of Area Method, etc. can be used to defuzzify the aggregated results. The problem output is then a financial representation of the input performance levels. Once developed, the problem components, such as the decision criteria, the membership functions, the production rules, etc. can be refined to enhance the representation of the company operating environment.

## 3.4 Business Valuation Process

This section discusses how these steps are integrated together to form the new business valuation process. Figure 3.4-1 shows the steps that are used in the newly developed process. The initial step involves identifying the industry related criteria. Data are gathered to support the criteria and analyzed to determine its availability, quality and any other relationships between input/output data. A Multiple Attribute Decision Making model is used for each of the major criteria to determine a score to indicate the relative impact, production processes, products/services and marketability and management and net operating profit. The next step is to develop a fuzzy logic model for the selected industry. This involves developing input and output tables and the supporting membership functions bridging the three major criteria inputs to the process output. The fuzzy output from the criteria score is then generated for the output variable. This is the Net Operating Profit. Finally, the projected incremental changes to the Net Operating Profit are used to generate Discounted Cash Flow for the company. What-if and sensitivity analysis can then be performed. Various performance parameters can be changed to then determine the positive or negative impact of the change on the Net Operating Profit. Each of these steps are summarized in more detail below:

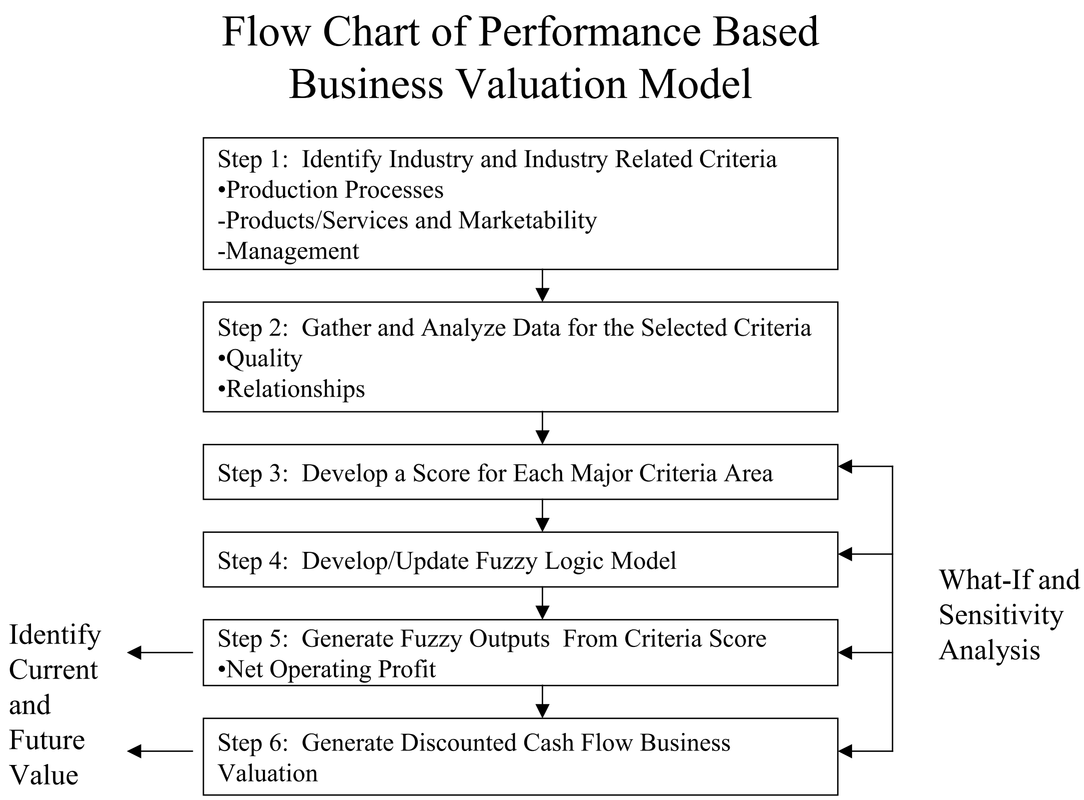



Figure 3.4-1. Flow Chart of Performance Based Business Valuation Model.

### 3.4.1 Step 1: Identify Industry and Industry Related Criteria.

This step involves selecting the industry to be studied and then determining criteria that can be used as metrics to measure the process, product and management. The industry to be studied is typically dictated by the problem at hand. In the practical application of this process, company employees would do the analysis for their companies and other companies in their industry. For investment analysis, a number of different industries may be studied to determine which industry and also which companies within the industry provide the best investment opportunities. In research efforts, one may select a company or industry where data are readily available and knowledge of the industry exists. A number of selection parameters were discussed in Section 2 above and would be applied in the selection of an industry or company within an industry to study.

Information from a number of different sources may be used to develop the decision criteria. Benchmarking information as well as industry performance measures, such as those discussed in annual reports and SEC filings provide operational data that can be used in the development of decision criteria. Sometimes various scorecard and performance metrics can be utilized in measuring the three major criteria. Typically, a longer and more hopeful list of decision criteria is initially developed. Then, depending on data availability and the testing of these decision criteria in the model, these decision criteria are reduced to a manageable set of data. Very important, though, is that the decision criteria should be representative of the performance of the company.

The goal is to provide metrics to measure how well a company is performing individually and within the industry as a whole. The three major criteria were selected to provide comprehensive coverage of key corporate activities and are represented in generic terms. The sub-criteria that support these major criteria will differ industry by industry. The three major criteria will be related to the output variables in the next step. Although, many more performance metrics exist, examples of the types of decision criteria across various industries are shown below:

- Production processes
    - Unit and Operating Cost
    - Unit and Operating Revenue
    - Profit Margin
    - Production Efficiencies
    - Utilization

- Products/services and marketability
    - On time performance
    - Product Life Cycle
    - Market Segment
    - Market Share
    - Competition

    - Customer Service

- Management
    - Overhead
    - Management Capability
    - Growth
    - Market Value
    - Stock Price

### 3.4.2 Step 2: Gather and Analyze Data to Support Criteria

Data for the industry and company being studied to support the decision criteria is gathered and analyzed. Depending on the specific analysis being performed, historical performance and financial data from a single company or multiple companies within an industry should be reviewed. Expert opinion can also be used to support the decision criteria and business valuation process. Companies analyzed can be of similar size or a variety of sizes, based on the intended use of the analysis. Various publicly available sources such as filings from the Security and Exchange Commission, and private sources of industry data can be used in the analysis. The industry data will be used to develop the framework of fuzzy control model.

Data gathered should also be reviewed for completeness and reasonability. If objective data does not exist, subjective and fuzzy data can be used to include the additional information into the decision process. If information is poor or missing, certain criteria may need to be eliminated from the analysis process altogether or until data can be collected to support the criteria. Both the input and output data are gathered in the analysis. This can then be used to analyze relationships between the inputs and outputs and extract information that may be useful in the development of the fuzzy logic control model. Statistical or regression analysis can be performed to aid in data analysis. The result of this step is a set of data which includes performance metrics (decision criteria) and output financial information that can be used in the new business valuation process.

### 3.4.3 Step 3: Develop a Score for Each Major Criteria Area

Using the decision criteria and data developed in steps 1 and 2, an indexed score is developed for each of the major criteria using the selected sub-criteria. This indexed score provides a representation of company performance by year or companies based on the data included in the data set. A Multiple Attribute Decision Making Methodology will be used to generate the indexed score. The Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methodology, developed by Hwang and Yoon (1981) has been selected for use in this research because of the relative score generated by the method. This MADM methodology is based on the concept that the chosen or higher ranking alternatives are desired. TOPSIS generates a relative score associated with the companies in the data set, based on how close an alternative (company) is to the best possible solution and how far away it is from the worst possible solution

The result of this step is a cardinal score for the three major criteria areas, Production Processes, Product/Services and Marketability and Management that are modeled in the process. Each company/year will have a score between zero and one that represents its performance in the associated operational area. TOPSIS generates a relative score from zero to one based on the computations in the methodology. The score is relative to the other company/years in the data set. The decision criteria associated with the major criteria can be weighted to differentiate between the importances of each to the overall performance in an area. The TOPSIS score provides the primary input into the fuzzy logic model.

### 3.4.4 Step 4: Develop/Update Fuzzy Logic Model

This step involves developing (or updating if it currently exists) the fuzzy logic model used to aggregate the three input variables (the major criteria which are production processes, products/services and marketability, and management) to the output variable (Net Operating Profit). The input variables have been selected to represent an overall quantification of corporate performance. The output variable, Net Operating Profit, is used to compute the discounted cash flow for a company.

Figure 3.4.4-1 shows the key components of a Fuzzy Logic Model (Bojadziev 1997). The major criteria scores generated by the selected scoring approach (TOPSIS) are the problem inputs. These crisp numbers are converted to linguistic variables based on the fuzzy sets developed for the model.

*If*.. *Then* rules are designed to produce a consequence from the input variables. *If*.. *Then* rules can be used to represent the interaction between certain areas in a company and capture information that may not be typically captured with numerical methods. The *If*.. *Then* rules or production rules are developed based on available data and/or expert opinion. These production rules can then be refined as more information becomes available.

The input data are then evaluated with the rules and this information is aggregated into a fuzzy output. The fuzzy output is defuzzified to result in a crisp output or action. In this case, the Net Operating Profit is used to compute Discounted Cash Flow for the business.

Fuzzy Logic Model

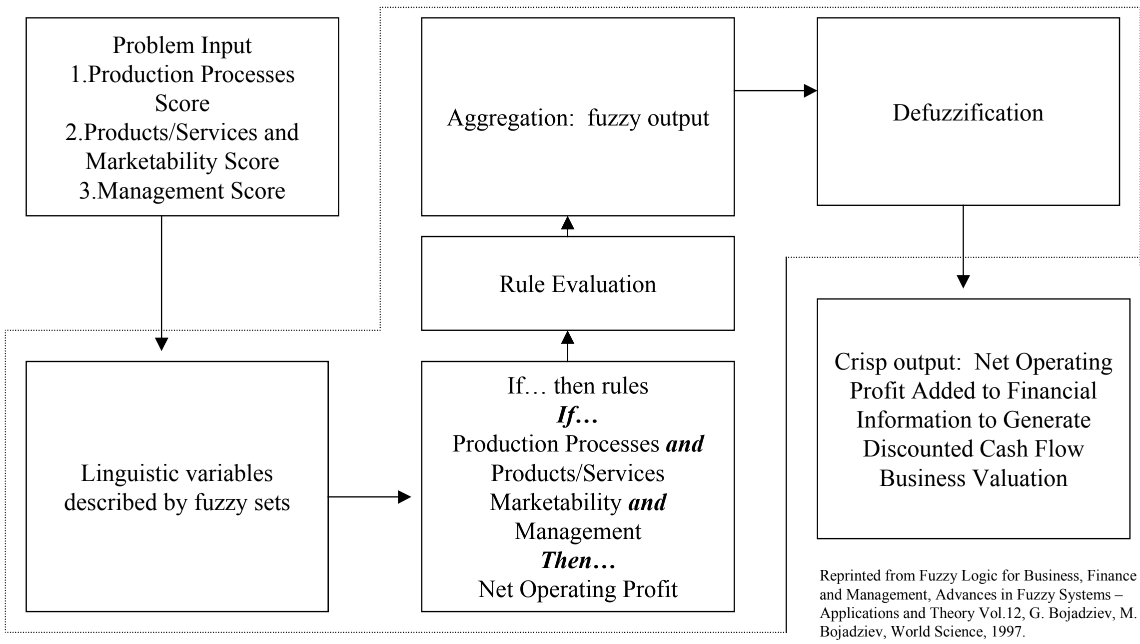



Figure 3.4.4-1. Fuzzy Logic Model.

### 3.4.5 Step 5: Generate Fuzzy Outputs From Criteria Score

The model described above is used to generate the fuzzy logic outputs for the three major criteria of the company being evaluated. The indexed score for the three major criteria is generated and used as an input for the fuzzy logic model. The scores are evaluated with the membership functions. The production rules are fired; the rule strength is evaluated and aggregated. The output from the model is then defuzzified into the resulting Net Operating Profit for the company for the year. If the company evaluation is being performed for a discounted cash flow business valuation, then projections for the performance metrics for the short and medium term planning horizon are generated and then used to generate the fuzzy control outputs from the criteria score. Using a fuzzy logic model such as this, the Net Operating Profit can be approximated and further used in the business valuation process. This process is repeated for each of the company/years in the data set or as required by the analysis.

### 3.4.6 Step 6: Generate Discounted Cash Flow Business Valuation

The output from the fuzzy logic model is used as an input to the computations for a Discounted Cash Flow (DCF). As discussed previously, this problem structure could be used in other areas than business valuation. Step 6 demonstrates how the type of output that is generated from this model could be used in a financial application, such as computing the Discounted Cash Flow for business valuation. Specific formulas for computing the Discounted Cash Flow are described in Chapter 2.

The use of the Discounted Cash Flow method for computing business value begins with the computation of the Net Operating Profit Less Accumulated Taxes (NOPLAT). NOPLAT represents the after tax profits of the company after adjusting the taxes to a cash basis. The results from the fuzzy logic model are used to compute the NOPLAT, which is used to further compute the DCF. The Net Operating Profit prediction from the fuzzy logic model is used to compute the Operating Earnings before interest, taxes and amortization (EBITA). The Net Operating Profit projection made from the model includes operating revenues, operating expenses, depreciation and amortization. However, EBITA, does not include amortization, and must be estimated and removed from the projection. The taxes on EBITA and changes in deferred taxes are subtracted from EBITA to generate the NOPLAT.

A forecast horizon is established and the forecast periods for the firm that is typically divided into near term, intermediate term and long term forecast periods. Detailed forecasts can be developed for the very near term such as one to three or five years. Average projections can then be developed for six to ten years. Beyond ten years (or the time frame determined by the valuator), a term called the continuing value of the firm, is computed. The continuing value of a firm is the long term forecast for the firm.

With the approach described in this paper, the fuzzy logic model is used to project Net Operating Profit for the firm based on changes to the performance related variables.

This, in turn, is used to compute the NOPLAT and FCF for each year in the forecast period (excluding the Continuing Value). The FCF is discounted to the present using the WACC. This FCF, in combination with the continuing value of a firm, generates the operating value of a firm. The continuing value must also be discounted to the present using the WACC.

To further use this information, the equity value of a firm may be computed. This information can be used to determine the stock prices of a firm based on the valuation and then compared to the current stock prices and used for decision-making purposes. To compute the equity value of a firm, the market value of non-operating assets such as excess cash, marketable securities, and investments in unconsolidated subsidiaries are added to the value of operations to obtain the enterprise value. Then, debt, minority interest and other non-equity sources of financing are subtracted to obtain the equity value. The equity value of the firm can be divided by the number of outstanding shares of stock and compared to current stock prices.

In essence, this final step shows how the performance metrics that were developed in Step 1 are used to compute the business value of a company. Sensitivity analysis and refinement can be used to gain further insight into the factors and performance areas that most affect corporate value.

## 3.5 Chapter Summary

This chapter provides a general overview of the new business model framework and analysis process developed in this research. A number of different theories and methodologies are integrated to arrive at this approach. From review of literature, this is a new and unique problem definition and process for business valuation. Knowledge across a number of fields was required to develop this approach. Both qualitative and quantitative information is used in the decision process. Each step of the process adds information to the business valuation process, some of which could not easily be captured with traditional business valuation.

# CHAPTER 4
# DEVELOPMENT OF THE METHODOLOGY TO ANALYZE A PRODUCTION INDUSTRY EXAMPLE

## 4.1 Development of a Production Industry Example

This chapter provides an example of the process applied to a generic production company and is used to describe and demonstrate the new process. The methodologies and concepts described in Chapter 2 and the overall concepts described in Chapter 3 are specifically tailored to the sample production company. Chapter 5 shows the methodology applied to two actual companies in the regional airline industry that is used to validate the process.

## 4.2 Step 1. Identify Industry and Industry Related Criteria

This step forms the foundation for the assessment framework used in the model. A combination of concepts including the development of decision criteria, key performance indicators, balanced scorecard and benchmarking provide the basis for establishing the evaluation framework. A hierarchy of decision criteria and key performance metrics are developed to assess the operating performance of a company in a given industry. The decision criteria provide a standard set of assessment criteria that can be used for assessing and benchmarking across the different operating characteristics and business models of the companies within an industry.

### Select Industry

Based on the analysis being performed, the company dictates the industry selected for the analysis. In this example, a generic production company was selected so that the process could be developed and demonstrated. Each industry is different and therefore requires different performance criteria to represent the operating characteristics of the industry. The industry selection criteria used in this research are described in Section 2.

Identify High-Level Performance Criteria for Industry

Based on the industry, many different sources exist for establishing high-level performance criteria, sub-criteria and performance metrics for the industry. Key in this process is developing a hierarchy of criteria that are representative of the industry operating characteristics and also generic enough to assess all of the company in an industry or sector of an industry. Sources for performance characteristics differ between industries. A general knowledge of the industry is required to understand, develop and customize the performance measures used in the analysis. The high-level performance criteria should represent the key operating characteristics for an industry.

High-level performance criteria should represent the key operating characteristics of an industry. Plus or minus seven criteria should be used at each level of the hierarchy. The use of the number seven is based on Miller's theory [Miller 1965] which is that seven plus or minus two represents the greatest amount of information an observer can give about an object on the basis of an absolute judgment [Chen and Hwang 1992]. Supporting sub-criteria and performance metrics are developed to support the high-level criteria.

In this research effort, three major criteria have been developed to encompass the ideas and concepts contained in studies such as the one described above as well as other benchmarking, key performance indicator and scorecard development efforts. It was deemed important to keep the number of criteria manageable in the initial study so that data could be gathered to support the criteria, but to insure that the primary performance areas were represented in the effort. As will be shown in this study, the three major criteria: Production Processes, Product/Services and Marketability and Management are the same for the example discussed in this chapter and for the airline industry. These three major areas encompass the core activities of a company. The performance criteria used in the airline industry are discussed in the following chapter. The main criteria and sub-criteria used in this production company example are shown in Figure 4.2.1-1.

## Hierarchy of Criteria Used in Production Company Example

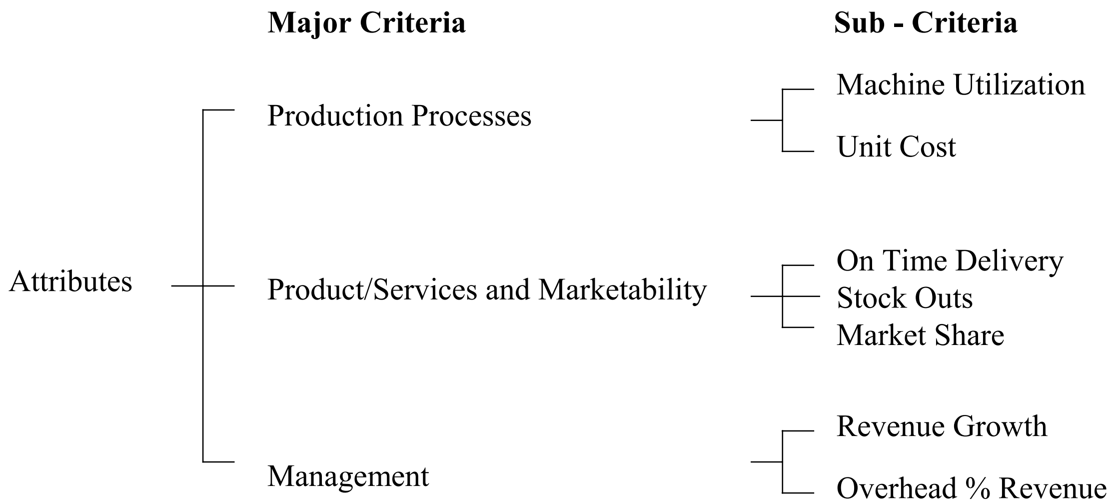



Figure 4.2.1-1.Hierarchy of Criteria Used in Production Company Example.

Using a hierarchical assessment approach provides a structured framework to assess and compare companies in an industry. Process flow models, work flow models, organizational models and supply chain models were researched to determine if they provided a better means to structure the assessment to value companies, identify opportunity areas within a company and compare various business models [Malone 1999, Koubarakis 1999, Yu 1993, Zxetie 2003]. It would be much too difficult using these types of approaches to provide a consistent means of comparison within and between companies. Because of this, the hierarchical performance metrics based assessment approach was used in the resulting process.

The criteria selected for the production example are defined in Table 4.2-1

Table 4.2-1. Definition of the Performance Metrics Used in the Production Company Example.

| Major Criteria | Performance Metrics | Definition |
|---|---|---|
| Production Processes | Machine Utilization | The average utilization of all of the machines in a company. |
| | Unit Cost | The average unit cost of the items produced in the company. |
| Product/Services and Marketability | On Time Delivery | The percent of deliveries to customers that are on time. |
| | Stock Outs | The percent of times that an item is not available to ship. |
| | Market Share | The overall percent market share of a company based on total revenue. This sums to 100% for the group of companies in the analysis by year. |
| Management | Revenue Growth | A factor that indicates an increase or decrease in revenue based on the previous year's revenue. Revenue Growth = Past years revenue/current years revenue. |
| | Overhead % Revenue | The ratio (percent) of total overhead expenses to total revenue. |

## 4.3 Step 2: Gather and Analyze Data for the Selected Company.

Data are gathered to support the decision criteria developed in Step 1. If the analyst is a company outsider, this data may be gathered from publicly available sources such as SEC filings, industry analyst reports and purchased benchmarked data. At times, the criteria developed in the initial step must be revised because certain data are incomplete or is not available. Data should be analyzed for reasonability and quality. If it appears that there are problems with the data, expert opinion can be used in the model as another source of information. This type of model provides the ability to incorporate both objective and subjective data.

Data for four production companies, Company A – D, manufacturing a similar product line were used to create. Data was developed for each of the companies for the years 2001 through 2004. The data used in this example was generated using a random generation process. The performance metrics for Companies A and D were developed so that they were higher performance levels than for Companies B and C. This was done to differentiate between the companies in the analysis and the results. Market share performance data are equal to 1.0 for every year. The assumption is that these four companies comprise the total market. The data for this example is shown in Table 4.3-1. CoA2001 represents Company A for the year 2001, etc.

Table 4.3-1. Example of Major Criteria Input Data.

| | Production Processes | | Product/Services and Marketability | | | Management | |
|---|---|---|---|---|---|---|---|
| | BENEFIT | COST | BENEFIT | COST | BENEFIT | BENEFIT | COST |
| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue |
| CoA2001 | 0.86 | 19.6 | 0.88 | 0.050 | 0.250 | 1.1 | 19.7 |
| CoA2002 | 0.87 | 19.1 | 0.90 | 0.040 | 0.258 | 1.14 | 15.5 |
| CoA2003 | 0.86 | 19.3 | 0.93 | 0.010 | 0.265 | 1.17 | 18.1 |
| CoA2004 | 0.92 | 16.7 | 0.95 | 0.020 | 0.273 | 1.14 | 16.4 |
| CoB2001 | 0.82 | 17.9 | 0.90 | 0.020 | 0.250 | 0.99 | 18.0 |
| CoB2002 | 0.78 | 20.0 | 0.88 | 0.030 | 0.245 | 0.97 | 16.0 |
| CoB2003 | 0.79 | 16.6 | 0.89 | 0.010 | 0.240 | 0.98 | 19.3 |
| CoB2004 | 0.76 | 15.0 | 0.85 | 0.040 | 0.235 | 0.98 | 19.3 |
| CoC2001 | 0.90 | 18.8 | 0.90 | 0.070 | 0.250 | 0.93 | 21.0 |
| CoC2002 | 0.82 | 20.9 | 0.75 | 0.060 | 0.235 | 0.91 | 21.7 |
| CoC2003 | 0.85 | 19.5 | 0.83 | 0.040 | 0.221 | 0.95 | 19.2 |
| CoC2004 | 0.86 | 19.5 | 0.82 | 0.060 | 0.208 | 0.98 | 22.5 |
| CoD2001 | 0.84 | 19.0 | 0.88 | 0.040 | 0.250 | 1.09 | 19.0 |
| CoD2002 | 0.89 | 18.0 | 0.93 | 0.020 | 0.263 | 1.1 | 16.3 |
| CoD2003 | 0.92 | 16.8 | 0.98 | 0.010 | 0.276 | 1.15 | 15.8 |
| CoD2004 | 0.91 | 13.7 | 0.98 | 0.020 | 0.289 | 1.12 | 14.1 |

Additionally, statistical analysis, such as regression and other techniques can be performed to determine if there are relationships between the various input and output variables used in the fuzzy logic model. This analysis can then be used to refine fuzzy sets and membership functions used in the process.

The data in Table 4.3-1 also shows a company's performance for a number of years. If an analyst is using this process to project company financial performance and input this information into a DCF business valuation, performance metrics, instead of financial projections are made for future years and this information is used in the DCF business valuation

## 4.4 Step 3: Develop a Score for Each Major Criteria Area.

The example that has been developed contains four companies A – D for the years 2001 – 2004 (See Table 4.3-1 for input data). Table 4.4-1 shows the output TOPSIS score for each of the companies by year for the major criteria Production Processes, Product/Services and Marketability and Management. The TOPSIS score represents the integrated overall performance in each area relative to the other companies and years in the data set. Each of the sub-criteria is either a cost or a benefit. With a cost, the smaller the number, the better the performance. With a benefit, the bigger the number, the better the performance (See Table 4.3-1 above). Each of the sub-criteria is also given a weight that can be changed in the TOPSIS model. For this example, they have all been set equal. The result is the score that is the Relative Closeness to the Ideal Solution. This information will be used in the fuzzy logic model when analyzing a company and the data set. The TOPSIS model is run for each of the different major criteria areas.

Table 4.4-1. Relative Scores by Major Criteria Area for Prediction Years.

| Company Year | Production Processes | Product Services and Marketability | Management |
|---|---|---|---|
| CoA2001 | 0.2928 | 0.3337 | 0.4317 |
| CoA2002 | 0.3496 | 0.501 | 0.8438 |
| CoA2003 | 0.3172 | 0.9145 | 0.6132 |
| CoA2004 | 0.6435 | 0.8409 | 0.7561 |
| CoB2001 | 0.4091 | 0.8124 | 0.4843 |
| CoB2002 | 0.125 | 0.6535 | 0.6225 |
| CoB2003 | 0.5199 | 0.8664 | 0.3568 |
| CoB2004 | 0.6174 | 0.483 | 0.3568 |
| CoC2001 | 0.4165 | 0.1354 | 0.16 |
| CoC2002 | 0.1457 | 0.1973 | 0.0828 |
| CoC2003 | 0.2842 | 0.4737 | 0.3453 |
| CoC2004 | 0.3006 | 0.1916 | 0.1197 |
| CoD2001 | 0.3145 | 0.4944 | 0.4806 |
| CoD2002 | 0.4801 | 0.8308 | 0.7364 |
| CoD2003 | 0.6326 | 0.9677 | 0.8201 |
| CoD2004 | 0.9736 | 0.8487 | 0.9127 |

These scores show how well the company performs relative to each of the other years based on the projections of performance for that year. This information will be used as input variables in the fuzzy logic model.

## 4.5 Step 4: Develop/Update Fuzzy Logic Model

The input variables used in the model are Production Processes, Product/Service and Marketability and Management. The output variable in this example is the Net Operating Profit. As discussed in Chapter 3, the new problem definition can be used to measure performance based on performance metrics and translate these inputs into a financial output variable using a fuzzy logic modeling approach. The new process can be used to solve problems at various levels and in different areas in a company and across a number of industries. In this example, the three input variables and one output variable are defined as fuzzy sets as shown below.

**Production Processes Score** = {**VL**(Very Low), **L**(Low), **M**(Medium), **H**(High), **VH**(Very High}

**Product/Service and Marketability Score** = {**VL**(Very Low), **L**(Low), **M**(Medium), **H**(High), **VH**(Very High}

**Management Score** = {**VL**(Very Low), **L**(Low), **M**(Medium), **H**(High), **VH**(Very High}

**Net Operating Profit** = {**VL**(Very Low), **L**(Low), **M**(Medium), **H**(High), **VH**(Very High}

The universal sets (operating domains) of the input and output variables for this example are:

$U_1 = \{x \mid 0 \leq x \leq 1.0\}$

$U_2 = \{y \mid 0 \leq y \leq 1.0\}$

$U_3 = \{z \mid 0 \leq z \leq 1.0\}$

$U_4 = \{w_l \mid 0 \leq w_l \leq 100\}$ (in millions)

Production rules in the fuzzy environment provide the flexibility to representatively model the fuzzy environment. Fuzzy logic models can be used to solve non-linear problems which can be represented in part with the production rules.

In this example, the production rules were developed in a simple manner. Each of the assessment levels, VL, L, M, H, VH was assigned a number between 1 and 5. VL = 1, L = 2, M = 3, H = 4 and VH = 5. The various combinations of the three areas and their assessment levels were generated. Since there are three areas and five different levels, there is 5 x 5 x 5 = 125 possible combination of assessments. This results in 125 production rules. The three initial conditions, *if*…and *if*… and *if*…lead to the resulting …*then* conclusion of the rule.

The production rule combinations were generated and can be seen in Table 4.5-1. To evaluate the output, first the numbers were assigned to the assessments of VL through VH. Next, the numerical assessments were summed across the rule. Finally, the total was divided by three (number of functional areas) and the results rounded and assigned an assessment level from VL to VH using the number assignment above. For example, the computations for Rule 1 in Table 4.5-1 is (VH =) 5 + (VH =) 5 + (VH =) 5 = 15/3 = 5 = VH. The resulting evaluation is then… VH which corresponds to the numerical assignment. The production rules were created using this process for example purposes only. When using this for an actual company, the functional areas may impact the financial output differently which could then be represented in the production rules. Management and experts in the company and the industry would develop the production rules for use in an actual situation.

Let the major criteria be represented as follows:

- Production Processes (PP)
- Products/Services and Marketability (PSM)
- Management (MG)

Let the output variables be represented as

- Net Operating Profit (NOP)

Table 4.5-1. Production Rules.

| Production Rules | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rule | 1 | *If* | PP is | VH | *and if PSM is* | VH | *and MGT is* | VH | *then* NOP is | VH |
| Rule | 2 | *If* | PP | VH | *and if PSM is* | VH | *and MGT is* | H | *then* NOP is | VH |
| Rule | 3 | *If* | PP | VH | *and if PSM is* | VH | *and MGT is* | M | *then* NOP is | H |
| Rule | 4 | *If* | PP | VH | *and if PSM is* | VH | *and MGT is* | L | *then* NOP is | H |
| Rule | 5 | *If* | PP | VH | *and if PSM is* | VH | *and MGT is* | VL | *then* NOP is | H |
| Rule | 6 | *If* | PP | VH | *and if PSM is* | H | *and MGT is* | VH | *then* NOP is | VH |
| Rule | 7 | *If* | PP | VH | *and if PSM is* | H | *and MGT is* | H | *then* NOP is | H |
| Rule | 8 | *If* | PP | VH | *and if PSM is* | H | *and MGT is* | M | *then* NOP is | H |
| Rule | 9 | *If* | PP | VH | *and if PSM is* | H | *and MGT is* | L | *then* NOP is | H |
| Rule | 10 | *If* | PP | VH | *and if PSM is* | H | *and MGT is* | VL | *then* NOP is | M |
| Rule | 11 | *If* | PP | VH | *and if PSM is* | M | *and MGT is* | VH | *then* NOP is | H |
| Rule | 12 | *If* | PP | VH | *and if PSM is* | M | *and MGT is* | H | *then* NOP is | H |
| Rule | 13 | *If* | PP | VH | *and if PSM is* | M | *and MGT is* | M | *then* NOP is | H |
| Rule | 14 | *If* | PP | VH | *and if PSM is* | M | *and MGT is* | L | *then* NOP is | M |
| Rule | 15 | *If* | PP | VH | *and if PSM is* | M | *and MGT is* | VL | *then* NOP is | M |
| Rule | 16 | *If* | PP | VH | *and if PSM is* | L | *and MGT is* | VH | *then* NOP is | H |
| Rule | 17 | *If* | PP | VH | *and if PSM is* | L | *and MGT is* | H | *then* NOP is | H |
| Rule | 18 | *If* | PP | VH | *and if PSM is* | L | *and MGT is* | M | *then* NOP is | M |
| Rule | 19 | *If* | PP | VH | *and if PSM is* | L | *and MGT is* | L | *then* NOP is | M |
| Rule | 20 | *If* | PP | VH | *and if PSM is* | L | *and MGT is* | VL | *then* NOP is | M |
| Rule | 21 | *If* | PP | VH | *and if PSM is* | VL | *and MGT is* | VH | *then* NOP is | H |
| Rule | 22 | *If* | PP | VH | *and if PSM is* | VL | *and MGT is* | H | *then* NOP is | M |
| Rule | 23 | *If* | PP | VH | *and if PSM is* | VL | *and MGT is* | M | *then* NOP is | M |
| Rule | 24 | *If* | PP | VH | *and if PSM is* | VL | *and MGT is* | L | *then* NOP is | M |
| Rule | 25 | *If* | PP | VH | *and if PSM is* | VL | *and MGT is* | VL | *then* NOP is | L |
| Rule | 26 | *If* | PP | H | *and if PSM is* | VH | *and MGT is* | VH | *then* NOP is | VH |
| Rule | 27 | *If* | PP | H | *and if PSM is* | VH | *and MGT is* | H | *then* NOP is | H |
| Rule | 28 | *If* | PP | H | *and if PSM is* | VH | *and MGT is* | M | *then* NOP is | H |
| Rule | 29 | *If* | PP | H | *and if PSM is* | VH | *and MGT is* | L | *then* NOP is | H |
| Rule | 30 | *If* | PP | H | *and if PSM is* | VH | *and MGT is* | VL | *then* NOP is | M |
| Rule | 31 | *If* | PP | H | *and if PSM is* | H | *and MGT is* | VH | *then* NOP is | H |
| Rule | 32 | *If* | PP | H | *and if PSM is* | H | *and MGT is* | H | *then* NOP is | H |
| Rule | 33 | *If* | PP | H | *and if PSM is* | H | *and MGT is* | M | *then* NOP is | H |
| Rule | 34 | *If* | PP | H | *and if PSM is* | H | *and MGT is* | L | *then* NOP is | M |
| Rule | 35 | *If* | PP | H | *and if PSM is* | H | *and MGT is* | VL | *then* NOP is | M |
| Rule | 36 | *If* | PP | H | *and if PSM is* | M | *and MGT is* | VH | *then* NOP is | H |
| Rule | 37 | *If* | PP | H | *and if PSM is* | M | *and MGT is* | H | *then* NOP is | H |
| Rule | 38 | *If* | PP | H | *and if PSM is* | M | *and MGT is* | M | *then* NOP is | M |
| Rule | 39 | *If* | PP | H | *and if PSM is* | M | *and MGT is* | L | *then* NOP is | M |
| Rule | 40 | *If* | PP | H | *and if PSM is* | M | *and MGT is* | VL | *then* NOP is | M |
| Rule | 41 | *If* | PP | H | *and if PSM is* | L | *and MGT is* | VH | *then* NOP is | H |
| Rule | 42 | *If* | PP | H | *and if PSM is* | L | *and MGT is* | H | *then* NOP is | M |
| Rule | 43 | *If* | PP | H | *and if PSM is* | L | *and MGT is* | M | *then* NOP is | M |
| Rule | 44 | *If* | PP | H | *and if PSM is* | L | *and MGT is* | L | *then* NOP is | M |

| Production Rules | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rule | 45 | *If* | PP | H | *and if PSM is* | L | *and MGT is* | VL | *then* NOP is | L |
| Rule | 46 | *If* | PP | H | *and if PSM is* | VL | *and MGT is* | VH | *then* NOP is | M |
| Rule | 47 | *If* | PP | H | *and if PSM is* | VL | *and MGT is* | H | *then* NOP is | M |
| Rule | 48 | *If* | PP | H | *and if PSM is* | VL | *and MGT is* | M | *then* NOP is | M |
| Rule | 49 | *If* | PP | H | *and if PSM is* | VL | *and MGT is* | L | *then* NOP is | L |
| Rule | 50 | *If* | PP | H | *and if PSM is* | VL | *and MGT is* | VL | *then* NOP is | L |
| Rule | 51 | *If* | PP | M | *and if PSM is* | VH | *and MGT is* | VH | *then* NOP is | H |
| Rule | 52 | *If* | PP | M | *and if PSM is* | VH | *and MGT is* | H | *then* NOP is | H |
| Rule | 53 | *If* | PP | M | *and if PSM is* | VH | *and MGT is* | M | *then* NOP is | H |
| Rule | 54 | *If* | PP | M | *and if PSM is* | VH | *and MGT is* | L | *then* NOP is | M |
| Rule | 55 | *If* | PP | M | *and if PSM is* | VH | *and MGT is* | VL | *then* NOP is | M |
| Rule | 56 | *If* | PP | M | *and if PSM is* | H | *and MGT is* | VH | *then* NOP is | H |
| Rule | 57 | *If* | PP | M | *and if PSM is* | H | *and MGT is* | H | *then* NOP is | H |
| Rule | 58 | *If* | PP | M | *and if PSM is* | H | *and MGT is* | M | *then* NOP is | M |
| Rule | 59 | *If* | PP | M | *and if PSM is* | H | *and MGT is* | L | *then* NOP is | M |
| Rule | 60 | *If* | PP | M | *and if PSM is* | H | *and MGT is* | VL | *then* NOP is | M |
| Rule | 61 | *If* | PP | M | *and if PSM is* | M | *and MGT is* | VH | *then* NOP is | H |
| Rule | 62 | *If* | PP | M | *and if PSM is* | M | *and MGT is* | H | *then* NOP is | M |
| Rule | 63 | *If* | PP | M | *and if PSM is* | M | *and MGT is* | M | *then* NOP is | M |
| Rule | 64 | *If* | PP | M | *and if PSM is* | M | *and MGT is* | L | *then* NOP is | M |
| Rule | 65 | *If* | PP | M | *and if PSM is* | M | *and MGT is* | VL | *then* NOP is | L |
| Rule | 66 | *If* | PP | M | *and if PSM is* | L | *and MGT is* | VH | *then* NOP is | M |
| Rule | 67 | *If* | PP | M | *and if PSM is* | L | *and MGT is* | H | *then* NOP is | M |
| Rule | 68 | *If* | PP | M | *and if PSM is* | L | *and MGT is* | M | *then* NOP is | M |
| Rule | 69 | *If* | PP | M | *and if PSM is* | L | *and MGT is* | L | *then* NOP is | L |
| Rule | 70 | *If* | PP | M | *and if PSM is* | L | *and MGT is* | VL | *then* NOP is | L |
| Rule | 71 | *If* | PP | M | *and if PSM is* | VL | *and MGT is* | VH | *then* NOP is | M |
| Rule | 72 | *If* | PP | M | *and if PSM is* | VL | *and MGT is* | H | *then* NOP is | M |
| Rule | 73 | *If* | PP | M | *and if PSM is* | VL | *and MGT is* | M | *then* NOP is | L |
| Rule | 74 | *If* | PP | M | *and if PSM is* | VL | *and MGT is* | L | *then* NOP is | L |
| Rule | 75 | *If* | PP | M | *and if PSM is* | VL | *and MGT is* | VL | *then* NOP is | L |
| Rule | 76 | *If* | PP | L | *and if PSM is* | VH | *and MGT is* | VH | *then* NOP is | H |
| Rule | 77 | *If* | PP | L | *and if PSM is* | VH | *and MGT is* | H | *then* NOP is | H |
| Rule | 78 | *If* | PP | L | *and if PSM is* | VH | *and MGT is* | M | *then* NOP is | M |
| Rule | 79 | *If* | PP | L | *and if PSM is* | VH | *and MGT is* | L | *then* NOP is | M |
| Rule | 80 | *If* | PP | L | *and if PSM is* | VH | *and MGT is* | VL | *then* NOP is | M |
| Rule | 81 | *If* | PP | L | *and if PSM is* | H | *and MGT is* | VH | *then* NOP is | H |
| Rule | 82 | *If* | PP | L | *and if PSM is* | H | *and MGT is* | H | *then* NOP is | M |
| Rule | 83 | *If* | PP | L | *and if PSM is* | H | *and MGT is* | M | *then* NOP is | M |
| Rule | 84 | *If* | PP | L | *and if PSM is* | H | *and MGT is* | L | *then* NOP is | M |
| Rule | 85 | *If* | PP | L | *and if PSM is* | H | *and MGT is* | VL | *then* NOP is | L |
| Rule | 86 | *If* | PP | L | *and if PSM is* | M | *and MGT is* | VH | *then* NOP is | M |
| Rule | 87 | *If* | PP | L | *and if PSM is* | M | *and MGT is* | H | *then* NOP is | M |
| Rule | 88 | *If* | PP | L | *and if PSM is* | M | *and MGT is* | M | *then* NOP is | M |
| Rule | 89 | *If* | PP | L | *and if PSM is* | M | *and MGT is* | L | *then* NOP is | L |
| Rule | 90 | *If* | PP | L | *and if PSM is* | M | *and MGT is* | VL | *then* NOP is | L |

| Production Rules | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Rule | 91 | *If* | PP | L | *and if PSM is* | L | *and MGT is* | VH | *then* NOP is | M |
| Rule | 92 | *If* | PP | L | *and if PSM is* | L | *and MGT is* | H | *then* NOP is | M |
| Rule | 93 | *If* | PP | L | *and if PSM is* | L | *and MGT is* | M | *then* NOP is | L |
| Rule | 94 | *If* | PP | L | *and if PSM is* | L | *and MGT is* | L | *then* NOP is | L |
| Rule | 95 | *If* | PP | L | *and if PSM is* | L | *and MGT is* | VL | *then* NOP is | L |
| Rule | 96 | *If* | PP | L | *and if PSM is* | VL | *and MGT is* | VH | *then* NOP is | M |
| Rule | 97 | *If* | PP | L | *and if PSM is* | VL | *and MGT is* | H | *then* NOP is | L |
| Rule | 98 | *If* | PP | L | *and if PSM is* | VL | *and MGT is* | M | *then* NOP is | L |
| Rule | 99 | *If* | PP | L | *and if PSM is* | VL | *and MGT is* | L | *then* NOP is | L |
| Rule | 100 | *If* | PP | L | *and if PSM is* | VL | *and MGT is* | VL | *then* NOP is | VL |
| Rule | 101 | *If* | PP | VL | *and if PSM is* | VH | *and MGT is* | VH | *then* NOP is | H |
| Rule | 102 | *If* | PP | VL | *and if PSM is* | VH | *and MGT is* | H | *then* NOP is | M |
| Rule | 103 | *If* | PP | VL | *and if PSM is* | VH | *and MGT is* | M | *then* NOP is | M |
| Rule | 104 | *If* | PP | VL | *and if PSM is* | VH | *and MGT is* | L | *then* NOP is | M |
| Rule | 105 | *If* | PP | VL | *and if PSM is* | VH | *and MGT is* | VL | *then* NOP is | L |
| Rule | 106 | *If* | PP | VL | *and if PSM is* | H | *and MGT is* | VH | *then* NOP is | M |
| Rule | 107 | *If* | PP | VL | *and if PSM is* | H | *and MGT is* | H | *then* NOP is | M |
| Rule | 108 | *If* | PP | VL | *and if PSM is* | H | *and MGT is* | M | *then* NOP is | M |
| Rule | 109 | *If* | PP | VL | *and if PSM is* | H | *and MGT is* | L | *then* NOP is | L |
| Rule | 110 | *If* | PP | VL | *and if PSM is* | H | *and MGT is* | VL | *then* NOP is | L |
| Rule | 111 | *If* | PP | VL | *and if PSM is* | M | *and MGT is* | VH | *then* NOP is | M |
| Rule | 112 | *If* | PP | VL | *and if PSM is* | M | *and MGT is* | H | *then* NOP is | M |
| Rule | 113 | *If* | PP | VL | *and if PSM is* | M | *and MGT is* | M | *then* NOP is | L |
| Rule | 114 | *If* | PP | VL | *and if PSM is* | M | *and MGT is* | L | *then* NOP is | L |
| Rule | 115 | *If* | PP | VL | *and if PSM is* | M | *and MGT is* | VL | *then* NOP is | L |
| Rule | 116 | *If* | PP | VL | *and if PSM is* | L | *and MGT is* | VH | *then* NOP is | M |
| Rule | 117 | *If* | PP | VL | *and if PSM is* | L | *and MGT is* | H | *then* NOP is | L |
| Rule | 118 | *If* | PP | VL | *and if PSM is* | L | *and MGT is* | M | *then* NOP is | L |
| Rule | 119 | *If* | PP | VL | *and if PSM is* | L | *and MGT is* | L | *then* NOP is | L |
| Rule | 120 | *If* | PP | VL | *and if PSM is* | L | *and MGT is* | VL | *then* NOP is | VL |
| Rule | 121 | *If* | PP | VL | *and if PSM is* | VL | *and MGT is* | VH | *then* NOP is | L |
| Rule | 122 | *If* | PP | VL | *and if PSM is* | VL | *and MGT is* | H | *then* NOP is | L |
| Rule | 123 | *If* | PP | VL | *and if PSM is* | VL | *and MGT is* | M | *then* NOP is | L |
| Rule | 124 | *If* | PP | VL | *and if PSM is* | VL | *and MGT is* | L | *then* NOP is | VL |
| Rule | 125 | *If* | PP | VL | *and if PSM is* | VL | *and MGT is* | VL | *then* NOP is | VL |

The fuzzy sets for the input variables Production Processes, Product/Services and Marketability and Management are shown in Figure 4.5.1-1. The scale for these variables are one potential numerical representation of the linguistic terms [Chen and Hwang, 1992]. Others scales may be appropriate based on the environment being modeled and the analyst's preference. Each of the fuzzy sets is defined in terms of the potential TOPSIS score that is always between 0 and 1.0.

TOPSIS Score for Input Variables

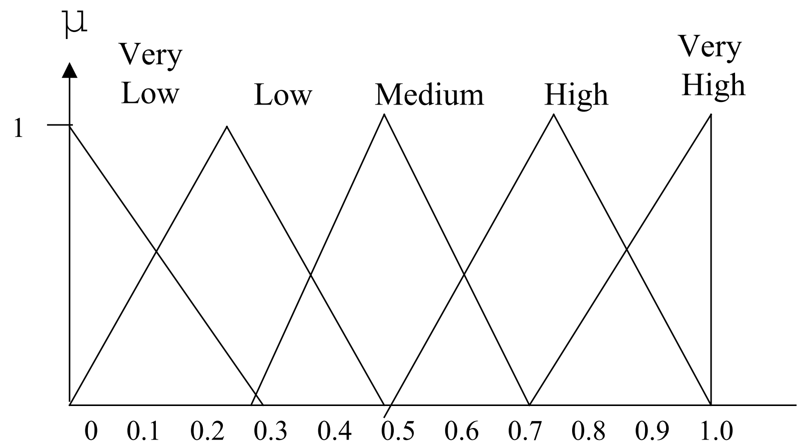



Figure 4.5.1-1. TOPSIS Score for Input Variables.

The membership functions of the terms of the linguistic variables Production Processes Score, Products/Services and Marketability Score and Management Score are shown in equation 4.5.1-1. These membership functions describe each of the right and/or left sides of the fuzzy numbers shown in Figure 4.5.1-1 above. It should be noted that the same membership functions are used for each of the three major criteria scores, therefore the definition of $\mu_{VL}(x) = \mu_{VL}(y) = \mu_{VL}(z)$, $\mu_L(x) = \mu_L(y) = \mu_L(z)$, etc.

$$\mu_{VL}(x) = \begin{cases} \dfrac{0.30 - x}{0.30} & \text{for } 0.00 \le x \le 0.30 \end{cases}$$

$$\mu_{L}(x) = \begin{cases} \dfrac{x}{0.25} & \text{for } 0.00 \le x \le 0.25 \\ \dfrac{0.50 - x}{0.25} & \text{for } 0.25 \le x \le 0.50 \end{cases}$$

$$\mu_{M}(x) = \begin{cases} \dfrac{x - 0.30}{0.20} & \text{for } 0.30 \le x \le 0.50 \\ \dfrac{0.70 - x}{0.20} & \text{for } 0.50 \le x \le 0.70 \end{cases} \qquad (4.5.1\text{-}1)$$

$$\mu_{H}(x) = \begin{cases} \dfrac{x - 0.50}{0.25} & \text{for } 0.50 \le x \le 0.75 \\ \dfrac{1.00 - x}{0.25} & \text{for } 0.75 \le x \le 1.00 \end{cases}$$

$$\mu_{VH}(x) = \begin{cases} \dfrac{x - 0.70}{0.30} & \text{for } 0.70 \le x \le 1.00 \end{cases}$$

The fuzzy sets for the output variable, Net Operating Profit, are shown in Figure 4.5.1-2.

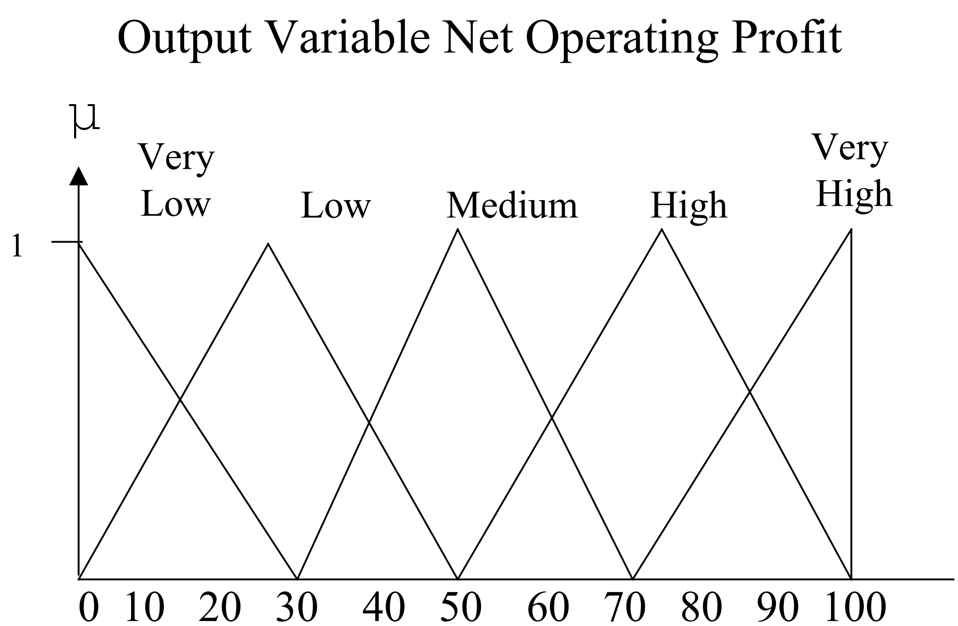


Figure 4.5.1-2. Output Variable Net Operating Profit (in millions).

The terms of linguistic variables Net Operating Profit using a range of 0 to 100,000,000 are defined by the membership function shown in equation 4.5-2. In this example, the output variable and terms are consistent with the input variables and terms. The range of 0 to 100 million Net Operating Profit is used for the fuzzy output variables and in the defuzzification process. In essence, this is the same as the input membership functions with 100 million applied to the 0 to 1 index of the input variable x values, i.e., 0.3 score on the input scale is 30 million on the output scale. In actuality, this would not be the case. However, using this data is beneficial in demonstrating some key aspects of the process that will be discussed later in this chapter.

$$\mu_{VL}(x) = \begin{cases} \frac{30 - x}{30} & \text{for } 0 \le x \le 30 \end{cases}$$

$$\mu_{L}(x) = \begin{cases} \frac{x}{25} & \text{for } 0 \le x \le 25 \\ \frac{50 - x}{25} & \text{for } 25 \le x \le 50 \end{cases}$$

$$\mu_{M}(x) = \begin{cases} \frac{x - 30}{20} & \text{for } 30 \le x \le 50 \\ \frac{70 - x}{20} & \text{for } 50 \le x \le 70 \end{cases} \qquad (4.5.1\text{-}2)$$

$$\mu_{H}(x) = \begin{cases} \frac{x - 50}{25} & \text{for } 50 \le x \le 75 \\ \frac{100 - x}{25} & \text{for } 75 \le x \le 100 \end{cases}$$

$$\mu_{VH}(x) = \begin{cases} \frac{x - 70}{30} & \text{for } 70 \le x \le 100 \end{cases}$$

The shape of the fuzzy numbers used to define the fuzzy set as shown in figures 4.5.1-1 and 2 are used in this case as a somewhat standard starting point for the use of this process. Developing membership functions to represent a problem is one of the most difficult aspects of using fuzzy logic. These linguistic terms and membership functions show that as one term is decreasing, the subsequent term is increasing, i.e., as Very Low decreases, Low increases. This provides some exclusivity in the definition of the membership functions. Additionally, starting with five levels of differentiation provides a number of different levels that are used to generate the results for the process.

As an analyst is more familiar with the environment and the modeling process, these term definitions and membership functions can be modified and refined. The membership functions used in the example are a generic model for illustrative purposes.

## 4.6 Step 5: Generate Fuzzy Outputs From Criteria Score

In this step, the results from the fuzzy logic model generate the predicted results. A sub-set of the data shown in Table 4.3-1 and 4.4-1 will be used to demonstrate this step of the process. This sub-set is shown in Tables 4.6.1-1 and 4.6.1-2.

Table 4.6.1-1. Performance Data for Company A (Subset of Table 4.3-1).

| | Production Processes | | Product/Services and Marketability | | | Management | |
|---|---|---|---|---|---|---|---|
| | BENEFIT | COST | BENEFIT | COST | BENEFIT | BENEFIT | COST |
| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue |
| CoA2001 | 0.86 | 19.6 | 0.88 | 0.050 | 0.250 | 1.1 | 19.7 |
| CoA2002 | 0.87 | 19.1 | 0.90 | 0.040 | 0.258 | 1.14 | 15.5 |
| CoA2003 | 0.86 | 19.3 | 0.93 | 0.010 | 0.265 | 1.17 | 18.1 |
| CoA2004 | 0.92 | 16.7 | 0.95 | 0.020 | 0.273 | 1.14 | 16.4 |

Table 4.6.1-2. Relative Scores by Major Criteria for Company A (Subset of Table 4.4-1).

| Company Year | Production Processes | Product Services and Marketability | Management |
|---|---|---|---|
| CoA2001 | 0.2928 | 0.3337 | 0.4317 |
| CoA2002 | 0.3496 | 0.501 | 0.8438 |
| CoA2003 | 0.3172 | 0.9145 | 0.6132 |
| CoA2004 | 0.6435 | 0.8409 | 0.7561 |

Matching the readings $x_0 = 0.2928$, $y_0 = 0.3337$ and $z_0 = 0.4317$ against the appropriate terms in Figure 4.5.1-1 and in Equation 4.5.1-1 shows the evaluations in Table 4.6.1-3

Table 4.6.1-3. Reading Evaluation for Company A

| | Production Processes | | | | | Product/Services and Marketability | | | | | Management | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Company Year | $\mu_{VL}(x)$ | $\mu_L(x)$ | $\mu_M(x)$ | $\mu_H(x)$ | $\mu_{VH}(x)$ | $\mu_{VL}(y)$ | $\mu_L(y)$ | $\mu_M(y)$ | $\mu_H(y)$ | $\mu_{VH}(y)$ | $\mu_{VL}(z)$ | $\mu_L(z)$ | $\mu_M(z)$ | $\mu_H(z)$ | $\mu_{VH}(z)$ |
| CoA2001 | 0.024 | 0.8288 | 0 | 0 | 0 | 0 | 0.665 | 0.1685 | 0 | 0 | 0 | 0.273 | 0.657 | 0 | 0 |
| CoA2002 | 0 | 0.6016 | 0.248 | 0 | 0 | 0 | 0 | 0.995 | 0.004 | 0 | 0 | 0 | 0 | 0.625 | 0.479 |
| CoA2003 | 0 | 0.7312 | 0.086 | 0 | 0 | 0 | 0 | 0 | 0.342 | 0.715 | 0 | 0 | 0.434 | 0.453 | 0 |
| CoA2004 | 0 | 0 | 0.2825 | 0.57 | 0 | 0 | 0 | 0 | 0.636 | 0.47 | 0 | 0 | 0 | 0.976 | 0.187 |

For Company A, the rule evaluation with the production rules for the readings is shown in Table 4.6.1-4.

Table 4.6.1-4. Rule Evaluation with the Production Rules

| | Production Processes | | | | | Product/Services and Marketability | | | | | Management | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Company Year | $\mu_{VL}(x)$ | $\mu_{L}(x)$ | $\mu_{M}(x)$ | $\mu_{H}(x)$ | $\mu_{VH}(x)$ | $\mu_{VL}(y)$ | $\mu_{L}(y)$ | $\mu_{M}(y)$ | $\mu_{H}(y)$ | $\mu_{VH}(y)$ | $\mu_{VL}(z)$ | $\mu_{L}(z)$ | $\mu_{M}(z)$ | $\mu_{H}(z)$ | $\mu_{VH}(z)$ | Rul Eval | Poss. |
| CoA2001 | 0.024 | 0 | 0 | 0 | 0 | 0 | 0.665 | 0 | 0 | 0 | 0 | 0.273 | 0 | 0 | 0 | L | 0.024 |
| CoA2001 | 0.024 | 0 | 0 | 0 | 0 | 0 | 0.665 | 0 | 0 | 0 | 0 | 0 | 0.659 | 0 | 0 | L | 0.024 |
| CoA2001 | 0.024 | 0 | 0 | 0 | 0 | 0 | 0 | 0.169 | 0 | 0 | 0 | 0.273 | 0 | 0 | 0 | L | 0.024 |
| CoA2001 | 0.024 | 0 | 0 | 0 | 0 | 0 | 0 | 0.169 | 0 | 0 | 0 | 0 | 0.659 | 0 | 0 | L | 0.024 |
| CoA2001 | 0 | 0.829 | 0 | 0 | 0 | 0 | 0.665 | 0 | 0 | 0 | 0 | 0.273 | 0 | 0 | 0 | L | 0.273 |
| CoA2001 | 0 | 0.829 | 0 | 0 | 0 | 0 | 0.665 | 0 | 0 | 0 | 0 | 0 | 0.659 | 0 | 0 | L | 0.659 |
| CoA2001 | 0 | 0.829 | 0 | 0 | 0 | 0 | 0 | 0.169 | 0 | 0 | 0 | 0.273 | 0 | 0 | 0 | L | 0.169 |
| CoA2001 | 0 | 0.829 | 0 | 0 | 0 | 0 | 0 | 0.169 | 0 | 0 | 0 | 0 | 0.659 | 0 | 0 | M | 0.169 |
| CoA2002 | 0 | 0.602 | 0 | 0 | 0 | 0 | 0 | 0.995 | 0 | 0 | 0 | 0 | 0 | 0.625 | 0 | M | 0.602 |
| CoA2002 | 0 | 0.602 | 0 | 0 | 0 | 0 | 0 | 0.995 | 0 | 0 | 0 | 0 | 0 | 0 | 0.479 | M | 0.479 |
| CoA2002 | 0 | 0.602 | 0 | 0 | 0 | 0 | 0 | 0 | 0.004 | 0 | 0 | 0 | 0 | 0.625 | 0 | M | 0.004 |
| CoA2002 | 0 | 0.602 | 0 | 0 | 0 | 0 | 0 | 0 | 0.004 | 0 | 0 | 0 | 0 | 0 | 0.479 | H | 0.004 |
| CoA2002 | 0 | 0 | 0.248 | 0 | 0 | 0 | 0 | 0.995 | 0 | 0 | 0 | 0 | 0 | 0.625 | 0 | M | 0.248 |
| CoA2002 | 0 | 0 | 0.248 | 0 | 0 | 0 | 0 | 0.995 | 0 | 0 | 0 | 0 | 0 | 0 | 0.479 | H | 0.248 |
| CoA2002 | 0 | 0 | 0.248 | 0 | 0 | 0 | 0 | 0 | 0.004 | 0 | 0 | 0 | 0 | 0.625 | 0 | H | 0.004 |
| CoA2002 | 0 | 0 | 0.248 | 0 | 0 | 0 | 0 | 0 | 0.004 | 0 | 0 | 0 | 0 | 0 | 0.479 | H | 0.004 |
| CoA2003 | 0 | 0.731 | 0 | 0 | 0 | 0 | 0 | 0 | 0.342 | 0 | 0 | 0 | 0.434 | 0 | 0 | M | 0.342 |
| CoA2003 | 0 | 0.731 | 0 | 0 | 0 | 0 | 0 | 0 | 0.342 | 0 | 0 | 0 | 0 | 0.453 | 0 | M | 0.342 |
| CoA2003 | 0 | 0.731 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.715 | 0 | 0 | 0.434 | 0 | 0 | M | 0.434 |
| CoA2003 | 0 | 0.731 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.715 | 0 | 0 | 0 | 0.453 | 0 | H | 0.453 |
| CoA2003 | 0 | 0 | 0.086 | 0 | 0 | 0 | 0 | 0 | 0.342 | 0 | 0 | 0 | 0.434 | 0 | 0 | M | 0.086 |
| CoA2003 | 0 | 0 | 0.086 | 0 | 0 | 0 | 0 | 0 | 0.342 | 0 | 0 | 0 | 0 | 0.453 | 0 | H | 0.086 |
| CoA2003 | 0 | 0 | 0.086 | 0 | 0 | 0 | 0 | 0 | 0 | 0.715 | 0 | 0 | 0.434 | 0 | 0 | H | 0.086 |
| CoA2003 | 0 | 0 | 0.086 | 0 | 0 | 0 | 0 | 0 | 0 | 0.715 | 0 | 0 | 0 | 0.453 | 0 | H | 0.086 |
| CoA2004 | 0 | 0 | 0.283 | 0 | 0 | 0 | 0 | 0 | 0.636 | 0 | 0 | 0 | 0 | 0.976 | 0 | H | 0.283 |
| CoA2004 | 0 | 0 | 0.283 | 0 | 0 | 0 | 0 | 0 | 0.636 | 0 | 0 | 0 | 0 | 0 | 0.187 | H | 0.187 |
| CoA2004 | 0 | 0 | 0.283 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 | 0 | 0.976 | 0 | H | 0.283 |
| CoA2004 | 0 | 0 | 0.283 | 0 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 | 0 | 0 | 0.187 | H | 0.187 |
| CoA2004 | 0 | 0 | 0 | 0.574 | 0 | 0 | 0 | 0 | 0.636 | 0 | 0 | 0 | 0 | 0.976 | 0 | H | 0.574 |
| CoA2004 | 0 | 0 | 0 | 0.574 | 0 | 0 | 0 | 0 | 0.636 | 0 | 0 | 0 | 0 | 0 | 0.187 | H | 0.187 |
| CoA2004 | 0 | 0 | 0 | 0.574 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 | 0 | 0.976 | 0 | H | 0.47 |
| CoA2004 | 0 | 0 | 0 | 0.574 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 | 0 | 0 | 0.187 | VH | 0.187 |

Recalling from Equation 2.4.2-1, the strength of the rule or the level of firing is determined by:

$$\alpha_{ijk} = \min(\mu_{Ai}(x_0), \mu_{Bj}(y_0), \mu_{Ck}(z_0)) \qquad \{2.4.2\text{-}1\}$$

This is done for all active rules to determine the rule strength table.

With the fuzzy inputs in this example, eight active rules are fired for Company A for each of the 4 years. Recalling from Equation 2.4.2-1, the strength of the rule or the level of firing is determined by

$$\alpha_{ijk} = \min(\mu_{Ai}(x_0), \mu_{Bj}(y_0), \mu_{Ck}(z_0)) \qquad \{2.4.2\text{-}1\}$$

This formula is used to determine the rule strength for all active rules in the rule strength table.

The strength of the rule or the possibility associated with the evaluation of the first output rule Company A for the year 2001 is:

$$\begin{aligned}\alpha_{ijk} &= \mu_{\mathbf{VL}}(0.024) \wedge \mu_{\mathbf{L}}(0.665) \wedge \mu_{\mathbf{L}}(0.273) \\ &= \min(0.024, 0.665, 0.273) \\ &= 0.024\end{aligned}$$

This evaluation done for each output rule for the company by year.

The output of each rule is defined by operation conjunction applied on its strength and conclusion. Recalling from equation 2.3.2-2, the output of each rule is defined by operation conjunction applied on its strength and conclusion as follows:

Output of rule 1: $\alpha_{ijk} \wedge \mu_{Sijk}(w)$ {2.4.2-2}

Eight rules for each year are active from this example; the following operation will be performed to aggregate the input. Based on the fuzzy decision rules set forth in Table 4.5-1 and the linguistic evaluation shown in Table 4.6.1-4, the following production rule is fired.

Rule 3: *If Production Processes is Very Low and Product/Service and Marketability is Low and Management is Low, then Net Operating Profit is Low.*

The conclusion of this rule, $\mu_{agg}$, is as follows where based on the production rule, $\mu_{Sijk}(w)$ = Low

Output Rule: $\min(0.024, \mu_{Sijk}(w) = L)$

Recalling from Chapter 2 and Equation 2.4.2-3, the outputs of the active rules must then be aggregated or combined in order to produce one control output. The max operation is used for aggregation. (Shown below in general with three "if" conditions, i.e., $2^3$ possible combinations).

$$\begin{aligned}\mu_{agg}(w) = {} & (\alpha_{ijk} \wedge \mu_{Sijk}(w)) \vee (\alpha_{ij+1k} \wedge \mu_{Sij+1k}(w)) \\ & \vee (\alpha_{ij+1k+1} \wedge \mu_{Sij+1k+1}(w)) \vee (\alpha_{i+1jk} \wedge \mu_{Si+1jk}(w)) \\ & \vee (\alpha_{i+1j+1k} \wedge \mu_{Si+1j+1k}(w)) \vee (\alpha_{i+1j+1k+1} \wedge \mu_{Si+1j+1k+1}(w)) \qquad \{2.4.2\text{-}3\} \\ & \vee (\alpha_{i+1jk+1} \wedge \mu_{Si+1jk+1}(w)) \vee (\alpha_{ijk+1} \wedge \mu_{Sijk+1}(w))\end{aligned}$$

$$\begin{aligned}\mu_{agg}(w) = \max \{ & (\alpha_{ijk} \wedge \mu_{Sijk}(w)), (\alpha_{ij+1k} \wedge \mu_{Sij+1k}(w)), (\alpha_{ij+1k+1} \wedge \mu_{Sij+1k+1}(w)), \\ & (\alpha_{i+1jk} \wedge \mu_{Si+1jk}(w)), (\alpha_{i+1j+1k} \wedge \mu_{Si+1j+1k}(w)), (\alpha_{i+1j+1k+1} \wedge \mu_{Si+1j+1k+1}(w)), \\ & (\alpha_{i+1jk+1} \wedge \mu_{Si+1jk+1}(w)), (\alpha_{ijk+1} \wedge \mu_{Sijk+1}(w))\}\end{aligned}$$

In this example, the aggregation function is as follows:

$$\begin{aligned}\mu_{agg}(w) = {} & (0.024 \wedge \mu_L(w)) \vee (0.024 \wedge \mu_L(w)) \vee (0.024 \wedge \mu_L(w)) \vee (0.024 \wedge \mu_L(w)) \\ & \vee (0.273 \wedge \mu_L(w)) \vee (0.659 \wedge \mu_L(w)) \vee (0.169 \wedge \mu_L(w)) \vee (0.169 \wedge \mu_M(w))\end{aligned}$$

The result is:

$\mu_{agg}(w) = \max\{\min(0.659, \mu_L(w)),\ \min(0.169, \mu_M(w))\}$

To generate the final dollar value, these membership functions must be defuzzified. The fuzzy set and membership functions defining the output variable are shown in Figure 4.5.1-2 and Equation 4.5.1-2. The center of area method (CAM) will be used to defuzzify the output. The interval [0,100] in millions will be divided into 10 equal parts with each length of 10. The substitution of $w_k$ into $\mu_{agg}(w) = 0, 10, \ldots, 100$ are

$\mu_{agg}(w) = [.4(10) + .659(20) + .659(30) + .4(40) + .169(50) + .169(60)/(.4 +.659 + .659 + .4 + .169 + .169) = 71.54/2.456 = 29, 129$ million Net Operating Profit.

This process is repeated for each of the years projected in the analysis. The rule evaluation and strength or possibility functions for the evaluation are shown in the table. This is used to defuzzify the results.

Table 4.6.1-5. Rule Evaluation and Possibility Functions for Company A.

| Company Year | $\mu_{VL}(x)$ | $\mu_L(x)$ | $\mu_M(x)$ | $\mu_H(x)$ | $\mu_{VH}(x)$ | $\mu_{VL}(y)$ | $\mu_L(y)$ | $\mu_M(y)$ | $\mu_H(y)$ | $\mu_{VH}(y)$ | $\mu_{VL}(z)$ | $\mu_L(z)$ | $\mu_M(z)$ | $\mu_H(z)$ | $\mu_{VH}(z)$ | Rule Eval | Poss. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CoA2001 | 0 | 0.829 | 0 | 0 | 0 | 0 | 0.665 | 0 | 0 | 0 | 0 | 0 | 0.659 | 0 | 0 | L | 0.659 |
| CoA2001 | 0 | 0.829 | 0 | 0 | 0 | 0 | 0 | 0.169 | 0 | 0 | 0 | 0 | 0.659 | 0 | 0 | M | 0.169 |
| CoA2002 | 0 | 0.602 | 0 | 0 | 0 | 0 | 0 | 0.995 | 0 | 0 | 0 | 0 | 0 | 0.625 | 0 | M | 0.602 |
| CoA2002 | 0 | 0 | 0.248 | 0 | 0 | 0 | 0 | 0.995 | 0 | 0 | 0 | 0 | 0 | 0 | 0.479 | H | 0.248 |
| CoA2003 | 0 | 0.731 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.715 | 0 | 0 | 0.434 | 0 | 0 | M | 0.434 |
| CoA2003 | 0 | 0.731 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.715 | 0 | 0 | 0 | 0.453 | 0 | H | 0.453 |
| CoA2004 | 0 | 0 | 0 | 0.574 | 0 | 0 | 0 | 0 | 0.636 | 0 | 0 | 0 | 0 | 0.976 | 0 | H | 0.574 |
| CoA2004 | 0 | 0 | 0 | 0.574 | 0 | 0 | 0 | 0 | 0 | 0.47 | 0 | 0 | 0 | 0 | 0.187 | VH | 0.187 |

The results for Company A for years 2001 through 2004 are shown in Table 4.6.1-6.

Table 4.6.1-6. Resulting Net Operating Profit for Company A.

| Company Year | Net Operating Profit (in thousands) |
|---|---|
| CoA2001 | 29,129 |
| CoA2002 | 59,514 |
| CoA2003 | 64,820 |
| CoA2004 | 77,190 |

This step provides a prediction of the Net Operating Profit for a company for a specific prediction year, based on their anticipated performance in the areas associated with the performance metrics. Overall, performance metrics provide the basis for the prediction, rather than financial information alone. The fuzzy logic model, as with any model, should be tuned to the environment over time. Information used in the model could be gathered, further analyzed and refined for use in the model. Expert opinion from seasoned analysts can also be used to refine the production rules. The end result of this step, however, is the predicted Net Operating Profit by Year that will be used in the computation of business value using the Discounted Cash Flow method.

## 4.7 Step 6: Generate Discounted Cash Flow Business Valuation

Table 4.7-1 shows the general computations required to generate a Discounted Cash Flow (DCF) business valuation using the information generated from the fuzzy logic control model. The approach to DCF business valuation described here is very simplistic. An experienced business valuator would provide additional insight, information and technical knowledge in a real business valuation scenario. In this example, there is a detailed four-year forecast for the years 2001 through 2004 that, for example purposes, simply uses the data that was generated in Step 5. After this point, the continuing value of the firm is computed. We are assuming that the predictions for the performance metrics would have been made in the year 2000 and that the data used in this example for Company A would be predictions for the years 2001 – 2004.

Table 4.7-1. Computations for Generating Discounted Cash Flow.

| Prediction Year for Company A | Company A 2001 | Company A 2002 | Company A 2003 | Company A 2004 |
|---|---|---|---|---|
| Predicted Net Operating Profit by Year (in millions) | $29 | $60 | $65 | $77 |
| Estimated Amortization | $2 | $5 | $3 | $2 |
| Operating Earnings Before Interest, Taxes and Amortization (EBITA) | $31 | $65 | $68 | $79 |
| Taxes on EBITA (39%) | $12 | $25 | $27 | $31 |
| Changes in Deferred Taxes | -$8 | -$9 | -$6 | -$11 |
| **Net Operating Profit Less Accumulated Taxes (NOPLAT)** | **$11** | **$31** | **$35** | **$37** |
| Net Investment | -$9 | -$11 | -$5 | -$5 |
| **Free Cash Flow** | **$2** | **$20** | **$30** | **$32** |
| Weighted Average Cost of Capital (WACC) | 6.7% | 6.7% | 6.7% | 6.7% |
| Present Value of Cash Flows | $2 | $17 | $24 | $23 |
| **Total Present Value of Cash Flows in 5-Year Planning Horizon** | **$66** | | | |
| Return on Invested Capital (ROIC) in perpetuity | 15% | | | |
| Expected growth rate in NOPLAT in perpetuity (g) | 5% | | | |
| Weighted Average Cost of Capital (WACC) in perpetuity | 6.7% | | | |
| **Continuing Value** | **$1,458** | | | |
| Present Value Of Free Cash Flow Years 1 - 4 | $66 | | | |
| Present Value of Continuing Value (discounted at WACC in perpetuity) | $1,055 | | | |
| **Operating Value** | **$1,120** | | | |
| Equity Value (Operating Value + Market Value of Non-Operating Assets - Debt and Non-equity sources of financing) *Example for this case* | $1,123 | | | |
| Most Recent Shares Outstanding (in millions) | 50 | | | |
| Price per share | $22.46 | | | |

Each of the terms used in the table above are briefly described below.

1. Predicted Net Operating Profit by Year (in millions) – This is the NOP generated by the fuzzy logic control model.
2. Estimated Amortization – Amortization is included in the NOP projection, so it must be removed from the prediction. Estimates are made regarding these quantities.
3. Operating Earnings Before Interest, Taxes and Amortization (EBITA) – This is the operating earning before interest, taxes and amortization with amortization removed from the prediction from the fuzzy logic control model.
4. Taxes on EBITA (39%) – Taxes on EBITA were determined by using an estimated tax rate of 39% applied to EBITA.
5. Changes in Deferred Taxes – Changes to the deferred taxes referred to actual income taxes adjusted to a cash basis. For this example, they were estimated and used in this forecast.
6. Net Operating Profit Less Accumulated Taxes (NOPLAT) – This represents the after-tax operating profits of the company after adjusting the taxes to a cash basis.
7. Net Investment – Net investment is the change in invested capital. Invested capital is the capital invested in the company by shareholders and creditors and operating and other non-operating activities.
8. Free Cash Flow (FCF) – Free cash flow is a company's true operating cash flow. It is the total after-tax cash flow generated by the company to all providers of the company's capital.
9. Weighted Average Cost of Capital (WACC) – The opportunity costs to all the capital providers weighted by their relative contribution to the company's total capital.
10. Present Value of Cash Flows – This is the free cash flows discounted to the present value using the WACC as the discount rate.
11. Total Present Value of Cash Flows in 5-Year Planning Horizon – Sum of cash flows for 5-year planning horizon.

12. Return on Invested Capital (ROIC) in perpetuity – The Return on Invested Capital is the NOPLAT divided by the Invested capital. In this case, it is an estimate of the ROIC projected for the years used to determine the continuing value of a company.
13. Expected growth rate in NOPLAT in perpetuity (g) – This is the expected growth rate in NOPLAT for the years used to determine the continuing value of a company.
14. Weighted Average Cost of Capital (WACC) in perpetuity – This is the WACC for the years used to determine the continuing value of a company.
15. Continuing Value – This is the resulting computation for the continuing value of a company. The formula is shown in Section 3. The base for the Continuing Value is shown in the table above and is the average NOPLAT over the shorter term planning horizon.
16. Present Value Of Free Cash Flow Years 1 – 5 – This is the Free Cash Flow discounted over the forecast horizon. In this case, a five year horizon was used.
17. Present Value of Continuing Value (discounted at WACC in perpetuity) – This is the quantity computed for the continuing value of the company discounted back to the present value. This is done based on the formula shown in Section 3 Step 6.
18. Operating Value – This is the sum of the present value of the FCF years 1 – 5 and the present value of the continuing value of the firm.
19. Equity Value (Operating Value + Market Value of Non-Operating Assets - Debt and Non-equity sources of financing) The equity value is the operating value of the firm plus the market value of non-operating assets minus the debt and non-equity sources of financing. The equity value of the firm can be used to estimate the share price of a stock. In this example, the operating value has been increased by 2.4 million to demonstrate this concept.
20. Most Recent Shares Outstanding – This is the most recent estimated of the shares outstanding for the company.
21. Price per share – The price per share is the equity value of the stock divided by the most recent outstanding shares.

The result of this example shows the operating value of the firm at $1,120 million and the resulting price per share of the firm at $22.46 per share. One of the primary inputs into the DCF calculation is the Net Operating Profit which is the predicted value from the fuzzy logic model. The other inputs into the DCF would be based on accounting information. This step shows how the predicted Net Operating Profit from the fuzzy logic model integrates with the business valuation process.

### 4.8 Reasonableness of New Business Valuation Process

The data developed and used shown in Tables 4.3-1 was used to test the reasonableness of the new business valuation process. The goal of the test was to determine whether the model using this data could generate inconsistent or unreasonable results. Reasonable results are those results that fall within the realm of possible outcomes. The TOPSIS ranking method and the fuzzy logic model used in the new business valuation process are used as discussion points for exploring the reasonableness of the results generated by the model

The data set in Table 4.3-1 was developed so that Companies A and D would be the higher performing companies for the various years and that Companies B and C would be the lower performing companies. A random number generator using the RANDBETWEEN function in MS Excel was used to set limits on the data that would be used for each of the criteria in the dataset by company. This data set provided a differentiation in input data that would provide a difference in performance and resulting financial output by company. This data set will be used further in the analysis.

A number of aspects associated with testing the robustness of the model were performed. The first was to determine whether the data used could generate output results outside of the realm of possibilities. The second was to show how concepts such as market share could be addressed in the model. The third was to show how one could use this process to identify areas that a manager may look in order to improve the performance of a company.

### 4.8.1 Can the New Process Generate Unreasonable Outputs?

The first step of the test for robustness in the model was to determine whether unreasonable outputs could be generated from this model. A relatively simple test was used to show that this would not be possible unless an analyst used completely unreasonable information within this process.

Table 4.8.1-1 shows the input data used to generate the TOPSIS performance score for the company. Also included in this table are the Positive-Ideal Solution (PIS) and the Negative-Ideal Solution (NIS) for the data set. The PIS represents the best possible scores for a decision criteria across all. The NIS represents the worst possible solution for a decision criteria across all criteria. The PIS and NIS are relative to all of the other data in the data set. The TOPSIS method uses the measures from the PIS and the NIS to determine the performance score of the alternative, or in this case, the Company – Year combination. Since the PIS and NIS are values that are contained within the data set, assuming that they are accurate and not an aberration, the performance scores generated by TOPSIS must be within the realm of operating possibilities. If new data are added to the existing data set, TOPSIS recalculates the PIS and NIS based on all of the data in the dataset. The scores in this part of the process must be bounded by the PIS and NIS used in TOPSIS. This means that the input into the fuzzy logic model must be within the realm of existing possibilities.

Table 4.8.1-1. Input Data with Positive and Negative-Ideal Solutions

| | Production Processes | | Product/Services and Marketability | | | Management | |
|---|---|---|---|---|---|---|---|
| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue |
| CoC2002 | 0.82 | 20.9 | 0.75 | 0.060 | 0.235 | 0.91 | 21.7 |
| CoC2001 | 0.90 | 18.8 | 0.90 | 0.070 | 0.250 | 0.93 | 21.0 |
| CoC2004 | 0.86 | 19.5 | 0.82 | 0.060 | 0.208 | 0.98 | 22.5 |
| CoA2001 | 0.86 | 19.6 | 0.88 | 0.050 | 0.250 | 1.10 | 19.7 |
| CoC2003 | 0.85 | 19.5 | 0.83 | 0.040 | 0.221 | 0.95 | 19.2 |
| CoB2002 | 0.78 | 20.0 | 0.88 | 0.030 | 0.245 | 0.97 | 16.0 |
| CoB2004 | 0.76 | 15.0 | 0.85 | 0.040 | 0.235 | 0.98 | 19.3 |
| CoD2001 | 0.84 | 19.0 | 0.88 | 0.040 | 0.250 | 1.09 | 19.0 |
| CoA2002 | 0.87 | 19.1 | 0.90 | 0.040 | 0.258 | 1.14 | 15.5 |
| CoB2003 | 0.79 | 16.6 | 0.89 | 0.010 | 0.240 | 0.98 | 19.3 |
| CoB2001 | 0.82 | 17.9 | 0.90 | 0.020 | 0.250 | 0.99 | 18.0 |
| CoA2003 | 0.86 | 19.3 | 0.93 | 0.010 | 0.265 | 1.17 | 18.1 |
| CoD2002 | 0.89 | 18.0 | 0.93 | 0.020 | 0.263 | 1.10 | 16.3 |
| CoA2004 | 0.92 | 16.7 | 0.95 | 0.020 | 0.273 | 1.14 | 16.4 |
| CoD2003 | 0.92 | 16.8 | 0.98 | 0.010 | 0.276 | 1.15 | 15.8 |
| CoD2004 | 0.91 | 13.7 | 0.98 | 0.020 | 0.289 | 1.12 | 14.1 |
| | | | | | | | |
| PIS | 0.92 | 13.7 | 0.980 | 0.010 | 0.289 | 1.170 | 14.100 |
| NIS | 0.76 | 20.9 | 0.750 | 0.070 | 0.208 | 0.910 | 22.500 |

The next question is whether the fuzzy logic model can produce results outside the realm of possibilities. To address this question, the membership functions established for the TOPSIS scores and the Financial output (Net Operating Profit) will be discussed. The process developed in this thesis uses fuzzy sets and linguistic terms with 5 different levels of the form seen in Figure 4.5.1-1 with membership functions given by Equation 4.5.1-1. These membership functions are membership functions that have been developed and used for representing linguistic variables [Chen and Hwang]. The conversion scales used as a starting point in the definition of the linguistic terms were selected so that as one term increases, the next term decreases, which would logically follow suit in performance measurement such as this. The TOPSIS score is the x-axis that is used as the input for the performance scores in each of the primary areas.

The same conversion scale that is used with the TOPSIS input variables is used when defuzzifying the results, however, it is indexed by minimum and maximum output financial information from the data set. In this example, it is assumed that all NOP fall between 0 and 100 million. The conversion scales for the input variables that are between 0 and 1.0 are used to index the NOP output of 0 to 100 million. If reasonable output data are indexed with the conversion scale shown in Figure 4.5.1-1 (in this case 0 to 100 million), a resulting output conversion scale such as Figure 4.5.1-2 will be generated.

To demonstrate the ability of the approach to generate reasonable answers, a test was run with the input data based on the use of the PIS and NIS solution. The PIS and NIS solutions were included in the test data to determine the results generated by the model. Additionally, the NIS was used as a base point and 25%, 50% and 75% of the NIS performance value was added to the NIS. This was done to determine how well the process would perform in generating incremental 25% improvements to the NIS and is shown in Table 4.8.1-2. The results of this analysis in respect to all of the data in the data set are shown in Table 4.8.1-3.

Table 4.8.1-2. PIS, NIS and 25% Increments.

| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue |
|---|---|---|---|---|---|---|---|
| PIS | 0.92 | 13.7 | 0.98 | 0.01 | 0.2894 | 1.17 | 14.1 |
| NIS | 0.76 | 20.9 | 0.75 | 0.07 | 0.2076 | 0.91 | 22.5 |
| 25% + NIS | 0.8 | 19.1 | 0.8075 | 0.055 | 0.2281 | 0.975 | 20.4 |
| 50% + NIS | 0.84 | 17.3 | 0.865 | 0.04 | 0.2485 | 1.04 | 18.3 |
| 75% + NIS | 0.88 | 15.5 | 0.9225 | 0.025 | 0.269 | 1.105 | 16.2 |

Table 4.8.1-3. Results from NIS Incremental Improvement Analysis.

| | Production Processes | | Product/Services and Marketability | | | Management | | |
|---|---|---|---|---|---|---|---|---|
| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue | Test Case Add Best Worst (000) |
| PIS | 0.920 | 13.700 | 0.980 | 0.010 | 0.289 | 1.170 | 14.100 | 100000 |
| CoD2004 | 0.91 | 13.7 | 0.98 | 0.020 | 0.289 | 1.12 | 14.1 | 83724 |
| CoD2003 | 0.92 | 16.8 | 0.98 | 0.010 | 0.276 | 1.15 | 15.8 | 79446 |
| CoA2004 | 0.92 | 16.7 | 0.95 | 0.020 | 0.273 | 1.14 | 16.4 | 77205 |
| NIS +75% | 0.880 | 15.500 | 0.923 | 0.025 | 0.269 | 1.105 | 16.200 | 76626 |
| CoD2002 | 0.89 | 18.0 | 0.93 | 0.020 | 0.263 | 1.1 | 16.3 | 75000 |
| CoA2003 | 0.86 | 19.3 | 0.93 | 0.010 | 0.265 | 1.17 | 18.1 | 64845 |
| CoB2001 | 0.82 | 17.9 | 0.90 | 0.020 | 0.250 | 0.99 | 18.0 | 62093 |
| CoB2003 | 0.79 | 16.6 | 0.89 | 0.010 | 0.240 | 0.98 | 19.3 | 60593 |
| CoA2002 | 0.87 | 19.1 | 0.90 | 0.040 | 0.258 | 1.14 | 15.5 | 59397 |
| NIS +50% | 0.840 | 17.300 | 0.865 | 0.040 | 0.249 | 1.040 | 18.300 | 50000 |
| CoB2004 | 0.76 | 15.0 | 0.85 | 0.040 | 0.235 | 0.98 | 19.3 | 47832 |
| CoD2001 | 0.84 | 19.0 | 0.88 | 0.040 | 0.250 | 1.09 | 19.0 | 46491 |
| CoB2002 | 0.78 | 20.0 | 0.88 | 0.030 | 0.245 | 0.97 | 16.0 | 40249 |
| CoA2001 | 0.86 | 19.6 | 0.88 | 0.050 | 0.250 | 1.1 | 19.7 | 30928 |
| CoC2003 | 0.85 | 19.5 | 0.83 | 0.040 | 0.221 | 0.95 | 19.2 | 30441 |
| NIS +25% | 0.800 | 19.100 | 0.808 | 0.055 | 0.228 | 0.975 | 20.400 | 25000 |
| CoC2001 | 0.90 | 18.8 | 0.90 | 0.070 | 0.250 | 0.93 | 21.0 | 25000 |
| CoC2002 | 0.82 | 20.9 | 0.75 | 0.060 | 0.235 | 0.91 | 21.7 | 25000 |
| CoC2004 | 0.86 | 19.5 | 0.82 | 0.060 | 0.208 | 0.98 | 22.5 | 25000 |
| NIS | 0.760 | 20.900 | 0.750 | 0.070 | 0.208 | 0.910 | 22.500 | 0 |

Table 4.8.1-4 shows the condensed results of the test analysis. As the table shows, the PIS results in a Net Operating Profit of 100,000,000 which is the maximum value of the defuzzification fuzzy set. The NIS results in a Net Operating Profit of 0 which is the minimum value used in the minimum value of the defuzzification fuzzy set. The NIS + 75% which would be the same as the PIS – 25% results in an output value of 76,626. This is consistent with the 75% level but accounts for the overlap between the linguistic terms Very High and High. The NIS + 50% results in a singleton representation of Medium. The NIS + 25% results in a NOP of 25,000. Although there is overlap between the linguistic terms Very Low and Low, the contribution of Very Low in the defuzzification process is 0 because of the conversion scale.

These results are logical based on the methods used in this process. Since TOPSIS generates a relative score based on the PIS and NIS, a 25%, 50% and 75% increase to the NIS would result in an approximate 25%, 50% and 75% increase in NOP, respectively.

Table 4.8.1-4. Condensed Results of the Test Analysis.

| | Production Processes | | Product/Services and Marketability | | | Management | | |
|---|---|---|---|---|---|---|---|---|
| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue | Net Operating Profit |
| PIS | 0.920 | 13.700 | 0.980 | 0.010 | 0.289 | 1.170 | 14.100 | 100000 |
| NIS + 75% | 0.880 | 15.500 | 0.923 | 0.025 | 0.269 | 1.105 | 16.200 | 76626 |
| NIS + 50% | 0.840 | 17.300 | 0.865 | 0.040 | 0.249 | 1.040 | 18.300 | 50000 |
| NIS + 25% | 0.800 | 19.100 | 0.808 | 0.055 | 0.228 | 0.975 | 20.400 | 25000 |
| NIS | 0.760 | 20.900 | 0.750 | 0.070 | 0.208 | 0.910 | 22.500 | 0 |

It should be noted that an analyst may find that other scales (positive and negative) and membership functions may be better adapted to their specific problem. However, if this process is used as a general guide in the initial development of the input and output variables, an output solution that is outside the realm of possibilities will not be generated. If however, unreasonable data and poorly utilized conversion scales are used in this process, the process itself will not be effective. It is the same concept of "garbage in – garbage out." The analyst using this process must understand the functionality of this process and the key elements associated with the development and use of it.

### 4.8.2 How Can Market Share be Addressed in this Process?

Table 4.3-1 (and 4.8.1-1) show the decision criteria Market Share under the major criteria Product/Services and Marketability in this example. By year, the market share for the four companies sums to one. The market share is measured by the percent of the total revenue volume of the companies in the data set. As the market share of one company increases, the market share of at least one of the other companies decrease. This would be used to represent a "zero sum gain" with the companies in the data set. This means that each company potentially has a different percent of the market share by year. The "zero sum game" approach provides one way to describe the changes in market share that may occur based on changes to the business environment.

The structure of this process allows for the inclusion of a variety of different decision criteria. Both a MADM and a fuzzy logic model are developed and integrated as part of this process. This process allows for the use of some of the powerful aspects of each of these technologies and the flexibility to represent criteria and information important to the decision maker.

### 4.8.3 How Can a Manager Use this Process to Improve the Performance of A Company?

The new business valuation process provides a new approach to determining performance area improvements and their associated financial impact. Using this tool to identify areas for performance improvement in a company is a driving factor in the development of the new process. Two different heuristics are described in this section that can facilitate this process. The first uses the concept of increasing the value of the NIS across all of the decision criteria simultaneously in equal percentage increments to determine the impact on the output variable. The second focuses on a specific area or areas, i.e., decision criteria, and inputs new values to determine the impact on the output variable.

These are only two of many different methods that can be used to identify areas of improvement in a company. For example, one may not choose to increase the NIS across all decision criteria simultaneously, but increase the value in different percentages for each decision criteria. Reference points other than the NIS may be used in the analysis, i.e., the current performance of a specific company. One may also focus on only one major criteria area, such Production Processes, and test the impact of making changes based on any of these different heuristic methods. Also, one may hold certain decision criteria at a given level and change the performance of the other decision criteria. Another method may be to identify investment costs associated with performance improvement levels, substitute the enhanced performance levels into the data set, determine the increase in company value from the model and then determining whether the payback warrants the dollar investment in performance improvement. This investment analysis could be done on a single year or multiple year basis. Overall, the goal is to explore the decision space and highlight areas that can identify improvement areas within the company.

#### 4.8.3.1 Sequential Simultaneous Increase in Negative-Ideal Solution

The heuristic process described in this section involves determining the increase in output performance based on simultaneously increasing the performance values of a company based on the Negative-ideal Solution in the data set. Increments can be chosen based on user preference, i.e., 25%, 10%, 1%, etc. and these incremental changes in performance included in the dataset to generate the results. This heuristic process is shown in the following steps:

Step I: Identify the NIS from the Data set – This involves identifying the worst values for each criteria in the data set.

Step II: Identify Increment – Select an increment value, $\delta$, which is between 0 and 100% to make the incremental steps.

Step III: Compute the Incremental Changes – This is done using the following formula:

$NISIncrement_{ij} = NIS_j + (i*\delta_i) * NIS_j$ for i = 1 to k where $(k*\delta_i) \leq 100\%$ and j = 1 to n number of criteria.

Step IV: Include $NISIncrement_i$ vector in the existing data set. – Depending on the size of the increment, include k generated increment vectors in the data set.

Step VI: Compute Results by Using Steps 3 through 6 of the business valuation process. – Run the newly developed incremental data through the new business valuation process. Analyze the results and repeat Steps I – VI as necessary.

This heuristic method tests the improvement of the performance metrics for a company by increasing each criterion by a specific amount, i.e., 25%, simultaneously. Tables 4.8.1-3 and 4.3.1-4 show the resulting performance values by increasing the NIS by 25%. Management can then use this information along with the current performance information of the company to determine potential courses of action and their associated potential financial impact and return. It can also be used to provide bounds of possibilities. This would show that if performance improved in the range of 25% to 50%, the company can expect a resulting range of financial improvement.

4.8.3.2 Focal Point Performance Area Improvement

This heuristic method provides a much more focused approach to developing and analyzing performance improvements and their impact within a company. With this approach, specific criteria are selected and then new goals for the performance of the criteria are input into the data set. This new process is applied to the changed criteria in the data set and the results are then generated. Using this approach, management can focus its analysis in a specific area.

Table 4.3.1-3 shows that for Company B in the year 2004, the NOP was 47,832 thousands. The performance information for the year showed that the On-Time Delivery was .85 or 85% and the Stockouts were .04 or 4%. Management chose to focus on these two areas and determine the impact of improvements on their overall NOP. To do this, they changed the input values for CoB2004 so that On-Time Delivery was .95 or 95% and the Stockouts were .02 or 2%. The results are shown in Table 4.8.3-1.

Table 4.8.3-1. Focal Point Performance Area Improvement Results

| | Production Processes | | Product/Services and Marketability | | | Management | | |
|---|---|---|---|---|---|---|---|---|
| Company Year | Machine Utilization | Unit Cost | On Time Delivery | Stock Outs | Market Share | Revenue Growth Factor | Overhead as a % of Total Operating Revenue | Net Operating Profit |
| PIS | 0.92 | 13.7 | 0.980 | 0.010 | 0.289 | 1.170 | 14.1 | 100000 |
| CoD2004 | 0.91 | 13.7 | 0.980 | 0.020 | 0.289 | 1.120 | 14.1 | 83724 |
| CoD2003 | 0.92 | 16.8 | 0.980 | 0.010 | 0.276 | 1.150 | 15.8 | 79446 |
| CoA2004 | 0.92 | 16.7 | 0.950 | 0.020 | 0.273 | 1.140 | 16.4 | 77205 |
| NIS + 75% | 0.88 | 15.5 | 0.923 | 0.025 | 0.269 | 1.105 | 16.2 | 76626 |
| CoD2002 | 0.89 | 18.0 | 0.930 | 0.020 | 0.263 | 1.100 | 16.3 | 75000 |
| CoA2003 | 0.86 | 19.3 | 0.930 | 0.010 | 0.265 | 1.170 | 18.1 | 64845 |
| CoB2001 | 0.82 | 17.9 | 0.900 | 0.020 | 0.250 | 0.990 | 18.0 | 62093 |
| **New CoB2004** | **0.76** | **15.0** | **0.950** | **0.020** | **0.235** | **0.980** | **19.3** | **61916** |
| CoB2003 | 0.79 | 16.6 | 0.890 | 0.010 | 0.240 | 0.980 | 19.3 | 60593 |
| CoA2002 | 0.87 | 19.1 | 0.900 | 0.040 | 0.258 | 1.140 | 15.5 | 59397 |
| NIS + 50% | 0.84 | 17.3 | 0.865 | 0.040 | 0.249 | 1.040 | 18.3 | 50000 |
| **Original CoB2004** | **0.76** | **15.0** | **0.85** | **0.04** | **0.235** | **0.98** | **19.3** | **47832** |
| CoD2001 | 0.84 | 19.0 | 0.880 | 0.040 | 0.250 | 1.090 | 19.0 | 46491 |
| CoB2002 | 0.78 | 20.0 | 0.880 | 0.030 | 0.245 | 0.970 | 16.0 | 40249 |
| CoA2001 | 0.86 | 19.6 | 0.880 | 0.050 | 0.250 | 1.100 | 19.7 | 30928 |
| CoC2003 | 0.85 | 19.5 | 0.830 | 0.040 | 0.221 | 0.950 | 19.2 | 30441 |
| NIS + 25% | 0.80 | 19.1 | 0.808 | 0.055 | 0.228 | 0.975 | 20.4 | 25000 |
| CoC2001 | 0.90 | 18.8 | 0.900 | 0.070 | 0.250 | 0.930 | 21.0 | 25000 |
| CoC2002 | 0.82 | 20.9 | 0.750 | 0.060 | 0.235 | 0.910 | 21.7 | 25000 |
| CoC2004 | 0.86 | 19.5 | 0.820 | 0.060 | 0.208 | 0.980 | 22.5 | 25000 |
| NIS | 0.76 | 20.0 | 0.750 | 0.070 | 0.208 | 0.910 | 22.5 | 0 |

The results show that the changes to the criteria result in an increase to the NOP from 47,832 to 61,619. Management may then be able to look at the costs associated with gaining that improvement and determine whether the investment in that performance area is beneficial to the company. The steps in this heuristic method are relatively simple.

Step I: Identify the Performance Area and Criteria to Test in the Analysis – This involves identifying the areas in which to focus the performance impact analysis. This may include one or more criteria for the company.

Step II: Modify Performance Criteria in Data Set – The performance criteria are modified to reflect the managers area of interest for the analysis. The performance criteria are modified in the data set.

Step III: Compute Results by Using Steps 3 through 6 of the business valuation process. – Run the newly developed incremental data through the new business valuation process. Analyze the results are repeat Steps I – VI as necessary.

This provides another approach to using this process to analyze the impact of company business performance on the financial output.

## 4.9 Chapter Summary

This chapter provides a step-by-step example of the approach to using the new business valuation process. An example of the computational procedures are given in each step to provide the reader with specific insight into the methods and computations used.

Additionally, the robustness of the model is tested and discussed in this chapter. Analysis in this chapter shows that the model is bounded by the Positive and Negative-ideal Solutions used in the TOPSIS method and bounded by the definition of the output variable linguistic terms. If linguistic terms and membership functions for the input and output variables are within the operating ranges of the data used in the analysis, the model does not output unreasonable results.

This chapter also discusses the use of the criteria Market Share. As the market share of one company increases and the market share of another company decreases in the business environment. The market share is measured by the percent of the total revenue volume of the companies in the data set. As the market share of one company increases, the market share of at least one of the other companies decrease year by year. Using the "zero-sum gain" approach provides one way to measure market share for the companies in the data set.

Two heuristic approaches to using this model to determining performance improvement opportunities and their impact is described. One method uses a sequential simultaneous increase in negative-ideal solution to test the impact of simultaneous increases in performance metrics on the financial outcome. The second method uses a focal point performance area improvement approach to test the impact of performance increases in a specified area. Either of these methods can be used to aid management and both can be used simultaneously as well. The goal is to aid management in identifying areas for potential performance improvement in the company.

# CHAPTER 5
# REGIONAL AIRLINE STUDIES

## 5.1 Introduction

This chapter provides an example of the process developed in this research applied to the regional airline industry. The regional airline industry was selected for the "real world" example due to a number of different selection parameters (See section 2.3.2). The goal of this section is to demonstrate the use of the process with actual data.

Two regional airlines, Atlantic Coast Airlines, called Independence Air, and SkyWest, Inc. were used in this analysis. The two airlines were selected because they have similar characteristics and are public companies with readily available data. The business valuation process was used to approximate the Net Operating Profit for the years 2001 – 2003. The data used in this section was extracted from the Bureau of Transportation Statistics web site, the annual reports for the companies and the 10-k report submitted to the Security and Exchange Commission (SEC) on their web site by each company.

The business valuation process was performed for each of the airlines individually and then for the airlines combined. This was done to determine differences in performance of the process for individual airlines and then to determine the impact on the model when combining the two companies. The business valuation process will use the original fuzzy logic model with the structure of the membership functions and five level fuzzy sets. This basic model structure, i.e., production rules, 5-level linguistic scale and membership functions for the input variables and the indexed 5-level linguistic scales and membership functions for the output variables is described in Chapters 3 and 4. From here, the membership functions and fuzzy sets will be modified in an attempt to better reflect the operating environment. The business valuation process will be applied to the two airlines combined with a revised fuzzy logic model and the results discussed.

## 5.2 Example Using Original Fuzzy Logic Model

### 5.2.1 Step 1. Identify Industry and Industry Related Criteria.

Looking at all of the potential choices, one of the supervisory committee members suggested looking at a new airline company called Independence Air which was formerly known as the regional airline Atlantic Coast Airlines. Preliminary analysis of this company showed interesting promise in that the original company was looking to transform itself from a regional airline to a regional hub (central scheduling and routing point) and spoke (satellite departures and destinations and low cost carrier, with its primary hub at Dulles Airport in Washington, DC. This company was assessed with the selection criteria described in Section 2 and was selected as the company within the airline industry to use as a test case in this analysis. A description of how Independence Air meets each of the selection criteria listed above is given below.

1. *Uniformity of business, services and products* – The airline industry provides a fairly standard service which is to transport individuals (or freight) from one destination to another destination. Although the equipment used, operating philosophy, repair in-house or outsourcing, pricing, advertising and intended markets can be different, in general, similar equipment and procedures are used to support this industry. This airline is a regional airline, which provides a narrower definition of an airline industry and basis for comparison. In this case, the analysis will be limited to transporting individuals and not address goods and material transportation such as that provided by Federal Express, Airborne, etc.

2. *Established industry* – The airline industry is an established industry. High capital investment, fixed facilities and basic need generated by this society make this industry one that has been in business a long time and will most likely stay that way in the future. The profile of operating philosophies has changed, moving from standard, legacy airlines to low cost carriers, changing

services, service levels and expectations required by individual companies. The industry however, overall, is established and will continue in the future.

3. *Company with new, interesting or successful approach to business* – One of the greatest success stories in the airline industry is Southwest Airlines. Southwest created and successfully implemented a new image and its version of the low cost carrier business model is one of the best and most stable airlines in the industry overall. Other new company business models, working to meet different needs within the market, specifically regional airlines with lower capacity aircraft, provide a new and interesting market to the airline industry. Regional airlines are also anticipated to be a high growth area in the airline industry. Additionally, Independence Air, previously Atlantic Coast Airlines, has a proven track record as a regional airline. It is looking to expand the regional airline market using a hub and spoke concept thereby potentially creating new markets and an expanded customer base. These reasons influenced the selection of Independence Air as the analysis company.

4. *Accessibility to data and information* – The airline industry is discussed and tracked in business literature and government information. Since the Federal Aviation Administration (FAA) governs this industry, much of the data regarding safety and other issues is available to the public in database and excel spreadsheet form on Department of Transportation (DOT), Bureau of Transportation and Statistics (BTS) and FAA web sites. The business and government data provide a good base point for enabling the successful completion of this research.

5. *Knowledge and/or experience with industry* – Having worked with the FAA on a number of projects dealing with staffing of inspectors in a variety of airports and with different types of aircraft during the last 10 years will provide some background and insight to information regarding the airline

industry. This should be beneficial in the overall analysis and application of the new business valuation process to the airline industry.

Initially, Independence Air was the only regional airline used to test the results of this process. Another regional airline, SkyWest, Inc. with similar performance characteristics and financial information was also used to test the results of this process for the regional airline industry.

Regional airlines represent a sub-segment of the overall airline industry and have experienced significant growth in recent years. Public information regarding the airline industry was available because of the government regulation in this industry. Using the airline industry provided access to information that may have been more difficult to get regarding specific company performance. In this example, assume that an airline industry analyst or a senior manager in an airline company has chosen to use this method to analyze the projected value of an airline company.

The performance metrics associated with two regional airlines will be assessed and used to develop a prediction of the Net Operating Profit for the airlines for each year. It is first necessary to develop a set of decision criteria that will be used to measure performance metrics associated with the three major criteria of Production Processes, Products/Services and Marketability and Management. Once those metrics are developed, data associated with the metrics will be gathered and assessed to determine a set of criteria that can be used in the business analysis.

A number of sources of information were used to develop the decision criteria. Studies and reports on the industry, SEC information, annual reports and in this case, government provided public performance information. Different areas were studied to develop the decision criteria used in this analysis. A study was reviewed specifically addressing airline industry metrics and financial performance. Also, performance metrics tracked on the Bureau of Transportation Statistics web site, the SEC web site and in annual reports were reviewed. From the studies and reports identified, a determination was made as to performance metrics that were potentially viable for use in the regional airline study. These performance metrics would then be further analyzed and refined to develop a final set of performance metrics/decision criteria to be used in the regional airline analysis.

One source used was a study performed specifically for the airline industry that uses econometric and statistical methods to determine the value relevance of non-financial performance variables and accounting information such as operating incomes, operating expenses and stock returns [Riley 2003]. Findings from this study and other studies cited in this research show that non-financial variables exhibit incremental value relevance over traditional accounting metrics which supports the premise of this thesis. The non-financial performance variables used in Riley's are listed below:

- Customer Service
    - Mishandled baggage
    - Customer complaints
    - On-time arrivals
    - Ticket oversales
    - In-flight service
- Revenue load factor (revenue ton miles divided by available ton miles)
- Market share (number of passengers for airline divided by total number of passengers for 10 largest airlines)
- Capacity (available ton miles)
- Economic and industry variables
    - Weighted average of quarterly state income data and geographic areas covered by airlines
    - Hub changes
    - Changes in the utilization of large airports
    - Changes in the number of all airports utilized
    - Haul lengths
    - Changes in the number of revenue departures
- Effect of bankruptcies

- Effects of airline accidents

This research was based on using the quarterly changes associated with most of these variables. The variables with the primary impact to stock returns (either positive or negative) were revenue load factor and available ton miles positively associated with stock returns while market share and customer dissatisfaction negatively associated with stock returns. Interestingly enough, one of the limitations cited in this study [Riley 2003] with using non-financial data was the lack of solid theoretical or analytical modeling foundation to capture opinions or soft data. The Multiple Attribute Decision Making and Fuzzy Logic methods used in this research would overcome the limitations discussed in that research because they do provide a theoretical foundation for measuring non-financial performance variables or soft data.

Using the data and study mentioned above, along with Department of Transportation (DOT) reports, Bureau of Transportation Statistics (BTS), FAA information, and Office of the Inspector General Data, a number of performance metrics were identified for potential use in the analysis. Data from all sources was not available, required expert opinion that also was not available or was not directly pertinent to this study. This meant that a sub-set of the identified and potentially viable decision criteria were explored in more detail to determine the potential use in the regional airline example. The three major criteria being used are Production Processes, Products/Services and Marketability and Management. Performance metrics that were identified for further exploration to support the three major criteria include:

Production Processes

- Revenue load factor
- Unit Cost
- Unit Revenue
- Available ton miles
- Available passenger miles
- Revenue aircraft hours flown

- Revenue departures performed
- Passenger enplanements
- Number of airline accidents
- Number of airline incidents
- Number of airline occurrences

Product/Services and Marketability

- Mishandled baggage
- Customer complaints
- On-time arrivals
- Ticket oversales
- In-flight service
- Number of destinations serviced
- Haul lengths
- Market share
- Aircraft in service

Management

- Fuel costs
- Overhead percent of revenue
- Revenue growth
- Age of fleet
- Number of different types of aircraft maintained by company
- Operating expenses

Financial data gathered associated with the decision criteria data included:

- Total operating revenue
- Net operating profit
- Net income

The top 20 regional airlines as identified by the Regional Airline Association in the year 2003 were used in the initial analysis. Data tables were created for each of the top 20 regional using the decision criteria data shown above. The data analysis associated with this data is discussed in Step 2.

### 5.2.2 Step 2: Gather and Analyze Data for the Selected Company.

Once the potential decision criteria for the regional airline industry were identified, the data for the top 20 regional airlines for a ten-year time frame from 1994 – 2003 was gathered and assessed. It became quickly apparent that data for all of the 20 regional airlines identified was not available or was not available in a form that was useful. The data identified for the analysis was incomplete for 12 of the 20 airlines. Of the remaining 8 airlines, data for only the past five years was available. This occurred because data was not submitted completely to the federal government, some of the regional airlines were subsidiaries of larger companies, i.e., American Eagle is a part of American Airlines and certain pieces of data could not be separated using the BTS data or the SEC 10-k data. This meant that to gain a complete picture of the "inputs and outputs," the number of airlines assessed and the criteria used to assess the airlines would need to be evaluated more closely. The data used in the analysis was either included or excluded based on the reasons shown in Table 5.2.2-1

Table 5.2.2-1. Preliminary Decision Criteria Assessed in the Analysis.

| Decision Criteria | Reason To Include or Exclude | Included? |
|---|---|---|
| **Production Processes** | | |
| Revenue load factor | Good criteria, however relates to Unit Revenue | No |
| Unit Cost | Measure of operating expenses to available seat miles. All airlines report this metric and used by industry analysts. | Yes |
| Unit Revenue | Measure of operating revenue to available seat miles. All airlines report this metric and used by industry analysts. | Yes |
| Available ton miles | Not always reported by airlines | No |
| Available passenger miles | Should be referenced to operating expenses or revenues and contained in Unit Cost and Unit Revenue | No |
| Revenue aircraft hours flown | Unable to get information for all airlines. | No |
| Revenue departures performed | Unable to get information for all airlines. | No |
| Passenger enplanements | Determined that should be referenced to some cost, revenue or equipment factor. | No |
| Number of airline accidents | Very few accidents to use in analysis. | No |
| Number of airline incidents | Appeared to make no difference in results in model. | No |
| Number of airline occurrences | Appeared to make no difference in results in model. | No |
| **Product/Services and Marketability** | | |
| Mishandled baggage | Incomplete information for all airlines and only approximately 2 year history. | No |
| Customer complaints | Incomplete information for all airlines and only approximately 2 year history. | No |
| On-time arrivals | Incomplete information for all airlines and only approximately 2 year history. | No |
| Ticket oversales | Incomplete information for all airlines and only approximately 2 year history. | No |
| In-flight service | Incomplete information for all airlines and only approximately 2 year history. | No |
| Number of destinations serviced | Complete information for last 5 years | Yes |
| Haul lengths | Complete information for last 5 years | Yes |
| Market share | Difficult to define market and not used. | No |
| Aircraft in service | Complete information for last 5 years | Yes |
| **Management** | | |
| Fuel costs | Not all information available in a singular form – was combined with other costs | No |
| Overhead percent of revenue | Complete information for last 5 years | Yes |
| Revenue growth | Complete information for last 5 years | Yes |

| Decision Criteria | Reason To Include or Exclude | Included? |
|---|---|---|
| Age of fleet | Complete information for last 5 years | Yes |
| Number of different types of aircraft maintained by company | Difficult to get exact numbers. Conflict from government site and annual reports. | No |
| Operating expenses | Too general of information for a decision criteria | No |
| **Financial data** | | |
| Total operating revenue | Does not show relationship to costs. | No |
| Net operating profit | Shows more pure view of operating revenues and costs and is a good starting point for DCF calculations | Yes |
| Net income | Incorporates tax considerations and may be diluted or modified more heavily by accounting principles. | No |

The criteria selected for use in the analysis from the originally identified decision criteria represent key considerations in the airline industry regarding production processes, products/services and marketability and management and are summarized below.

Input Decision Criteria

- Production processes
  - Unit Cost
  - Unit Revenue
  - Passenger Load Factor
- Products/services and marketability
  - Aircraft in service
  - Number of destinations
  - Average passenger trip length
- Management
  - Age of fleet
  - Overhead Percent of Revenue of Salaries and Benefits
  - Revenue Growth

Output Predicted Variable

- Net Operating Profit.

Table 5.2.2-2 shows the airlines used in the initial 5-year analysis.

Table 5.2.2-2. Companies used in Preliminary 5-Year Analysis.

| Carrier Name |
|---|
| Air Wisconsin Airlines Corp |
| American Eagle Airlines,inc |
| Atlantic Coast Airlines |
| Atlantic Southeast Airlines |
| Continental Express Airline |
| Horizon Air |
| Mesaba Airlines |
| Skywest Airlines, Inc. |

The data from 1999 – 2003 was preliminarily tested with the new process and the results showed that the process could be applied to the regional airline industry. However, with the tragedy of September 11, 2001, it was felt that a longer set of data for one or more companies may provide a better long-term representation of relationships between the inputs and outputs used in the model and the ability for the model to approximate the Output Variable.

At this point, data for two companies were identified for continued analysis. Information was available for a ten year time period for the performance criteria identified above. The data for the two companies for the three major criteria and nine sub-criteria over the ten-year time frame is shown Table 5.2.2-3 below. The code DH1994 represents Atlantic Coast Airlines (DH) for the year 1994. The code OO1994 represents SkyWest, Inc (OO) for the year 1994. These are carrier codes used by the Bureau of Transportation Statistics to represent each of these companies. The table also uses Cost and Benefit to represent whether smaller is a better number (cost) or bigger is a better number (benefit).

Table 5.2.2-3. Example of Major Criteria Input Data.

| | Production Processes | | | Product/Services and Marketability | | | Management | | |
|---|---|---|---|---|---|---|---|---|---|
| | BENEFIT | COST | BENEFIT | BENEFIT | BENEFIT | BENEFIT | COST | COST | BENEFIT |
| | Unit Revenue | Unit Cost | Passenger Load Factor | Aircraft in Service | Number of Destinations | Average Passenger Trip Length | Age of Fleet (Years) | Percent Total Operating Revenue Salaries and Benefits | Revenue Growth |
| | | | | | | | | | |
| DH1994 | 0.179 | 0.189 | 0.443 | 56 | 42 | 254 | 4.9 | 0.262 | 1.0901 |
| DH1995 | 0.215 | 0.198 | 0.477 | 54 | 41 | 245 | 4.9 | 0.259 | 0.9877 |
| DH1996 | 0.237 | 0.211 | 0.465 | 57 | 39 | 245 | 4.7 | 0.244 | 1.1626 |
| DH1997 | 0.239 | 0.205 | 0.488 | 65 | 43 | 252 | 5.1 | 0.241 | 1.1258 |
| DH1998 | 0.206 | 0.168 | 0.562 | 74 | 53 | 313 | 5.4 | 0.235 | 1.4113 |
| DH1999 | 0.195 | 0.168 | 0.581 | 84 | 51 | 320 | 5.8 | 0.243 | 1.1981 |
| DH2000 | 0.205 | 0.194 | 0.577 | 105 | 53 | 336 | 4.4 | 0.238 | 1.3029 |
| DH2001 | 0.177 | 0.164 | 0.576 | 117 | 64 | 384 | 3.1 | 0.282 | 1.2762 |
| DH2002 | 0.175 | 0.161 | 0.675 | 137 | 84 | 396 | 3.6 | 0.268 | 1.3167 |
| DH2003 | 0.189 | 0.166 | 0.714 | 145 | 85 | 395 | 4.1 | 0.242 | 1.1524 |
| OO1994 | 0.216 | 0.188 | 0.475 | 55 | 48 | 200 | 6 | 0.284 | 1.2460 |
| OO1995 | 0.188 | 0.171 | 0.501 | 60 | 48 | 236 | 5 | 0.27 | 1.1923 |
| OO1996 | 0.169 | 0.166 | 0.492 | 63 | 48 | 264 | 5 | 0.265 | 1.1259 |
| OO1997 | 0.173 | 0.163 | 0.508 | 60 | 48 | 270 | 3.67 | 0.248 | 1.1327 |
| OO1998 | 0.181 | 0.160 | 0.509 | 60 | 64 | 249 | 4.9 | 0.255 | 1.0683 |
| OO1999 | 0.217 | 0.177 | 0.553 | 102 | 64 | 213 | 5.4 | 0.262 | 1.5319 |
| OO2000 | 0.232 | 0.192 | 0.566 | 107 | 63 | 228 | 5.6 | 0.259 | 1.1491 |
| OO2001 | 0.212 | 0.189 | 0.611 | 131 | 66 | 278 | 6 | 0.278 | 1.1508 |
| OO2002 | 0.178 | 0.151 | 0.687 | 149 | 81 | 356 | 4.8 | 0.259 | 1.2867 |
| OO2003 | 0.151 | 0.132 | 0.718 | 185 | 106 | 393 | 4.7 | 0.254 | 1.1467 |

### 5.2.3 Step 3: Develop a Score for Each Major Criteria Area.

The TOPSIS model is run for each of the different major criteria areas. TOPSIS can assign different weights to each of the criteria. In this case, all weights for the sub-criteria are defined to be equal. The approach used in this analysis is that data from the first 7 years would be used as the starting point for the process and then the process would be used to predict or approximate the NOP for the years 2001 – 2003. These results would then be compared to the actual NOP to determine their accuracy.

It is anticipated that this process will be performed from the perspective of an analyst that is looking at information through the years and then is modifying their model based on the changes in information. The assumption is that the analyst would develop the model based on the current data (assuming that it is the year 2000), i.e., data from 1994 through 2000. Then, as information became available, the model would be re-run with the new data and would be tuned to the new information. In the first part of this chapter where the process is performed using the original model structure discussed in Chapters 3 and 4, the membership functions and scales used for this process will not change. In the second part of this chapter, as additional information becomes available for each new year, the model will be adapted to the new information.

A TOPSIS score is then generated for the years 1994 – 2000, 1994 – 2001, 1994 – 2002 and 1994 – 2003. The analyst would use this process to approximate one, two or three years, in this example, based on their knowledge at a given point. In this case, the assumption is that the analyst is at the very end of the year 2000 and is using this process to predict for years 2001 first, then 2001 and 2002 and finally 2001, 2002 and 2003. Instead of making financial predictions, the analyst will make performance metric predictions and then input these predictions into the model/process to predict the financial results. These performance predictions can be made for any number of years in the future. In this case, they are made one year (2001), two years (2001 and 2002) and three years (2001, 2002 and 2003) years into the future. The results of these predictions are then tested against the actual results. In this example, the actual performance information for the years 2001, 2002 and 2003 will be used so that the results from using the process can be compared to the actual Net Operating Profit.

An example of the input and output from the TOPSIS score generation process for DH in the years 1994 – 2001 is shown in Table 5.2.3-1. The input data to the TOPSIS method is the Unit Revenue, Unit Cost and Passenger Load Factor for each year. The weights are set to equal and the Cost/Benefit associated with the criteria are shown in the table. Running the TOPSIS process then generates the output TOPSIS score. The TOPSIS method is described in Chapter 2 and include calculating the normalized ratings for each decision criteria, calculating the weighted normalized ratings for each decision criteria, identifying the positive and negative ideal solutions, calculating the separation measures and calculating the similarities to the positive-ideal solution. These results are shown in

Table 5.2.3-1 below. This process is repeated for Product/Services and Marketability and Management for each of the company/year combinations used in this analysis. The TOPSIS scores for the major criteria will then be input into the fuzzy logic model.

Table 5.2.3-1. Example of TOPSIS Score Input and Output for Production Processes

| | Production Processes | | | |
|---|---|---|---|---|
| | BENEFIT | COST | BENEFIT | |
| | Unit Revenue | Unit Cost | Passenger Load Factor | TOPSIS Score for Production Processes |
| DH1994 | 0.179 | 0.189 | 0.443 | 0.2215 |
| DH1995 | 0.215 | 0.198 | 0.477 | 0.4134 |
| DH1996 | 0.237 | 0.211 | 0.465 | 0.4662 |
| DH1997 | 0.239 | 0.211 | 0.488 | 0.5260 |
| DH1998 | 0.206 | 0.205 | 0.562 | 0.6814 |
| DH1999 | 0.195 | 0.168 | 0.581 | 0.6281 |
| DH2000 | 0.205 | 0.168 | 0.577 | 0.5697 |
| DH2001 | 0.177 | 0.194 | 0.576 | 0.5441 |

This section will analyze the two companies individually and both of the companies combined. TOPSIS is a relative process so when the minimum and maximum data in the model change, the relative scores will also change. TOPSIS must then be re-run to account for this. Because of this, a performance score must be generated for each company individually and then for the two companies combined for the three different prediction scenarios. The scores for the specific airline for each of the prediction year in the major criteria area are shown in Table 5.2.3-2a - c.

Table 5.2.3-2a. Relative Scores by Major Criteria Area for Independence Air.

| 2001 | Net Operating Profit | PP Scores | PSM Scores | MGT Scores | 2002 | Net Operating Profit | PP Scores | PSM Scores | MGT Scores | 2003 | Net Operating Profit | PP Scores | PSM Scores | MGT Scores |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DH1994 | -23278 | 0.2215 | 0.0686 | 0.3183 | DH1994 | -23278 | 0.1824 | 0.0492 | 0.3191 | DH1994 | -23278 | 0.2237 | 0.0993 | 0.1656 |
| DH1995 | 12845 | 0.4134 | 0.0381 | 0.2843 | DH1995 | 12845 | 0.3346 | 0.0272 | 0.2866 | DH1995 | 12845 | 0.3687 | 0.0813 | 0.2332 |
| DH1996 | 20263 | 0.4662 | 0.0355 | 0.4414 | DH1996 | 20263 | 0.3936 | 0.0251 | 0.44 | DH1996 | 20263 | 0.409 | 0.0812 | 0.2442 |
| DH1997 | 28943 | 0.526 | 0.1529 | 0.3407 | DH1997 | 28943 | 0.4377 | 0.1085 | 0.3377 | DH1997 | 28943 | 0.4395 | 0.1164 | 0.2802 |
| DH1998 | 52691 | 0.6814 | 0.4128 | 0.4624 | DH1998 | 52691 | 0.5709 | 0.2994 | 0.4539 | DH1998 | 52691 | 0.528 | 0.254 | 0.2933 |
| DH1999 | 49292 | 0.6281 | 0.4896 | 0.2861 | DH1999 | 49292 | 0.5624 | 0.3466 | 0.2796 | DH1999 | 49292 | 0.5155 | 0.2827 | 0.3178 |
| DH2000 | 24087 | 0.5697 | 0.7083 | 0.6015 | DH2000 | 24087 | 0.4987 | 0.4974 | 0.5978 | DH2000 | 24087 | 0.4478 | 0.3775 | 0.3252 |
| DH2001 | 44194 | 0.5441 | 1 | 0.7353 | DH2001 | 44194 | 0.4992 | 0.6882 | 0.7408 | DH2001 | 44194 | 0.4629 | 0.5026 | 0.3262 |
| | | | | | DH2002 | 62633 | 0.6174 | 1 | 0.7451 | DH2002 | 62633 | 0.5812 | 0.6831 | 0.3405 |
| | | | | | | | | | | DH2003 | 137903 | 0.6458 | 0.7197 | 0.3526 |

Table 5.2.3-2b. Relative Scores by Major Criteria Area for SkyWest.

| DATA 2001 | NOP | PP | PSM | MGT | DATA 2002 | NOP | PP | PSM | MGT | DATA 2003 | NOP | PP | PSM | MGT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| OO1994 | 24680 | 0.4309 | 0 | 0.2206 | OO1994 | 24680 | 0.3483 | 0 | 0.2184 | OO1994 | 24680 | 0.3831 | 0 | 0.218 |
| OO1995 | 20341 | 0.3435 | 0.148 | 0.3652 | OO1995 | 20341 | 0.2791 | 0.1112 | 0.3664 | OO1995 | 20341 | 0.3195 | 0.0812 | 0.3667 |
| OO1996 | 5710 | 0.2822 | 0.2432 | 0.3291 | OO1996 | 5710 | 0.2419 | 0.1884 | 0.3311 | OO1996 | 5710 | 0.2501 | 0.1387 | 0.3314 |
| OO1997 | 15417 | 0.3358 | 0.2456 | 0.5858 | OO1997 | 15417 | 0.2874 | 0.1939 | 0.5896 | OO1997 | 15417 | 0.296 | 0.1444 | 0.5903 |
| OO1998 | 33958 | 0.3891 | 0.2921 | 0.3443 | OO1998 | 33958 | 0.3298 | 0.236 | 0.3467 | OO1998 | 33958 | 0.3451 | 0.1751 | 0.347 |
| OO1999 | 82819 | 0.6405 | 0.5895 | 0.5503 | OO1999 | 82819 | 0.4979 | 0.4167 | 0.5467 | OO1999 | 82819 | 0.4862 | 0.2965 | 0.5459 |
| OO2000 | 89047 | 0.6395 | 0.6574 | 0.2214 | OO2000 | 89047 | 0.5258 | 0.4578 | 0.2214 | OO2000 | 89047 | 0.5033 | 0.323 | 0.2212 |
| OO2001 | 65564 | 0.6367 | 1 | 0.114 | OO2001 | 65564 | 0.5446 | 0.6772 | 0.113 | OO2001 | 65564 | 0.5011 | 0.4769 | 0.1127 |
| | | | | | OO2002 | 119555 | 0.6247 | 1 | 0.5066 | OO2002 | 119555 | 0.604 | 0.6888 | 0.5065 |
| | | | | | | | | | | OO2003 | 108480 | 0.5695 | 1 | 0.4301 |

Table 5.2.3-2c. Relative Scores by Major Criteria Area for Two Companies.

| DATA 2001 | NOP | PP | PSM | MGT | DATA 2002 | NOP | PP | PSM | MGT | DATA 2003 | NOP | PP | PSM | MGT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DH1994 | -23278 | 0.2199 | 0.1557 | 0.3231 | DH1994 | -23278 | 0.1864 | 0.1272 | 0.3249 | DH1994 | -23278 | 0.2237 | 0.0993 | 0.1656 |
| DH1995 | 12845 | 0.4125 | 0.1268 | 0.2902 | DH1995 | 12845 | 0.3407 | 0.1038 | 0.2928 | DH1995 | 12845 | 0.3687 | 0.0813 | 0.2332 |
| DH1996 | 20263 | 0.4603 | 0.1279 | 0.4301 | DH1996 | 20263 | 0.3932 | 0.1039 | 0.431 | DH1996 | 20263 | 0.409 | 0.0812 | 0.2442 |
| DH1997 | 28943 | 0.5111 | 0.1916 | 0.341 | DH1997 | 28943 | 0.4324 | 0.1526 | 0.3408 | DH1997 | 28943 | 0.4395 | 0.1164 | 0.2802 |
| DH1998 | 52691 | 0.6609 | 0.4127 | 0.4723 | DH1998 | 52691 | 0.5565 | 0.3333 | 0.4671 | DH1998 | 52691 | 0.528 | 0.254 | 0.2933 |
| DH1999 | 49292 | 0.6224 | 0.475 | 0.2846 | DH1999 | 49292 | 0.5474 | 0.3748 | 0.2812 | DH1999 | 49292 | 0.5155 | 0.2827 | 0.3178 |
| DH2000 | 24087 | 0.5559 | 0.6574 | 0.583 | DH2000 | 24087 | 0.4727 | 0.5059 | 0.5824 | DH2000 | 24087 | 0.4478 | 0.3775 | 0.3252 |
| DH2001 | 44194 | 0.5378 | 0.8657 | 0.6903 | DH2001 | 44194 | 0.4888 | 0.6765 | 0.6944 | DH2001 | 44194 | 0.4629 | 0.5026 | 0.3262 |
| OO1994 | 24680 | 0.4566 | 0.1246 | 0.2488 | DH2002 | 62633 | 0.611 | 0.9132 | 0.6988 | DH2002 | 62633 | 0.5812 | 0.6831 | 0.3405 |
| OO1995 | 20341 | 0.4421 | 0.1743 | 0.3529 | OO1994 | 24680 | 0.3756 | 0.102 | 0.245 | DH2003 | 137903 | 0.6458 | 0.7197 | 0.3526 |
| OO1996 | 5710 | 0.3902 | 0.237 | 0.3167 | OO1995 | 20341 | 0.3759 | 0.1412 | 0.3526 | OO1994 | 24680 | 0.3965 | 0.0779 | 0.4076 |
| OO1997 | 15417 | 0.435 | 0.237 | 0.5841 | OO1996 | 5710 | 0.3449 | 0.1918 | 0.3177 | OO1995 | 20341 | 0.3785 | 0.1076 | 0.431 |
| OO1998 | 33958 | 0.4757 | 0.3383 | 0.3241 | OO1997 | 15417 | 0.385 | 0.1935 | 0.589 | OO1996 | 5710 | 0.334 | 0.1469 | 0.4658 |
| OO1999 | 82819 | 0.6678 | 0.5106 | 0.5041 | OO1998 | 33958 | 0.4178 | 0.2906 | 0.3259 | OO1997 | 15417 | 0.3738 | 0.1493 | 0.4672 |
| OO2000 | 89047 | 0.6668 | 0.5519 | 0.2358 | OO1999 | 82819 | 0.5437 | 0.4346 | 0.4983 | OO1998 | 33958 | 0.4108 | 0.2271 | 0.4971 |
| OO2001 | 65564 | 0.66 | 0.7395 | 0.1688 | OO2000 | 89047 | 0.5545 | 0.4654 | 0.2338 | OO1999 | 82819 | 0.5167 | 0.337 | 0.5407 |
| | | | | | OO2001 | 65564 | 0.58 | 0.6444 | 0.1662 | OO2000 | 89047 | 0.5223 | 0.3581 | 0.5821 |
| | | | | | OO2002 | 119555 | 0.6474 | 0.9029 | 0.4675 | OO2001 | 65564 | 0.5299 | 0.4972 | 0.5899 |
| | | | | | | | | | | OO2002 | 119555 | 0.6304 | 0.6964 | 0.6955 |
| | | | | | | | | | | OO2003 | 108480 | 0.5969 | 0.9945 | 0.6995 |

These scores show how well the regional airline performs relative to each of the other years based on the projections of performance for that year. This information will be used as input variables in the fuzzy logic model discussed in the next step.

### 5.2.4 Step 4: Develop/Update Fuzzy Logic Model Using Initial Structure

The input variables used in the model are the TOPSIS scores for Production Processes, Product/Service and Marketability and Management. There will be only one output variable in this example which will be Net Operating Profit. The single company analysis for both companies and a two-company analysis will be performed with the initial structure.

#### 5.2.4.1 Fuzzy Logic Model for Single and Two Companies Using Initial Structure

The single company analysis using the initial structure required the analyst to use the 5-level membership functions described in Equation 4.5.1-1 and shown in Figure 4.5.1-1.

The production rules for the fuzzy logic model used for the regional airlines in this analysis are shown in Table 4.5.1.

To determine the output variables for the membership functions, different membership functions were used for each of the output variables, Net Operating Profit. The data showed that the Net Operating Profit for SkyWest was approximately in the range of 0 to 120 million. The data showed that the Net Operating Profit for Independence Air was approximately in the range of –30 to 140 million. The 5-level range used for the TOPSIS score, between 0 and 1.0, was used to index the Net Operating Profit output membership functions. For example,

$$\mu_{VL}(w) = \begin{cases} \dfrac{0.30 - w}{0.30} & \text{for } 0 \le w \le 0.30 \end{cases}$$

would translate to

$$\mu_{VL}(w) = \begin{cases} \dfrac{.30(120) - w}{.30(120)} & \text{for } 0 \le w \le .30(120) \end{cases}$$

which would then equal the membership function, $\mu_{VL}(w)$, seen below and in equation (5.2.4.1-1).

$$\mu_{VL}(w) = \begin{cases} \dfrac{36 - w}{36} & \text{for } 0 \le w \le 36 \end{cases}$$

It should also be noted that the range of NOP used for the two-company scenario was the same as that for Independence Air, because it included the range for SkyWest. These membership functions could be formulated in a number of different ways, however, this approach was selected for this analysis.

The membership functions for the Net Operating Profit, w, for Sky West for the years 2001 – 2003 are shown in Equation 5.2.4.1-1 and Figure 5.2.4.1-1.

$$\mu_{VL}(w) = \begin{cases} \frac{36 - w}{36} & \text{for } 0 \le w \le 36 \end{cases}$$

$$\mu_{L}(w) = \begin{cases} \frac{w}{30} & \text{for } 0 \le w \le 30 \\ \frac{60 - w}{30} & \text{for } 30 \le w \le 60 \end{cases}$$

$$\mu_{M}(w) = \begin{cases} \frac{w - 36}{24} & \text{for } 36 \le w \le 60 \\ \frac{84 - w}{24} & \text{for } 60 \le w \le 84 \end{cases} \qquad (5.2.4.1\text{-}1)$$

$$\mu_{H}(w) = \begin{cases} \frac{w - 60}{30} & \text{for } 60 \le w \le 90 \\ \frac{120 - w}{30} & \text{for } 90 \le w \le 120 \end{cases}$$

$$\mu_{VH}(w) = \begin{cases} \frac{w - 84}{36} & \text{for } 84 \le w \le 120 \end{cases}$$

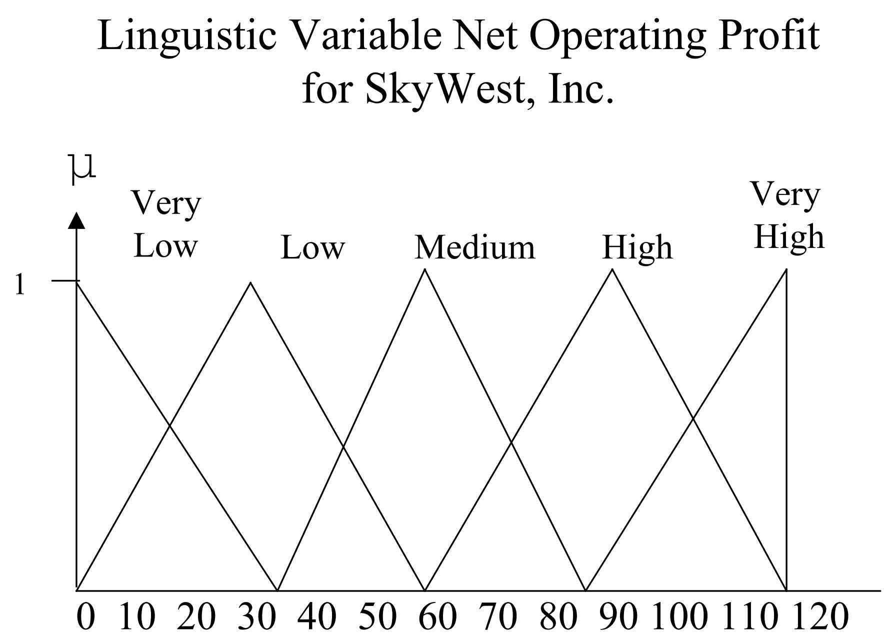



Figure 5.2.4.1-1. Linguistic Variables for NOP for SkyWest, Inc (in millions).

The membership functions for the Net Operating Profit, w, for Independence Air and the two company case for the year 2001 – 2003 are shown in 5.2.4.1-2 and Figure 5.2.4.1-2.

$$\mu_{VL}(w) = \begin{cases} \frac{21 - w}{51} & \text{for } -30 \le w \le 21 \end{cases}$$

$$\mu_{L}(w) = \begin{cases} \frac{w}{42.5} & \text{for } -30 \le w \le 12.5 \\ \frac{55 - w}{42.5} & \text{for } 12.5 \le w \le 55 \end{cases}$$

$$\mu_{M}(w) = \begin{cases} \frac{w - 21}{34} & \text{for } 21 \le w \le 55 \\ \frac{89 - w}{34} & \text{for } 55 \le w \le 89 \end{cases} \qquad (5.2.4.1\text{-}2)$$

$$\mu_{H}(w) = \begin{cases} \frac{w - 55}{42.5} & \text{for } 55 \le w \le 97.5 \\ \frac{140 - w}{42.5} & \text{for } 97.5 \le w \le 140 \end{cases}$$

$$\mu_{VH}(w) = \begin{cases} \frac{w - 89}{51} & \text{for } 89 \le w \le 140 \end{cases}$$

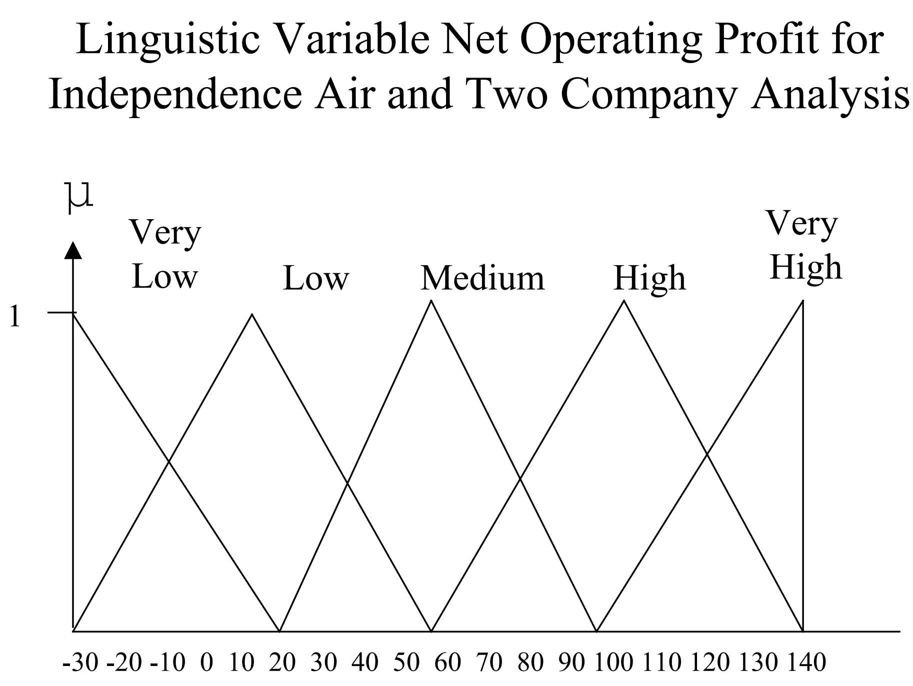



Figure 5.4.2.1-2. Linguistic Variables for Independence Air and Two Company Analysis (in millions).

5.2.5. Step 5: Generate Fuzzy Outputs From Criteria Score Using Initial Structure

Production Processes, Product/Services and Marketability and Management are represented by the variables x, y, and z, respectively. The fuzzy inputs for each airline over the three-year prediction time frame are used in this example. Each of the criteria scores for Production Processes, Product/Services and Marketability and Management is matched against the appropriated membership function described in equations 4.5.1-1, 5.2.4.1-1 and 5.2.4.1-2. The output of each rule is defined by operation conjunction applied on its strength and conclusion. The possibility functions and output NOP for each company individually is shown in Tables 5.2.5-1 and Table 5.2.5-2. These analyses are based on making projections from the year 2000 for the years 2001 – 2003. Either a one year, two year or three year projection is made. Analysis Year represents the results that would be generated if only one year projection were made beyond the year 2000.

Table 5.2.5-1. Predictions for Independence Air.

| Projection Year | Company – Year | Membership | Possibility | Predicted NOP |
|---|---|---|---|---|
| One Year | DH2001 | H | 0.780 | |
| | DH2001 | VH | 0.118 | 90,550 |
| Two Year | DH2001 | M | 0.590 | |
| | DH2001 | H | 0.753 | 94,778 |
| | DH2002 | H | 0.470 | |
| | DH2002 | VH | 0.150 | 99,300 |
| Three Year | DH2001 | L | 0.148 | |
| | DH2001 | M | 0.695 | 41,428 |
| | DH2002 | M | 0.594 | |
| | DH2002 | H | 0.203 | 61,009 |
| | DH2003 | M | 0.583 | |
| | DH2003 | H | 0.066 | 72,124 |

Table 5.2.5-2. Predictions for SkyWest, Inc.

| Projection Year | Company – Year | Membership | Possibility | Predicted NOP |
|---|---|---|---|---|
| One Year | OO2001 | M | 0.547 | |
| | OO2001 | H | 0.456 | 75,850 |
| Two Year | OO2001 | L | 0.114 | |
| | OO2001 | M | 0.623 | 71,318 |
| | OO2002 | H | 0.499 | 90,000 |
| Three Year | OO2001 | L | 0.624 | |
| | OO2001 | M | 0.451 | 57,321 |
| | OO2002 | M | 0.480 | |
| | OO2002 | H | 0.416 | 75,919 |
| | OO2003 | M | 0.280 | |
| | OO2003 | H | 0.653 | 81,662 |

Table 5.2.5-3 shows the predictions for both SkyWest and Independence Air combined.

Table 5.2.5-3. Predictions for SkyWest and Independence Air

| Projection Year | Company – Year | Membership | Possibility | Predicted NOP |
|---|---|---|---|---|
| One Year | DH2001 | M | 0.048 | |
| | DH2001 | H | 0.552 | 94,752 |
| Two Year | DH2001 | M | 0.120 | |
| | DH2001 | H | 0.706 | 75,764 |
| | DH2002 | M | 0.006 | |
| | DH2002 | H | 0.445 | 96,833 |
| Three Year | DH2001 | L | 0.148 | |
| | DH2001 | M | 0.695 | 44,227 |
| | DH2002 | M | 0.594 | |
| | DH2002 | H | 0.203 | 69,496 |
| | DH2003 | M | 0.590 | |
| | DH2003 | H | 0.263 | 72,066 |
| One Year | OO2001 | M | 0.640 | |
| | OO2001 | H | 0.132 | 65,117 |
| Two Year | OO2001 | L | 0.280 | |
| | OO2001 | M | 0.578 | 30,775 |
| | OO2002 | M | 0.263 | |
| | OO2002 | H | 0.590 | 72,535 |
| Three Year | OO2001 | M | 0.551 | |
| | OO2001 | H | 0.120 | 64,898 |
| | OO2002 | M | 0.023 | |
| | OO2002 | H | 0.522 | 95,975 |
| | OO2003 | H | 0.516 | |
| | OO2003 | M | 0.003 | 97,015 |

Table 5.2.5-4 shows a summary of the results of the single and two-company analysis. Included in the results is the actual Net Operating Profit numbers and an indication of whether the process predicted correctly whether the prediction moved higher or lower.

Table 5.2.5-4. Results of Process Using Initial Structure and One and Two Company Analysis.

One Company Scenario

| | Actual Net Operating Profit | Using Data Thru 2001 - DH 2001 | Predicted Increase/ Decrease Correctly | Using Data Thru 2002 - DH 2002 | Predicted Increase/ Decrease Correctly | Using Data Thru 2003 - DH 2003 | Predicted Increase/ Decrease Correctly |
|---|---|---|---|---|---|---|---|
| DH2000 | 24087 | ------- | ------- | ------- | ------- | ------- | ------- |
| DH2001 | 44194 | 90550 | Y | 94778 | Y | 41428 | Y |
| DH2002 | 62633 | ------- | ------- | 99300 | Y | 61009 | Y |
| DH2003 | 137903 | ------- | ------- | ------- | ------- | 72124 | Y |

| | Actual Net Operating Profit | Using Data Thru 2001 - OO 2001 | Predicted Increase/ Decrease Correctly | Using Data Thru 2002 - OO 2002 | Predicted Increase/ Decrease Correctly | Using Data Thru 2003 - OO 2003 | Predicted Increase/ Decrease Correctly |
|---|---|---|---|---|---|---|---|
| OO2000 | 89047 | ------- | ------- | ------- | ------- | ------- | ------- |
| OO2001 | 65564 | 75850 | Y | 71318 | Y | 57321 | Y |
| OO2002 | 119555 | ------- | ------- | 90000 | Y | 75919 | Y |
| OO2003 | 108480 | ------- | ------- | ------- | ------- | 81662 | N |

Two Company Scenario

| | Actual Net Operating Profit | Using Data Thru 2001 - 2001 | Predicted Increase/ Decrease Correctly | Using Data Thru 2002 - 2002 | Predicted Increase/ Decrease Correctly | Using Data Thru 2003 - 2003 | Predicted Increase/ Decrease Correctly |
|---|---|---|---|---|---|---|---|
| DH2000 | 24087 | ------- | ------- | ------- | ------- | ------- | ------- |
| DH2001 | 44194 | 94752 | Y | 75764 | Y | 44227 | Y |
| DH2002 | 62633 | ------- | ------- | 96833 | Y | 69496 | Y |
| DH2003 | 137903 | ------- | ------- | ------- | ------- | 72066 | Y |
| OO2000 | 89047 | ------- | ------- | ------- | ------- | ------- | ------- |
| OO2001 | 65564 | 65117 | Y | 30775 | Y | 64898 | Y |
| OO2002 | 119555 | ------- | ------- | 72535 | Y | 95975 | Y |
| OO2003 | 108480 | ------- | ------- | ------- | ------- | 97015 | N |

As can be seen in the table, the results are varied. It appears that the more predictions made, the better the computed prediction. Looking at the raw input data, in most cases, the performance metrics increase as the years increase. This means that the relative scores generated by the TOPSIS model would be higher and the defuzzified NOP would tend to be closer to the upper range of the output variable membership function for any given data set. A larger number of data points can provide a greater differentiation between the performances of one year to the next.

The use of Fuzzy Logic in a model enables the decision maker to model a non-linear environment, thus allowing the decision maker to model circumstances where there may be increases and decreases in performance and the predictions or approximations are not forced into following a linear trend as is with linear regression.

The best numerical predictions or approximations tend to occur when the two company scenario is used for the three year prediction. These predictions are closest to the actual NOP for each of the companies for each of the years. However, using the initial structure established for the production rules, linguistic variables and membership functions, the prediction of the increase or decrease of NOP prediction was not as good for the year 2003 for each of the companies.

### 5.2.6 Step 6: Generate Discounted Cash Flow Business Valuation

The NOP predicted in Step 5 would be used to compute the Discounted Cash Flow for the business. A DCF is not computed for the sample data for the airline industry. This is not done because the detail and focus of this effort is to show how the results of this process fit into the DCF process that is given as an example in Section 4.

The following section will look at refinements to the model to determine if improvements can be made with the predictions.

## 5.3. Two Company Scenario with Revised Process Model

This section describes an attempt to generate a better solution by revising the production rules, membership functions and linguistic variables used in the process. When modeling an environment, the initial solution is typically just a starting point. There is a large amount of flexibility in the modeling and refinement process. Only one approach is given in this section. It is well understood, however, that many other modifications and refinements could be made to potentially improve the results.

The development approach for the revisions is the same in Steps 1 – 3 described in Section 5.2.1 through 5.2.3. The decision criteria, data and TOPSIS scores remain the same for the analysis. The revisions to the model begin with Step 4 of the business valuation process.

### 5.3.1 Step 4: Develop/Update Fuzzy Logic Model

An analysis was done with the major criteria TOPSIS scores along with the associated NOP to determine if relationships or patterns existed in the data that could be used to better develop the membership functions. Data from Atlantic Coast Airlines and SkyWest for the years 1994 through 2000 was used in the approach to develop the model and membership functions. Data for the years 2001 through 2003 was used to validate the model. Initially scores were generated using TOPSIS for the three major criteria areas, Production Processes, Product/Services and Marketability and Management. The TOPSIS score, along with the Net Operating Profit for those years, is shown in Table 5.3.1-1.

Table 5.3.1-1. TOPSIS Scores Used in Model Development for Two Company Scenario

| | Net Operating Profit | Production Processes | Product/ Services and Marketability | Management |
|---|---|---|---|---|
| DH1994 | -23278 | 0.2331 | 0.1989 | 0.3544 |
| DH1995 | 12845 | 0.4391 | 0.1616 | 0.3128 |
| DH1996 | 20263 | 0.4828 | 0.1635 | 0.4743 |
| DH1997 | 28943 | 0.5372 | 0.2523 | 0.3803 |
| DH1998 | 52691 | 0.6873 | 0.5350 | 0.5415 |
| DH1999 | 49292 | 0.6331 | 0.6173 | 0.3242 |
| DH2000 | 24087 | 0.5674 | 0.8064 | 0.6520 |
| OO1994 | 24680 | 0.4900 | 0.1601 | 0.2814 |
| OO1995 | 20341 | 0.4675 | 0.2282 | 0.3944 |
| OO1996 | 5710 | 0.4071 | 0.3093 | 0.3509 |
| OO1997 | 15417 | 0.4531 | 0.3054 | 0.3954 |
| OO1998 | 33958 | 0.4975 | 0.4256 | 0.3545 |
| OO1999 | 82819 | 0.7047 | 0.6317 | 0.5718 |
| OO2000 | 89047 | 0.6876 | 0.6764 | 0.2678 |

The TOPSIS scores and Net Operating Profit were used to develop the membership functions for Production Processes, Product/Services and Marketability and Management. The model was developed using data from 1994 through 2000. These ranges of scores were used to develop the membership functions that define the linguistic variables Low, Medium and High scores for each of the major criteria as shown in Table 5.3.1-2. A triangular fuzzy number represents each of these membership functions for the TOPSIS score. The membership functions developed based on these ranges remained constant in the application of the approach for the two-company validation.

A TOPSIS score for each of the major criteria areas was generated for each company by year. To predict the Net Operating Profit for 2001, the data for 2001 for both companies was included in the 1994 through 2000 data set and a score for each of the major criteria was generated. This information was run through the fuzzy logic model and then defuzzified to generate the prediction for 2001. This process was repeated for the years 2002 and 2003 for each of the companies.

The goal was to divide data into logical ranges and formulate linguistic variables for Low Medium and High for the membership functions used for the TOPSIS scores and the

NOP output. Table 5.3.1-2 shows three ranges of scores used to develop the membership functions.

Table 5.3.1-2. Ranges and Scores for Membership Functions

| | Production Processes | Product/Services and Marketability | Management |
|---|---|---|---|
| Low | 0-.5 | 0-.35 | 0-.4 |
| Medium | .45-.65 | .15-.65 | .25-.55 |
| High | .60-1.0 | .60-1.0 | .5-1 |

The information shown above is then used to refine the shape and membership functions associated with the data. Both the shape of the fuzzy numbers and the definition were tested in this analysis. These variables are defined in terms of triangular and trapezoidal shape as seen in Figures 5.3.1-1 and 5.3.1-2

**Production Processes Score** = {**L**(low), **M**(medium), **H**(high)}

**Product/Service and Marketability Score** = {**L**(low), **M**(medium), **H**(high)}

**Management Score** = {**L**(low), **M**(medium), **H**(high)}

**Net Operating Profit** = {**L**(low), **M**(medium), **H**(high)}

In the refinement analysis, it was determined to make some assumptions when developing the membership functions for the NOP output. Initially, it was assumed that the output variable would encompass the output range seen in the historical data. Then, as each year's predictions were made and the actual results for the year were learned, general growth patterns would be incorporated into the output membership functions. This is done because in actuality, analysts adjust their models at least on a yearly basis, if not more frequently. In this example, two different sets of linguistic variables and membership functions are used to define the output Net Operating Profit.

Figure 5.3.1-1 shows the triangular and trapezoidal fuzzy numbers that are used to represent Low (-$30 million to 20 million), Medium ($10 million to $50 million) and High (40 million to $100million) Net Operating Profit for the years 2001 and 2002 for both companies.

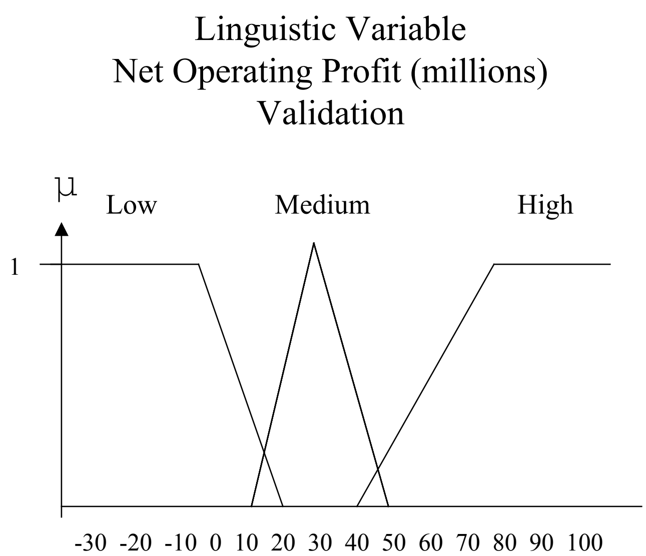



Figure 5.3.1-1. Initial Linguistic Variable Net Operating Profit for Both Companies in the Years 2001 and 2002 (in millions).

Figure 5.3.1-2 shows the triangular and trapezoidal fuzzy numbers that are used to represent Low (-$30 million to 50 million), Medium ($20 million to $90 million) and High (60 million to $140million) Net Operating Profit for the year 2003 predictions for both companies.

**Linguistic Variable**
**Net Operating Profit (millions)**
**Validation**

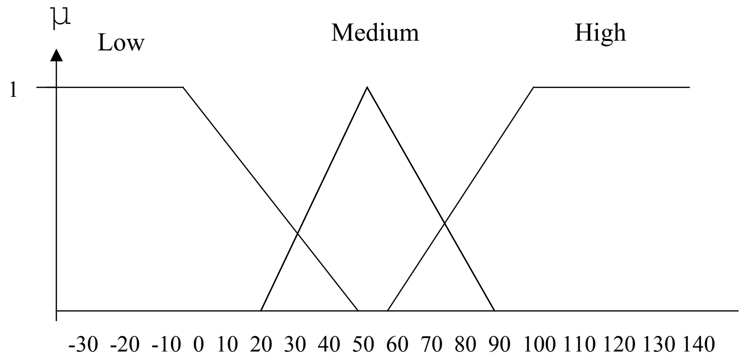



Figure 5.3.1-2. Linguistic Variable NOP for Two Companies for Year 2003 (millions).

Similarly, this type of information can be used to model a fuzzy set for the Production Processes TOPSIS Score. In this case a Low TOPSIS score is 0.0 – 0.50, a Medium TOPSIS Score is between 0.45 and 0.65 and a High TOPSIS score is between 0.60 and 1.0. They are shown in Figure 5.3.1-3 below.

**Linguistic Variable**
**Production Processes TOPSIS Score**

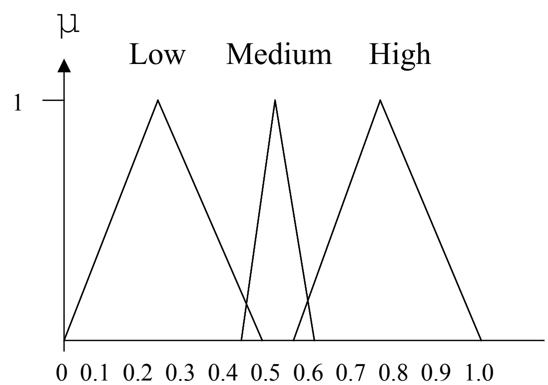



Figure 5.3.1-3. Linguistic Variable Production Processes TOPSIS Score.

Each of the three major criteria TOPSIS scores has different membership functions. All used triangular fuzzy numbers which are similar to that shown in 5.3.1-2. These membership functions could also be defined where there are a higher number of scores with a possibility of 1.0 for low or very low and high or very high where low and high are trapezoidal membership functions such as those shown in Figure 5.3.1-2 for low and high and Figure 2.1.3.5-1 for very low and very high.  The impact of this type of change to the membership functions would be in the aggregation and defuzzification functions.  The possibility of low and high would be one when the TOPSIS score is either very high or very low.  In the rule evaluation the minimums would be higher for both low and high. This would cause the defuzzified crisp numbers to be lower when the rule evaluation is low and higher when the rule evaluation is high.

The universal sets (operating domains) of the input and output variables are

$U_1 = \{x \mid 0 \leq x \leq 1.0\}$

$U_2 = \{y \mid 0 \leq y \leq 1.0\}$

$U_3 = \{z \mid 0 \leq z \leq 1.0\}$

$U_4 = \{w_l \mid -30 \leq w_l \leq 150\}$ (in millions)

The output variables Net Operating Profit is defined with triangular and fuzzy terms. These variables are defined in terms of triangular and trapezoidal shape as seen in Figure 5.3.1-1 and 5.3.1-2.  The resulting membership functions are shown in equations 5.3.1-1 and 5.3.1-2

The membership functions, w, for the Net Operating Profit for the years 2001 and 2002 (Figure 5.3.1-1) for the revised two company scenario are defined below.

$$\mu_L(w) = \begin{cases} 1 & \text{for } w \leq 0 \\ \frac{20 - w}{20} & \text{for } 0 \leq w \leq 20 \end{cases}$$

$$\mu_M(w) = \begin{cases} \frac{w - 10}{20} & \text{for } 10 \leq w \leq 30 \\ \frac{50 - w}{20} & \text{for } 30 \leq w \leq 50 \end{cases} \qquad (5.3.1\text{-}1)$$

$$\mu_H(w) = \begin{cases} \frac{70 - w}{30} & \text{for } 40 \geq w \geq 70 \\ 1 & \text{for } w \geq 70 \end{cases}$$

The membership functions, w, for the Net Operating Profit for the year 2003 (Figure 5.3.1-2) for the revised two company scenario is defined below.

$$\mu_L(w) = \begin{cases} 1 & \text{for } w \le 0 \\ \frac{50 - w}{50} & \text{for } 0 \le w \le 50 \end{cases}$$

$$\mu_M(w) = \begin{cases} \frac{w - 20}{35} & \text{for } 20 \le w \le 55 \\ \frac{90 - w}{35} & \text{for } 55 \le w \le 90 \end{cases} \qquad (5.3.1\text{-}2)$$

$$\mu_H(w) = \begin{cases} \frac{w - 60}{40} & \text{for } 60 \ge w \ge 100 \\ 1 & \text{for } w \ge 100 \end{cases}$$

The terms of linguistic variables Production Processes Score are defined by the membership function shown in equation 5.3.1-3.

$$\mu_L(x) = \begin{cases} \frac{x}{0.25} & \text{for } 0.00 \le x \le 0.25 \\ \frac{0.5 - x}{0.25} & \text{for } 0.25 \le x \le 0.5 \end{cases}$$

$$\mu_M(x) = \begin{cases} \frac{x - 0.45}{0.10} & \text{for } 0.45 \le x \le 0.55 \\ \frac{0.65 - x}{0.10} & \text{for } 0.55 \le x \le 0.65 \end{cases} \qquad (5.3.1\text{-}3)$$

$$\mu_H(x) = \begin{cases} \frac{x - 0.60}{0.20} & \text{for } 0.50 \le x \le 0.80 \\ \frac{1.0 - x}{0.20} & \text{for } 0.80 \le x \le 1.00 \end{cases}$$

The definition of the membership functions for the Product/Services and Marketability TOPSIS Scores is shown in equation 5.3.1-4.

$$\mu_L(y) = \begin{cases} \dfrac{y}{0.175} & \text{for } 0.00 \le y \le 0.175 \\ \dfrac{0.35 - y}{0.175} & \text{for } 0.175 \le y \le 0.35 \end{cases}$$

$$\mu_M(y) = \begin{cases} \dfrac{y - 0.15}{0.25} & \text{for } 0.15 \le y \le 0.40 \\ \dfrac{0.65 - y}{0.25} & \text{for } 0.40 \le y \le 0.65 \end{cases} \qquad (5.3\text{-}4)$$

$$\mu_H(y) = \begin{cases} \dfrac{y - 0.60}{0.20} & \text{for } 0.60 \le y \le 0.80 \\ \dfrac{1.0 - y}{0.20} & \text{for } 0.80 \le y \le 1.00 \end{cases}$$

The definition of the membership functions for the Management TOPSIS Scores is shown in equation 5.3.1-5.

$$\mu_L(z) = \begin{cases} \dfrac{z}{0.20} & \text{for } 0.00 \le z \le 0.20 \\ \dfrac{0.40 - z}{0.20} & \text{for } 0.20 \le z \le 0.40 \end{cases}$$

$$\mu_M(z) = \begin{cases} \dfrac{z - 0.25}{0.15} & \text{for } 0.25 \le z \le 0.40 \\ \dfrac{0.40 - z}{0.15} & \text{for } 0.40 \le z \le 0.55 \end{cases} \qquad (5.3.1\text{-}5)$$

$$\mu_H(z) = \begin{cases} \dfrac{z - 0.50}{0.25} & \text{for } 0.50 \le z \le 0.75 \\ \dfrac{1.0 - z}{0.25} & \text{for } 0.75 \le z \le 1.00 \end{cases}$$

The three input variables and the one output variable result is a series of *n* x *m* x *p* rules in the format

*If $x$ is $A_i$ and $y$ is $B_j$ and $z$ is $C_k$ then $w$ is $S_l$*

The production rules used in this validation example are shown in Table 5.3.1-3:

Let the major criteria be represented as follows:

- Production Processes (PP)

- Products/Services and Marketability (PSM)
- Management (MG)

Let the output variable be represented as

- Net Operating Profit (NOP)

Table 5.3.1-3. Production Rules.

| Production Rules |
|---|
| Rule 1: *If Production Processes (PP) is High and Products/Services and Marketability (PSM) is High and Management (MG) is High, then Net Operating Profit (NOP) is High;* |
| Rule 2: *If PP is H and PSM is H and MG is M, then NOP is H;* |
| Rule 3: *If PP is H and PSM is H and MG is L, then NOP is H;* |
| Rule 4: *If PP is H and PSM is M and MG is H, then NOP is H;* |
| Rule 5: *If PP is H and PSM is L and MG is H, then NOP is M;* |
| Rule 6: *If PP is L and PSM is H and MG is H, then NOP is M;* |
| Rule 7: *If PP is M and PSM is H and MG is H, then NOP is H;* |
| Rule 8: *If PP is L and PSM is L and MG is L, then NOP is L;* |
| Rule 9: *If PP is L and PSM is L and MG is M, then NOP is L;* |
| Rule 10: *If PP is L and PSM is L and MG is H, then NOP is L;* |
| Rule 11: *If PP is L and PSM is M and MG is L, then NOP is L;* |
| Rule 12: *If PP is L and PSM is H and MG is L, then NOP is M;* |
| Rule 13: *If PP is M and PSM is L and MG is L, then NOP is L;* |
| Rule 14: *If PP is H and PSM is L and MG is L, then NOP is M;* |
| Rule 15: *If PP is M and PSM is M and MG is M, then NOP is M;* |
| Rule 16: *If PP is M and PSM is M and MG is L, then NOP is M;* |
| Rule 17: *If PP is M and PSM is M and MG is H, then NOP is M;* |
| Rule 18: *If PP is M and PSM is L and MG is M, then NOP is M;* |
| Rule 19: *If PP is M and PSM is H and MG is M, then NOP is M;* |
| Rule 20: *If PP is H and PSM is M and MG is M, then NOP is M;* |
| Rule 21: *If PP is L and PSM is M and MG is M, then NOP is M;* |
| Rule 22: *If PP is H and PSM is M and MG is L, then NOP is M;* |
| Rule 23: *If PP is L and PSM is M and MG is H, then NOP is M;* |
| Rule 24: *If PP is M and PSM is H and MG is L, then NOP is M;* |
| Rule 25: *If PP is L and PSM is H and MG is M, then NOP is M;* |
| Rule 26: *If PP is H and PSM is L and MG is M, then NOP is M;* |
| Rule 27: *If PP is M and PSM is L and MG is H, then NOP is M;* |

The results of the application of this revised fuzzy logic model is shown in the following section.

### 5.3.2 Step 5: Generate Fuzzy Outputs From Criteria Score

Production Processes, Product/Services and Marketability and Management TOPSIS scores are the fuzzy inputs for each airline for the time prediction periods of 2001, 2002 and 2003. Each of the criteria score readings for Production Processes, Product/Services and Marketability and Management is matched against the appropriated membership function described in equations 5.3.1-3, 5.3.1-4, and 5.3.1-5. The output of each rule is defined by operation conjunction applied on its strength and conclusion. The results of this are shown in Table 5.3.2-1.

Table 5.3.2-1. Predictions for SkyWest and Independence Air with Revisions

| Projection Year | Company – Year | Membership | Possibility | Predicted NOP |
|---|---|---|---|---|
| One Year | DH2001 | H | 0.122 | 75,000 |
| Two Year | DH2001 | M | 0.045 | |
| | DH2001 | H | 0.222 | 70,860 |
| | DH2002 | H | 0.205 | 75,000 |
| Three Year | DH2001 | L | 0.148 | |
| | DH2001 | M | 0.286 | 42,660 |
| | DH2002 | M | 0.397 | 55,000 |
| | DH2003 | M | 0.042 | |
| | DH2003 | H | 0.237 | 105,250 |
| One Year | OO2001 | M | 0.303 | 30,000 |
| Two Year | OO2001 | M | 0.700 | 30,000 |
| | OO2002 | M | 0.026 | |
| | OO2002 | H | 0.486 | 75,412 |
| Three Year | OO2001 | M | 0.201 | 55,000 |
| | OO2002 | H | 0.218 | 110,000 |
| | OO2003 | H | 0.027 | 110,000 |

These results are summarized in Table 5.3.2-2.

Table 5.3.2-2. Summary of Results with Revisions for Two Companies.

| | Net Operating Profit | 2001 | Predicted Increase/ Decrease Correctly | 2002 | Predicted Increase/ Decrease Correctly | 2003 | Predicted Increase/ Decrease Correctly |
|---|---|---|---|---|---|---|---|
| DH2000 | 24087 | ------- | ------- | ------- | ------- | ------- | ------- |
| DH2001 | 44194 | 75000 | Y | 70860 | Y | 42660 | Y |
| DH2002 | 62633 | ------- | ------- | 75000 | Y | 55000 | Y |
| DH2003 | 137903 | ------- | ------- | ------- | ------- | 105250 | Y |
| OO2000 | 89047 | ------- | ------- | ------- | ------- | ------- | ------- |
| OO2001 | 65564 | 30000 | Y | 30000 | Y | 55000 | Y |
| OO2002 | 119555 | ------- | ------- | 75412 | Y | 110000 | Y |
| OO2003 | 108480 | ------- | ------- | ------- | ------- | 110000 | N |

The results with the revisions to the membership functions show that the magnitude of the predictions, especially with the three year predictions were closer to the actual NOP than using the original structure. This is shown in Table 5.3.2-3 below.

Table 5.3.2-3. Comparison of Original Model Results and Revised Model Results for Three Year Predictions.

| | Net Operating Profit | Three Year Predictions Using Original Model (2003) | Three Year Predictions Using Revised Model (2003) |
|---|---|---|---|
| DH2000 | 24087 | ------- | ------- |
| DH2001 | 44194 | 44227 | 42660 |
| DH2002 | 62633 | 69496 | 55000 |
| DH2003 | 137903 | 72066 | 105250 |
| OO2000 | 89047 | ------- | ------- |
| OO2001 | 65564 | 64898 | 55000 |
| OO2002 | 119555 | 95975 | 110000 |
| OO2003 | 108480 | 97015 | 110000 |

Additionally, the processes ability to predict the increase or the decrease of the NOP was better with the revised process model. This does not lead to the conclusion that the revised version is significantly better than the original version of the process. However, it may say that analyzing the data as part of the process and including this analysis in the development of the membership functions, etc. may lead to a better process.

It should also be noted that differentiation between answers was less with the 3 levels than the 5 levels. This can be seen with the defuzzification to "Average" values associated with the various levels of the linguistic variables. The average value of Medium was 30,000 for 2001 and 2002, 55,000 was an average value of Medium for the year 2003, etc.

The predicted NOP is generated from the process developed and described in this dissertation. The performance metrics themselves provide basis for the prediction, rather than financial information alone. This is a new and different approach. The fuzzy logic model, as with any model, should be tuned to the environment over time. Expert opinion from seasoned analysts can be used to refine the production rules and input data when subjective data are included. The end result of this step, however, is the predicted Net Operating Profit by Year that will be used in the computation of business value using the Discounted Cash Flow method.

### 5.3.3 Step 6: Generate Discounted Cash Flow Business Valuation

The general computations shown in the example section of the report would be used to generate a discounted cash flow based on the projections shown above. Instead of using actual or projected Net Operating Profit, the prediction process from the fuzzy logic model would be used to predict the Net Operating Profit. From that point, various accounting information and assumptions would be used to supply the additional information required to compute the DCF. Although the DCF is a result of this process, the details associated with its computations are not the focus and key contribution of this effort. Therefore, the specific yearly estimates and computations will not be performed in the validation. The predicted NOP, and the process developed to generate it, is the primary focus of the effort.

## 5.4 Chapter Summary

This chapter provides an example of the use of the new business valuation process applied to actual data in a specific industry.  Decision criteria are generated based on typically reported performance data that is considered to be key drivers of business performance.  The performance criteria are used to generate performance scores for the major criteria.  This information is then used in the fuzzy logic model, along with the production rules and the rule evaluation, possibilities and defuzzified crisp results are then generated.  The results generated by the model in both the initial structure case and then the revised case is promising.  It appears that refining the initial model, based on data analysis, can also improve the solutions that are generated.

# CHAPTER 6
# CONTRIBUTIONS AND CONCLUSIONS

## 6.1 Thesis Summary

The driving force behind this thesis was the concept that using performance metrics along with traditional measures to determine the current and future value of a company provides enhancements to the current approach to business valuation. Balance sheet and financial statement information do not provide a complete picture of the overall health of a company. This research defined a problem, developed a solution structure and a process to enhance the current business valuation process. Three primary areas within a company, Production Processes, Products/Services and Marketability and Management are used to measure performance within a company. The performance metrics drive the predictions and approximations. This information can be used to enhance management and decision making and provide additional information for investment analysts.

The problem definition is one where key performance drivers (non-financial) impact the financial worth a company. Non-traditional methods must be used to address this environment. Key performance metrics in the major areas must be identified for an industry and the data required to support the metrics gathered and assessed for individual companies. This may not be a linear environment, and, in most cases, will not be exact thereby requiring methods that encompass approximations and uncertainties. The problem itself contains performance metrics as inputs, fuzzy and approximate relationships between performance metrics and financial information as the bridge between the inputs and outputs. Crisp financial information is output which can be used in a traditional sense for decision making purposes. A unique process is required to encompass all the elements of problems of this nature.

The unique process developed in this thesis encompasses many positive characteristics associated with known technologies and integrates these characteristics into a new process. The performance of a company in a major focus area is described by the performance metrics of a company to those within the industry subset. Linguistic variables, membership functions and production rules are used to approximate the relationships in the industry and provide the ability to model a linear and non-linear environment. The resulting crisp financial information can then be input into traditional business valuation. This financial information can be used to determine the impact of performance on the current and future financial well being of a company.

The new process was demonstrated in a number of ways in this research. An example was developed and run representing hypothetical companies in the production industry. This example provided a step-by-step demonstration of the process using an initial structure developed for the model and shows how the results integrate with DCF business valuation. The reasonableness of the process was tested. Additionally, a description and computational procedures were given to show how a manager could use this process to improve the performance of their company.

The new process is applied to actual data in the regional airline industry. Initially, the new process is applied to each of the airlines individually and then the process is applied to the two airlines combined. The process uses the original fuzzy logic model with the structure of the membership functions and five level fuzzy sets. Decision criteria are generated based on typically reported performance data. The performance criteria are used to generate performance scores for the major criteria. This information along with the production rules and the rule evaluation is then used in the fuzzy logic model. The output from the model is defuzzified and crisp results are then generated. The membership functions and fuzzy sets are then modified in an attempt to better reflect the operating environment. The process is applied to the two airlines combined with a revised fuzzy logic model.

The results that are generated by the model with both the initial case and then the revised case are promising. The results show that approximations can be made in the range of the actual data and that it can predict increases and decreases in the output variable. The results show that the predictions are better as more data are introduced into the process.

It appears that refining the initial model, based on data analysis, can also improve the solutions that are generated. Refinements shown took the form of linguistic variables, membership functions and production rules. Other refinements to the model may be made but were not tested at this time.

Overall, this research has involved a significant amount of analysis of methodologies that were required to support this concept, data that was used in the analysis and validation, and computations to support the process. The results, however, provide a problem definition that can be applied in a variety of areas and a process that can be used to solve problems of this nature.

## 6.2 Conclusions and Contributions

There are some key benefits that are associated with the new process. The flexibility to tune the new process over time is limitless. New data and new criteria can be used in the process as they become available. Subjective data and criteria can also be used to enhance the "real world" fuzzy environment being modeled. Membership functions and production rules can be tuned to represent changes in the environment and goals of the decision makers. The new process is able to model a linear environment as well as a non-linear environment, which may be better tailored to reflect the dynamic aspects of various industries.

The performance-based approach used in this process also provides a benchmark against the financial information typically presented in SEC filings and annual reports. For example, if a model such as this was developed for a given industry, and certain performance-based characteristics change dramatically in a company this should be represented in their financial statements. If financial statements do not reflect drastic changes in operational performance, questions can be raised as to the validity of the financial statement information. This might help to reduce problems such as those that occurred with companies such as Enron, WorldCom, etc.

In the process developed in this research, Multiple Attribute Decision Making using TOPSIS provides the ability to integrate and assess performance metrics for a company. Fuzzy logic provides the ability to model the key performance criteria in a fuzzy logic model and model a vague and non-linear environment. The end result is a performance metric based process that can measure the current and future worth of a company.

### 6.2.1 Definition of Problem

A new type of problem has been defined in this thesis. The new problem is defined in terms of the following components.

- Functional or operational areas that define the success of the company such as Production Processes, Product/Services and Marketability and Management.

- Quantifiable (objective of subjective) metrics representing company performance at an operating level.

- Ability to differentiate between the importances of performance metrics within the overall functional or operational area.

- Vague or imprecise relationships between performance metrics and overall functional or operational performance.

- Complex (non-linear) and imprecise relationships between overall functional or operational performance and financial estimates.

- Human knowledge beyond historical data needed to represent the relationships between performance metrics, functional area performance and financial estimates.

This problem has a nearly universal application in the corporate environment. Most companies can define performance metrics, but have no way to understand how those metrics affect the bottom line. There are many complex and vague relationships between areas of the company and, in turn, representations of how these areas affect the overall performance of a company.

A number of scenarios and problem application areas are given below.

1. Given one company, define its value where management and investors can used the process for performance improvement, company analysis and investment purposes.

2. Given several companies, provide a better benchmark of performance in an industry and comparative assessment of companies.

### 6.2.2 Structure of Problem Solution

The problem identified in this research consists of the definition of performance based metrics and the process by which they are translated to financial information. The problem definition has a new and unique structure. The problem structure is broken down into a number of components.

- Major decision criteria are chosen and performance metrics established and collected
- Performance scoring for major criteria using Multiple Criteria Decision Making
- Fuzzification of major criteria with membership functions and linguistic representation
- Aggregation of major criteria and linguistic variables using production rules
- Defuzzification of output into financial information

Performance metrics for the three major operational areas of a company are defined in terms of Production Processes, Product/Services and Marketability and Management. The performance metrics are decision criteria that are used in a Multiple Attribute Decision Making method to score a company in a given operational area of performance. Although methods that generate only a rank order (ordinal score) can score the performance of a company in a given operational area, MADM methods that differentiate performance between zero and one (a cardinal score) provide more information regarding the difference between alternatives and can be easily used.

Fuzzification of the performance scoring is performed based on the development of membership functions associated with the performance levels generated from the performance scoring. The performance scores are associated with a degree of membership (membership functions) to the various fuzzy sets and linguistic variables.

The three major criteria areas are aggregated based on a set of production rules and the rule strength is determined based on their evaluation in the membership functions. Production rules allow the decision maker to model the operating environment with flexibility (as a note, this can also be done with the membership functions) Membership functions are developed for the output variable or variables which is used in defuzzification. The problem output is then a financial representation of the input performance levels. Once developed, the problem components, such as the decision criteria, the membership functions, the production rules, etc. can be refined to enhance the representation of the company operating environment.

### 6.2.3 New Process to Solve Problems

The problem definition and structure use performance metrics, performance level scoring and operational rules and characteristics in a vague and imprecise environment to generate financial output information. The result is a mapping from performance metrics to financial information with a series of transformation and evaluation steps. A new process has been developed to solve this problem that combines a number of theories and analysis techniques to arrive at a unique approach. This concept crosses and integrates methods from the fields of business, industrial engineering, mathematics and economics.

The six steps in the new process are

Step 1: Identify Industry and Industry Related Criteria
Step 2: Gather and Analyze Data for the Selected Company
Step 3: Develop a Score for Each Major Criteria Area
Step 4: Develop/Update Fuzzy Logic Model
Step 5: Generate Fuzzy Outputs from Criteria Score
Step 6: Generate Discounted Cash Flow Business Valuation

These steps form the foundation of the process and have been described and applied in this research.

### 6.2.4 New Approach Enhances and Extends Current Methods

The new problem structure and approach provides an enhancement to current methods. In this application, the performance metrics are used to predict the Net Operating Profit for airlines. As shown in the example, this performance metric based prediction is done for a number of years which is then input into a DCF business valuation model. The research performed in this study integrates with existing methods and does not replace these methods.

Typically, forecasts that would be input into a DCF business valuation model would be made based on historical financial data. With this method, performance and operational information is used to drive the forecasts into the future. This process using MADM and fuzzy logic, provides flexibility that is not available in traditional methods. A non-linear environment can easily be modeled within the framework of a fuzzy logic model. Fuzzy logic is a universal approximator and provides a sound theoretical basis for the new process.

Future approximations can be made based on anticipated future performance levels, not only historical data or financial data. Additional performance metrics, specifically in the area of non-financial performance metrics, are integrated into the overall valuation process. This necessitates the use of information that has not previously been integrated into the overall business valuation process. Integrating performance information into the business valuation process provides insight into the company operations and how, as operational performance changes, corporate dollar value is affected. This information aids in directing management to performance areas that will have the greatest financial impact on the company. This performance driven approximation capability provides a new and enhanced dimension to business valuation and other problems of this nature.

### 6.2.5 New Approach Provides Ability to Determine Impact of Operational Efficiency on Current and Future Corporate Value

A key benefit of this process is that it provides a process to determine the impact of operational efficiency on the current and future value of a company. Specific performance areas are identified and measured and, through the process, their relationship to the financial output is determined. This business valuation process provides an analytical tool to determine how increases or decreases in performance in key areas of the company impact the overall corporate value. The tool provides a meaningful way for managers to direct improvement efforts and enhance operations in areas that provide value to the company. This company analysis information can be used in near term management decisions or the impact of performance changes can be seen in the overall business value. This can be useful in investment related decisions.

Initial methods have been described to use this process to aid management in identifying improvement areas. These methods include the Sequential Simultaneous Increase in Negative-Ideal Solution and Focal Point Performance Area Improvement. The first method increases performance metrics sequentially and simultaneously across all decision criteria and then determines the impact of these increases on the overall financial performance of the company. The second method selects specific performance metrics and tests the financial impact of increasing or decreasing these metrics. Many other methods or variations of these methods can be developed, however, these provide a structured starting point in the application of this process.

### 6.2.6 Data Gathered For Two Regional Airlines Which is Useful in Other Research

The data for two regional airlines is gathered as part of this effort. This information is based in SEC filings, Annual Reports and the Bureau of Transportation Statistic information. This information can be useful in other research efforts. The yearly data provides information that is useful. Also, the performance metrics used in this analysis can be used as a base point for analyzing other regional airlines. Data for these performance metrics for other regional airlines could be gathered and a similar analysis performed with other regional airlines.

## 6.3 Future Work

There are a number of areas that can be further pursued to enhance this research. The process used to solve this type of problem can be adapted to various industries and application areas and modified to include a variety of different methodologies. A number of different studies can also be developed applying this process to various examples using actual data.

### 6.3.1 Structured Study of the Impact of Different Fuzzy Sets on Process

This consists of studying the impact of using different fuzzy sets, membership functions, linguistic variables and production rules on the results generated by the process. A small test of this was performed in the Chapter 5 with the Regional Airline Studies. Testing different fuzzy set models could provide insight into the use and results of this process and expand and enhance the capabilities of management and analysts.

### 6.3.2 Use of Other Methodologies in the Process

This process integrated two sound and fundamental methodologies, MADM and fuzzy logic. The MADM method used in this research was TOPSIS. Other MADM methods can be used to generate a score for input into the fuzzy logic model. Some MADM methods generate a cardinal score and others generate an ordinal rank. Even if the method generates an ordinal rank, this rank order can be used in the membership functions as is, by designing the membership functions to handle the ordinal rank, or it can be translated into a cardinal representation of score. If the input decision criteria are vague or imprecise, fuzzy MADM methods can be used to accommodate this environment. In addition, fuzzy linguistics and the Order Weighted Aggregator may also prove to be beneficial for use in this process.

Future work can include testing other MADM methods in the existing process, using different membership functions in the problem, production rules and using different linguistic variables in the fuzzy logic model. This may be done to test the differences between using the current approach, i.e., TOPSIS and other methods. Also, fuzzy MADM may be used where the performance metrics or decision criteria are also vague and imprecise. The problem characteristics and the approach allow for the flexibility to test these other methods and basic problem constructs.

Another area of future work with this process is to use or develop other search methods to identify areas of improvement for a company. The structure of the problem may lend itself to other search techniques, such as MOST, and even potentially the use of various interior point methods. Using techniques such as this can help facilitate the use of this process by management in improving company operations.

### 6.3.3 Study Time Lag Between Performance Changes and Financial Results

Investment made to improve performance levels and the realized changes in performance levels in many cases will not be immediate. There may be a time lag between the time that the investment is made, the time that performance improvement actually occurs and the financial benefits that are realized by the company. Additional studies can be performed using this business valuation process to determine the timing between the performance changes and the impact on financial value. Results from this study can be beneficial in economic analysis studies in the analysis of investment and performance payback periods.

### 6.3.4 Use of Process in Other Industries

The research in this thesis is based on applying the developed process to a sample production company and the regional airline industry. This process could be used and applied across all industries where meaningful performance metrics and financial information is available.

Establishing the decision criteria to measure the performance of a company in a variety of industries is one of the most challenging tasks associated with using this process. The data that is most readily reported and easily available provides are candidates for the performance metrics used in the process. Securities and Exchange Commission data are available for all public companies. Private data sources can also be purchased and used for other specific industries in question. Appendix A shows a cross industry list of potential decision criteria that could be used in a variety of industries. Not all of these performance metrics are relevant to every industry, and it is not recommended that all of these performance metrics be used within one process model for a given industry. These performance metrics/decision criteria however, provide a starting point for developing and applying this process to other industries.

It is intended in the development of this process that the three major decision criteria or areas be used across all industries. There may arise a need to modify these three major decision criteria to better meet the needs of a given industry, however, these three major criteria provide significant breadth in representing company performance. If changes to the three major criteria are necessary, the changes should encompass the goal which is to provide a broad representation of the key areas of performance in a company. If these major areas increase or decrease, the structure of the model would change to include these new areas, their membership functions, the linguistic variables and the production rules. The key is to represent the most important performance areas within an industry, which can then be used in the remainder of the process.

### 6.3.5 Process Applied to Different Problem Areas

The new process can be applied to areas other than business valuation. The problem defined in this research is structured to translate performance metrics into financial information. In this research, this problem and process is being used to perform business valuation. This same problem structure and process could also be applied in a number of different areas. Examples of these different areas are shown in Chapter 3, Table 3.2-1. Further research can include applying the process to lower levels of a company and within specific areas of operation. In this case, the major criteria used in the process may change and the performance metrics/decision criteria used in the process may be at a more detailed level.

Additionally, the high level corporate analysis may prompt further analysis in a specific area. For example, if high level management performed the high level analysis with the new process and determined that they want to increase the on-time delivery in a company, they can use this same process to identify areas at a lower, more specific performance area that can contribute to the overall profitability of a company.

## 6.4 Usefulness of Research

It is the hope of this research effort that this is an approach that can be useful and beneficial to the business world. This process incorporates additional information into the decision process to enhance the decision making process. Testing this process with actual examples will provide additional insight as to the benefits of this research.

# Appendix A

## Cross Industry Performance Metrics/Decision Criteria

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| COMPANY INFORMATION | Company Information | Type of business |
| COMPANY INFORMATION | Company Information | Type of entity (S-corp, limited-liability, etc.) |
| COMPANY INFORMATION | Company Information | Family owned (Y/N) |
| COMPANY INFORMATION | Company Information | Management commitment to business success/growth (Low - High) |
| COMPANY INFORMATION | Company Information | Capital intensive of business (low to high) |
| COMPANY INFORMATION | Company Information | Potential positive or negative changes in business overall (increase or decrease in profit or revenue) |
| COMPANY INFORMATION | Company Information | Management view of need for change indicated by new systems, initiatives or procedures in company. (low need to high need).. |
| COMPANY INFORMATION | Company Aggregate Financial Trends | Gross Revenues (5 year historical + 5 year projected) |
| COMPANY INFORMATION | Company Aggregate Financial Trends | Expenses (5 year historical + 5 year projected) |
| COMPANY INFORMATION | Company Aggregate Financial Trends | Profit (EBIT) (5 year historical + 5 year projected) |
| COMPANY INFORMATION | Company Aggregate Financial Trends | Cash Flow (5 year historical + 5 year projected) |
| COMPANY INFORMATION | Company Aggregate Financial Trends | Working capital carried (current assets minus current liabilities) (5 year historical + 5 year projected |
| ECONOMIC CONDITIONS | Economy | The growth or decline of the economy in the next 5 - 10 years - by year |
| ECONOMIC CONDITIONS | Economy | The growth or decline of the economy associated with this industry in the next 10 years - by year |
| ECONOMIC CONDITIONS | Interest Rates | Projected interest rates 1 to 4 years - by year |
| ECONOMIC CONDITIONS | Interest Rates | Projected interest rate 5 to 9 years - by year |
| ECONOMIC CONDITIONS | Interest Rates | Projected interest rate 10+ years - |
| ECONOMIC CONDITIONS | Consumer Confidence | The trend in consumer confidence for the next 5 years by year |
| STRATEGIC PLANNING | Strategy Development | Well defined short-term, mid-term and long-term business strategy (low to high) |
| STRATEGIC PLANNING | Strategy Management | Business strategy metrics and performance measures captured and used throughout all levels of the company (none to all) |
| LEADERSHIP | Leadership | Perceived Overall Organizational Leadership (poor to excellent) |
| LEADERSHIP | Social Responsibility | Perceived Social Responsibility of Leadership (none to highly responsible) |
| LEADERSHIP | Key Employee Profile | Key employee profile |
| LEADERSHIP | Key Employee Profile | Key employee |
| LEADERSHIP | Key Employee Profile | Functional Area |
| LEADERSHIP | Key Employee Profile | Position |
| LEADERSHIP | Key Employee Profile | Leadership ability (low to high) |
| LEADERSHIP | Key Employee Profile | Competitiveness of salaries in industry including benefits and bonuses (not competitive - very competitive) |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| **PRODUCTS** | **Life Cycle Analysis** | Life cycle analysis of the current key product lines |
| **PRODUCTS** | **Life Cycle Analysis** | Key product or service (SIC and NAICS codes). |
| **PRODUCTS** | **Life Cycle Analysis** | Introduction year |
| **PRODUCTS** | **Life Cycle Analysis** | Anticipated life |
| **PRODUCTS** | **Life Cycle Analysis** | Revenue by year from introduction |
| **PRODUCTS** | **Life Cycle Analysis** | Expenses by year from introduction |
| **PRODUCTS** | **Life Cycle Analysis** | Profit by year from introduction |
| **PRODUCTS** | **Life Cycle Analysis** | Inventory balance during the middle of the year and end of year |
| **PRODUCTS** | **Life Cycle Analysis** | Amount of obsolete or unsalable inventory. |
| **PRODUCTS** | **Proprietary** | Proprietary or unique products or services, such as patents or registered trademarks in relationship to others in industry (low to high) |
| **PRODUCTS** | **Product or Service Differentiation** | Overall uniqueness/differentiation of company in industry (very common, very unique) |
| **PRODUCTS** | **Product or Service Differentiation** | To what degree are company products or services and trade names readily recognizable in key markets (low to high) |
| **PRODUCTS** | **Product Leader** | Degree to which the company known as a leader in quality |
| **PRODUCTS** | **Product Leader** | Degree to which the company known as a leader in service |
| **PRODUCTS** | **Product Leader** | Degree to which the company known as a leader in price (higher quality - higher price, higher quality - lower price) |
| **RESEARCH AND DEVELOPMENT** | **R & D Budget** | Percent of total R & D budget to sales or profit (EBIT) |
| **RESEARCH AND DEVELOPMENT** | **Product Introduction** | New product introductions compared to other companies in same industry - quantify or few to many |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Product life cycle analysis of new products or services |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Key product or service (SIC and NAICS codes). |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Introduction year |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Anticipated life |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Anticipated revenue by year from introduction |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Anticipated expenses by year from introduction |
| **RESEARCH AND DEVELOPMENT** | **Life Cycle Analysis** | Anticipated profit by year from introduction |
| **RESEARCH AND DEVELOPMENT** | **Proprietary** | Proprietary or unique products or services, such as patents or registered trademarks in relationship to others in industry (low to high) |
| **RESEARCH AND DEVELOPMENT** | **Competitive Gap** | Research activities fill "competitive gap" in company (low to high) |
| **HUMAN RESOURCES** | **Human Resources policies and procedures** | Create and manage human resources (HR) planning, policy and strategies |
| **HUMAN RESOURCES** | **Recruit, source and select employees** | Recruit, source and select employees |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| **HUMAN RESOURCES** | **Recruit, source and select employees** | Sales per employee statistics over the past few years |
| **HUMAN RESOURCES** | **Recruit, source and select employees** | Gross profit per employee statistics over the past few years |
| **HUMAN RESOURCES** | **Recruit, source and select employees** | Relationship of company benefit package to an industry standard benefit package (poor - same - better) |
| **HUMAN RESOURCES** | **Develop and counsel employees** | Develop and counsel employees |
| **HUMAN RESOURCES** | **Develop and counsel employees** | Use of work teams by company for responsibilities and decision makers |
| **HUMAN RESOURCES** | **Develop and counsel employees** | Average annual hours of formal classroom training per employee |
| **HUMAN RESOURCES** | **Develop and counsel employees** | Percent of total annual labor costs used for training |
| **HUMAN RESOURCES** | **Reward and retain employees** | Reward and retain employees |
| **HUMAN RESOURCES** | **Reward and retain employees** | Monetary awards to employees |
| **HUMAN RESOURCES** | **Reward and retain employees** | Recognition to employees |
| **HUMAN RESOURCES** | **Reward and retain employees** | Annual turnover rate for all employees |
| **HUMAN RESOURCES** | **Redeploy and retire employees** | Redeploy and retire employees |
| **HUMAN RESOURCES** | **Redeploy and retire employees** | Unemployment benefits paid |
| **HUMAN RESOURCES** | **Redeploy and retire employees** | Retirement per employee paid???? |
| **HUMAN RESOURCES** | **Manage employee information** | Manage employee information |
| **HUMAN RESOURCES** | **Manage employee information** | Full-time employees work for the company (pasts 5 years) |
| **HUMAN RESOURCES** | **Manage employee information** | Part-time employees work for the company (past 5 years) |
| **HUMAN RESOURCES** | **Manage employee information** | Worker's compensation or claims or worker's compensation rating (low to high for industry) |
| **HUMAN RESOURCES** | **Labor unions** | Labor unions in company or industry (company/industry - yes/no) |
| **HUMAN RESOURCES** | **Contract labor** | Contract labor |
| **ENVIRONMENTAL AND SAFETY** | **Manage Environmental Health and Safety** | To what degree are there health, safety and environment impacts in the industry |
| **ENVIRONMENTAL AND SAFETY** | **Manage Environmental Health and Safety** | To what degree are there health, safety and environment impacts in the company beyond what is common in the industry |
| **ENVIRONMENTAL AND SAFETY** | **Environmental Health and Safety Programs** | To what degree are health, safety and environmental programs in place (low to high) |
| **ENVIRONMENTAL AND SAFETY** | **Environmental Health and Safety Training** | To what degree are all employees trained regarding health, safety and environmental programs (% employees) |
| **ENVIRONMENTAL AND SAFETY** | **Environmental and Safety Certification** | Has plant achieved ISO 14000 certification? |
| **ENVIRONMENTAL AND SAFETY** | **Energy Consumption** | Change in energy consumption per unit of production, % |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| ENVIRONMENTAL AND SAFETY | OSHA-reportable Incident Rate | For the most recent calendar year, what was plant's OSHA-reportable incident rate per 100 employees |
| ENVIRONMENTAL AND SAFETY | Lost-workday Rate | Lost-workday rate (lost workdays per 100 employees) |
| ENVIRONMENTAL AND SAFETY | Percent Change in Worker's Compensation Costs | Percent change in workers' compensation costs over the last 3 years |
| FINANCIAL | Aggregate Financial Metrics | Profitability (EBIT) as a % of revenue |
| FINANCIAL | Aggregate Financial Metrics | Expenses (SG&A) as a % of revenue |
| FINANCIAL | Aggregate Financial Metrics | COGS as a % of revenue |
| FINANCIAL | Aggregate Financial Metrics | Sales Growth (year over year change) |
| FINANCIAL | Aggregate Financial Metrics | COGS year over year change |
| FINANCIAL | Aggregate Financial Metrics | Net asset turns |
| FINANCIAL | Major Fixed Assets | Breakdown the company's major fixed assets based on type, age, condition, original cost, current depreciated book vale, current estimated FMV, maintenance costs per year, deferred maintenance and degree of technological advancement of the items. (ASSET BASED VALUATION) |
| FINANCIAL | Fixed Costs | What costs must be paid regardless of sales volume per month and at what amount? |
| FINANCIAL | Fixed Cost Reduction | Identify ways that fixed costs can be reduced and estimate how much the reduction will be? |
| FINANCIAL | Breakeven analysis | What is approximate breakeven level of sales on a monthly and annual basis? |
| FINANCIAL | Variable Costs | What are key variable costs (e.g., labor, raw materials, utilities, T & E), what are they for the company and what are they for the industry in terms of percentage of sales? |
| FINANCIAL | Variable Cost Reduction | Identify ways that variable costs can be reduced and estimate how much the reduction will be? |
| FINANCIAL | Rental Space | What is the per-foot rental rate, above average, average, or below average in regards to similar premises in the area? |
| FINANCIAL | Rental Rate Increases or Decreases | What are the potential increases or decreases in rental rates per year based on the current facilities? |
| FINANCIAL | Manage Accounting and Reporting | Percent budget of total sales spent on planning and management accounting, revenue accounting and general accounting and reporting |
| FINANCIAL | Process Payroll | Process payroll ( a measure such as time and number of employees or time/employee) |
| FINANCIAL | Proccess Accounts Payable and Expenses | Process accounts payable and expense reimbursements (a measure such as turn-around time) |
| FINANCIAL | Manage Treasury Operations and Internal Controls | Manage treasury operations and internal controls |
| FINANCIAL | Manage Financial Resources | Manage taxes (Taxes paid per year historically, for company and industry) |
| FINANCIAL | Days of Inventory | Days of Inventory - Raw, WIP, Finished Goods |
| FINANCIAL | Days Sales Outstanding (Receivables) | Days sales outstanding |
| FINANCIAL | Days Payables Outstanding (Payables) | Days payable outstanding |
| FINANCIAL | Facility Management | Maintenance expenditures on facilities |
| FINANCIAL | Facility Requirements | Are the current facilities sufficient? |
| FINANCIAL | New Facility Requirements | What are the anticipated costs and benefits of new, in process or proposed facility enhancements |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| FINANCIAL | Disposal | Anticipated dollar recovery of disposal from capital assets |
| TECHNOLOGY | Automated Operations | To what degree are the company's operations automated or computerized (low to high) |
| TECHNOLOGY | Technologicial Development in Industry | What is the rate of technological development in this business industry (slow to fast)? |
| TECHNOLOGY | Competitive Technology | How important is it to have the latest technology to main competitiveness (unimportant to critical)? |
| INFORMATION TECHNOLOGY | Key Information System Profile | For Each Key Information System |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | Information system management planning |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | Application development and maintenance |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | Information technology infrastructure management |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | IT service support |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | Are new technologies available to enhance the key IT systems |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | New technology implementation (upgrade) using change management principles |
| INFORMATION TECHNOLOGY | | Profile any IT system upgrades, including the area, the cost, the development and the implementation time frame. |
| INFORMATION TECHNOLOGY | Manage Information Technology and Knowledge | Profile any new IT systems needed, including the area, the cost, the development and the implementation time frame. |
| INFORMATION TECHNOLOGY | Performance Visibility to Top Management | Overall visibility of company performance to top management |
| INFORMATION TECHNOLOGY | Performance Visibility to Departments | Departmental data accessibility and performance measurement |
| INFORMATION TECHNOLOGY | Performance Visibility to Manufacturing | Manufacturing data accessibility and performance measurement |
| INFORMATION TECHNOLOGY | Enterprise System Integration | Enterprise system (none, partially integrated, fully integrated) |
| INFORMATION TECHNOLOGY | Automated Integration with Suppliers | Automated integration with suppliers (manual, EDI, etc.) |
| INFORMATION TECHNOLOGY | Automated Integration with Customers | Automated integration with customers (manual, EDI, etc.) |
| INFORMATION TECHNOLOGY | Overall Rating | Overall rating of information systems in company |
| MARKETING | Marketing, distribution and channel strategy | Defined marketing, distribution and channel strategy |
| MARKETING | Customer strategy development | Customer strategy development |
| MARKETING | Key Competitors | Competitor Profile (For each major competitor) |
| MARKETING | Key Competitors | Competitor name. |
| MARKETING | Key Competitors | Position in the market based on sales |
| MARKETING | Key Competitors | Pricing strategy of the competitor |
| MARKETING | Key Competitors | Key strengths of competitor |
| MARKETING | Key Competitors | Key weaknesses of competitor |
| MARKETING | Key Competitors | Does the competitor excel (low to high)? |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| MARKETING | Advertising, Pricing and Promotion | Manage advertising, pricing and promotional activities |
| MARKETING | Advertising, Pricing and Promotion | Company pricing strategy, i.e. price leader, low cost, cost plus profit |
| MARKETING | Advertising, Pricing and Promotion | Percent of sales are devoted to advertising |
| MARKETING | Advertising, Pricing and Promotion | Type of advertising that works best for industry and type of advertising used |
| MARKETING | Advertising, Pricing and Promotion | Advertising and marketing effectiveness |
| MARKETING | Manage Sales Partners and Alliances | Manage sales partners and alliances |
| MARKETING | Sales Opportunities and Sales Pipeline | Manage sales opportunities and sales pipeline |
| MARKETING | Sales Opportunities and Sales Pipeline | Company sales in relationship to industry sales trends |
| MARKETING | Sales Opportunities and Sales Pipeline | Forecast for future industry sales |
| MARKETING | Sales Opportunities and Sales Pipeline | Sales approach (e.g., inside salesperson, outside salesperson, distributors)? |
| MARKETING | Sales Opportunities and Sales Pipeline | Requirements to generate increased sales |
| MARKETING | Company Web Site | Usefulness of company website (low to high) |
| CUSTOMER AND SUPPLIER | Manage External Relationships | Manage External Relationships |
| CUSTOMER AND SUPPLIER | Manage External Relationships | Build investor relationships |
| CUSTOMER AND SUPPLIER | Manage External Relationships | Manage government and industry relationships |
| CUSTOMER AND SUPPLIER | Manage External Relationships | Manage relations with board of directors |
| CUSTOMER AND SUPPLIER | Manage External Relationships | Manage legal and ethical issues |
| CUSTOMER AND SUPPLIER | Manage External Relationships | Manage public relations program |
| CUSTOMER AND SUPPLIER | Manufacturing Processes as Impacting Customers and Suppliers | Manufacturing processes (production, inbound material shipment, customer orders) |
| CUSTOMER AND SUPPLIER | Manufacturing Processes as Impacting Customers and Suppliers | Push, pull (JIT) , CONWIP or other |
| CUSTOMER AND SUPPLIER | Manufacturing Processes as Impacting Customers and Suppliers | Type of process |
| CUSTOMER AND SUPPLIER | Manufacturing Processes as Impacting Customers and Suppliers | To what degree based on sales or product produced |
| CUSTOMER AND SUPPLIER | Supplier Relations | Are key suppliers certified? |
| CUSTOMER AND SUPPLIER | Supplier Relations | Do resident suppliers manage/replenish inventories? |
| CUSTOMER AND SUPPLIER | Supplier Relations | What percent of supplier orders are delivered on-time (request date) |
| CUSTOMER AND SUPPLIER | Supplier Relations | Percent of purchased material (dollar volume) that no longer requires incoming inspection. |
| CUSTOMER AND SUPPLIER | Supplier Relations | Lead time of key suppliers, number of days |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | General pipeline measurement (time, quantity and $) |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Customer authorization to order receipt time |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Order receipt to order entry complete time |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Order entry complete to start manufacture |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Start manufacturer to order complete manufacturer |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Order complete manufacturer to customer receipt |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Customer receipt to installation complete |
| CUSTOMER AND SUPPLIER | General Pipeline Measurement | Backorders |
| CUSTOMER AND SUPPLIER | Customer Satisfaction | Are customer-satisfaction surveys conducted regularly? |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Customer Base Analysis |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Total customers are served each week, month or year |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Company percent of total customers in industry served each week, month or year |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | What percentage of sales come from the top one, three, five and ten customers? |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Key factor influencing customer loyalty |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Potential for increase in customer base based on percent sales increase (0% = none on up to increased based on current sales level of company) |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Percent of repeat sales business - customer satisfaction |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Percent of one time only business |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Percent of total sales that is local |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Percent of total sales that is regional |
| CUSTOMER AND SUPPLIER | Customer Base Analysis | Percent of total sales that is national |
| CUSTOMER AND SUPPLIER | Seasonal Effect | Seasonal effect on company's products or services, profile throughout year |
| CUSTOMER AND SUPPLIER | Seasonal Effect on Working Capital | Seasonal effect on working capital by month |
| CUSTOMER AND SUPPLIER | Mark-up percent | Typical markup or range in markup percent |
| CUSTOMER AND SUPPLIER | Bad Debt | Bad debt experience of the company |
| CUSTOMER AND SUPPLIER | Customer Base | Certainty of continued customer base - (low - high) |
| CUSTOMER AND SUPPLIER | Manage Customer Service | Develop customer care/customer service strategy |
| CUSTOMER AND SUPPLIER | Manage Customer Service | Develop and manage customer profiles |
| CUSTOMER AND SUPPLIER | Manage Customer Service | Manage customer service transactions |
| CUSTOMER AND SUPPLIER | Manage Customer Service | Perform account management |
| CUSTOMER AND SUPPLIER | Supplier Base | Supplier Profile (For each key supplier) |
| CUSTOMER AND SUPPLIER | Supplier Base | Key supplier name |
| CUSTOMER AND SUPPLIER | Supplier Base | Longevity of service of supplier |
| CUSTOMER AND SUPPLIER | Supplier Base | Key raw materials or inventory supplied |
| CUSTOMER AND SUPPLIER | Supplier Base | Criticality of material (critical and cannot be supplied by other suppliers, critical but can be supplied by others, non-critical) |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| CUSTOMER AND SUPPLIER | Supplier Base | Backup supplier for critical material |
| CUSTOMER AND SUPPLIER | Supplier Base | Level of integration with company (low to high) |
| CUSTOMER AND SUPPLIER | Supplier Base | Seasonality of supply (low to high) |
| CUSTOMER AND SUPPLIER | Supplier Base | Supplier relationships - potential additional advantageous or deteriorating supplier relationships. |
| CUSTOMER AND SUPPLIER | Procurement Planning and Management | Plan for and acquire necessary resources |
| CUSTOMER AND SUPPLIER | Procurement Planning and Management | Procure materials and services |
| MANUFACTURING | Manufacturing Operations | To what degree are the manufacturing processes and operations automated or computerized (low to high) |
| MANUFACTURING | Manufacturing Equipment | To what degree is the manufacturing equipment automated in regards to the available automation in this industry (low to high or antiquated, status quo or state-of-the-art) |
| MANUFACTURING | Manufacturing Methods | To what degree are state of the art methods being used in manufacturing and to improve operations (increase throughput, reduce cycle time, reduce WIP)? |
| MANUFACTURING | Manufacturing Operations | Annual capacity utilization (total annual production divided by design capacity) |
| MANUFACTURING | Manufacturing Operations | To what extent has plant adopted cellular manufacturing practices |
| MANUFACTURING | Manufacturing Operations | To what extent has plant adopted focused-factory production systems |
| MANUFACTURING | Manufacturing Operations | To what extent has plant adopted JIT/continuous-flow production methods |
| MANUFACTURING | Manufacturing Operations | To what extent has plant employ an internal "pull" system with kanban signals? |
| MANUFACTURING | Manufacturing Operations | What is the current standard order-to-shipment lead time (days) |
| MANUFACTURING | Manufacturing Operations | Production Flexibility |
| MANUFACTURING | Manufacturing Operations | Labor Flexibility |
| MANUFACTURING | Manufacturing Operations | Capacity Flexibility |
| MANUFACTURING | Manufacturing Profile | The degree to which technology in manufacturing processes effect the overall competitiveness in the industry |
| MANUFACTURING | Manufacturing Profile | The level of technology used in the manufacturing processes in the company (low to high) |
| MANUFACTURING | Process Management | Value Creation Process |
| MANUFACTURING | Process Management | Support Process |
| MANUFACTURING | Manage Improvement and Change | Measure organizational performance |
| MANUFACTURING | Manage Improvement and Change | Conduct process and functional performance assessments |
| MANUFACTURING | Manage Improvement and Change | Conduct knowledge management assessments |
| MANUFACTURING | Manage Improvement and Change | Benchmark performance |
| MANUFACTURING | Manage Improvement and Change | Manage change |
| MANUFACTURING | Quality | Has manufacturing received ISO 9000 certification? |
| MANUFACTURING | Quality | Implemented Quality Techniques (for each technique) |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| MANUFACTURING | Quality | Implemented Technique |
| MANUFACTURING | Quality | Degree of Implementation |
| MANUFACTURING | Quality | First pass yield for all finished products, % |
| MANUFACTURING | Quality | Defect rate |
| MANUFACTURING | Quality | Scrap/rework costs as a percent of sales |
| MANUFACTURING | Quality | Warranty costs as a percent of sales |
| MANUFACTURING | Inventory Management | Percent change in total plant unit volume over the last 3 years |
| MANUFACTURING | Inventory Management | Annual raw materials turns |
| MANUFACTURING | Inventory Management | Annual work-in-process (WIP) turns |
| MANUFACTURING | Inventory Management | Annual finished goods turns |
| MANUFACTURING | Inventory Management | Annual total inventory turns |
| MANUFACTURING | Forecast Accuracy | Unit forecast accuracy |
| MANUFACTURING | Forecast Accuracy | Dollar forecast accuracy |
| MANUFACTURING | Productivity and Cost Management | Current productivity as annual value-added per employee, $ |
| MANUFACTURING | Productivity and Cost Management | Current productivity as sales per employee, $ |
| MANUFACTURING | Productivity and Cost Management | Approximate 3-year manufacturing-cost change per unit of product shipped, excluding purchased materials costs, % |
| MANUFACTURING | Productivity and Cost Management | Approximate 3-year cost change per unit of product ship0ped, including purchased materials costs, % |
| MANUFACTURING | Productivity and Cost Management | Change in plant-level profitability (annual value of shipments minus materials and manufacturing costs) over the last 3 years, % |
| MANUFACTURING | Productivity and Cost Management | Order Management Cost |
| MANUFACTURING | Productivity and Cost Management | Material Acquisition Cost |
| MANUFACTURING | Productivity and Cost Management | Inventory Carrying Cost |
| MANUFACTURING | Returns | Returns processing cost as % product revenue |
| MANUFACTURING | Returns | Returns inventory status |
| MANUFACTURING | Returns | Return cycle times |
| MANUFACTURING | Returns | Cycle time to process excess product returns for resale, days |
| MANUFACTURING | Returns | Cycle time to process obsolete & end of life product returns for disposal, days |
| MANUFACTURING | Returns | Cycle time to repair or refurbish returns for use, days |
| MANUFACTURING | Returns | Percent actual achievement versus published service agreement cycle time, % |
| MANUFACTURING | Returns | Number of repairs performed as % total number of units shipped annually |
| MANUFACTURING | Returns | Number of repairs performed internally as a % total number repairs performed |
| MANUFACTURING | Returns | Number of repairs performed externally (by third party) as a % of total number repairs |
| MANUFACTURING | Returns | Cost of units repaired/refurbished internally as a % of total |
| MANUFACTURING | Returns | Cost of units repaired/refurbished externally as a % of total |

| Main Area | Sub Area | Performance Metrics/Decision Criteria |
|---|---|---|
| **LOGISTICS** | **Distribution Operations** | To what degree are the distribution operations automated or computerized (low to high) |
| **LOGISTICS** | **Distribution Equipment and Communications** | To what degree is the distribution equipment automated in regards to the available automation in this industry (low to high) |
| **LOGISTICS** | **Distribution Methods** | To what degree are state of the art methods being used in distribution and to improve operations (increase throughput, reduce inroute inventory, etc.)? |
| **LOGISTICS** | **Overall Process** | Integration of Supply, Production and Delivery Process |
| **LOGISTICS** | **Deliver Products and Services** | Delivery of product to customer |
| **LOGISTICS** | **Manage Logistics** | Manage logistics overall |
| **LOGISTICS** | **Manage Warehousing** | Manage warehousing |
| | | |
| **** Different Types of Constraints that may be known about the business** | | |
| **CONSTRAINTS** | **Constraints** | What types of capacity constraints does the business face (e.g., floor space, seating capacity, labor supply, equipment)? |
| **CONSTRAINTS** | **Constraints** | How much could sales be increased without the need for additional "space" or major asset acquisitions? |
| **CONSTRAINTS** | **Constraints** | Based on the state of affairs (size of premise, labor, and access to raw materials), how much could sales increase without substantial changes in the resource base? |
| **CONSTRAINTS** | **Constraints** | Are there any past, present or anticipated legal actions related to the company and what is the anticipated impact on company finances? |
| **CONSTRAINTS** | **Constraints** | Show all types of contractual relationships, what area of the company they impact and the duration of the contract. |
| **** Potential Grouping of Business Results** | | |
| **BUSINESS RESULTS** | **Business Results** | Customer-Focused Results |
| **BUSINESS RESULTS** | **Business Results** | Product and Service Results |
| **BUSINESS RESULTS** | **Business Results** | Financial and Market Results |
| **BUSINESS RESULTS** | **Business Results** | Human Resource Results |
| **BUSINESS RESULTS** | **Business Results** | Organizational Effectiveness Results |
| **BUSINESS RESULTS** | **Business Results** | Governance and Social Responsibility Results |

## Appendix B

## Airline Industry Performance Metrics/Decision Criteria

| Major Criteria | Sub-Criteria | Key Performance Indicators (KPIs) |
|---|---|---|
| **Safety** | Accidents | Fatalities to passenger accidents |
| **Safety** | Accidents | Injuries to passenger accidents |
| **Safety** | Violations | Incidents to passengers |
| **Safety** | Violations | Ground citations |
| **Safety** | Violations | Perception of safety of airline |
| **Customer - Supplier Relations** | Customer Service | Mishandled baggage |
| **Customer - Supplier Relations** | Customer Service | Customer complaints |
| **Customer - Supplier Relations** | Customer Service | On-time arrivals |
| **Customer - Supplier Relations** | Customer Service | On-time departures |
| **Customer - Supplier Relations** | Customer Service | Ticket oversales |
| **Customer - Supplier Relations** | Customer Service | In-flight service |
| **Customer - Supplier Relations** | Customer Service | Flight cancellations |
| **Customer - Supplier Relations** | Alliances | Utilization of outsourcing |
| **Customer - Supplier Relations** | Alliances | Suppliers relations |
| **Customer - Supplier Relations** | Alliances | Partnering |
| **Operational Performance** | Infrastructure | Gate utilization |
| **Operational Performance** | Infrastructure | Regularity Limitations |
| **Operational Performance** | Infrastructure | Level of established infrastructure |
| **Operational Performance** | Labor | Flexibility |
| **Operational Performance** | Labor | Cost |
| **Operational Performance** | Equipment | Age |
| **Operational Performance** | Equipment | Fleet structure |
| **Operational Performance** | Equipment | Maintenance |
| **Operational Performance** | Equipment | Aircraft utilization |
| **Operational Performance** | Equipment | Utilized available ton miles |
| **Operational Performance** | Scheduling | Scheduling model efficiency |
| **Operational Performance** | Scheduling | Adaptability of equipment to schedule changes |
| **Operational Performance** | Scheduling | Flexibility to market changes |
| **Operational Performance** | Network Connectivity | Business model suited to type of network |
| **Operational Performance** | Network Connectivity | Business model suited to type of traffic |

| | | |
|---|---|---|
| **Operational Performance** | Benchmarking performance | Adopting of best business practices of successful LCC |
| **Operational Performance** | Benchmarking performance | Adopting of best business practices of legacy airlines |
| **Operational Performance** | Benchmarking performance | Tracking and use of operational performance metrics |
| **Human Resources** | Management Capabilities | Leadership |
| **Human Resources** | Management Capabilities | Experience |
| **Human Resources** | Human Resources | Employee Satisfaction |
| **Human Resources** | Human Resources | Comparative salary and benefits in industry |
| **Corporate Positioning** | Marketing | Ability to stimulate market |
| **Corporate Positioning** | Marketing | Has unique market niche |
| **Corporate Positioning** | Marketing | Meets market need |
| **Corporate Positioning** | Marketing | Airline network in respect to targeted market |
| **Corporate Positioning** | Marketing | Entry/business model timing in regards to market |
| **Corporate Positioning** | Market Share | Current market share |
| **Corporate Positioning** | Market Share | New or existing market potential |
| **Corporate Positioning** | Growth | Market growth potential for regional airlines |
| **Corporate Positioning** | Growth | Passenger growth potential for airline |
| **Corporate Positioning** | Growth | Company growth potential in relationship to industry growth |
| **Corporate Positioning** | Demographics | Per capita income of travelers |
| **Corporate Positioning** | Demographics | Per capita income of airline geographic area |
| **Corporate Positioning** | Demographics | Business travelers |
| **Corporate Positioning** | Demographics | Leisure travelers |
| **Corporate Positioning** | Competitive Position | Perception of wealth creating capability |
| **Corporate Positioning** | Competitive Position | Size of competitive barriers |
| **Corporate Positioning** | Competitive Position | Price positioning |
| **Corporate Positioning** | Competitive Position | Flight frequencies to markets |
| **Corporate Positioning** | Competitive Position | Brand or airline image |
| **Corporate Positioning** | Competitive Position | Competitive marketplace dynamics in industry |
| **Corporate Positioning** | Competitive Position | Hub selection compatibility with business model |
| **Corporate Positioning** | Competitive Position | Hub selection in respect to competitors |
| **Corporate Positioning** | Competitive Position | Location well situated to improve network scope |
| **Corporate Positioning** | Sustainability | Sustainability of pricing structure |
| **Corporate Positioning** | Sustainability | Ability of other airlines to compete |
| **Corporate Positioning** | Sustainability | Flexibility of airline to change |
| **Corporate Positioning** | Sustainability | Flexibility of competitors |
| **Corporate Positioning** | Risk | Probability of success |

| | | |
|---|---|---|
| **Corporate Positioning** | Risk | Ability to estimate operating revenues and expenses |
| **Corporate Positioning** | Risk | Perceived market response to new service or new fare system |
| **Corporate Positioning** | Strategic Planning | Short and long term strategic plan |
| **Corporate Positioning** | Strategic Planning | Short and long term financial plan |
| **Innovation and Technology** | Innovation | Uniqueness of concept |
| **Innovation and Technology** | Innovation | Level of differentiation |
| **Innovation and Technology** | Technology | Use of new technology to enhance operations |
| **Innovation and Technology** | Technology | Maximization of automation of key processes and operations |
| **Financial Positioning** | Passenger Statistics | Cost per Seat Mile (CASM) |
| **Financial Positioning** | Passenger Statistics | Load factor (revenue ton miles / available ton miles) |
| **Financial Positioning** | Passenger Statistics | Revenue passenger miles |
| **Financial Positioning** | Passenger Statistics | Scheduled Revenue Passenger Enplaned |
| **Financial Positioning** | Passenger Statistics | Non Scheduled Revenue Passenger Enplaned |
| **Financial Positioning** | Passenger Statistics | Revenue Aircraft Departures Performed |
| **Financial Positioning** | Passenger Statistics | Revenue Aircraft Departures Scheduled |
| **Financial Positioning** | Corporate Statistics | Percent Administrative and Overhead Expenses |
| **Financial Positioning** | Corporate Statistics | Operating Profit.Loss |
| **Financial Positioning** | Corporate Statistics | Return on invested capital |
| **Financial Positioning** | Corporate Statistics | Revenue growth |
| **Financial Positioning** | Corporate Statistics | Current ratio |
| **Financial Positioning** | Corporate Statistics | Operating Margin |
| **Financial Positioning** | Corporate Statistics | Profit Margin |
| **Financial Positioning** | Corporate Statistics | Capital Turnover |

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| American Productivity and Quality Center | Website: http://www.apqc.org |
| Malcolm Baldridge National Quality Award | Website: http://www.quality.nist.gov |
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