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A New Approach to Measure Intangibles in the Economic Analysis of Advanced Technology Projects

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Presented to

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In Partial Fulfillment

of the Requirements for the Degree

Doctor of Philosophy

in Industrial Engineering

By

Khaled A. Eldressi

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A new Approach to Measure Intangibles in the Economic Analysis of Advanced Technology Projects

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"My lord! Advance me in knowledge" Holy Qur'an, Surah 20-Taha: 114.

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ABSTRACT

Current global demand for products with more advanced features and capabilities, less weight, and increased aesthetics has driven manufacturers to make significant investments in machinery and tools. Company decisions to invest in advanced technologies are often strategically aimed toward short-term return and frequently do not conform to traditional cost accounting practices, which, in many cases, may lead to rejection of investment due to inappropriate measurement techniques.

In revitalizing the manufacturing sector of the United States, manufacturing companies have been encouraged by a multitude of incentives to invest capital in plant and equipment enhancements in order to meet and exceed market expectations. The capital investment made by these companies is expected to enhance the capacity to make new products while expanding existing production capacity. The investments in advanced manufacturing and technology systems are often extensive and their successful implementation requires the full support and commitment of senior management. Traditional justification methods are often directly tied to company cash flow and short return period and the investments in advanced technology projects are often rejected as a result of the long-term return commitment. In this research, we have developed a methodology to measure the intangible attributes, yet include both tangible and intangible attributes in the economic decision-making process. Multiple attributes that may influence the decision process are included and measured in the proposed method. We present a comprehensive numerical example demonstrating the capability of the methodology. Additionally, we present conclusions and recommendations for future research in this important area to the manufacturing sector.

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Chapter 1 Introduction

The main goal behind Financial Accounting (FA) is to serve financial statement users with useful data that can help them with efficient decision making. Financial statements fail to provide relevant estimates of companies' values and thus provide less information about both the current and future financial situation of the company. As suggested by Goldfinger (1997), the ability of a company to create and manipulate intangible assets becomes the source of its wealth and economic value. Indeed, this value creation is no longer limited to the production of material goods. In this context, it is to a company's advantage to enlarge its investments in intangible assets in order to guarantee the future success of the organization. However, these investments cannot be reflected in the balance sheet because of the existence of very restrictive accounting criteria for the recognition of assets and their evaluation. In this context, an obvious sign of the loss of relevance of accounting information is the increasing "market value" — "book value" gap of companies' equity in financial markets. Lev and Zarowin (1999) have documented a significant increase in the market-to-book ratio of United States (US) firms. Indeed, this ratio has jumped from 0.81 in 1973 to 1.69 in 1992, which means that nearly 40% of the market value of companies does not reflect in the balance sheet.

According to Lev and Zarowin, the new way of dealing with intangibles does not only provide value creation for companies, but also questions the efficiency of traditional financial measures. This means that the traditional accounting model needs to be changed since it only takes manufacturing or commercial activities into consideration. This modification needs to take intangibles into account, which enhance the usefulness of accounting information. In order to provide financial statement users with relevant investment and credit decision-making information, clear guidelines for the identification of intangible elements should be developed. In addition, a set of criteria for valuation and adequate standards for financial reporting are also needed.

There exists an evident tension between accounting standards establishers and information users. Because of their volatile nature and measurement challenges, intangibles are normally usually excluded from financial statements in spite of their value. However, according to their linkage and contribution businesses, they offer an important resource for stakeholders. In this context, the decision-making process does not take advantage of financial reports that exclude return and are only based on traditional accounting rules. Therefore, it becomes obvious that the use of approaches identifying and measuring intangibles is certainly able to contribute to improving decision-making. Thus, the identification, measurement, and reporting of intangibles represents crucial components of the innovation cycle. Furthermore, in newly emerged business models, knowledge creation, capture, reuse, and diffusion represent the main sources of value creation. In summary, companies needing to increase their value have to start by finding the key contributing drivers to that increase. This comes by investing in intangibles especially because these assets are essential for innovation and thus for wealth creation.

In the literature, there are several and different definitions of the term "Intangibles". *"Intangibles"* are defined by Blair and Wallman (2003) as "*non-physical factors that contribute to the production of goods or the provision of services or that are expected to generate future productive benefits to the individuals or firms that control their use".* In general, an intangible asset comes with a set of properties including the challenge of verifying its existence, the inability of trading it in an organized market, the fluctuation of its value, the strong interlink with a specific activity, product, service, or business, and the missing finite life of these intangibles. Examples of intangible assets include patents and trademarks, processes, human know-how, brand names, development expenditure, databases, and strategic alliances.

There have been several arguments about the contribution of intangibles to the creation of the company's value (Cohen, 2005), (Andriessen, 2004), (Lev, 2001), and (Brockington, 1996). In this context, intangibles have been historically considered as a cumulative amount, or also goodwill, without having a direct impact on national wealth nor being included in the firms' financial statements. Goodwill represents a residual incorporating all intangibles that cannot be measured separately.

1.1 Decision Making

Decision making is the process of making a reasonable choice among a number of available alternatives by sufficiently minimizing the uncertainty about these alternatives. In this context, the decision-making process strongly depends on the information-aggregation function. Based on the above definition, decision-making does not eliminate uncertainty but rather reduces it.

Many criteria are involved in the decision-making process in addition to other sub-criteria that are used in order to rank the alternatives of a decision. In some scenarios, we may deal with intangible criteria that are very difficult to measure. However, different criteria can help with the tasks of ranking the alternatives and creating priorities for both criteria and alternatives.

1.2 Manufacturing Systems

Stemming from the Latin base manufactum, which means ‘made by hand’, the term "manufacture" originally appeared in 1662. Later on, manufacturing was defined in 1983 by the International Conference on Production Research (ICPR) as "a series of interrelated activities and operations involving the design, materials selection, planning, quality assurance, management, and marketing of industrial products."

Manufacturing was rated in 1991 by the National Academy of Engineering/Science in Washington DC as one of three most important factors for America's economic growth and national security, together with science and technology (Hitomi, 1996). In this context, Skinner (1969) has emphasized that the main purpose of manufacturing is to help the company meet its needs for survival, profit, and growth. Hence, manufacturing can be seen as a major part of the strategic concept relating the company’s strengths and resources to the available market opportunities. While each strategy creates a unique manufacturing task, the ability of manufacturing management to meet that task is the key measure of its success. Thus, manufacturing is very important especially with its history extending over several thousand years and its two important features, which are the role of manufacturing in providing basic means for human existence and creating the wealth of nations (Hitomi, 1994).

The manufacturing system can be seen as an arrangement of tasks and processes properly put together in order to generate finished products starting from a selected group of raw materials and semi-finished products. Based on this, the manufacturing models can be classified into two groups, (i) optimization models where a set of criteria and constraints generate a single or a set of decisions or course of action, and (ii) performance models where the measures of system performance are estimated for a given set of decisions and system parameters (Altiok, 1997). Similarly, depending on the nature of their production operations, industries can also be divided into two types. The first type is known as manufacturing industries which can be identified by discrete-item production such as cars, computers, and machine products. On the other hand, the second type is known as process industries and can be represented by chemicals and plastics, petroleum products, food processing, steel, and cement (Groover, 2001). Using some aspects of manufacturing engineering, the study presented in this research will be more oriented toward the performance models of manufacturing industries.

Advanced Manufacturing Systems (AMS) can be defined as a group of both hardware and software-based technologies. Provided that this combination is properly implemented and evaluated, AMS leads to improving the firm's efficiency and effectiveness in products' manufacturing. In this scenario, technology does not just mean the manufacturing plant and equipment. However, it should combine both hardware and software (Samson, 1991). Many companies seek to maintain a competitive edge in the marketplace by exploiting the advantage of modern manufacturing technologies. These technologies involve the use of advanced automated systems such as computer-aided design (CAD), computer-aided process planning (CAPP), and computer-aided manufacturing (CAM). Similarly, flexible manufacturing systems (FMS), telecommunications technology, distributed database management, data processing and control, robotics, CNC machine tools, automated storage and retrieval systems (AS/RS) automated guided vehicle (AGV), automatic sensors, vision systems, manufacturing resources planning (MRP), and just-in-time (JIT) are also involved (Naik and Charavart, 1987).

1.3 Economic Justification

In order for manufacturing industries in the United States to be more competitive in the future, these industries have to be encouraged to invest their capital in plant and equipment. In addition, the purpose of this investment is not recommended to be only directed toward expansion. It should also be directed towards having appropriate state-of-the-art technologies for engineering and manufacturing hardware including CAD, CAM, flexible manufacturing systems (FMSs), and computer integrated manufacturing (CIM). Moreover, the implementation of novel managerial techniques for the control of production, quality, and inventory is required. These techniques include material requirement planning (MRP), total quality management (TQM), just in time (JIT), computer aided process planning (CAPP), and group technology (GT).

The justification process is still considered by several industries as a low-level capital budgeting or equipment replacement. In general, the justification methods that are currently considered by manufacturers include the payback period, net present value, internal rate of return, and benefit/cost ratio. In an effort to meet their strategic goals, organizations need to take into account the intangible and non-quantifiable benefits when making such decisions.

In the literature, many researchers have tremendously contributed in order to categorize and justify different automation technologies using numerous approaches. For example, Meredith and Suresh (1986) have discussed several justification approaches such as economic, analytical, and strategic approaches. These different approaches will be presented and studied in detail in the upcoming chapter.

1.4 Justification Techniques and Approaches

In light of the above, multiple approaches exist that have been studied in order to justify the investment of AMT. These techniques and approaches can be grouped into four categories:

- Economic approaches

Involve classical financial justification techniques of the payback period (PP), return-on-investment (ROI), internal rate of return (IRR), and net present value (NPV).

- Analytic approach

Involve value analysis, portfolio analysis and risk analysis (Meredith 1985).

- Strategic approaches

Involve analysis of competitive advantage, business objectives, research and development objectives, and technical importance,

- Integrated approaches

Involving multi-attributes utility theory and expert systems.

1.5 Intangible Assets: Nature and Classification

The classification of intangibles needs to be done by first setting a classification purpose. Indeed, a classification criterion cannot be assigned a true or false value. However, the importance of this criterion varies depending on the suggested purpose of classification (Rosing 1978). In this context, different items in accounting have been categorized based on a number of reasons. For instance, in order to help users calculate a number of measures like liquidity and solvency, the classification into current and non-current assets is required. Moreover, the use of classification in accounting allows identification of the way different measures are assigned for different classes of assets including the historical cost of non-current assets and the fair value of financial items.

While there has been no stated purpose for the classification of intangibles in most articles studying this classification as concluded by Walker (2009), it is obvious that this classification is useful for management purposes. Indeed, in order to conduct successful management, different resources need to be marked with clear and visible labels. Classifying these resources into different categories represents a good way for accomplishing the intended task (Kaufman & Schneider, 2004). In the literature, there have been many proposals for the classification of intangible assets. For example, Lev (2001) has classified intangibles into four groups when dealing with the tradition of intellectual capital:

1. Discovery/learning; R&D as an example
2. Customer-related; brands, trademarks, distribution channels
3. Human-resource; education, training, and compensation systems
4. Organization capital; structural organization design, business processes

The concept of "intellectual capital" has been extensively used and discussed in the literature. This concept is sometimes used in some references, including (Lev 2001), as synonymous with "intangibles". It has also been claimed, in a literature review elaborated by (Kaufmann and Schneider, 2004), that a well-established and generally accepted definition or classification of intellectual capital is missing. In a novel work that has strongly influenced other researchers, (Edvinson and Malone, 1997) have classified intellectual capital into two categories; where the first one is linked to employees and is most often called human capital and the second category is related to internal processes and structures and is most often named structural capital or organizational capital. The external structure, also called relational capital or customer capital, has been recently introduced as a third category and is related to customers. However, this classification can be seen as very abstract with quite broad categories that especially have no clear goal for this classification (Kaufmann and Schneider, 2004). Later on, a more elaborated literature study was been made by (Wyatt, 2008) dealing with this topic and resulted in the following resources' classes:

Technology resources

1. R&D expenditures

Human resources

2. Human capital

Production resources

3. Advertising and brands
4. Customer loyalty
5. Competitive advantage
6. Goodwill

There are several more refined classifications that have been proposed in financial accounting. As explained previously, there exists a clear reason behind these classifications, which include measurement purposes, informing external users, or which are driven by other purposes (e.g. Tax purposes). In order to establish a useful and accurate classification, the latter should have no overlap between different categories. As a more redefined classification, the Financial Accounting Standards Board (FASB, 1985a) classification can be seen as particularly helpful in the respect of avoiding overlapping categories. In this context, seven different classes of assets have been proposed by the FASB and are given as follows:

- Assets based on the technology
- Assets based on the customer
- Assets based on the market
- Assets based on the workforce
- Assets based on the contract
- Assets based on the organization
- Assets based on the statutory

In the literature, there have been several ways of defining intangible depending on the nature of these assets. For instance, according to Baruch Lev, assets can be classified into two groups by distinguishing "rivalry" and "non-rivalry" assets. In this context, he classifies physical and financial assets in the rival category due to the competition between different users in the use of these assets. However, these assets cannot be simultaneously exploited in many places. To support this, Baruch Lev gives the example of airline companies where each route has its own assigned airplane and has related financial capital invested in that airplane, and that cannot be dedicated by another route. Consequently, intangible assets have been identified as "non-rivalry" assets. In this case, many users can share these assets in different ways. Coming back to the example of airline companies, while the reservation system is considered as an intellectual property of the company, multiple users can simultaneously use this system (Stepjen, 2001).

In light of the above, the classification of intangibles turns out to be an easier task than deciding on their nature. According to the FASB's asset definition, which is similar to the IASB's definition, (International Accounting Standards Board), an asset is defined as "a probable future economic benefit obtained or controlled by a particular entity as a result of past transactions or events" (Statement No 6, paragraph 25). However, Edmund Jenkins and Upton (2001) have examined whether this definition of assets can also be considered for intangible assets. To this end, they have discussed if having a well-trained and happy workforce can be considered as a source of future economic benefit. While the response to this question can be positive since those factors are important to a business, it can also have a negative answer. Indeed, this is mainly due to the existence of a major control issue over the benefits generated from these assets especially when it flows from workforces which cannot be fully controlled. A second aspect that is related to these assets is linked to the criteria of "resulting of past transaction". In this context, while it is relatively easy to identify a "past event" when purchasing a patent, it becomes a more challenging task that can take many years when it comes to developing certain a drug within the company. The main reason behind this is that the second task is generated by an intangible asset (Jenkins and Upton, 2001)

1.6 Problem Statement and Motivation

Since the 1990s, the topic of intangibles has been the focus of attention for both academic research and business practices. A significant amount of literature attempts to understand the nature of intangibles, to measure and manage them, as well as to assess the value relevance of different intangible elements. However, several problems and gaps were observed after reviewing related literature which motivates us to conduct the present study.

Given the economic importance of intangibles, a number of intangible measurement frameworks and models have been developed and different guidelines have been constructed (Sveiby, 1997a); (Mouritsen et al., 2001); (Bontis et al., 1999); (Marr et al., 2003); and (Meritum, 2002). Due to the lack of appropriate measurement tools, the level of intangible disclosure across countries and sectors tends to be very low (Beattie and Thomson, 2007). Because of the qualitative nature of many commonly applied measurement frameworks, an intangible disclosure is expressed qualitatively rather than quantitatively and the type of information varies across companies and countries. As a result, it is difficult to conduct quantitative empirical studies in the field of intangible measurement and it is also challenging to assess the value of intangibles (Bollen et al., 2005); and (Marr et al., 2003). Although several research efforts have dealt with measure intangibles and intangible attributes, only a few studies have contributed in this regard, either using qualitative approaches (e.g., Cuganesan, 2005); (Johanson et al., 2001a); and

(Holland, 2004) or quantitative approaches (e.g., Bontis, 1998); (Cabrita and Vaz, 2006); (Maxham et al., 2008); (Nagar and Rajan, 2005); and (Wang and Chang, 2005).

The main goal behind this research is to elaborate a methodology allowing the measurement of intangibles in terms of economic and decision perspectives. Many of the attributes that have a significant effect on corporations' decisions are intangibles, which include the manufacturer's reputation, the warranty period, product aesthetics, and expandability. Because of the inefficiency of the traditional evaluation techniques, it is very challenging to measure most of these attributes based on traditional cash flow analysis. Moreover, the analysis conducted to evaluate these attributes using traditional techniques is incomplete.

1.7 Overview of the Proposed Solution Method and Contributions

The introduction of computer technology has revolutionized manufacturing and its associated activities such as finance, accounting, inventory control, design, manufacturing processes, quality control, and reliability. Advanced computer controlled manufacturing systems often require massive initial investments. Generally, such investments are not affordable by smaller corporations and their returns are only realized after long periods of time. The high initial investment and long projects' return time combined with many intangible benefits are some of the major issues which have been considered by many researchers and scholars. Many methods to measure intangible attributes have been introduced, however, the majority of these methods aimed at measuring attributes subjectively. This methodology developed and introduced in this research is a deterministic decision model which incorporates both tangible and intangible attributes in the selection of advanced manufacturing and technology-based systems. The proposed methodology is composed of three primary objectives including strategic competitive performance, managerial performance, and financial performance resulting in rank ordering alternatives.

The contribution of this research is the development of a decision using both strategic and tactical attributes of investment alternatives. This model introduces two performance measures namely, net present qualitative flow (NPQF) and net present operational flow (NPOF). Measures of the performance of objectives are evaluated using composite programming. This method proven to be robust and easy to utilize by decision makers.

The proposed method is applicable to a variety of decision problems when intangible attributes can dominate the selection process.

A numerical example is used to demonstrate the application of the proposed model. Conclusions and recommendations for future expansion of the model will also be discussed in this research.

1.8 Chapter Organization

This proposal is divided into five chapters. Chapter 1 presents the background problem and the motivation behind this research attempt. Chapter 2 presents a comprehensive literature review of economic justification and measures intangible approaches related works. The research methodology with emphasis on the problem definition and the proposed method are presented in Chapter 3. In Chapter 4, numerical examples are used to validate the proposal methodology. Finally, the conclusions and future work are reported in Chapter 5.

Chapter 2 Economic Justification Methods

The process of prerequisite justification represents one of the main components of advanced manufacturing systems. In this context, many projects have often been turned down because they do not include the qualitative or intangible benefits in the justification procedure, while the financial hurdles set by the company are not met because of insufficient direct cost savings. In this chapter, we will review several methods implemented by firms to justify the economic investments and to describe under what conditions these methods are most appropriate to be employed.

Manufacturing systems that might need to go through justification can be classified as follows:

1. Stand-alone: this is concerned with the addition of a single new machine to replace an outdated existing machine or to produce a new product.

2. Linking: this represents the combination of several stand-alone pieces of equipment to form a work cell.

3. Integration: this includes linking and automating the entire processes of design, planning, handling, machining, and the support systems' computer integrated manufacturing (CIM).

Figure 2.1 displays a classification of the economic justification methods for advanced manufacturing systems cited in the literature of Meredith and Suresh (1986). The economic justification techniques in this figure are classified as follows:

1. Traditional Economic Justification Methods.

2. Analytical Methods.
3. Strategic Methods.
4. Integration Methods.

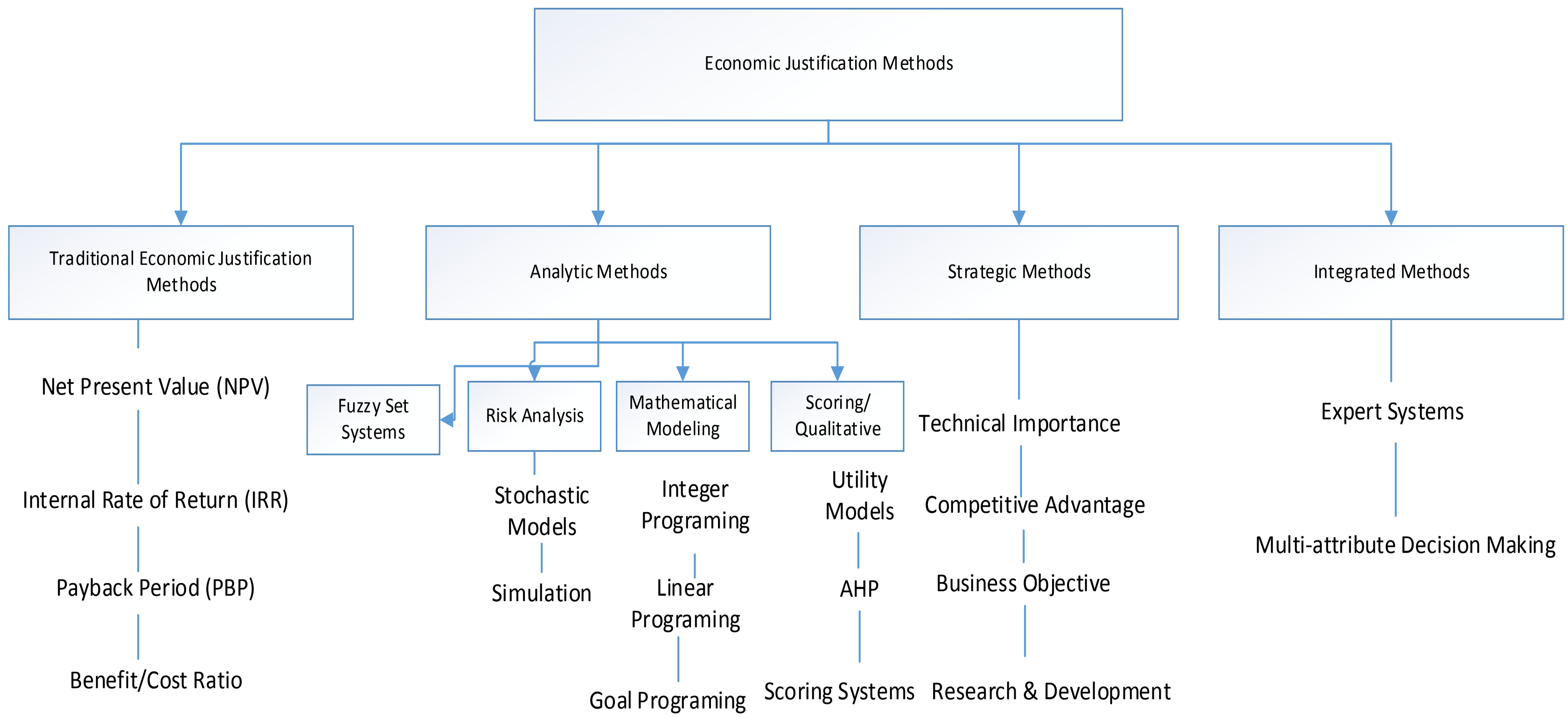

Figure 2.1 Classification of Economic Justification Methods (Adapted from Meredith and Suresh, 1986)

2.1 Traditional Economic Justification Methods

There are several approaches that firms traditionally use for the economic justification of the (their) projects. These include net present value (NPV), internal rate of return (IRR), payback, and benefit/cost ratio (B/C). In this section, we present a short description of each of these methods with numerical examples.

a) Net Present Value (NPV)

The NPV technique, also called discounted cash flow, presents a popular capital budgeting technique taking into account the time value of money. The NPV of an investment is used as a key to decide with or against a proposed investment in projects such as the purchase of a new piece of equipment, or the expansion of an existing plant. The NPV is evaluated using the following equation:

$$NPV = \sum_{j=0}^{n} \frac{x_j}{(1+i)^j}, \quad (2.1)$$

where

NPV = Net Present Value (already defined)

x_j = annual net cash flow in year j

i = the minimum acceptable rate of return

j = the year in which the cash flow x_j occurs

n = number of years of cash flow

Decision Criteria for the NPV

The project is said to be economically justifiable if the net present value generated is greater or equal to zero (NPV $\geq$ 0). Otherwise, the project will be considered economically undesirable.

Advantages and disadvantages of the NPV

The NPV method comes with the main benefit of taking into account the effect of time on the value of money. However, this technique requires more computations than other techniques that do not take the present value of cash flows into consideration. Moreover, the NPV assumes that the cash generated by investment projects is immediately reinvested. However, this reivestment is not always possible because of economic condition changes.

Example:

50 hectares are owned by an engineering company, and the company was decided the mineral rights to the mining company. The project will be ongoing from 6 to 16 years. A proposal is made by the engineering company to the mining company for a yearly payment of $20,000 for the next 20 years beginning from year 1, a payment of $10,000 after six years, and $15,000 after sixteen years. How much should the company pay in the case of immediate lease pay off by the mining company assuming that the investment has a yearly interest rate of 16%?

Figure 2.2 shows the cash flow from the owner's perspective, and we need to find the NPV of the 20 years' uniform series.

NPV = 20,000(P/A, 16%, 20) + 10,000 (P/F, 16%, 6) + 15,000 (P/F, 16%, 16) = $124,075.

The uniform series of $20,000 starts at the end of year 1, so the P/A factor determines the net present value at year 0.

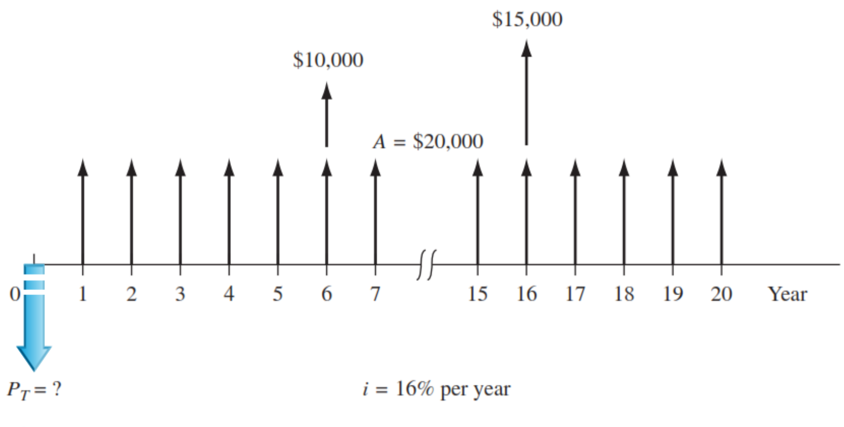

Figure 2.2 Diagram of a Uniform Series and Single Amounts

b) Internal Rate of Return (IRR)

The IRR method, also known as the time-adjusted rate of return, [Leland, and Tarquin, 2008] is a technique that, like NPV, takes the time value of money into consideration . In this technique, the analysis of the investment project is performed by making a comparison between the IRR and the company's minimum required rate of return.

The IRR is the rate that the investment promises to generate in returns during the project's useful life. The minimum required rate of return value is set by the management and is usually equal to the company's capital cost.

In this technique, the project is said to be acceptable only if the IRR promised by the investment project is greater or equal to the minimum acceptable required rate of return (MARR). If this condition is not verified, the project is not accepted.

Mathematically, the IRR is determined by the following expression:

$$0 = \sum_{j=0}^{n} \frac{x_j}{(1+i)^j}, \tag{2.2}$$

where

x_j = annual net cash flow in year j

i = the internal rate of return

j = the year in which the cash flow x_j occurs

n = number of years of cash flow

Decision Criteria for the IRR

The economic desirability of a capital investment is determined by making a comparison of the IRR and the MARR. If the MARR for a project is smaller or equal to IRR, the project is considered economically desirable. Otherwise, the project is determined economically undesirable.

Advantages and disadvantages of IRR:

Advantages:

- IRR perfectly uses the theory of the time value of money.
- It is a good method in order to assign equal value to different cash flows.
- It allows checking the income of any project without the need to calculate the cost of capital.

Disadvantages:

- In some scenarios, IRR is not good enough for comparing two projects.

- When the present values of cash inflow and outflow, the IRR becomes complex to understand and calculate.

Example

Calculate the internal rate of return for cash flows of \$10,000 invested at t = 0, \$8000 received in the second year, and \$9000 received in the fifth year. The NPV equation to determine i^* is:

0 = -10,000 + 8000(P/F, I, 2) + 9000(P/F, I, 5)

i^* = 16.815%

c) Payback Period (PBP)

The payback period is also called the payout period. This period is defined as the time required in order to recover the initially invested money from the investment's cash outcome. This PBP method can be seen as one of the simplest techniques used to appraise the investment. The payback period ***n*** is an estimated time for revenues, savings, and any other monetary benefits needed to recover the initial investment with an additional stated rate of return *i*. (Newnan, 2009).

The payback period can be expressed mathematically by

$$0 = \sum_{j=0}^{n} x_j \ , \tag{2.3}$$

where

x_j = Annual net cash flow in year j

n = Payback period

Advantages and Disadvantages of (PBP)

Advantages of the payback period are:

- The PBP can be simply calculated.
- The PBP can also serve as an indicator of the risk that might be involved in the project. Indeed, the payback period is a measure of the certainty of cash inflows especially when inflows that come later in the life of a project are expected to be more uncertain.
- The PBP assigns a useful ranking of projects with early money return when the firm is facing liquidity problems.

Disadvantages:

- The PBP method does not consider the effect of time on the value of money and can cause wrong decisions to be made. The discounted PBP method is a variation of the PBP which attempts to remove this drawback.
- This method neglects the cash flows occuring after the payback period.

Example:

A global engineering construction design contract having a value of $18 million has been recently approved by the board of directors of Halliburton International. This project is set to produce annual cash flows of around $3 million. In case either party involved in the contact decides to withdraw during the first ten years of the agreement, then $3 million is paid to Halliburton during the ten years of the contract period.

(*a*) If *i* = 15%, compute the payback period.

(*b*) Determine the no-return payback period and compare it with the answer for *i* = 15%.

Solution:

a) The net cash flow each year is \$3 million. The single \$3 million payment could be received at any time within the 10-year contract period.

   In \$1,000,000 unites,

   0 = -18 + 3(P/A, 15%, n) + 3(P/F, 15%, n)

   The 15% payback period is found by trial and error and is given by *n* = 15.3 years. Thus, during the period of 10 years, the contract will not deliver the required return.

b) If Halliburton requires absolutely no return on its \$18 million investment, the results in *n* = 5 years are as follows (in \$ million).

   0 = -18+5(3) + 3

d) Benefit/cost (B/C) ratio

The benefit/cost ratio has been widely used in order to assess the desirability of public projects. Although several variations of the B/C ratio exist, there is a common basic method. In this approach, all cost and benefit estimates need to be expressed in terms of a common monetary unit (Present Worth (PW), Annual Worth (AW), or Future Worth (FW) coming at the discount rate [Blank, Leland, and Anthony Tarquin, 2008].

The benefit/cost ratio can be mathematically expressed by

$$B/C = \frac{PW\ of\ Benefits}{PW\ of\ Costs} = \frac{AW\ of\ Benefits}{AW\ of\ Costs} = \frac{FW\ of\ Benefits}{FW\ of\ Costs}\,. \qquad (2.4)$$

The decision guideline is simple and is as follows:

If B/C ≥1.0, the project is accepted as economically justified based on the used estimates and discount rate.

If B/C < 1.0, the project is not economically acceptable.

Example

$15 million in grants is given to develop new engineering methods. The grants will extend over a 10-year period and will create an estimated saving of $1.5 million per year with a discount rate of 6% per year. An estimated $200,000 per year will be removed from other funding programs.

$500,000 per year operating costs will be incurred from the regular M&O budget. Use the B/C method to determine if the granting program is economically justified.

Solution:

We will use annual worth (AW) as the common monetary equivalent.

AW of investment cost: $15,000,000(A/P, 6%, 10) = $2,038,050 per year

AW of M&Q cost $500,000 per year

AW of non-benefit $200,000 per year

$$B/C = \frac{1{,}500{,}000 - 200{,}000 - 500{,}000}{2{,}038{,}050 + 500{,}000} = \frac{1{,}300{,}000}{2{,}538{,}050} = 0.51.$$

The project is not justified, since the B/C ratio < 1.0.

2.2 Analytic Methods

2.2.1 Fuzzy Set Systems

According to (Zimmer, 1983), humans tend to be more successful and efficient with qualitative forecasting than with quantitative predictions. Further, in the case of providing numerical estimates, they become more interfered by bias decisions (Karwowski and Mital, 1986). Linguistic fuzzy models allow for translating expressions from verbal to numerical representation. In this context, these models make it easier to deal with quantitative expressions and also resolve the dilemma of the quantitative forecasts required by scoring models. For instance, there are several references that study how to fuzzy cash flows involved in the analysis of traditional engineering economic (Behrens and Choobineh, 1989), (Buckley, 1987), and (Ward, 1985).

As an example, we assign two fuzzy variables in the following approach:

1. X = "IMPORTANCE", and 2. Y = "CAPABILITY".

These two variables can help the analyst determine the importance of goals set by the technologies used. In addition, it allows evaluating the capability of each technology to meet the company’s goals. For instance, if we say that the ability of a given technology in reducing the lead-time, which represents a very important goal of the company, is above average, then we can use the fuzzy linguistic variable CAPABILITY for the term “above average” and the fuzzy variable IMPORTANCE for the term “very important”.

2.2.2 Risk Analysis

2.2.2.1 Stochastic Methods

One efficient way to quantify the relationship between different random events is through the use of stochastic processes. Indeed, these processes are very important in several natural and engineering science areas. They are extremely useful in analyzing the variability inherent in biological and medical processes, dealing with uncertainties that affect managerial decisions, and for several other applications.

The word "stochastic" means "random" or "chance" and its antonym is "sure," "deterministic," or "certain". Indeed, in the case of a stochastic model, the predicted set is selected from the possible outcomes which different likelihoods or probabilities. On the other hand, in a deterministic model, a single outcome is selected from a given set of circumstances.

2.2.2.2 Decision Trees

Hazen (1992, 1993) introduced stochastic trees as a type of Markov chain model for medical decisions. These models provide convenient means to account for medical treatment options and were included in the medical literature by Beck and Pauker (1983). The main advantage of these trees is the ability to account for risks occuring not only in the present but also in the near and distant future. A stochastic tree can be equivalently characterized in many ways:

1. Continuous-time Markov chain with additional chance and decision nodes.
2. Decision tree with additional stochastic transitions.
3. Multi-state DEALE model (Beck et, al., 1982).
4. Continuous-time version of a Markov cycle tree (Hollenberg 1984).

While a universal set of symbols means that a decision tree does not exist, the most commonly used notations in accountancy education are squares (□) for 'decisions' and circles (○) for 'outcomes'. A decision tree diagrammatically represents a problem that includes all possible actions that can be taken and different outcomes that can obtained for each possible course of action. This model is particularly convenient when a series of decisions and/or outcomes are included in different stages during the decision-making process.

Figure 2.3 shows the basic structure of a decision tree.

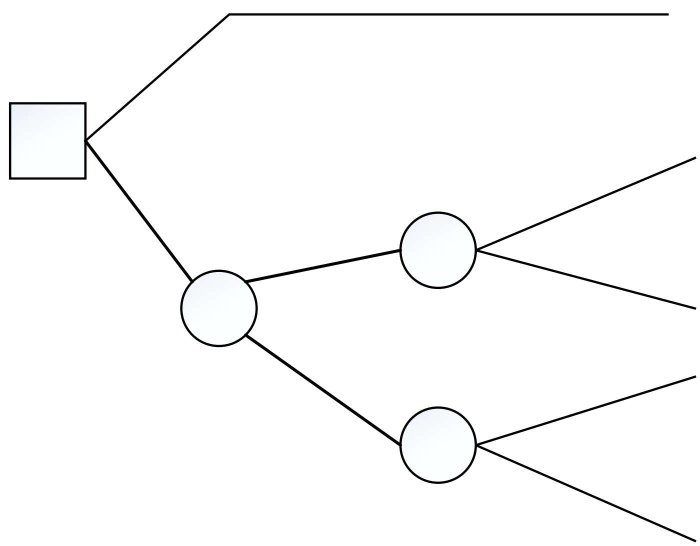

Figure 2.3 The Basic structure of a Decision Tree

Once the basic tree has been presented, different probabilities and expected values need to be included.

Example:

Assume the project has the initial investment and cash flow distribution as in figure 2.4. We assume the cash flows are the same for each year, and the life of the project is two years (Stevens, 1994).

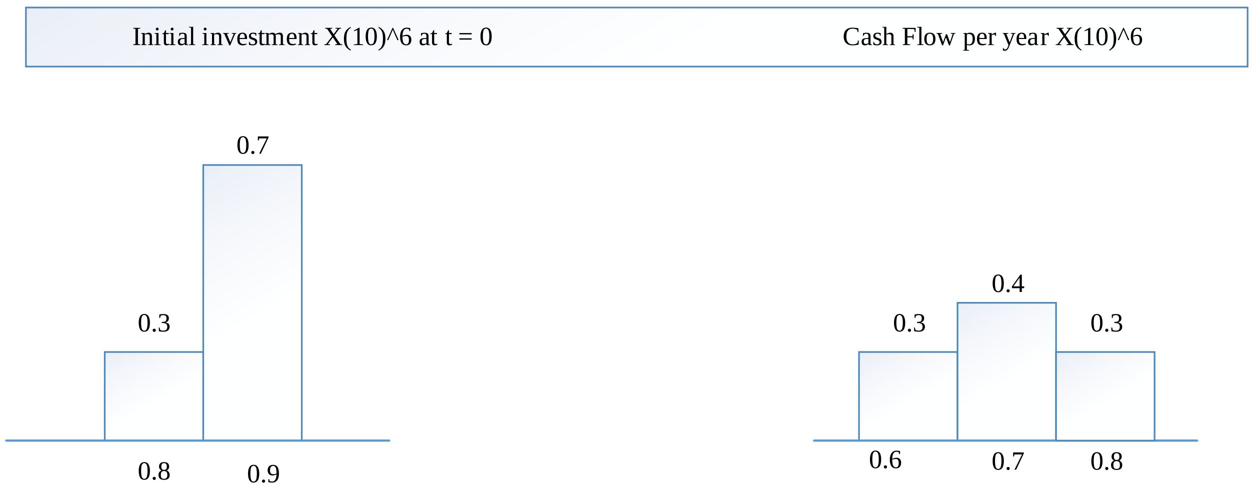

Figure 2.4 Cash Flow Distribution

In figure 2.5, we present a detailed decision tree where each branch shows the outcomes, net present value, and the probability. We assume the minimum acceptable rate of return is 15%, and we can calculate the NPV as:

NPV = 600,000(P/F 15, 2) + 600,000(P/F 15, 1) – 900000 = 75,480

The probability of this outcome is (0.7) (0.3) (0.3) = 0.063.

Since the project is acceptable with a positive value, we need to consider the large value of (500,640).

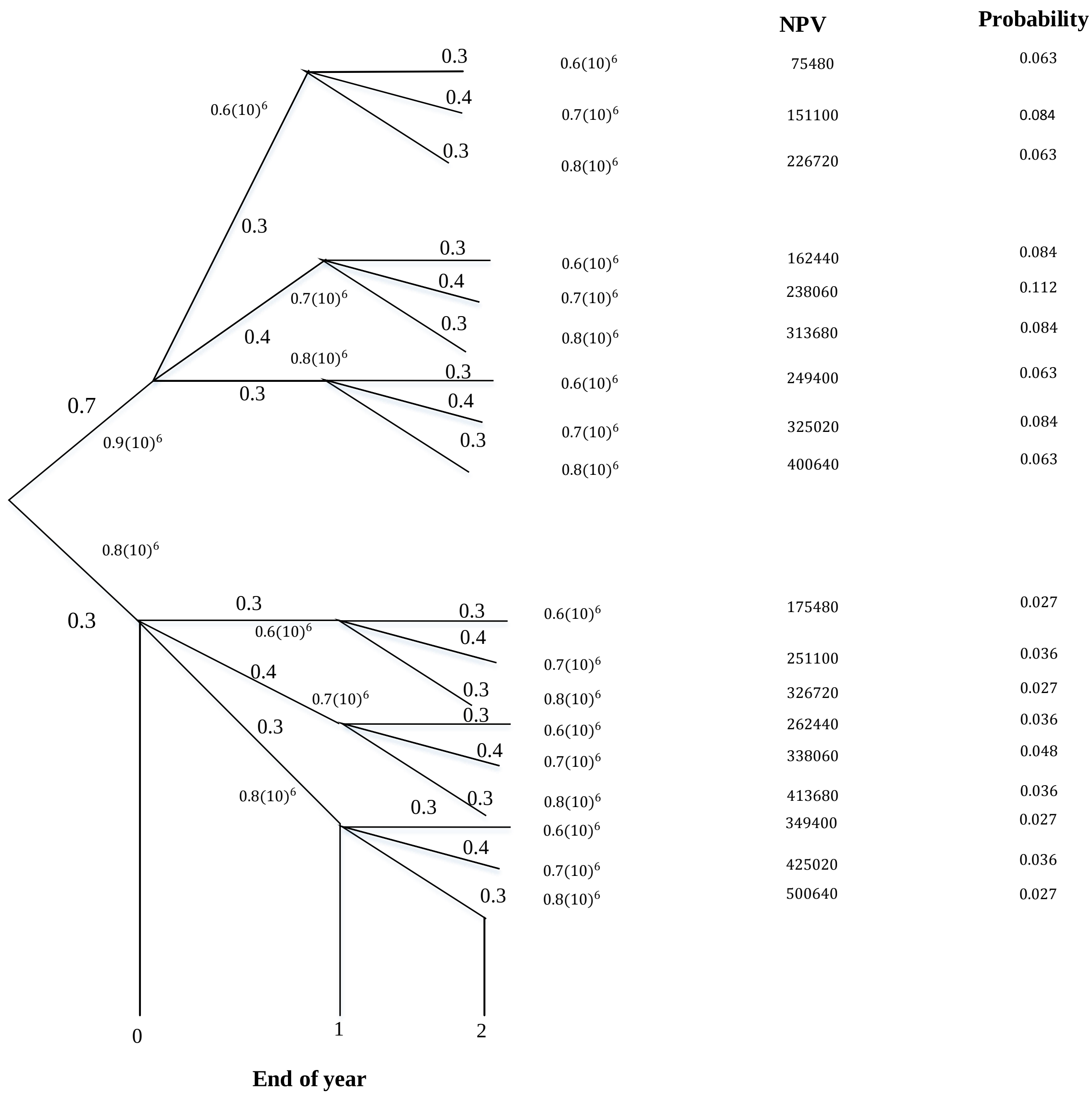

Figure 2.5 Decision Tree

2.2.2.3 Monte Carlo Simulation (MCS)

First introduced during World War II, "Monte Carlo" was used as a code name for the secret work at Los Alamos where the allied forces tried to discover the atomic bomb. Nowadays, this method is extensively used and it is very powerful when dealing with the analysis of complex systems. Indeed, MCS applications are very wide and are not only applicable to stocastic processes but also to deterministic problems. The use of MCS instead of traditional simulation methods is determined by three major points:

1. In MCS, time is not as an important variable as it is for stochastic simulations.

2. In the MCS method we deal with independent observations. In the simulation, however, the experiment is done over time where the observations are serially correlated and hence dependent.

3. In this technique, unlike simulation, simplified representations of stochastic input variables can be employed in order to express the responses in straightforward manner.

The MCS technique can also be applied in order to obtain the Net Present Value and help the decision maker to choose from the alternatives.

Example:

Assume we have a project where the variables have been estimated and shown in figure 2.6.

The following information is applicable for this project:

1. Debt ratio = 22%.

2. Debt capital to recover the installments over the life of the project and the cost of debt capital is 12%.
3. The tax depreciation is based on a MACRA model of 7 years (See Table 2.1).
4. The salvage values have been obtained by random numbers in the simulation.
5. The tax rate is to be assumed as a constant value of 0.35% for each year.

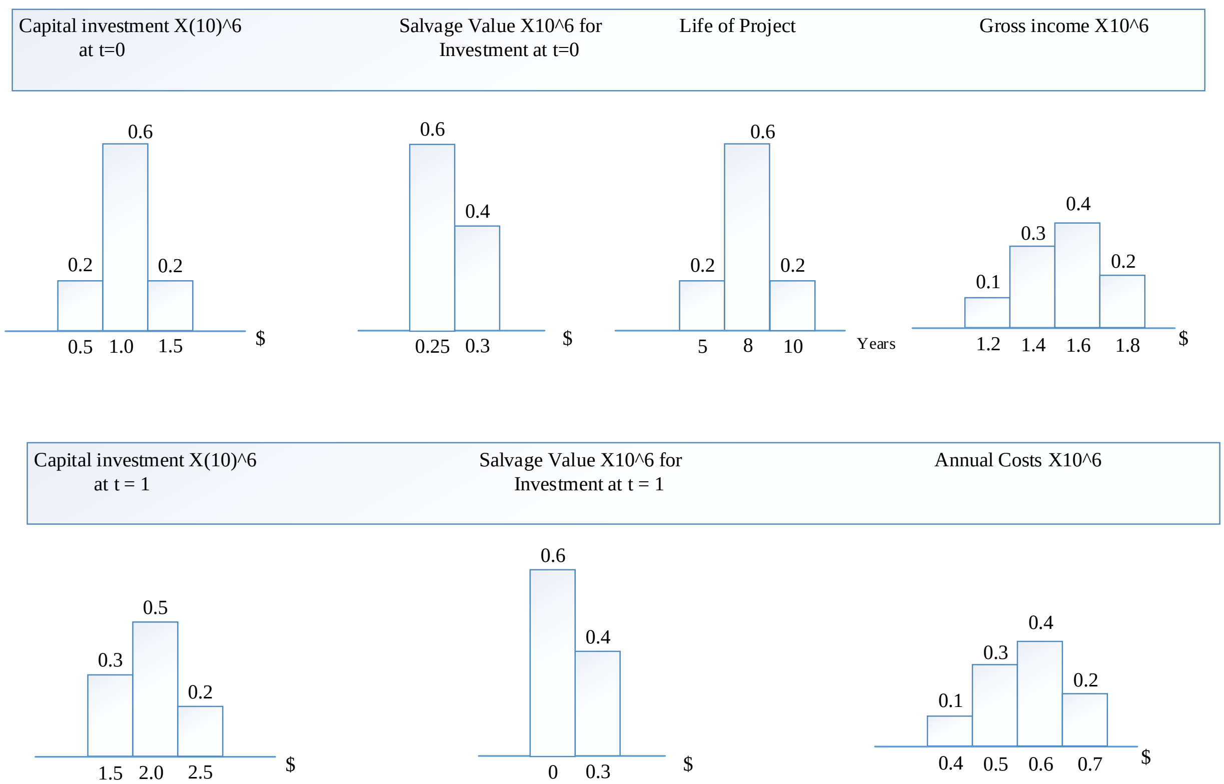

Figure 2.6 Distribution of Cash Flow Variables

The first step is to generate three random numbers for the life of the project, capital investment, and the investment's salvage value at year 0. Assume those three random numbers are 83, 91, and 61. Referring to figure 2.6 the values for life, investment, and salvage are, 10 years, $1,500,000, and $300,000. Next, we generate two random numbers for capital investment and a salvage value for year 1. Assuming we generate 92 and 44 as two random numbers, referring to Figure 2.6 the investment is $2,500,000 and the salvage value is zero.

The tax depreciation is calculated using the MACRS percentage and the values shown in table 2.1. The amount of borrowed money is $1,500,000 (0.22) = $ 330,000, which is occur in year 0, and $ 2,500,000 (0.22) = $550,000 which is occur in year 1. We can calculate the debt recovery in years 0 through 10 as

$$\frac{330{,}000}{10} = \$\ 33{,}000$$

and in years 2 through 10 as

$$\frac{550{,}000}{9} = \$\ 61{,}111.$$

The interest is computed on the basis of 12% on the unpaid balance.

Ten random numbers are generated for gross income (GI) and ten random numbers are also generated for the annual costs as we can see in table 2.2. Then, the net cash flows are calculated for each year. We used the following formula:

$$CFAT = (GI-C-I) - (GI-C-I-D) * TR - DR + S \ , \qquad (2.5)$$

where:

CFAT = Cash Flow after Tax

GI = Gross Income

C = Cost

I = Interest

D = Depreciation

TR = Tax Rate

DR = Debt Recovery

S = Salvage value

For example the cash flows for years 0, 1, and 10 are:

X_0 = -1,500,000 +0.22(1,500,000) = -$1,170,000.

X_1 = (1,400,000 – 400,000 – 39,600) – (1,400,000 – 400,000 – 39,600 – 214350)*0.35 – 2,500,000 + 500,000 - 33,000 = $ -1,283,717

X_{10} = (1,400,000 – 500,000 – 11,296) – (1,400,000 – 500,000 – 11,296)*0.35 - 94,111 + 300,000 = $ 783,547.

It is now possible to calculate the net present value since we have all cash flows in table 2.2, and by using the return on equity of 25% the net present value is $ -371,968.

Now we can repeat the whole procedure with different random numbers or including random variables to achieve more net present values. The Simulation Monte Carlo procedure should be used along with various computer programs.

Table 2-1 MACRS Depreciation Rates (Stevens, 1994).

Year	5 Years	7 Years	10 Years	15 Years
1	20.00	14.29	10.00	5.00
2	32.00	24.49	18.00	9.50
3	19.20	17.49	14.40	8.55
4	11.52	12.49	11.52	7.70
5	11.52	8.93	9.22	6.93
6	5.76	8.92	7.37	6.23
7	-	8.93	6.55	5.90
8	-	4.46	6.55	5.90
9	-	-	6.56	5.91
10	-	-	6.55	5.90
11	-	-	3.28	5.91
12	-	-	-	5.90
13	-	-	-	5.91
14	-	-	-	5.90
15	-	-	-	5.91
16	-	-	-	2.95

Please note that the MACRS Depreciation period (MP) is:

1. $M \leq 4$ then MP = 3
2. $4 < M < 10$ then MP = 5
3. $10 \leq M < 16$ then MP = 7
4. $16 \leq M < 20$ then MP = 10.

Table 2-2 Simulation value for Monte Carol Example

End of Year	Capital Investment and Salvage	Tax Depreciation for K_0	Tax Depreciation for K_1	Debt Recovery for K_0	Debt Recovery for K_1	Interest for K_0	Interest for K_1	RN GI	Gross Income GI	RN C	Costs C	Cash Flow Xe
0	-$1,500,000	-	-	-	-	-	-	-	-	-	-	-$1,170,000
1	-$2,500,000	214350	-	$33,000		39600	-	33	$1,400,000	03	$400,000	-1,283717
2		367350	357250	$33,000	$61,111	35640	66000	55	$1,600,000	87	$700,000	678433
3		262350	612250	$33,000	$61,111	31680	58667	29	$1,400,000	24	$500,000	738273
4		187350	437250	$33,000	$61,111	27720	51334	63	$1,600,000	44	$600,000	723114
5		133950	312250	$33,000	$61,111	23760	44001	70	$1,600,000	20	$500,000	733014
6		133800	223250	$33,000	$61,111	19800	36668	18	$1,400,000	11	$500,000	579152
7		133950	223000	$33,000	$61,111	15840	29335	06	$1,200,000	77	$600,000	391458
8		66900	223250	$33,000	$61,111	11880	22002	54	$1,600,000	66	$600,000	635418
9		-	111500	$33,000	$61,111	7920	14669	12	$1,400,000	85	$700,000	385231
10	S = 300,000	-	-	$33,000	$61,111	3960	7336	30	$1,400,000	21	$500,000	783547
		-	-									

RN: Random Number

V: Salvage Value

2.2.3 Mathematical Modeling

2.2.3.1 Linear Programming (LP)

Linear programming represents a foundation for many analytical decision-making problems. A conventional linear program contains:

1- Variables that are also called decisions and can take numerical values,

2- Constraints which are used to limit the feasible region of different values and must be linear functions of the decision variables

3- An objective function that must be linear in the variables (Bosch, 2005) and defines which particular assignment of feasible values for the variables is optimal, where optimal means an assignment that maximizes or minimizes (depending on the objective's type) the objective function.

LP models are used in a wide range of applications including product mix, portfolio selection, and distribution. These models are mainly needed to find optimal solutions for the optimization problems studied. The simplex algorithm represents a common technique to obtain LP problem solutions. This type of algorithm progressively looks for solutions which improve from one stage to the next. The process continues until no further improvement is observed and the optimal solution is then reached (Taha, 2007).

Example:

Reddy Mikks produces both interior and exterior paints from two raw materials Ml and M2. The following table provides the basic data for the problem:

Table 2-3 Interior and Exterior Paint Raw Material

	Tons of raw material per ton of		
	Exterior Paint	Interior Paint	Maximum Daily Availability (tons)
Raw Material, *M*1	6	4	24
Raw Material, *M*2	1	2	6
Profit per ton ($1000)	5	4	

According to a market survey, the daily demand for interior paint cannot exceed that for exterior paint by more than 1 ton. In addition, the daily demand for interior paint is limited to 2 tons. In this case, Reddy Mikks wants to select the optimum product mix of interior and exterior paints that maximizes the total daily profit, and the LP model has three basic components:

1. Decision variables that we are looking for.
2. Objective (goal) that we need to optimize.
3. Constraints that need to be satisfied by the solution.

As a first essential step in the development of the model, we need to find a correct definition of decision variables. After this, the construction of the objective function and the constraints become more straightforward.

For the problem studied, we need to determine the daily amounts to be produced of exterior and interior paints. In this case, the variables of the model are defined as:

x_1 = daily produced tons of exterior paints

x_2 = daily produced tons of interior paints

In order to formulate the objective function, we can see that the company's goal is to *maximize* the total daily profit of both paints. Knowing that the benefits per ton of exterior and interior paints are five and four thousand dollars, respectively, we have

Total profit from exterior paint = $5x_1$ thousand dollars

Total profit from exterior paint = $4x_2$ thousand dollars

If *z* is the total daily profit (in thousands of dollars), the objective of the company is given as:

$$\text{Maximize } z = 5x_1 + 4x_2 \, , \tag{2.6}$$

In the second step, we need to construct the constraints restricting raw material usage and production demand.

Raw material *M* l used by the two paints = $6x_1 + 4x_2$ tons/day

Similarly,

Raw material *M* 2used by the two paints = $1x_1 + 2x_2$ tons/day

The associated restrictions for *M*l and *M*2 are given as

$$6x_1 + 4x_2 \le 24 \qquad \text{(Raw materials } M1\text{) and} \tag{2.7}$$

$$x_1 + 2x_2 \le 6 \qquad \text{(Raw materials } M2\text{).} \tag{2.8}$$

The first demand restriction stipulates that the excess of the daily production of interior over exterior paint, $x_2 - x_1$, should not exceed 1 ton, which translates to:

x_2 - $x_1 \leq 1$ (Market limit). (2.9)

The second demand restriction stipulates that the maximum daily demand of interior paint is limited to 2 tons, which translates to:

$x_2 \leq 2$ (Demand limit). (2.10)

An implicit restriction is that variables x_1 and x_2 cannot assume negative values. The **non-negativity restrictions**, $x_1 \geq 0$, $x_2 \geq 0$, account for this requirement. Thus, the complete Reddy Mikks model is:

Maximize $z = 5x_1 + 4x_2$, (2.11)

$6x_1 + 4x_2 \leq 24$, (2.12)

$x_1 + 2x_2 \leq 6$, (2.13)

$x_2 - x_1 \leq 1$, (2.14)

$x_2 \leq 2$, and (2.15)

$x_1 - x_2 \geq 0$. (2.16)

The goal of this problem is to find the best feasible solution or alternative that maximizes the total profit. Given the above problem, any values of x_1 and x_2 satisfying *all* five constraints is a **feasible solution** otherwise it is infeasible. For example, the solution, x_1 = 3 and x_2 = 1 ton per day, verifies all constraints and then it is feasible. To verify this result, substitute (x_1= 3, x_2 = 1) on the left-hand side of each constraint. In constraint (1) we have $6x_1 + 4x_2$= 6*3 + 4*1 = 22, which is less than the right-hand side of the constraint (= 24). Constraints 2 through 5 yield similar conclusions and are verified. On the other hand, the solution x_1 = 4 and x_2 = 1 is infeasible because it does not satisfy constraint (1), 6*4 + 4*1 = 28, which is larger than the right-hand side (= 24).

2.2.3.2 Integer Programming (IP)

Integer Programming (IP) or Discrete Optimization represents a technique of modeling a very wide range of problems involving indivisibilities (i.e., yes/no investment decisions) and non-convexities (i.e., economies of scale and fixed cost allocation) where all variables need to be integers.

In order to develop and solve IP models in a successful manner, we should consider the following aspects:

1. Creativity in formulations
2. Looking for IP formulations with a strong relaxation
3. Avoiding symmetry
4. Considering multi-constraints formulations
5. Considering multi-variables formulations

The integer variables are mostly limited to take values 0 and 1 referring to yes/no decisions. In these scenarios, the models can be seen as a set of linear programs with logical statements. When all variables need to take integer values, the IP is referred to as a pure integer-programming problem.

Project Selection Example

The following table gives the expected returns of five different projects and the associated yearly expenditures for a three year planning horizon.

Table 2-4 Project Expenditures per Year with Returns

	Expenditures (Million $) / yr.			
Project	1	2	3	Returns (Million $)
1	5	1	8	20
2	4	7	10	40
3	3	9	2	20
4	7	4	1	15
5	8	6	10	30
Available funds (million $)	25	25	25	

Which project should be selected over the considered 3-year horizon?

In this case, the problem reduces to a "yes-no" decision for each project. Let us define the binary variable x_j as:

$$x_j = \begin{cases} 1, & if\ project\ j\ is\ selected \\ 0, & if\ project\ j\ is\ not\ selected \end{cases}$$

The ILP model is:

$$\text{Maximize } z = 20x_1 + 40x_2 + 20x_3 + 15x_4 + 30x_5\,, \quad (2.17)$$

$$5x_1 + 4x_2 + 3x_3 + 7x_4 + 8x_5 \leq 25\,, \quad (2.18)$$

$$x_1 + 7x_2 + 9x_3 + 4x_4 + 6x_5 \leq 25\,, \quad (2.19)$$

$$8x_1 + 10x_2 + 2x_3 + x_4 + 10x_5 \leq 25, \text{ and} \quad (2.20)$$

$$x_1, x_2, x_3, x_4, x_5 = (0, 1). \quad (2.21)$$

Using AMPL, Solver, or TORA, the optimum integer solution is given by

$x_1 = x_2 = x_3 = x_4 = 1,\ x_5 = 0,$ with z = 95 (million $). The solution shows that all but project 5 must be selected.

2.2.3.3 Goal Programming

Goal programming (GP) represents an efficient and powerful methodology for modeling, solving, and analysing problems with multiple and conflicting goals and objectives. Indeed, this approach can be seen as the “workhorse” of multiple objective optimization thanks to its extensive list of successful practical applications.

Example:

All single-objective problems and most multiple-objective ones can be classified into a model format designated as the multiplex model. These problems can be solved via the most appropriate version of a multiplex or sequential GP algorithm. As an example, consider a conventional linear programming problem has the following traditional form:

$$Maximize\ z = 10x_1 + 4x_2\ , \quad (2.22)$$

$$\text{Subject to:} \qquad 10x_1 + 4x_2 \leq 100\ , \quad (2.23)$$

$$x_2 \geq 4\ \text{, and} \quad (2.24)$$

$$x \geq 0. \quad (2.25)$$

While the above simple single-objective model can be solved by inspection, we transform it into the multiplex form for the sake of illustration. To this end, we modify each constraint by adding and subtracting a negative and a positive deviation variable, respectively. In addition, we multiply the original objective function by a negative one in order to transform the maximizing objective function into minimizing. The new resulting model can be written in multiplex form:

Lexicographically minimize $\mathbf{U} = \{(\rho_1 + \eta_2), (-10x_1 - 4x_2)\}$, (2.21)

Satisfy $x_1 + x_2 + \eta_2 - \boldsymbol{\rho_1} = 100$, (2.22)

$x_2 + \boldsymbol{\eta_2} - \rho_1 = 4$, and (2.23)

$\boldsymbol{x}, \boldsymbol{\eta}, \boldsymbol{\rho} \geq \mathbf{0}$. (2.24)

The additional negative and positive deviation variables to the constraints give an indication that a solution to the problem may result in a negative deviation ($\eta_1 > 0$), or a positive deviation ($\rho_i > 0$), or no deviation ($\rho_i + \eta_i = 0$) for a given constraint i. Thus, we can underachieve, overachieve, or precisely satisfy a given constraint. In the new multiplex formulation, we present the deviation variables that need to be minimized in bold typeface.

2.2.4 Scoring — Qualitative Methods

2.2.4.1 Utility Model

Utility models are different from one country to another and therefore there a global agreement of its term does not exist. Indeed, looking at different national laws, this model is referred to as an “innovation patent”, a “utility innovation”, a “utility certificate”, and a “short term patent” in Australia, Malaysia, France, and Belgium, respectively. Utility models are sometimes defined as intangible subject matter which includes technical concepts or inventions. In some cases, a utility model is granted a protection equivalent to that of a patent protection. In this context, the utility model terminology falls between patent law protection and sui generis design law. In summary, it is still a non-clearly defined concept when placed in an intellectual property area (Stevens, 1994).

A utility function for a particular decision-maker can be constructed by proposing several gambles (also called lotteries) to the decision-maker. However, before this is done, two set points must be established. These two points are set arbitrarily, but should be chosen so that the range of monetary values usually encountered by the decision-maker is covered. These set points can be established arbitrarily because the utility is measured on a relative scale. This scenario is analogous to having different freezing and boiling points on thermometers (Fahrenheit and Centigrade). As an example of the construction of a utility function, the following two set points are established for a decision-maker:

0 utiles = $0

100 utiles =$ 300,000

Utiles are fictitious units that reflect the relative worth of monetary values. These two set points are shown in figure 2.8 (Stevens, 1994).

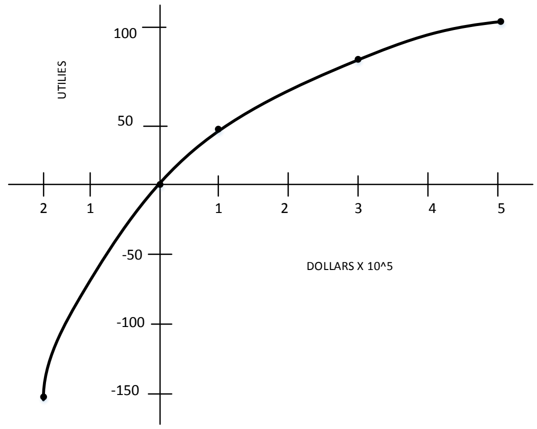

Figure 2.7 Utility Function

The next step is to propose gambling with probability.

Gamble X	Gamble Y
\$100,000 P1=1	\$500,000 P2=?

Example:

Table 2-5 Two Data of Gambling Decision

Gamble X		Gamble Y	
\$400,000	P1= 0.7	\$400,000	P2= 0.6
\$200,000	P1= 0.3	\$200,000	P2= 0.4

The expected utility for each gamble is calculated in the following manner.

By using figure 2.8, we find:

U (\$400,000) = 90 utilities, U (\$200,000) = 70 utilities

E [U(X)] = 0.7U (\$400,000) + 0.3U (200,000) = 0.7*90 + 0.3*70 = 84 utilities

$$E [U(Y)] = 0.6U (\$400,000) + 0.4U (200,000) = 0.6*90 + 0.4*70 = 82 \text{ utilities}$$

which indicates that Gamble X is selected and it is the decision maker's choice since its expected utility is the largest.

2.2.4.2 The Analytic Hierarchy Process (AHP)

The AHP was proposed by Thomas (Saaty, 1980) as an efficient process to help with complex decision-making problems. This process allows the setting of priorities and making the optimal decision by first dividing complex decisions into a series of pairwise comparisons. At the next step, the results are synthetized and the AHP captures both subjective and objective aspects of the decision. Furthermore, the AHP reduces the bias in the decision by incorporating a useful tool in order to evaluate the degree of consistency of the decision maker's evaluations. The AHP takes into consideration a set of evaluation criteria and a set of alternative options containing the optimum decision. In general, it is not evident that the best option is also optimum for every criterion since some of these criteria could be contrasting. On the other hand, the optimal choice is the one that is achieving a suitable trade-off among different criteria. In this context, AHP provides the decision-maker with a different weight for each evaluation criterion based on pairwise comparisons between different criteria. Thus, a more important criterion is assigned a higher weight. The performance of the option of the considered criterion is said to be better if it has a higher score. Finally, the AHP criteria's weights are combined with the options' scores which allows the assignment of a global score for each of these options, and thus allows ranking these options. The global score for a given option is obtained by summing the scores obtained from all criteria multiplied by their correspondent weights.

Criteria

	C_1	C_2	C_3	……………	C_N
Alt.	W_1	W_2	W_3	……………	W_N
A_1	a_{11}	a_{12}	a_{13}	…………….	a_{1N}
A_2	a_{21}	a_{22}	a_{23}	…………….	a_{2N}
A_3	a_{31}	a_{32}	a_{33}	…………….	a_{3N}
.	.	.	.	. .	.
A_M	a_{M1}	a_{M2}	a_{M3}	……………..	a_{MN}

Figure 2.8 A Typical Decision Matrix

$$A^{*}_{AHP} = \max_{i} \sum_{j=1}^{N} q_{ij}\, w_j, \quad i = 1, 2, \dots, M$$

Example (Triantaphyllou et, al., 1998)

We have four criteria with the same unit and three alternatives. The relative weights of the four criteria are:

W1= 0.25, W2= 0.20, W3=0.45, and W4= 0.30.

We assume that the corresponding values are:

$$A = \begin{bmatrix} 30 & 25 & 20 & 30 \\ 15 & 35 & 20 & 35 \\ 35 & 15 & 35 & 15 \end{bmatrix}$$

As explained previously, pairwise comparisons are used by APH in order to compute the relative performance of each alternative in terms of each decision criterion. The following decision matrix gives the used relative data:

	Criteria			
	C_1	C_2	C_3	C_4
Alt.	0.25	0.20	0.45	0.30
A_1	30/80	25/75	20/75	30/80
A_2	15/80	35/75	20/75	35/80
A_3	35/80	15/75	35/75	15/80

Figure 2.9 Decision Matrix

Each column of the decision matrix is normalized and the total is one. We need to apply the formula:

A1 (AHP Score) = (30/80)*0.25 + (25/75)*0.20 + (20/75)*0.45 + (30/80)*0.30 = 0.393

Similarly,

A2 (AHP Score) = 0.392

A3 (AHP Score) = 0.41

Thus, A3 has the highest AHP score (0.41) and represents the best alternative in the maximization case.

2.2.4.3 Scoring Model

This multi-objective, deterministic, scoring method (Parsaei and Wilhelm, 1989) is built on a linear additive model proposed by (Klee, 1971). It is designed to evaluate a company's needs in automated manufacturing technologies for both the short and long term. This scoring method is implemented in two phases:

1- Phase I examines the desirability of the available long-term (strategic) automation proposals.
2- Phase II perform an evaluation of each short-term (tactical) alternative to implement the proposal selected in the first phase.

Fig. 2.11 represents both phases involved in this method. In order to implement this method, two ordinal scale weights need to be evaluated. Two examples of such weights are illustrated in tables 2.6 and 2.7.

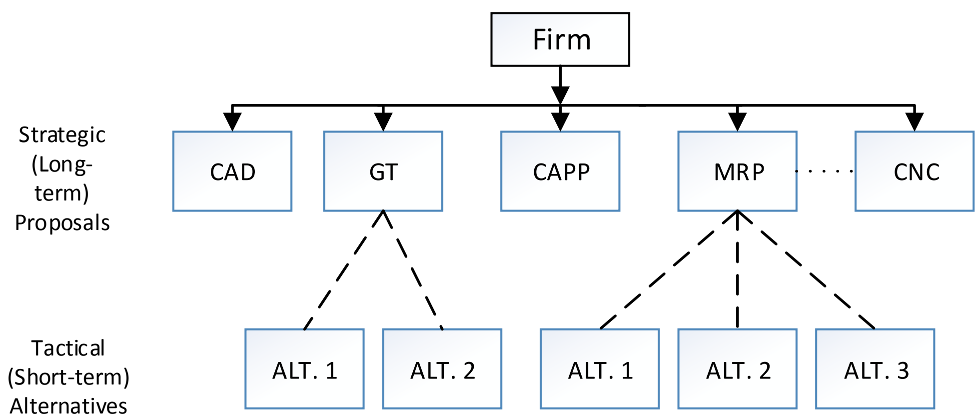

Figure 2.10 Graphical Representation of Strategic Proposals and Tactical Alternatives

The model used by both phases in this method is expressed by

$$\text{Max}Q_j = \sum_{i=1}^{n} W_i X_{ij}.$$

Q_j= Score assigned to the j^{th} decision alternative.

W_i= Weight assigned to the i^{th} attribute reflecting its relative importance in the decision process.

X_{ij}= Expected performance of the jth alternative with the i^{th} attribute.

Example: Assuming that all attributes are independent, an example illustrating this method is presented in tables 2.8 and 2.9.

Table 2-6 Ordinal Scale Weights Ranking the Importance of Strategic or Tactical Decisions (Parsaei and Whilem, 1989).

Very Important	1.00
Important	0.75
Necessary	0.50
Unimportant	0.25

Table 2-7 Ordinal Scale Weights Measuring the Performance of each Strategic or Tactical Decisions on each Attribute (Parsaei and Whilem, 1989).

Superior	1.00
Good	0.80
Above Average	0.60
Average	0.40
Below Average	0.20
Poor	0.00

Table 2-8 Selection Process for the Best Strategic Proposal (Phase I)

i	P_i^*	Attributes	Proposal 1		Proposal 2		Proposal 3	
			X_{i1}	$P_i\ X_{i1}$	X_{i2}	$P_i\ X_{i2}$	X_{i3}	$P_i\ X_{i3}$
1	0.125	Schedule Flexibility	0.60	0.075	0.80	0.10	0.60	0.075
2	0.187	Product Flexibility	0.60	0.112	0.60	0.112	1.00	0.187
3	0.250	Enhancement of Product Quality	0.80	0.200	0.80	0.200	1.00	0.250
4	0.250	Cost reduction and Savings	1.00	0.250	0.80	0.200	0.60	0.150
5	0.187	Safety Improvements	0.60	0.112	1.00	0.187	1.00	0.187
		N_j		0.749		0.799		0.849
		Normalized N_j		0.882		0.941		1.00**

Table 2-9 Selection Process for the Best Available Alternative (Phase II)

i	W_i^*	Attributes	Proposal 1		Proposal 2		Proposal 3	
			Y_{i1}	$W_i\ Y_{i1}$	Y_{i2}	$W_i\ Y_{i2}$	Y_{i3}	$W_i\ Y_{i3}$
1	0.250	Schedule Flexibility	0.80	0.200	1.00	0.250	0.40	0.100
2	0.100	Product Flexibility	0.80	0.080	0.80	0.080	1.00	0.100
3	0.200	Enhancement of Product Quality	0.60	0.120	0.60	0.120	0.80	0.160
4	0.250	Cost reduction and Savings	0.80	0.200	0.60	0.150	1.00	0.250
5	0.200	Safety Improvements	0.60	0.120	0.40	0.080	0.80	0.160
		V_j		0.720		0.680		0.770
		Normalized V_j		0.935		0.883		1.00**

* W_i is defined on a ratio scale.

** The best available alternative (Max $V_j = \sum_{i=1}^{n} W_i\, Y_{ij}$)

2.3 Strategic Methods

Strategic approaches present less technicality when compared to analytical and economic approaches. These approaches are directly related to the goals of the firm, which presents one of its main advantages. On the other hand, these approaches overlook the project’s economic and tactical impacts and fully focus on the strategic impact, which represents one of its main disadvantages. Economic justification calculations are frequently combined with strategic considerations, but analytic evaluations are rarely included because of their time and trouble. However, in order to understand the total impact of the project, the economic and analytic implications should also be evaluated if a strategic approach is used. To this end, four main approaches are commonly used (Meredith and Suresh, 1986), which are presented below.

2.3.1 Technical Importance

From a strategic viewpoint, the technical importance needs to be undertaken first to reach the desired goal of the project. In this context, justification under the umbrella of technical importance makes the project a prerequisite for an important follow-on task. While an eventual negligible or even disadvantageous return can happen, a more useful effort cannot be attempted without a prior implementation of this activity. Such activities are commonly grouped with the desired follow-on project in a “package” that should be agreed upon by the approval committee. For instance, firms planning to use cellular manufacturing usually find it necessary to start by conducting a part-family classification and coding analysis even without an apparent value of this analysis. In addition, before the implementation of material requirements planning (MRP) systems, the accuracy of inventory and bill of material records should commonly exceed 95%. Finally, it is crucial for the firm to start in the automation process to get onto the automation learning curve before the competition gets so far ahead and the firm can not catch up (Meredith and Suresh, 1986).

2.3.2 Business Objectives

The project’s justification clearly represents a strategic approach which especially helps the company reach its business goals. In order to verify the achievement of these goals, 'key indicators' of this achievement exist. These indicators reflect when the firm is losing control and when it needs to make more effort.

As an example, by using state-of-the-art and sophisticated computerized production systems, a company gives the impression that it is advanced, although this progress may not take place. Moreover, many firms aim to attain a uniform product quality, which can be done through automation. Furthermore, automation may allow significantly better customer service by drastically reducing lead times, which is perhaps a strategic business objective that is fighting foreign price competition (Meredith and Suresh, 1986).

2.3.3 Competitive Advantage

In this justification method, the firm can gain an advantage through the implementation of this project. This advantage represents a very important task for the company even though it does not take part in the company's strategic business objectives. The situation of a competitive advantage can result from a particular set of conditions or from the growth of an existing advantage held by the company.

This kind of situation usually occurs in different areas of technology. For instance, a firm may gain a significant advantage over its competitors by holding a crucial patent. Similarly, several automation cases raise opportunities for competitive advantages. These advantages are due to several unexpected benefits including the reduction in space requirements, improvement of the processing quality, increase in performance capability, and the restriction of design times.

'The competitive necessity' represents a subcategory of this approach where the project becomes an obligation for the company to retain its completion advantage in a given market. This necessity targets all forms of automation and can be captured in the cliché 'automate, emigrate, or evaporate' (Meredith and Suresh, 1986).

2.3.4 Research and Development (R&D)

While dealing with a project as an R&D investment is subject to failure, it has enough strategic promise to justify the investment. Indeed, specific projects should exist that will eventually succeed and provide returns for the company in order to recover all the failures especially as nothing is gained without risk.

One example of an R&D approach is to establish a one group technology line in order to achieve a clear output regarding its efficiency, cost, problems, and benefits. This approach is often implemented by firms in order to promise automation ideas. However, because of the risk, it may minimize the resources provided to the pilot project, after that it fails and the second stage of full implementation is abandoned. In this context, firms need to be careful not to pre-ordain failure if the required resources at the pilot stage are withheld (Meredith and Suresh, 1986).

2.4 Integrated Methods

2.4.1 Expert Systems Approaches (ES)

Expert systems are computer programs that attempt to provide expert-level problem-solving abilities in some application areas (Nau, 1983). A wide variety of methods has been used to process the knowledge of these programs (Reggia, 1982). The capability of an expert to justify the conclusions of a project is referred to as answer justification. In addition, answer justification abilities help analyze errors made by a beginning expert system and teach problem-solving methods with completed expert systems.

Expert systems or knowledge-based systems are a product of the artificial intelligence research theory, which have recently demonstrated value in solving practical problems

(Hong, 1984). This relatively new software technology has already been applied to a large variety of useful applications. These include fields as diverse as a medical diagnosis (Shortliffe, 1976), mineral exploration (Duda, et al., 1978), and chemical analysis (Buchanan and Feigenbaum, 1978).

Figure 2.12 highlights the fact that the database, the control structure (rule interpreter), and knowledge base are separate.

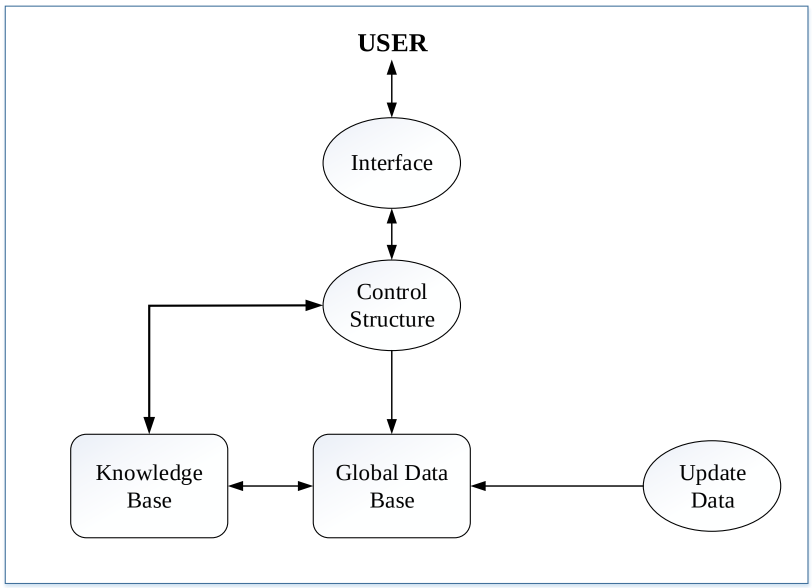

Figure 2.11 A Model of a Knowledge-Based System (William and LeClair, 1992).

2.4.2 Multi-Criteria Decision Making (MCDM)

MCDM is a method that supports the multi-objectives decision-making processes (Belton 2002, Keeney 1993, and Roy 2005). This technique has been widely employed in order to support a large number of problems requiring complex decisions (Figueira, 2005), and (Keefer, 2004). Dealing with real-systems MCDM models is not an easy task. The challenge behind this is caused by the models' intrinsic complexity where multiple objectives have to be formulated, defined, and measured by attributes. In addition, it is sometimes challenging to deal with the definition of a set of evaluated alternatives especially as it is a difficult task for decision-makers to think creatively about the problem and to find innovative alternatives. On a broader level, the role of problem structuring as a first step to the structuring of an MCDM model is mostly neglected in the literature. The problem-structuring phase represents a crucial phase of the intervention requiring proper management in order to have a joint effect on the company for both the decision analysts and the decision analysis. The literature dealing with MCDM models' structuring is still very limited and most of it focuses on problem structuring and problem structuring methods without a direct connection to MCDM.

MCDM refers to a decision-making process in which many conflicting criteria are involved. There are multiple MCDM examples including the personal context where a purchased house is characterized by several factors including price, size, style, and comfort. In a business context, MCDM problems are more complicated and are usually on a large scale.

While there have always been a wide range of MCDM problems, this discipline is new and was developed 30 years ago during the period of computer technology advancement. Indeed, this advancement solved many complex MCDM problems. Moreover, with the huge deployment of computer systems, a large amount of information has been generated and helped resolve many MCDM issues and contributed to supporting the decision-making process. Several techniques exist which are used to solve MCDM problems (Hwang and Yoon, 1981). While a couple of these techniques are ad-hoc and theoretically/empirically unjustified (Stewart, 1992), new techniques were developed in the early 1990s in order to provide consistent and rational results that allow dealing with uncertainties, and to provide transparency to the analysis processes (Stewart, 1992 and Dyer et al., 1992).

In the text that follows, we first summarize the main characteristics of MCDM problems then we provide a list of MCDM's analysis techniques.

2.4.2.1 Classification of MCDM Methods

In the literature, several MCDM methods exist where each method comes with its own characteristics. These methods can be classified based on different protocols. For instance, methods can be classified according to the type of used data. Indeed, there are multiple ways for classifying MCDM methods (Chen and Hwang, 1992), for example, deterministic, stochastic, or fuzzy MCDM. In some cases, a combination of these methods can occur (e.g., a combination of fuzzy and stochastic methods). Moreover, the number of decision makers can be another criterion to classify MCDM methods. In this context, single decision makers and group decision makers exist in MCDM and more details about this classification can be found in the Journal of Group Decision Making. The type and main features of the information can also be used in order to classify deterministic-single decision maker-MADM methods (Chen and Hwang, 1992).

2.4.2.2 Multi-Criteria Decision Making Methods

Multi-criteria methods are the most common branches of decision-making. These methods deal with the problems of some decision criteria and take part in the general class of Operations Research (OR) models. This class is also named multi-criteria decision-making (MCDM) and can be divided into Multi-Objective Decision Making (MODM) and Multi-Attribute Decision Making (MADM) (Zimmermann, 1991). MODM is designed to study decision problems with a continuous decision space. One example of these methods is mathematical programming problems with multiple objective functions such as the "vector-maximum" problem (Kuhn and Tucker, 1951). On the other hand, MADM are designed to solve problems which have discrete decision spaces and thus need to first identify the set of decision alternatives. In order to help decision makers select from a discrete set of alternative decisions, MADM employs numeric techniques. These decisions can be achieved based on the impact of different alternatives on certain criteria and thus on the overall utility of decision makers. Some multi-dimensional methods have been widely employed in spite of the criticism received by this class of methods. These widely used methods include ELECTRE (Benayoun, et al., 1966) and TOPSIS (Hwang and Yoon, 1981).

2.4.3 Some MCDM Areas of Application

There are several industrial engineering MCDM applications including decision analysis in integrated manufacturing (Putrus, 1990), technology investment's evaluation (Boucher and McStravic, 1991), flexible manufacturing systems (Wabalickis, 1988), layout design (Cambron and Evans, 1991), and other engineering problems (Wang and Raz, 1991). As an application, in the system‘s upgrade of a computer integrated manufacturing (CIM) facility, we can have many available configurations, i.e., different alternatives, to choose from. In this scenario, the decision should consider a number of factors that can serve as decision criteria for this problem including cost, software, performance characteristics, maintenance, and expandability. On the other hand, some other applications aim at determining the relative importance of all considered alternatives. For example, in a problem studying the funding of a set of competing projects, i.e., competing alternatives, we need to find the relative importance of these projects. This way, the budget that should be attributed to each project can be proportionally distributed according to their relative importance.

In summary, multi-criteria decision-making methods occupy a critical role in several real life problems. Indeed, the evaluation of a set of alternatives as a function of a set of decision criteria is involved, in one way or another, in most local or federal government, industry, or business activities. In several cases, these criteria can conflict with each other. Furthermore, the pertinent data is often very expensive to collect.

Chapter 3 Proposed Methodology

3.1 Introduction

Normally economy grows in certain patterns. These patterns include finding new resources for gas or oil, a more educated workforce with better skills enter job markets, or a new technology may speed up the way business is conducted. However, the most effective way or pattern to grow the economy and enhance productivity is to improve and grow capital stock. In the engineering economic and decision making discipline, capital investment is spending or investing the company's cash and saving on capital assets. Capital assets normally include assets such as equipment for producing goods, services, and transportation. Improved capital assets increase productivity. This includes labor productivity or more output by reducing waste and scrape rates. Investment in new machinery and developing skills in turn generates growth and creates economic prosperity.

Manufacturing companies worldwide have been implementing new technology to improve the quality of their products while keeping the cost rate reasonable and making their products more affordable.

Many techniques such as lean production systems, just in time (JIT) manufacturing, and Six Sigma have aided manufacturers in improving the quality of their products, and making them more durable which has helped them gain a larger segment of the market over time.

Although, manufacturing and production systems have witnessed a massive amount of innovation, the performance measurement systems have remained relatively unchanged and the gap between technology advancement and lack of accurate measurement techniques has always been the subject for debate in decision makers' theories.

Two of the biggest challenges in advanced manufacturing systems have been what to measure and how to measure intangibles.

The traditional economic analysis method has primarily concentrated on identifying quantifiable attributes of investment in advanced manufacturing systems.

In the 1990's, alternative approaches to the cost traditional accounting system were presented (LeClair, et al., 1992), however, the usefulness of these systems have frequently been questioned due to their complex structure. Many manufacturing companies were reluctant to adopt newly proposed methods due to difficulties in their implementations (Dixon et. al., 1990; White, 1996). The integration of methods to measure the feasibility of the investment in advanced manufacturing often results in further complications and becomes problematic (Ghalayini and Nobel, 1996).

Advanced manufacturing systems are known for their ability to produce higher quality products, reduce set up time, production flexibility, more consistency in final products, reduced time to market, and smaller defects.

Some of the above referenced outcomes are hard if not impossible to measure using traditional cash flow methods.

To adequately analyze and assess advanced manufacturing technology systems, the model must be able to take into consideration both quantitative and qualitative attributes associated with alternatives.

Advanced manufacturing technology systems often have their own specific characteristics. These systems normally have many intrinsic features for which the traditional cash flow analysis falls short of measuring their potential benefits.

The model proposed in this chapter takes into account strategic, tactical, and financial objectives. The financial outcomes of advanced manufacturing technology attributes are often assessed using net present value which is a single index and concludes if cash flow generated by an investment over a given life can recover this invested capital at a predetermined rate normally known as the minimum acceptable rate of return (MARR).

However, strategic objectives represent qualitative factors and often the decision maker's uses attribute to describe these objectives. Although these qualitative attributes are often hard to quantify they play an important role in making the final decision.

3.2 An overview

Traditional and non-traditional economic justification methods have been well documented in literature since late the 1980's and early 1990's (Meredith et al., 1986, Parsaei et al., 1989). Some of methods introduced in the literature use different factors to measure the economic desirability of advanced manufacturing systems.

Table 3.1 presents a summary of the structured methods used for justification of advanced technology systems. The table also presents factors included in these methods and in the qualitative and quantitative nature of these factors. Although table 3.3 identifies several methods used to justify the investment in advanced manufacturing systems, many of methods listed are single objectives and do not lend themselves to capture the multi-objective attributes associated with advanced manufacturing systems.

Table 3-1 Objectives, Attributes, and Performance Measure for the Sourcing Analysis

Objective	Attributes	Performance Measure
Objective 1 Maximize strategic competitive performance	Product affordability	NPOF
	Quality of end product	NPOF
	Quality of work environment	NPOF
	Reliability of end product	NPOF
	Flexibility in product mix	NPOF
	Expandability of production Equipment	NPOF
	Flexibility in production quantity	NPOF
	Reliability of production equipment	NPOF
Objective 2 Maximize managerial performance	Employee morale	NPQF
	Opportunity for employee advancement	NPQF
	Clarity in company's vision and mission	NPQF
	Company's stability	NPQF
	Change of trend in technology	NPQF
	Change in regulation requirements	NPQF
Objective 3 Maximize the financial performance	Product Cost	NPV
	Net Present Value	NPV

Multiple Criteria Decision Methodology

The primary goal of this research is to introduce a multiple criteria evaluation method for the economic decision process to include both quantitative and qualitative attributes. Figure 3.2 is a pictorial representation of decision process for the proposed methodology.

This methodology incorporates three objectives in its structure. These include strategic, managerial, and financial.

Objectives:

Objective 1: Maximizing Strategic Competitive Performance

This objective defines the performance of the investment with the overall priorities of the organization. The organization priorities may include the characteristics of the product or outcomes generated as a result of the selection of a capital investment. (Hill 1994, Rone and Rozen 1992, Crow et al., 1997). Some of these objectives include product affordability, quality of product, quality of work environment, and reliability of production equipment.

The strategic objective is normally formulated by a company at the planning stage. It is primarily concerned with the long term goals of the corporation and where the company wants to position itself in the future. The attributes which define this objective are product affordability (cost of production), end product quality, end product reliability, product mix flexibility, production equipment expandability, production quantity flexibility, and production equipment reliability.

Objective 2: Maximizing Managerial Performance

This objective defines the performance of the organization's policy with regards to employees' morale and professional advancement opportunities. (Demmel and Askin 1992), and (Dobler et al., 1984).

Managerial performance is often difficult to measure, however, it can significantly influence the company's future and its ability to exist and advance in the market. Employee morale is often defined as the way employees feel and how they perceive the company. When the corporate policy and its future vision becomes less transparent or employees are totally ignored in the decision-making process lack of shared governess, the morale erodes and decline. Employee development and advancement deals with how a company creates a growth path for its employees to gain further skills and become professionally mature in order to accept more responsibilities and help the company to achieve its long term goals.

Low morale, lack of opportunity to grow professionally and job dissatisfaction often lead to absenteeism and ultimately high turnover (Demmel and Askin 1992 and Parsaei 2011) furthermore, any capital investment in advanced manufacturing technology may become obsolete in the future (Walker 1988).

Since the organization seeks to minimize investment risk becoming obsolete over a period of time, this objective must be factored into an overall evaluation of the capital investment decision. (Dobler et al., 1984).

Many organizations consciously try to postpone any major investment in advanced technology (late adapter). These organizations are mainly concerned with the fact that no matter how many investments are made and how devoted they are to upgrading and updating their existing production equipment, their investment quickly becomes obsolete. Although, a new investment may appear to be costly for an organization, it can often help the company remain competitive in the market and meet the demand of its customers.

Objective 3: Maximizing Financial Performance

Financial performance is often considered to be one of the main pillars of capital investment. Hence the proposed model in this study measures the financial performance of capital investment alternatives. The company's financial performance is often synonymous with its ability to capture a large share of the market and in turn increase its sales volume and enhance its profit margin. One of most common methods for a company to measure its financial performance is to increase its shareholders' wealth for which a company's net present value is calculated.

Operation and maintenance are the costs related to the day to day running of a company and its upkeep. Normal operating labor, maintenance force, labor turnover, training, direct and indirect costs including healthcare, supervision, setup, expediting, and insurance are all included in operation and maintenance costs.

Some sample attributes normally used to measure the financial performance of a company include installation, spare parts, software development, and tooling.

Based on the three objectives which have been introduced, figure 3.1 shows an overview of the structure of the decision process for the proposed methodology. Each level of the objective has many attributes, and after comparing all attributes we can select our alternative based on level three.

Table 3.2 displays a list of attributes and their unit measurements in order to measure and assess the economic desirability of investment alternatives.

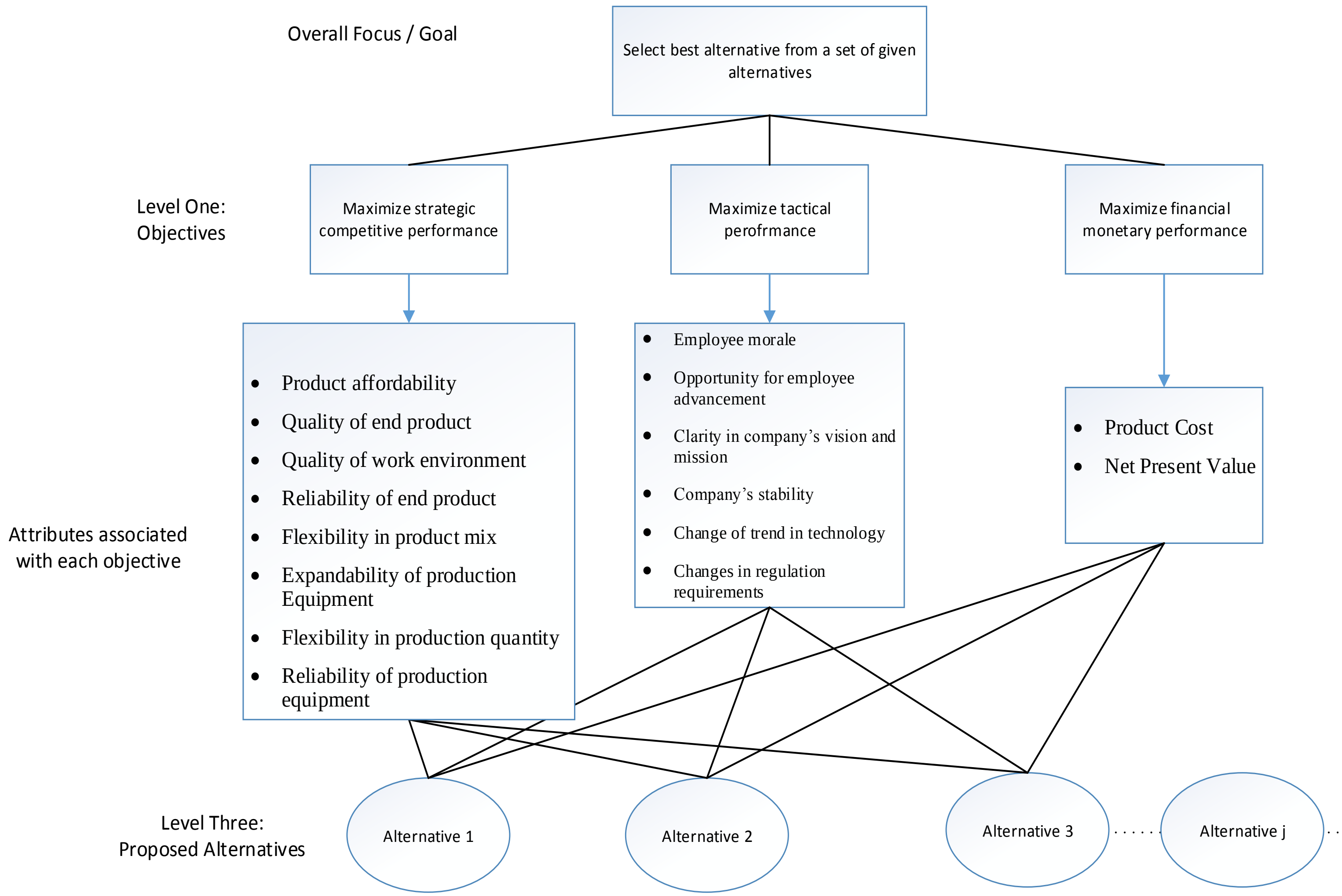

Figure 3.1 An overview of structure of decision process for the proposed methodology

Table 3-2 Attributes and Unit of Measurement

	Attributes	Unit of Measurements
	Product affordability	Price to be proportion to consumer income (minimize)
	Quality of end product	Cost per unit of scrap (minimize)
	Quality of work environment	Cost of turnover (minimize)
	Reliability of end product	No. of returned items (minimize)
	Flexibility in product mix	Cost per changeover (minimize)
	Expandability of production Equipment	Total number of product varieties (maximize)
	Flexibility in production quantity	Cost per unit for changing order (minimize)
	Reliability of production equipment	Cost of down time (minimize)
	Employee morale	Qualitative flow (maximize)
	Opportunity for employee advancement	Qualitative flow (maximize)
	Clarity in company's vision and mission	Qualitative flow (maximize)
	Company's stability	Qualitative flow (maximize)
	Change of trend in technology	Cost of inventory flow (minimize)
	Change in regulation requirements	Cost per unit production loss flow (minimize)
	Product Cost	Cost per unit of production (minimize)
	Net Present Value	Cash flow (maximize)

A literature survey outlines several methods to measure the economic desirability of advanced manufacturing systems since the early 1980's.

Table 3.3 provides a list of these methods and identifies factors considered in the justification process as well as their ability to measure the qualitative and quantitative attributes associated with capital investment.

Table 3-3 Traditional and Non-Traditional Proposed Economic Justification Methods and the Focus and Factors Considered in the Review Process

Methodology	Factors Considered	Qualitative or Quantitative	Introduced by
Traditional Economic Justification Methods			
1. Net Present Value (NPV)	Depreciation Effect, Cash from Sales, Tax	Quantitative	Meredith J., Suresh C., 1986 Soni R., Parsaei H., Liles D. 1992
2. Internal Rate of Return (IRR)	Cost of Capital	Quantitative	
3. Payback Period (PBP)	Cash Flow	Quantitative	
Analytical Methods			
1. Fuzzy Linguistic Methods	Collecting Data, Variable Attributes	Qualitative	Wilhelm M., Parsaei H., 1991, Buckley J., 1986, Herrera F., Viedma E., Martinez L., 2008.
2. Risk Analysis a) Stochastic Models	Random Variable for Historical Data	Quantitative / Qualitative	Taylor H., Karlin S., 1998, Breiman L., 1969, Hazen G., 1992, 1993, 2001
b) Simulation	Random Sampling, Curve fitting	Quantitative / Qualitative	Raychaudhuri S., 2008, Poulter S., 1998, Haugh M., 2004
3. Mathematical Molding a) Integer Programming	Formulation with many Variables, Branch and Bound Parameters, Avoid Symmetry	Quantitative	Bosch R., Trick M., 2005, Wolsey L., 1998, Taha H., 2002.
b) Linear Programing	Constraints, Objectives	Quantitative	Chinneck J., 2001, Strayer J., 1989, Balogun O., Jolayemi E., Akingbade T., Muazu T., 2012.
c) Goal Programing	Type of Goals: (Lower one-sided, upper one-sided, and	Quantitative / Qualitative	Ignizo J., Romero C., 2003, Romero C., 2001, Tamiz M., Jones D., 1996,

4. Scoring / Qualitative	Two-sided goals)		Schniederjans M., Hoffman J., Sirmans G., 1995.
a) Utility Models	Attributes Weighting	Qualitative	Suthersanen U., 2006, Fishburn P., 1970, Keeny and Raiffa, 1976, Analytis P., Kothiyal A., Katsikopoulos K., 2014.
b) AHP	Limitation of use	Qualitative	Kumar S., Vaidya O., 2004, Al Harbi K., 2001, Alidi A., 1996.
c) Scoring Systems	Cost, Different Score Weight, Time	Qualitative	Parsaei H., Wilhelm M., 1989, Parsaei H., Karwowski W., Wilhelm M., 1988, Parsaei H., Liles D., 1990, Suknovic M., Radojevic G., 2009.
Strategic Methods 1. Technical Importance 2. Competitive Advantage 3. Business Objective 4. Research & Development	Time	Qualitative Qualitative Qualitative Qualitative	Meredith J., Suresh C., 1986
Integrated Methods 1. Expert System	Knowledge, Particular Problem Matches the System Knowledge,	Qualitative	Klein D., 1985, Dhar V., 1987, Henghold W., LeClair S., 1992.
2. Multi – attributes Decision Making	Risk, Uncertainty, Weights and Priorities	Qualitative	Steuer R., Na P., 2003, Kolli S., Parsaei H., 1992, Steuer R., Na P., 2002.

Research has long realized the shortcomings of management accounting of the traditional financial accounting approaches, however, only a small number of methods using non-financial approaches has been introduced over the past three decades.

The proposed methodology is an important factor regarding several of the methodologies reviewed in the in this dissertation in Chapter 2. The unique feature of the proposed method is that it includes both qualitative and quantitative attributes in the analysis and economic justification of advanced manufacturing systems.

Many economic justification methods introduced in the past only consider quantitative attributes and convert them into one single measurement, namely the net present value (NPV).

The method presented in this research measures both quantitative and qualitative attributes and allows a decision maker to take a more structured look into advanced manufacturing technology systems and subsequently make a more robust and sound decision.

Figure 3.2 displays a flow chart of the steps involved in the implementation of the proposed methodology.

The proposed method consists of three levels. At level one, the primary objectives of capital investment including strategic competitive performance, tactical performance, and financial monetary performance are identified.

This methodology not only analyzes each available alternative, but looks ahead to assess the performance of each alternative using the appropriate attributes for stated primary objectives.

After the attributes the parameters are determined, the methodology executes the final stage- the actual attribute performance evaluation of the alternatives and yields the rank ordering of the alternatives based on the overall, weighed performance measure across all attributes. This measure is computed via the composing programming, distance-based, multiple criteria decision making approach.

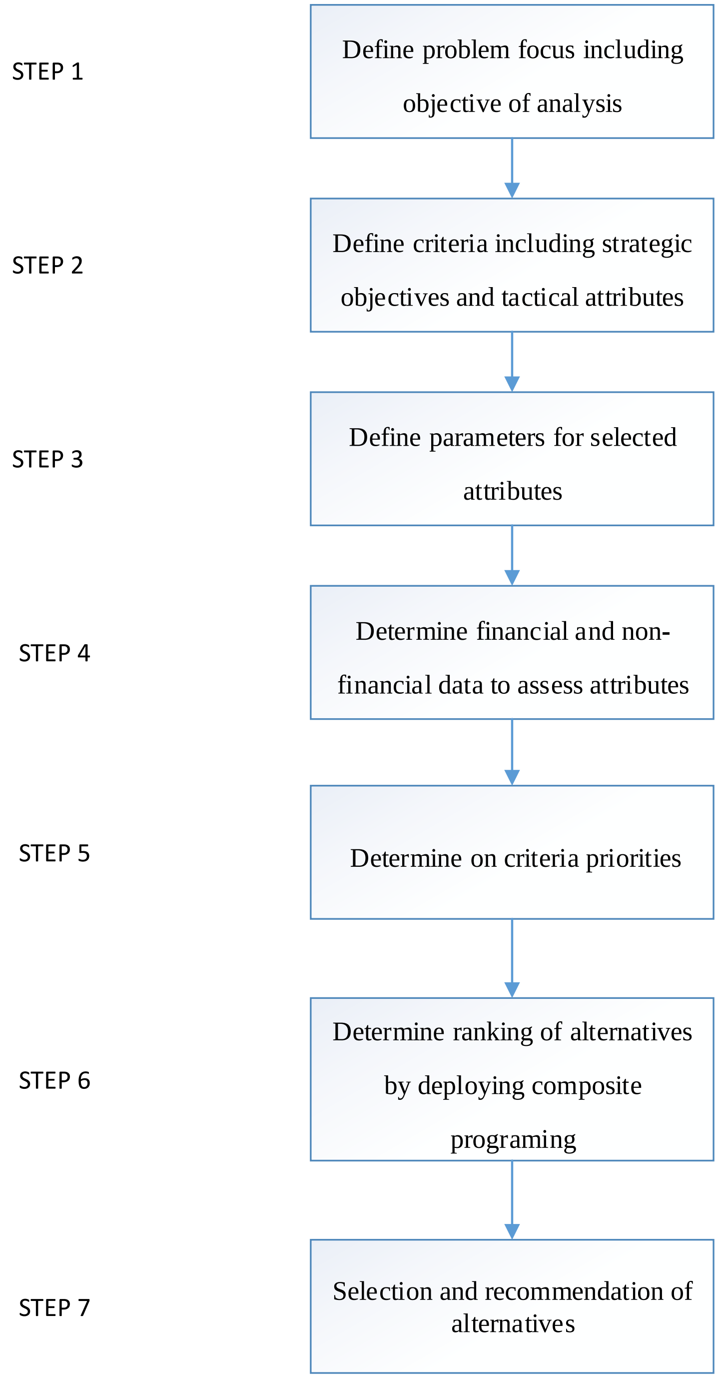

Figure 3.2 A flowchart for implementing the methodology proposed for project selection

3.3 Monetary or Financial Index

The methodology presented in this research uses return on investment by calculating the net present value for each alternative based on the invested capital and the cash flow generated for that investment.

The minimum attractive rate of return (MARR) used in the calculation of the net present value for each given alternative may be generated using the company's after tax cost of capital.

In this study we pursue the classical or traditional forms to express generating the net present value for the alternative.

The following formula has been used in this study to determine the net present value (NPV):

$$\boldsymbol{NPV_i = \sum_{j=0}^{n} X_{ij}\,(1 + MARR)^{-j}}\,, \tag{3.1}$$

where:

X_{ij} = After tax cash flow for alternative i (i=1, ………..I) during the period j (j = 0, ..………, J)

i = Number of given alternatives (i = 1, ………..I)

j = Number of periods the cash flow generated (j = 0, ………., J)

MARR = Minimum Attractive Rate of Return , assumed to be fixed over the j period.

The model presented in this research uses a large number of qualitative attributes associated with proposed alternatives, thus showing the need to introduce an index to scale the outcomes into two boundaries such as (-1) and (+1) where (-1) could represent the least attractive and (+1) represents the most attractive alternative. In earlier studies conducted by Demmel and Askin and Padillo and Diaby in 1992 and 1999, respectively, such an index was introduced.

The net present qualitative flow (NPQF) in the developed model is introduced to evaluate and convert each net present value into this scale in which the attractiveness of alternatives are ranged between (-1) and (+1).

Table 3-4 Scale for Evaluation of Qualitative Attribute Performance (Q_{ijk}) (Adapted from Satty and Kerns 1985, and Padillo 1999) (See table 4.4).

Rating	Definition
0	No impact. Negligible positive or negative attribute performance.
2, -2	Moderate positive or negative attribute performance.
4, -4	Strong positive or negative attribute performance.
6, -6	Very strong or demonstrated positive or negative attribute Performance.
8, -8	Maximum or minimum attribute performance.
1, 3, 5, 7, -1, -3, -5, -7	For compromise between above values.

3.4 Performance Measurement of an Alternative

3.4.1 Net Present Qualitative Flow (NPQF):

In this study the Net Present Qualitative Flow (NPQF) based on the model presented by (Demmel, Askin and Padillo, Diaby) is used. In addition, a scale of qualitative performance evaluated proposed by Satty and Kearns (1985) is adapted and used in this study.

The net present qualitative flow (NPQF) as stated earlier in this study employs the net present qualitative flow which gives a decision maker the rate of the expected impact of each alternative relation to each qualitative attribute in each time period.

$$\boldsymbol{NPQF_{ik} = \sum_{j=0}^{n} Q_{ikj} (1+h)^{-j}}, \tag{3.2}$$

where:

j: is the total number of time periods

Q_{ijk} : is the expected performance or impact of the alternative i with respect to the attribute k in the time period j

h: is the qualitative interest rate

The term expressed by (1+h) can be viewed as a weight applied to the expected performance Q_{ijk} to represent the importance of the attribute over time. A higher value taken by h can be interpreted as having less importance than attribute performance in future time periods.

In this study it is assumed that the expression (1+h) is a product of two elements, (1+p) and (1+u). This expression is adapted from Padillo and Diaby who assumed h is a combined qualitative interest rate per compounding period and can take value (0% to 100%). It is further assumed, as in the discounted cash flow concept, the decision maker prefers the outcomes are achieved sooner.

Based on Padillo and Diaby (1999), h and p values are equal with the following equation:

$$(1+h)= (1+p)\ (1+u) \qquad (3.3)$$

h: Qualitative discounting rate [0%, 100%]

p: the rate of decision maker impatience to achieve outcomes (0%, 41.42%)

u: the rate of uncertainty per period which can take the value from low to very high (0%, 41.42%)

This is how we can calculate p and u from equation (3):

when h = 0

then p and u = 0

when h = 100% then

(1+1) = (1+p) (1+u) = 2

The only solution here is p and u = 41.42%

3.4.2 Net Present Operational Flow (NPOF)

In this study we stated that several attributes in economic justification of advanced manufacturing technology systems are quantitative or monetary, but it is difficult to measure them in terms such as monetary, quality, and timely delivery to market. Although, methods exist to measure quality with regards to mean time between failures, these methods conceptually measure the reliability of the production process or product durability. Most of these methods are probabilistic and heavily rely on mathematical models and a substantial amount of data and finally the computation becomes quite involved.

Therefore, this study uses net present operational flow (NPOF) which is conceptually similar to net present qualitative flow (NPQF) and can be expressed by the following:

$$\boldsymbol{NPOF_{ik} = \sum_{j=0}^{n} O_{ikj}\,(1+h)^{-j}}\,, \tag{3.4}$$

where:

j : is the total number of the time period

O_{ijk} : is the expected performance of the alternative *i* with respect to the attribute k in the time period j

h: is qualitative interest rate

The expression (4) requires the decision maker to gather estimates for each alternative *i* during each time period *j*.

The expression (4) is the same as in the qualitative flow analysis.

3.5 Measure of Criteria Importance

The foundation of the justification of advanced manufacturing technology systems is quite suitable to use composite programming to measure the trade-off among alternatives and subsequently select the most desirable candidate.

In the economic justification of advanced manufacturing technology systems, after all competing attributes are listed, it is logical for the decision maker to obtain a measurement of the relative importance of the problem's criteria, main objectives and attributes. Many methods have previously been employed by researchers in multiple objective decision analysis.

The principle developed in this research and which is similar to the Analytic Hierarchy Process (AHP) was developed by Satty in 1980. The methodology requires pairwise comparisons to be carried out considering the relative importance of each attribute in a set with respect to its overarching objective.

The selection of the best alternative is based on the calculation of a composite distance, A_j , which is defined by:

$$A_j = \left\{ \sum_{r=1}^{3} \beta_r \left(\sum_{k \in S_r} \alpha_{rk} \left[\frac{f_{ik-g_k}}{u_k - g_k} \right]^{p_k} \right)^{q/p_k} \right\}^{1/q}, \qquad (3.5)$$

where:

$1 \leq p \leq \infty$, (r = 1, 2, 3) and $1 \leq q \leq \infty$;

$0 \leq \beta_r \leq 1$, (r = 1, 2, 3), and $\sum_{r=1}^{3} \beta_r = 1$;

$0 \leq \alpha_{rk} \leq 1$, ($k \in S_r$), and $\sum_{k \in S_r} \alpha_{rk} = 1$, (r = 1, 2, 3, 4)

k : attribute, r = objective

f_{ik} : Performance score for alternative *j* for attribute *i*

u_k = ideal attribute (is equal = 1) (Zeleny 1982)

g_k : non - ideal attribute (is equal 0, or -1) (Zeleny, 1982)

α_{rk} : relative importance of the k^{th} attribute (1 ≤ k ≤ n (r)) within objective r

β_r : relative importance of the r^{th} objective (1 ≤ r ≤ 3)

p_k: Distance parameter measure importance of the attribute from "ideal"

q : Distance parameter measure importance of the objective from "ideal"

S_r : Set of attributes for objective r

The use of composite programming allows the conduction of a two-level trade-off analysis. The first level trade-off is between the problem's objectives, and the second level between the attributes. The methodology at this stage employs two-level weighted decision measures to evaluate advanced manufacturing using a set of priorities.

Where:

K = 1,2,3,and 4 for a given alternative j ∈ J

The ranking of advanced manufacturing technology proposals or alternatives is based on A_j. Technically, the alternative with the maximum or highest value of A_j is recommended as the most desirable candidate. Hence, the alternative with the A_j value of "1.0" technically holds the maximum distance or the j^{th} alternative is the best alternative in the set. Chapter 4 illustrates a numerical example to show the application of this proposed methodology.

Chapter 4 Numerical Example

In Chapter 2, different justification approaches have been surveyed and illustrated. In Chapter 3 the proposed methodology has been described. As a result, the proposed methodology can be explained further by means of a numerical example in this chapter. In the numerical example, the four alternatives have been shown in table 4.1 which shows the decision to choose to buy a fully integrated system or to integrate it.

4.1 Sourcing Alternatives and Performance Evaluation

The criterial structure provided by the decision makers (DM) was previous shown in table 3.1. The time periods used for the financial, operational, and qualitative assessment of the alternative were defined by semi-annuals (a total of ten).

In objective three (optimize the financial performance), the financial analysis was based on an annual discount rate of 13%. The performance of the alternatives with respect to the attributes in objectives two and three (qualitative) were assigned by the decision makers based on their experience and knowledge. For alternative 1 (purchase standalone systems and outsource the integration), the NPV is $3,151,350 as show in table 4.1.

Table 4-1 Alternatives Description and NPV Results

Alternatives (j)	Description	NPV ($)
1	Purchase standalone systems and outsource the integration	3,151,350**
2	Purchase standalone systems and integrated them in house	-3,278,546
3	Purchase a partial integrated system	-3,543,850
4	Purchase a fully integrated system	-3,872,250

** Minimum value for normalizing

The yearly rate of impatience (p) and uncertainty (u) were stated by the decision makers for each of the non-financial attributes in the sourcing analysis. In order to calculate the **NPOF** and **NPQF** the impatience rate (p), and uncertainty rate (u) should be incorporated into qualitative discount rates (h). Table 4.2 shows all the discount rates which were used in the decision numerical example.

Table 4-2 Financial and Qualitative Discount Rates

Attributes	Impatience (p)	Uncertainty (u)	Yearly (h)	Semi-annually (h)
Product affordability	20%	5%	26%	12.25%
Quality of end product	35%	5%	41.75%	19.06%
Quality of work environment	30%	5%	36.5%	16.8%
Reliability of end product	41.42%	10%	55.56%	24.72%
Flexibility in product mix	20%	20%	44%	20%
Expandability of production equipment	20%	20%	44%	20%
Flexibility in production quantity	10%	10%	21%	10%
Reliability of production equipment	35%	10%	48.5%	21.86%
Employee morale	30%	30%	69%	30%
Opportunity for employee advancement	30%	30%	69%	30%
Clarity in company’s vision and mission	35%	35%	82.25%	35%
Company’s stability	30%	30%	69%	30%
Change of trend in technology	25%	25%	56.25%	25%
Change in regulation requirements	25%	25%	56.25%	25%
Net Present Value	-	-	13%	6.3%

Table 4-3 Expandability of Production Rates

Rates	Description
5	Excellent
4	Very Good
3	Good
2	Average
1	Below Average

Table 4.3 shows the expandability of production rates which is attribute number 6 in objective 1 (optimize strategic competitive performance). Regarding objective 2 (optimize managerial performance), table 4.5 shows no impact on employee morale, and these rates were based on table 4.4 which is adapted from Satty and Kerns 1985, and Padillo 1999.

Table 4-4 Scale for Evaluation of Qualitative Attribute Performance (Q_{ijk}) (Adapted from Satty and Kerns 1985, and Padillo 1999).

Rating	Definition
0	No impact. Negligible positive or negative attribute performance
2, -2	Moderate positive or negative attribute performance
4, -4	Strong positive or negative attribute performance
6, -6	Very strong or demonstrated positive or negative attribute performance
8, -8	Maximum or minimum attribute performance
1, 3, 5, 7, -1, -3, -5 -7	For compromise between above values

In addition, the evaluation of opportunity for employee advancement was strong attribute performance as shows in the table. The clarity in the company's vision and mission was very clear from the first year, and continue with the same rate and the performance of this alternative is expected to be strong during the years. Also, the company's stability will be very good since they have a very clear vision.

Tables 4.5 to 4.8 show the performance of alternative 1, 2, 3, and 4 for other attributes in the model. The tables represent the multi-attributes and performance evaluation of alternative 1, 2, 3, and 4 during the 10 semi-annuals spanning the analysis. In the first semi-annual, the quality of end product is expected to be low, because of no previous data or learning period. As well as the flexibility in the product mix which is increase relatively over the time as the number of returned items are minimum. In addition, reliability of production equipment will decrease over the time since the cost per unit for changing the order will increase over the time.

Table 4-5 NPOF and NPQF analysis for alternative 1 (Purchase a fully integrated system)

	Semi-annually (t)									
Objective / attribute	1	2	3	4	5	6	7	8	9	10
Objective 1										
Product affordability	4.00	4.00	4.00	4.00	4.50	4.50	4.50	4.50	5.00	5.00
Quality of end product	95%	95%	96%	96%	97%	97%	98%	98%	99%	99%
Quality of work environment	95%	95%	96%	96%	97%	97%	98%	98%	99%	99%
Reliability of end product	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Flexibility in product mix	90%	90%	90%	90%	92%	92%	92%	92%	95%	95%
Expandability of production Equipment	5	5	5	5	5	5	5	5	5	5
Flexibility in production quantity	95%	95%	95%	95%	95%	95%	95%	95%	95%	95%
Reliability of production equipment	95%	95%	95%	95%	90%	90%	90%	90%	85%	85%
Objective 2										
Employee morale	0	0	0	0	0	0	0	0	0	0
Opportunity for employee advancement	5	5	5	5	5	5	5	5	5	5
Clarity in company's vision and mission	6	6	6	6	6	6	6	6	6	6
Company's stability	4	4	4	4	4	4	4	4	4	4
Change of trend in technology	-2	-2	-2	-2	-2	-2	-3	-3	-3	-3
Changes in regulation requirements	-3	-3	-3	-3	-3	-3	-3	-4	-4	-4

Table 4-6 NPOF and NPQF analysis for alternative 2 (Purchase a partial integrated system)

	Semi-annually (t)									
Objective / attribute	1	2	3	4	5	6	7	8	9	10
Objective 1										
Product affordability	4.5	4.5	4.5	4.5	4.5	4.5	5.00	5.00	5.50	5.50
Quality of end product	92%	92%	92%	92%	94%	94%	95%	95 %	96%	96%
Quality of work environment	91%	92%	93%	95%	96%	97%	98%	98 %	99%	99%
Reliability of end product	94%	94%	94%	94%	94%	94%	94%	94 %	94%	94%
Flexibility in product mix	90%	90%	90%	90%	91%	91%	92%	92 %	94%	94%
Expandability of production Equipment	4	4	4	4	4	4	4	4	4	4
Flexibility in production quantity	94%	94%	94%	94%	94%	94%	94%	94 %	94%	94%
Reliability of production equipment	94%	94%	94%	94%	91%	91%	91%	91 %	85%	85%
Objective 2										
Employee morale	1	1	1	1	1	1	1	1	1	1
Opportunity for employee advancement	4	4	4	4	4	4	4	4	4	4
Clarity in company's vision and mission	4	4	4	4	4	4	4	4	4	4
Company's stability	5	5	5	5	5	5	5	5	5	5
Change of trend in technology	-3	-3	-3	-3	-2	-2	-2	-2	-3	-3
Changes in regulation requirements	-4	-4	-4	-4	-4-	4-	4-	4-	4-	4-

Table 4-7 NPOF and NPQF analysis for alternative 3 (Purchase standalone system and integrated them in house)

	Semi-annually (t)									
Objective / attribute	1	2	3	4	5	6	7	8	9	10
Objective 1										
Product affordability	5.20	5.20	5.20	5.20	5.50	5.50	5.50	5.50	6.00	6.00
Quality of end product	93%	93%	93%	93%	95%	95%	95%	95%	97%	97%
Quality of work environment	93%	93%	94%	95%	95%	97%	97%	98%	99%	99%
Quality of work environment	95%	95%	96%	96%	97%	97%	98%	98%	99%	99%
Reliability of end product	94%	94%	94%	94%	94%	94%	94%	94%	94%	94%
Flexibility in product mix	90%	90%	90%	90%	93%	93%	93%	93%	94%	94%
Expandability of production Equipment	3	3	3	3	3	3	3	3	3	3
Flexibility in production quantity	93%	93%	93%	93%	93%	93%	93%	93%	93%	93%
Reliability of production equipment	93%	93%	93%	93%	90%	90%	90%	90%	85%	85%
Objective 2										
Employee morale	-1	-1	-1	-1	-1	-1	-1	-1	-1	-1
Opportunity for employee advancement	2	2	2	2	2	2	2	2	2	2
Clarity in company's vision and mission	3	3	3	3	3	3	3	3	3	3
Company's stability	5	5	5	5	5	5	5	5	5	5
Change of trend in technology	-4	-4	-4	-4	-3	-3	-3	-3	-2	-2
Changes in regulation requirements	-3	-3	-3	-3	-3	-3	-4	-4	-5	-5

Table 4-8 NPOF and NPQF analysis for alternative 4 (Purchase standalone systems and outsource the integration)

	Semi-annually (t)									
Objective / attribute	1	2	3	4	5	6	7	8	9	10
Objective 1										
Product affordability	5.50	5.50	5.50	5.50	6.00	6.00	6.00	6.00	6.50	6.50
Quality of end product	94%	94%	94%	94%	95%	95%	96%	96%	97%	97%
Quality of work environment	94%	94%	95%	96%	97%	97%	97%	98%	98%	99%
Reliability of end product	93%	93%	93%	93%	93%	93%	93%	93%	93%	93%
Flexibility in product mix	90%	90%	90%	90%	91%	91%	92%	92%	93%	93%
Expandability of production Equipment	3	3	3	3	3	3	3	3	3	3
Flexibility in production quantity	92%	92%	92%	92%	92%	92%	92%	92%	92%	92%
Reliability of production equipment	94%	94%	94%	94%	91%	91%	85%	85%	80%	80%
Objective 2										
Employee morale	-2	-2	-2	-2	-2	-2	-2	-2	-2	-2
Opportunity for employee advancement	3	3	3	3	3	3	3	3	3	3
Clarity in company's vision and mission	2	2	2	2	2	2	2	2	2	2
Company's stability	3	3	3	3	3	3	3	3	3	3
Change of trend in technology	-5	-5	-5-	5-	-4	-4	-4	-4	-2	-2
Changes in regulation requirements	-4	-4	-4	-4	-3	-3	-3	-3	-2	-2

4.2 Attribute Performance Score

After all evaluation of the alternative attributes was completed, the NPOF and NPQF values were computed. Table 4.9 shows the computation of NPOF values for the attribute “Cost per unit”.

In addition, the NPV, NPOF, and NPQF measures of each alternative were converted into less performance scores by using the attribute score function which is presented in chapter three (section: 3.2).

Table 4-9 NPOF analysis of sourcing alternatives objective 1 attribute 1 (Product affordability)

Semi-annually (t)	Alternatives (j)			
	1	2	3	4
1	4.00**	4.50	5.20	5.50
2	4.00	4.50	5.20	5.50
3	4.00	4.50	5.20	5.50
4	4.00	4.50	5.20	5.50
5	4.50	4.50	5.50	6.00
6	4.50	4.50	5.50	6.00
7	4.50	5.00	5.50	6.00
8	4.50	5.00	5.50	6.00
9	5.00	5.50	6.00	6.50
10	5.00	5.50	6.00	6.50
NPOF	23.99	26.26	30.19	32.38
Normalize (f)	1.0000	0.9135	0.7946	0.7409
Min	23.99			

** US Dollar

Table 4.10 shows the computation of NPOF values for the attribute “Quality of end product”.

In addition, the NPV, NPOF, and NPQF measures of each alternative were converted into less performance scores by using the attribute score function which is presented in chapter three (section: 3.2).

Table 4-10 NPOF analysis of sourcing alternatives objective 1 attribute 2 (Quality of end product)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	93%**	94%	93%	94%
2	93%	94%	93%	94%
3	93%	94%	93%	94%
4	93%	94%	93%	94%
5	95%	95%	95%	95%
6	95%	95%	95%	95%
7	95%	96%	95%	96%
8	95%	96%	95%	96%
9	97%	97%	97%	97%
10	97%	97%	97%	97%
NPOF	4.17	4.10	4.10	4.10
Normalize (f)	0.9832	1.0000	1.0000	1.0000
Min	4.10			

** Percentage.

Tables from 4.9 to 4.22 presented all attribute scores for alternative 1. And the same way we need to create all scores for all attributes of the remaining alternatives.

Table 4-11 NPOF analysis of sourcing alternatives objective 1 attribute 3 (Quality of work environment)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	95%	91%	93%	94%
2	95%	92%	93%	94%
3	96%	93%	94%	95%
4	97%	95%	95%	96%
5	97%	96%	95%	97%
6	97%	97%	97%	97%
7	98%	98%	97%	97%
8	98%	98%	98%	98%
9	99%	99%	99%	98%
10	99%	99%	99%	99%
NPOF	4.53	4.39	4.46	4.49
Normalize (f)	0.9691	1.0000	0.9843	0.9777
Min	4.39			

** Percentage.

Table 4-12 NPOF analysis of sourcing alternatives objective 1 attribute 4 (Reliability of end product)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	95%**	94%	94%	93%
2	95%	94%	94%	93%
3	95%	94%	94%	93%
4	95%	94%	94%	93%
5	95%	94%	94%	93%
6	95%	94%	94%	93%
7	95%	94%	94%	93%
8	95%	94%	94%	93%
9	95%	94%	94%	93%
10	95%	94%	94%	93%
NPOF	3.42	3.38	3.38	3.35
Normalize (f)	0.9795	0.9911	0.9911	1.0000
Min	3.35			

** Percentage.

Table 4-13 NPOF analysis of sourcing alternatives objective 1 attribute 5 (Flexibility in product mix)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	90%**	90%	90%	90%
2	90%	90%	90%	90%
3	90%	90%	90%	90%
4	90%	90%	90%	90%
5	92%	91%	93%	91%
6	92%	91%	93%	91%
7	92%	92%	93%	92%
8	92%	92%	93%	92%
9	95%	94%	94%	93%
10	95%	94%	94%	93%
NPOF	3.82	3.81	3.82	3.80
Normalize (f)	0.9947	0.9974	0.9947	1.0000
Min	3.80			

** Percentage.

Table 4-14 NPOF analysis of sourcing alternatives objective 1 attribute 6 (Expandability of production equipment)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	5**	4	3	3
2	5	4	3	3
3	5	4	3	3
4	5	4	3	3
5	5	4	3	3
6	5	4	3	3
7	5	4	3	3
8	5	4	3	3
9	5	4	3	3
10	5	4	3	3
NPOF	20.96	16.77	12.58	12.58
Normalize (f)	0.6000	0.7505	1.0000	1.0000
Min	12.58			

** Rate.

Table 4-15 NPOF analysis of sourcing alternatives objective 1 attribute 7 (Flexibility in production quantity)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	95%**	94%	93%	92%
2	95%	94%	93%	92%
3	95%	94%	93%	92%
4	95%	94%	93%	92%
5	95%	94%	93%	92%
6	95%	94%	93%	92%
7	95%	94%	93%	92%
8	95%	94%	93%	92%
9	95%	94%	93%	92%
10	95%	94%	93%	92%
NPOF	5.84	5.78	5.71	5.65
Normalize (f)	0.9675	0.9775	0.9895	1.0000
Min	5.65			

** Percentage.

Table 4-16 NPOF analysis of sourcing alternatives objective 1 attribute 8 (Reliability of production equipment)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	95%**	94%	93%	94%
2	95%	94%	93%	94%
3	95%	94%	93%	94%
4	95%	94%	93%	94%
5	90%	91%	90%	91%
6	90%	91%	90%	91%
7	90%	91%	90%	85%
8	90%	91%	90%	85%
9	85%	85%	85%	80%
10	85%	85%	85%	80%
NPOF	3.66	3.64	3.61	3.60
Normalize (f)	0.9836	0.9890	0.9972	1.0000
Min	3.60			

** Percentage.

Table 4-17 NPQF analysis of sourcing alternatives objective 2 attribute 1 (Employee morale)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	0**	1	-1	-2
2	0	1	-1	-2
3	0	1	-1	-2
4	0	1	-1	-2
5	0	1	-1	-2
6	0	1	-1	-2
7	0	1	-1	-2
8	0	1	-1	-2
9	0	1	-1	-2
10	0	1	-1	-2
NPQF	0	3.09	-3.09	-6.18
Normalize (f)	0.0000	-0.5000	0.5000	1.0000
Min	-6.18			

**Rate.

Table 4-18 NPQF analysis of sourcing alternatives objective 2 attribute 2 (Opportunity of employee advancement)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	5**	4	3	3
2	5	4	3	3
3	5	4	3	3
4	5	4	3	3
5	5	4	3	3
6	5	4	3	3
7	5	4	3	3
8	5	4	3	3
9	5	4	3	3
10	5	4	3	3
NPQF	15.46	12.37	9.27	9.27
Normalize (f)	0.5996	0.7494	1.0000	1.0000
Min	9.27			

**Rate.

Table 4-19 NPQF analysis of sourcing alternatives objective 2 attribute 3 (Clarity in company's vision)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	6**	4	3	2
2	6	4	3	2
3	6	4	3	2
4	6	4	3	2
5	6	4	3	2
6	6	4	3	2
7	6	4	3	2
8	6	4	3	2
9	6	4	3	2
10	6	4	3	2
NPQF	16.29	10.86	8.15	5.43
Normalize (f)	0.3333	0.5000	0.6663	1.0000
Min	5.43			

**Rate.

Table 4-20 NPQF analysis of sourcing alternatives objective 2 attribute 4 (Company's stability)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	4**	5	5	3
2	4	5	5	3
3	4	5	5	3
4	4	5	5	3
5	4	5	5	3
6	4	5	5	3
7	4	5	5	3
8	4	5	5	3
9	4	5	5	3
10	4	5	5	3
NPQF	12.36	15.46	15.46	9.27
Normalize (f)	0.7500	0.5996	0.5996	1.0000
Min	9.27			

**Rate.

Table 4-21 NPQF analysis of sourcing alternatives objective 2 attribute 5 (Change of trend in technology)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	-2**	-3	-4	-5
2	-2	-3	-4	-5
3	-2	-3	-4	-5
4	-2	-3	-4	-5
5	-2	-2	-3	-4
6	-2	-2	-3	-4
7	-3	-2	-3	-4
8	-3	-2	-3	-4
9	-3	-3	-2	-2
10	-3	-3	-2	-2
NPQF	-7.76	-9.74	-12.83	-16.16
Normalize (f)	0.4801	0.6027	0.7939	1.0000
Min	-16.16			

**Rate.

Table 4-22 NPQF analysis of sourcing alternatives objective 2 attribute 6 (Change in regulation requirements)

Alternatives (j)				
Semi-annually (t)	1	2	3	4
1	1**	-1	2	2
2	1	-1	2	2
3	1	-1	2	1
4	1	-1	2	1
5	0	-2	-1	0
6	0	-2	-1	0
7	-1	-2	-1	-1
8	-1	-2	-1	-1
9	-2	-2	-2	-2
10	-2	-2	-2	-2
NPQF	1.50	-4.78	3.27	2.94
Normalize (f)	-0.3138	1.0000	-0.6841	-0.6151
Min	-4.78			

**Rate.

Table 4-23 Attribute performance score versus alternative matrix

Objective / attribute	1	2	3	4	u_k	g_k
Objective 1						
Product affordability	1.0000	0.9135	0.7946	0.7409	1	0
Quality of end product	0.9832	1.0000	1.0000	1.0000	1	0
Quality of work environment	0.9691	1.0000	0.9843	0.9777	1	0
Reliability of end product	0.9795	0.9911	0.9911	1.0000	1	0
Flexibility in product mix	0.9947	0.9974	0.9947	1.0000	1	0
Expandability of production Equipment	0.6000	0.7505	1.0000	1.0000	1	0
Flexibility in production quantity	0.9675	0.9775	0.9895	1.0000	1	0
Reliability of production equipment	0.9836	0.9890	0.9972	1.0000	1	0
Objective 2						
Employee morale	0.0000	-0.5000	0.5000	1.0000	1	-1
Opportunity for employee advancement	0.5996	0.7494	1.0000	1.0000	1	0
Clarity in company’s vision and mission	0.3333	0.5000	0.6663	1.0000	1	0
Company’s stability	0.7500	0.5996	0.5996	1.0000	1	0
Change of trend in technology	0.4801	0.6027	0.7939	1.0000	1	0
Changes in regulation requirements	-0.3138	1.0000	-0.6841	-0.6151	1	-1
Objective 3						
Net Present value	1.0000	0.9612	0.8892	0.8138	1	0

In table 4.23 the values of u_i and g_k were given in Chapter 3. For u_k this should be 1 for the ideal attributer, and g_k (anti-ideal) should be 0 or -1. See Chapter 3.

4.3 Evaluating the Performance Score

After calculating all attributes for each alternative we can start to construct table 4.23, which represents the attribute performance score versus the alternative matrix.

The decision makers performed this analysis over two time periods, one for each of the five years (a semi-annual evaluation).

As illustrated in table 4.24, the relative importance of each objective has been performed with respect to the overall decision problem. The decision makers assessed the relative importance of the objectives with respect to year 1. This was accomplished through a pairwise comparison matrix (Satty, 1980) and by using Satty's scale of relative importance which set the most important objective in year 1. By using the same scale we were able to set the second, third, and fourth important objectives for year 1.

For example, the evaluation for year 1 is: E_1= [0.4151, 0.0788, 0.3806]. These values are the weights of relative importance of the problem objectives with respect to year 1. Then we have 5 evaluations for 5 years as:

E_1= [0.4151, 0.0788, 0.3806], E_2= [0.4326, 0.0665, 0.3704].

E_3= [0.4255, 0.0796, 0.3738], E_4= [0.4055, 0.0695, 0.3917].

E_5= [0.4355, 0.0788, 0.3569].

After calculating the priorities of the objectives for each year, the decision makers proceed to evaluate the priorities of the years with respect to each objective. Now we need to weight the five years respect to objective 1. The result is shown in table 4.24 as:

C1 = [0.35, 0.18, 0.37], C2 = [0.25, 0.22, 0.25]

C3 = [0.20, 0.30, 0.15], C4 = [0.10, 0.15, 0.12]

C5 = [0.10, 0.15, 0.11].

Table 4-24 Stochastic Matrix for Problem Objectives and Time Periods

	Strategic Competitive Performance	Managerial Performance	Financial Performance	t = 1	t = 2	t = 3	t = 4	t = 5
Strategic Competitive Performance	0	0	0	0.4151	0.4326	0.4255	0.4055	0.4355
Managerial Performance	0	0	0	0.0788	0.0665	0.0796	0.0695	0.0788
Financial Performance	0	0	0	0.3806	0.3704	0.3738	0.3917	0.3569
t = 1	0.35	0.18	0.37	0	0	0	0	0
t = 2	0.25	0.22	0.25	0	0	0	0	0
t = 3	0.20	0.30	0.15	0	0	0	0	0
t = 4	0.10	0.15	0.12	0	0	0	0	0
t = 5	0.10	0.15	0.11	0	0	0	0	0

The average of each objective over the five years will give the objective priorities over the entire planning vertical. For example, objective weight B1 is calculated as:

$$\beta_1 = \frac{0.4151+0.4326+0.4255+0.4055+0.4355}{5} = 0.4228$$

$$\beta_2 = \frac{0.1868+0.2105+0.2246+0.2078+0.1828}{5} = 0.2025$$

$$\beta_3 = \frac{0.3806+0.3704+0.3738+0.3917+0.3569}{5} = 0.3747$$

and so on for the rest of the objectives' weight over the five years as shown in table 4.25.

4.3.1 Set of criteria weights

After all priorities were evaluated as shown in table 4.25, the result was summarized and evaluated.

Some of the strategic competitive performance attributes are weighted quite except some of attributes weighted lower priority which are Flexibility in product mix and Flexibility in production quantity.

In the managerial performance employee morale and opportunity for employee advancement are given higher priority compared to the two other attributes.

The change in regulation requirements had higher importance than the risk of change of the trend in the technology attribute importance.

Throughout the decision making problem, the decision makers place the objectives of strategic competitive performance and the financial performance with the greatest weight (0.4228, and 0.3747 respectively).

Table 4-25 Criteria Weights

Objective/attribute	Objective Index k	Attribute Index i	Attribute Weight, a_{ki}	Objective Weight, β_k
Optimize strategic competitive performance				0.4228
Product affordability	1	1	0.2027	
Quality of end product	1	2	0.2111	
Quality of work environment	1	3	0.2122	
Reliability of end product	1	4	0.1133	
Flexibility in product mix	1	5	0.0435	
Expandability of production Equipment	1	6	0.1022	
Flexibility in production quantity	1	7	0.0121	
Reliability of production equipment	1	8	0.1029	
Optimize managerial performance				0.2025
Employee morale	2	1	0.2198	
Opportunity for employee advancement	2	2	0.2101	
Clarity in company's vision and mission	2	3	0.1387	
Company's stability	2	4	0.0714	
Change of trend in technology	2	5	0.1205	
Change in regulation requirements	2	6	0.2395	
Optimize the financial performance				0.3747
Net present value	3	1	1.0000	

4.4 Rank Ordering of Sourcing Alternatives

With the results of Tables 4.23, and 4.25 we are ready to use the composite programming formula (Equation 3.5)

$$A_j = \left\{ \sum_{r=1}^{3} \beta_r \left(\sum_{k \in S_r} \alpha_{rk} \left[\frac{f_{ik-} g_k}{u_k - g_k} \right]^{p_k} \right)^{q/p_k} \right\}^{1/q}$$

The ranking of the alternatives is based on A_i values of the composite measures. Table 4.26 shows the rank orders of four sourcing alternatives for different combinations of distance parameters (p, q).

In our problem p_k = 1 or 2, and q = 1 or 2 seem to be good choices.

We use Mathematica software to solve this problem.

Table 4-26 Rank Ordering of Scoring Alternatives for Selected Distance Parameters

Distance Parameters	Ranking	Alternatives (j)	A_j
$q = 1$;	1	2	0.9234
$p_k = 1$;	2	1	0.8881
(k = 1, 2, 3)	3	3	0.8608
	4	4	0.8482
$q = 1$;	1	2	0.9304
$p_k = 2$;	2	1	0.8978
(k = 1, 2, 3)	3	3	0.8787
	4	4	0.8676
$q = 2$;	1	2	0.9284
$p_k = 1$;	2	1	0.9046
(k = 1, 2, 3)	3	3	0.8744
	4	4	0.8594
$q = 2$;	**1**	**2**	**0.9338**
$p_k = 2$;	2	1	0.9115
(k = 1, 2, 3)	3	3	0.8862
	4	4	0.8738

As shown in Table 4.26 the alternative 2 should be chosen based on the higher score.

Chapter 5 Conclusion and Future Work

Economic justification of advanced manufacturing systems requires more study and research due to its complex nature. Although, several articles published earlier have tried to address this issue, more investigations in incorporating intangibles in the evaluation and justification of these systems are still pertinent.

5.1 Conclusion

This research work presented a methodology for incorporating quantitative and qualitative measures in the evaluation of advanced manufacturing projects. The financial, strategic, and managerial performances of three objectives of the model were presented. The methodology used the Scale for Evaluation of Qualitative Attribute Performance proposed by Saaty and Kearns (1985) which was adapted to obtain the net present qualitative flow (NPQF) and net present operational flow (NPOF) of given alternatives. The model presented in this study used a large number of qualitative attributes associated with each proposed alternatives. The net present quantitative flow, NPQF, converted each net present value into a scale in which the attractiveness of alternatives are ranged between (-1) and (+1). Furthermore, this study developed a net present operational flow, NPOF, which is conceptually similar to net present quantitative flow and required the decision maker to gather estimate for each alternative during each time period.

Measures of the performance of the objectives were evaluated using composite programming. The analysis presented in this research provided a ranking of alternatives. In addition to the alternatives' ranking, the analysis provided an understanding of the objectives that help and support the evaluation of advanced manufacturing projects.

Composite programing as presented in this research provided a unique approach to measure both qualitative and quantitative attributes which co-exist in advanced manufacturing systems. The numerical example was provided to demonstrate the application of the proposed methodology.

This research methodology can be used by decision makers to analyze the economic feasibility of alternatives incorporating both qualitative and quantitative features. The contributions of this research include:

- Objective assessment of both quantitative and qualitative attributes in a unified and simple approach.
- The presented methodology which possesses a unique feature that allows both qualitative and quantitative attributes included in the decision process.
- Incorporating both strategic and tactical objectives in decision process and allowing decision maker to generate a better and informed conclusion.
- Methodology which allows decision makers to rank alternatives and select the most desirable candidate.

As manufacturing systems features and abilities become more advanced and complex, justification methods must be able to keep up with these advances and be responsive to the needs of the decision maker.

5.2 Recommendations for Future Work

Chapter 4 presented the application of the proposed methodology using a numerical example.

The following includes some recommendations for future work to further enhance the economic justification methodology.

- The economic justification process requires the inclusion of several elements that are intangibles and hard to be quantify. In this research it was assumed that all attributes are independent. The future work must concentrate on situations where attributes are interdependent and the selection of one may positively or negatively impact others.
- The ease of calculation and simplicity of a method undoubtedly increases its popularity and acceptance by the decision makers. The future work must equally focus on the ease of implementation and demonstrates the methodology's robustness.
- All strategic and tactical attributes in this study assumed to be equally important and no weigh was assigned to rank them according to some order. The future work should incorporate the situation in which both strategic and tactical attributes are ranked based on their relative importance and recommended alternative truly represent the preferred choice.

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