THE USE OF PORTFOLIO MANAGEMENT WITH TARGET COSTED PROCESS ORIENTED PRODUCTS UNDER CONDITIONS OF UNCERTAINTY

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(ABSTRACT)

The present trend towards shorter product lives means that manufacturers are faced with less time whereby production costs can be controlled and reduced. As a result many companies are turning towards the use of Systems Engineering and cost management techniques that are intended to reduce product costs during the design phases of the product life.

One of the many cost management tools that are presently in use is target costing. An iterative process, target costing attempts to reduce the cost of manufacturing products by using value engineering techniques so that identified target costs can be realized. As a step improvement program, the ability of a company to obtain its target cost in not always certain. Target profits from individual products are grouped together into portfolios and then managed according to company strategic profit plans.

This report investigates methods used for identifying the uncertainties that can exist in the target costing process and suggests the potential use efficient portfolio techniques for the management of process oriented or continuous products.

The report also suggests a number of follow-on projects that could encompass the use of specific decision support systems for the examination of both target costing uncertainties and portfolio management.

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GLOSSARY

TARGET COST - a modified standard cost of a product for a given quality level as derived from customer requirements and competitive constraints. The cost relates to the entire life cycle of the product, the setting of a target cost has to take into account future technology and process developments.

TARGET COSTING - a comprehensive cost planning, cost management and cost control concept which is used primarily at the early stages of product design in order to influence product cost depending on the market-derived requirements.

DESIGN TO COST - for the purpose of this report, Design to Cost refers to the efforts of management and production personnel in attempting to design a product to meet identified target costs. This principle is the main initiative of cost planning and control in the design phase.

TARGET PROFIT - although there is no generally accepted definition of target profit it is usually considered to be application of Return on Sales that a company sets. It is based on long-term profit planning and depends on factors like corporate strategy, business sector and competitive situations.

VALUE ENGINEERING - the systematic analysis of product function structures in order to influence and balance their costs versus their benefit and thereby increase the value of the product. The object of value engineering can be products, their manufacturing processes or means of assembly.

CHAPTER 1

INTRODUCTION

The development and design phases of the product life cycle are now recognized as the areas where significant cost savings can be made in the manufacturing of a product. The short life cycle of manufactured goods demands that costs savings be planned for and designed into a product long before the first system comes off the production line.

1.1. THE SYSTEMS ENGINEERING APPROACH

Systems engineering is a structured procedure which serves to apply both scientific and engineering efforts to create a well defined and designed product or system based on established customer needs. While often it is popular to address only certain segments of a product's cost, Systems Engineering stresses the total life cycle perspective associated with the development and design of a product. Systems Engineering includes the application of effort to:

1. *Transform an operational need into a description of system performance parameters and a preferred system configuration through the use of an interactive process of functional analysis, synthesis, optimization, definition, design, test, and evaluation;*
2. *Incorporate related technical parameters and assure compatibility of all physical, functional, and program interfaces in a manner that optimizes the total system definition and design; and,*

3. *Integrate performance, producibility, reliability, maintainability, manability, supportability, and other specialties into the overall engineering effort* [1].

Figure 1.1 depicts the life cycle of a product and serves to illustrate how the upstream efforts during the development and design phase can either positively or negatively influence the cost of the system's or product's useful life.

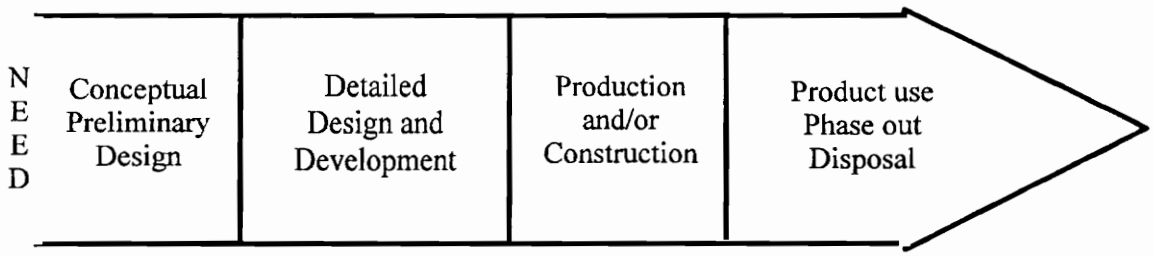


Figure 1.1 The System Life Cycle [2].

The inclusion of Systems Engineering in a product's life cycle should assist in establishing the requirements to which the system or product is to be designed, tested, produced and supported. Ideally the design parameters should identify a product's performance, effectiveness, capacity, accuracy, size, reliability, maintainability, and desired manufacturing process. Clearly this type of integration can only be accomplished through an interactive process involving the classical engineering design disciplines of electrical, mechanical and so on, but also through the inclusion of support disciplines of human factors and logistic engineering, marketing, accounting and production functions.

In considering the economics of design for a product, a multitude of factors and contributors that can occur throughout the life cycle must be considered and examined.

An overview of some of these considerations, as they can be related to a particular phase of a product life cycle, are demonstrated in Figure 1.2.

From Figure 1.2 it is clear that many considerations go into determining the total life cycle cost of a product, but it should be concluded that many of the early decisions regarding costs and product configuration will have a large impact on most of the later costs in the life cycle.

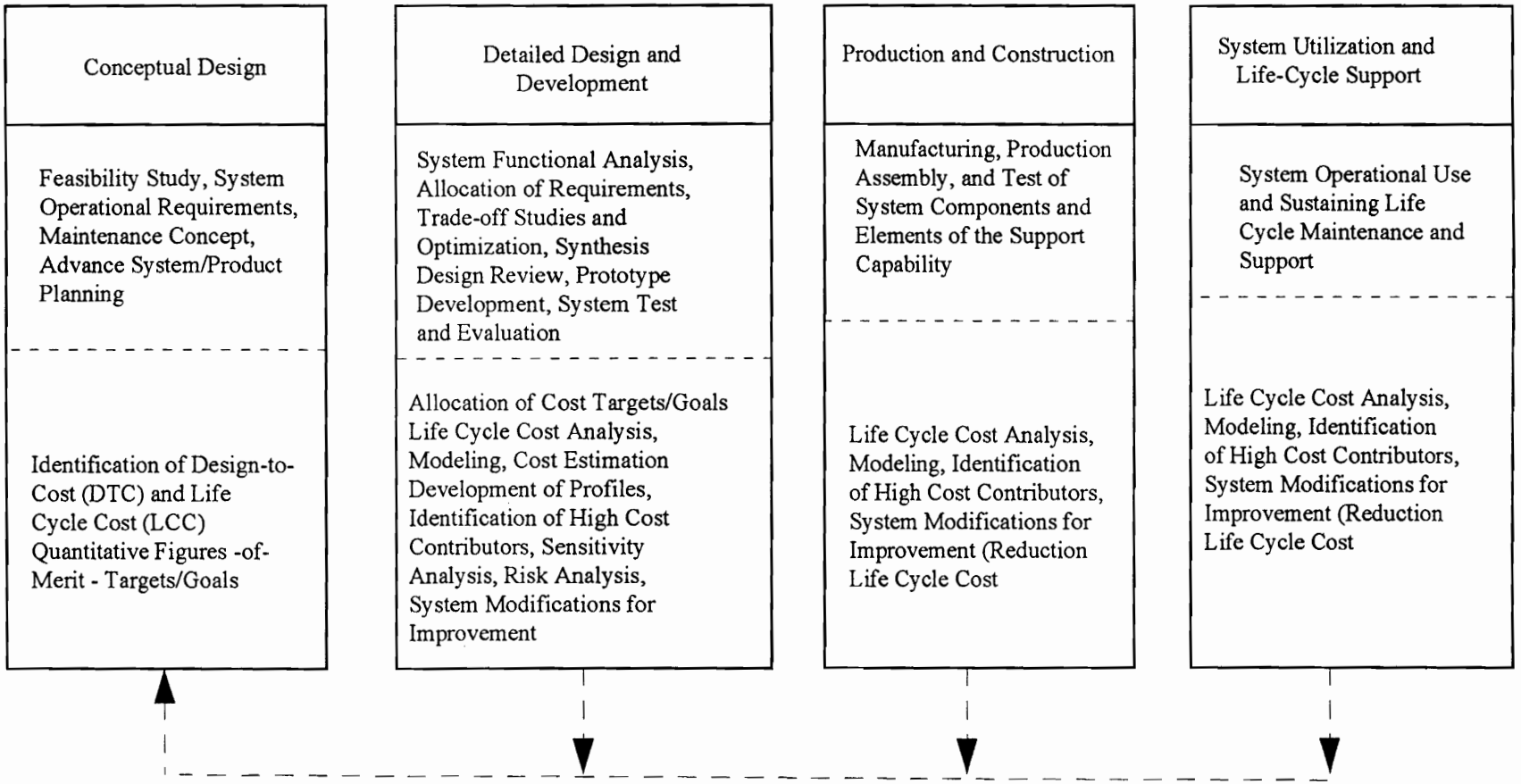


Figure 1.2. Cost Consideration in the System Life Cycle [3].

1.2. THE REPORT DOMAIN

The emphasis of this report, in terms of the Systems Engineering process, is concentrated on the development and design phases. At this time in the product life cycle the overall product or system design configuration has been established, and now the process must be converted into the final design by means of hardware, software, assembly and component purchases. The overall process includes:

1. *Definition of system elements*: subsystems, units, assemblies, lower-level component parts, software, data, and the elements of logistic support (spare/repair parts, test and support equipment, facilities, personnel, technical data);
2. *Preparation of design data*: specifications, drawings, databases and electronic data files, trade-off study reports, analysis results, predictions and so on, describing all facets of the system;
3. *Development of physical models of the system or major system components*: engineering laboratory models, service test models, mock-ups, and prototype models for the purpose of test and evaluation; and,
4. *Conductance of system integration and test*: the verification of system characteristics and that requirement have been met. Deficiencies are noted and corrected through redesign, system modification and retest as necessary [4].

These steps and guidelines will be carried out according to specific checklists and processes which would include the application of design criteria, analysis and trade off studies, and the utilization of design aids. A cost management tool that can facilitate the Systems Engineering process during the development and design phase is target costing.

Target costing is an emerging cost management tool that incorporates a number of Total Quality Management techniques and concepts that attempt to improve the overall effectiveness and efficiency of a product design before the product is produced. The primary objective of target costing is to design a product so that it can be manufactured for the lowest possible cost and meet the customer's needs. In essence the process involves identifying an ideal cost for a product and then designing and manufacturing the product, to that identified cost, using engineering techniques.

Although commonly used in Japan, target costing has only recently become a management tool that is accepted in the United States. As such, there is limited knowledge and a lack of printed literature, in English, on the subject of target costing.

1.3. OBJECTIVE

The objective of this report is to provide a further understanding of some of the concepts involved in and related to target costing and to investigate the possible use of a portfolio management technique with target costing. Specifically, the report will consider the use of efficient portfolio analysis as a management tool for use with target costing on continuous or process oriented products when normally distributed uncertainties are introduced into the process.

It is hoped that the report will spawn new inventive ideas for additional research into the topic and result in a better overall awareness of tools that can potentially be used with target costing. As an emerging cost management method in US industry, target costing has numerous applications that can be explored and exploited.

1.4. ORGANIZATION OF THIS REPORT

This report is organized into eight chapters. The general goals and objectives for this report are presented in this chapter. The background and overview of target costing

are presented in Chapter 2. The consideration of portfolio management under conditions of uncertainty is introduced as an area within target costing where additional investigation and research could be undertaken.

Chapter 3 examines some of the common management tools that can be used with target costing. Specifically, the Cost Breakdown Structure and the computer software program ISECOST are examined. An examination of manufacturing uncertainties and a possible method for their inclusion into the target costing process are presented in Chapter 4.

Efficient portfolio management for the continuous product case is introduced in Chapter 5 and the relationship between stock market portfolios and continuous products which are target costed is examined.

Chapter 6 details how quadratic programming can be used to optimize a portfolio and create one which is efficient in terms of minimizing risk and uncertainty. The use of a software program called "Investmaster" is introduced in this chapter. Chapter 7 illustrates an alternative method for the determination of expected target profits and the related variances which can be used in the quadratic programming algorithm for the creation of an efficient target costed portfolio.

Finally, Chapter 8 presents the findings and conclusions of this report and presents recommendations and potential research extensions.

CHAPTER 2

TARGET COSTING

In today's business world every company is looking for a competitive advantage that will enable them to position themselves ahead of their competitors. The three primary areas where companies attempt to obtain a competitive advantage are concerned with time, quality and production costs. A myriad of management tools are available for companies, large and small, to employ in attempts of obtaining even slight advantages in bringing their product to market. The concentration of this report will examine the process of utilizing management tools that reduce life cycle costs and employ pro-active cost cutting techniques. In most instances, the effective use of these management tools and procedures is accomplished during the design phase of the life cycle, long before the first product ever comes off the assembly line. One process, which is becoming more prevalent as a design and development management tool, is Target Costing.

2.1. COST MANAGEMENT

Generally speaking, cost management tools are required by businesses to accomplish a variety of functions. These tools are used to provide guidance in strategic and cost planning, cost control, performance measurement and waste management. Clearly, one cost management method or tool cannot meet of all these objectives.

The shortening of product lives has also had a powerful effect on the manufacturing mind set and on the operation of companies. Product life cycles are often only one or two years in length. The design of automobiles, for instance, changes annually, while the life cycle of high-tech electronic based products is sometimes shorter than one year in length. Consumers, meanwhile, are demanding these new and varied products at a record pace. Traditionally, the cost controls for products and equipment

were applied during the manufacturing phase of the life cycle. Now, given the short life cycle of products, most cost cutting measures cannot be implemented before production is completed. Once a product design is finalized and production is started, there simply is not much that can be done to reduce cuts before the production line is shut down and reconfigured.

Manufacturers have learned that to be effective, cost management must be applied during the development and design phases of a project. In recognizing that more than 80 percent of product cost is determined by the time the product design and processing is complete, cost management must start at the conception and design phases [5]. The importance of using costing tools during the development and design phase can be illustrated when a product life cycle is examined. Figure 2.1 shows how the cost of life cycle phases must change to accommodate the shorter product life cycles, if cost controls are to be used.

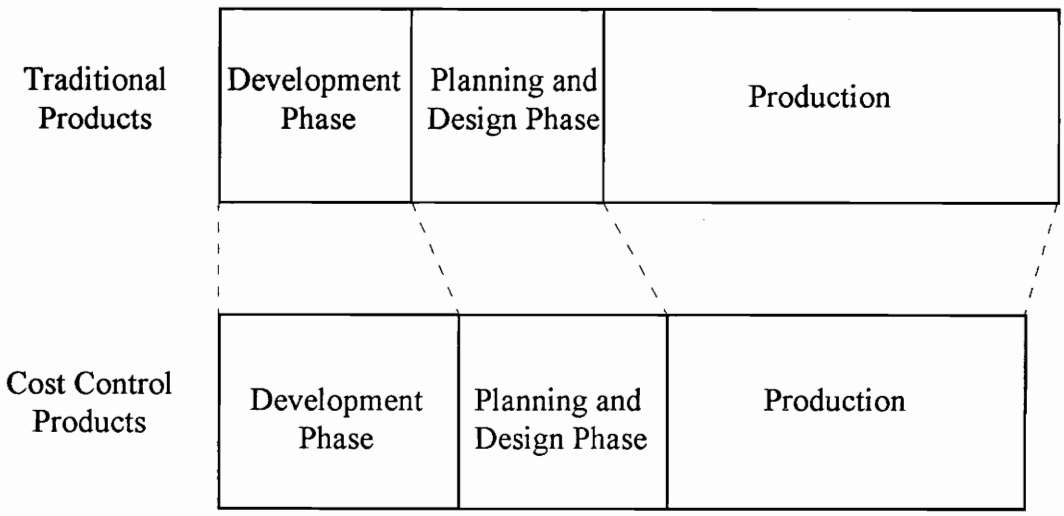


Figure 2.1. Comparison of costs between traditional and cost control products [6].

The focus of cost management is being switched from the production stage to the upstream stage of product planning and product design. Managers must recognize that cost management, to be effective, also has to be connected to a company's long term profit and financial strategy. This coupling of strategy and practice forces a company to focus efforts on profits and products with an integrated plan.

Comprehensive cost management techniques have also shifted the emphasis away from the "How much does it cost?" syndrome. Historically, manufacturers in the United States have examined the product cost question as an after the fact analysis. Once a design is finalized the new product is evaluated in the accounting department. The cost of material, labor, and other manufacturing overhead is established using standard accounting procedures. The marketing department is then asked to determine whether the new product could be sold how many can be sold annually, and more importantly asked how much the product could be sold for. This type of product design and development technique results in a biasing towards the manufacturing of certain products. By basing the selling price of a product on what the product costs to produce, this process avoids products that involve high quality, and high priced products, that also incur high production costs, and favors products that are cheap to produce.

The use of target costing, as a cost management tool, helps avoid this historically popular approach to costing. The process promotes the evaluation of products based on their respective profit producing capabilities over the long term.

2.2. BACKGROUND OF TARGET COSTING

The underlying theme of target costing is "What should the new product cost?", and not "What does it cost?". While traditional costing techniques have generally been concerned with looking backwards in order to calculate product cost and profitability, target costing is concerned with developing product and process costs in a more pro-

active and forward-looking manner. Although there is not one completely accepted definition, target costing can be defined as a cost management tool for reducing the overall cost of a product over its entire life cycle. The main purpose of target costing is to reduce cost at the planning and design phases of the product life cycle, i.e. at the upstream stage of the production process [7]. This goal is accomplished with the help of production, engineering,
R & D, marketing and accounting departments. Target costing, used for product planning, can be seen to have had origins in the evolution of management by objective. The objective is to make a quality product at the lowest possible cost.

As a tool, it is especially popular among high-tech companies in order to achieve high productivity and strong competitiveness. Originating in, and now widely used in Japan, target costing has made a relatively recent emergence in North America. Although the concept became known to many US companies in the mid to late 1980's, companies are still evaluating and testing target costing for practical applications. Based on 1992 data taken from Japanese firms, there are a high percentage of firms using target costing.

The statistical breakdown of industries that demonstrate substantial use of target costing are the automotive industry (100%), followed by the electrical industry (88.5%), and then the production of machinery (82.6%) and precision equipment (75%). The industries that show limited use of target costing would be chemical/ pharmaceutical industry (31.6%), Food (28.6%), steel (23.1%) and pulp/paper (0%) [8].

The departments of a standard company that utilize target costing techniques are design (22.0%), accounting and product planning (both 17.6%), production technology (14.3%) and development (12.1%) [9].

Within most companies target costing is essentially a team oriented and cross functional process. In Japan the normal composition of a target costing team is made up of the following functional groups; production technology (73.6%), design

(70.8%), purchasing (67.9%), development (54.7%), marketing (46.2%), manufacturing (45.3%), product planning (41.5%), and accounting (37.7%). Normally no one person is assigned the responsibility for the target costing process [10].

The exact use and goal of using target costing varies from company to company. Atsugi Motor Parts, part of Nissan Motors, is credited with first using target costing in 1976. It was used "to reduce the current level of standard costing by autonomous efforts for improvement at each plant." More simply, target costing was used in conjunction with the company's TQM program to reduce costs at each plant [11]. Daihatsu Motors used target costing to establish a plant strategy which attempted to control cost by the use of automation and flexible manufacturing. Target costing provided the tool through which profit maximization could be measured [12].

Realizing that there can be differences in exactly how target costing is employed between companies, there are recognizable practices that all companies use. Most companies establish a target cost at the design phase then work towards obtaining the prescribed goal. There are three general methods for setting target costs:

1. *Derive the target cost from profit planning.* A "top down" approach where the target cost is derived from sales and target profit. No input on setting the target cost comes from lower management.
2. *Derive target cost from engineering planning.* A "bottom up" approach where engineers estimate target costs depending on technical skills and experience, and the availability of facilities.
3. *Combine the two methods.* A combination of the "top down" and the "bottom up" approach. Target costs are more akin to top management decision makers but these types of decisions need the cooperation and

support of employees. It is generally felt that the combination method is the most successful [13].

As a simple overview of the process target costing typically uses three distinct steps in its application:

1. Planning and design products of high quality that best meet customer's needs.
2. Setting the target cost for the products and then establishing the target cost by applying Value Engineering (VE)
3. Attaining the target cost at the production stage, using standard costing.

2.3. APPLICATION OF TARGET COSTING

The application of target costing generally can occur in one of two ways. In the first method a company receives an order from a customer for a product and a project is created to consider the feasibility of the proposal. Marketability, potential market size, and the exact needs of the customer are all examined during this project planning phase. In the second alternative, a company is considering entering into production of a new product or product line. In either case appropriate cost estimates are prepared at this time by comparing cost data from similar products and projects. Once cost estimates are finalized, the completed proposal is reviewed by a project review committee.

2.3.1. Target Costing Process

After the review is finished a final decision is made as to whether to accept the new product proposal. If the project is approved an engineering development plan is created. The plan includes the basic development concepts, quality standards, production facility requirements, and development schedules. An overview of the target costing steps and procedures are shown in Figure 2.2.

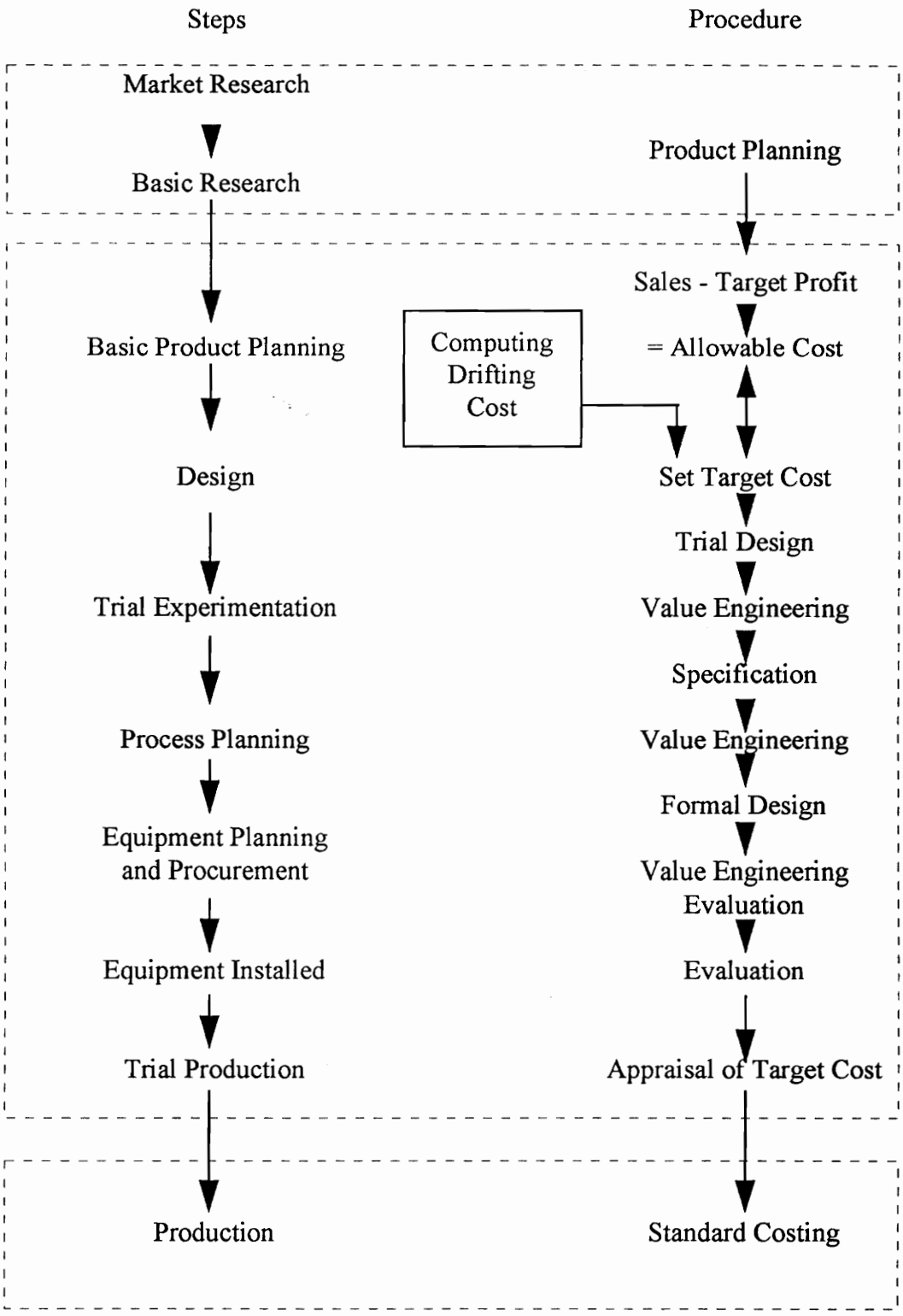


Figure 2.2. The production steps and management procedures in Target Costing [13].

The first phase of the target costing procedure is product planning. This product planning is comprised of the action that is taken that culminates in the creation of an engineering development plan.

The second procedural step is to establish a target cost for the new product. The setting of target costs is not a simple and straightforward process. In the case of a new product, first a target selling price must be established by the company. Often the target selling price is set by evaluating market research, competitive research, and the needs of the users. This form of target pricing is called *market into company* and according to Sakurai [14] is considered to be the most valid approach to target pricing. Other approaches to establishing a target price are by using secondary information in order to avoid the inherent problems of doing a complete market research study.

The target profit is derived from profit planning and is set by management according to long term profit planning and the cost of capital. Target profit should be based on factors like corporate strategy, industry outlook and the competitive situation. In most instances the target profit is expressed as a percentage of target price, and thus in a sense is similar to profit margin. The target profit, which a company wishes to obtain, is deducted from the target selling price. This new profit reduced figure is called the allowable cost. The allowable cost represents the highest acceptable cost for the product based on the level of quality required by the customer and competitive forces involved. A drifting cost is then established. The drifting cost is the estimated cost of producing the product using the existing technology and procedures in the company. The difference between the drifting cost and allowable costs represents the cost that the target costing process is trying to eliminate. A simple numerical illustration of target price, profit, allowable cost and drifting cost is shown in Figure 2.3. In reality the target cost and allowable cost are the same.

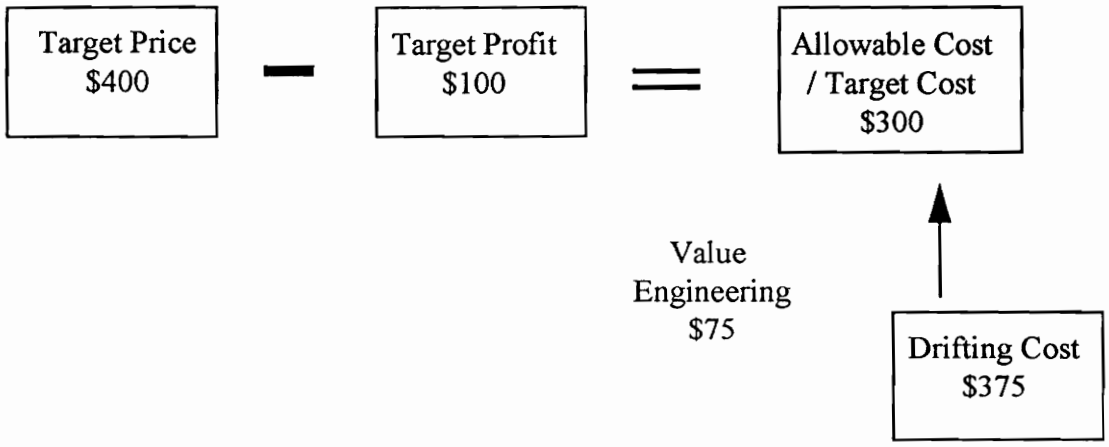


Figure 2.3. Practical Example of Target Costing [15].

In Figure 2.3 the target price for a product is set at $400. The company, based on its strategic profit planning model, has determined that it wishes to realize a target profit of 25% or $100 on this product. Therefore, the allowable cost or target cost is set at $300. The company then assesses what it would cost to make the desired product using their present manufacturing and costing techniques. In this example, that amount is determined to be $375. The present method manufacturing cost is now defined as the drifting cost. The difference between the drifting cost and the target cost, $375 - $300 = $75 in this case, is the production cost that the company will attempt to eliminate by the target costing process. This reduction in production cost, of $75, is the amount that value engineering will try to remove.

Once the target cost is established the real work begins. It is now the goal of production personnel to manufacture the new product at the target cost. The reduction of drifting costs, towards allowable costs, is an involved process that may require taking many incremental steps. As illustrated in Figure 2.2 a trial design is made and then

reviewed with the intent of cutting manufacturing costs without adversely affecting quality or performance. Often the process involves the breaking down of products into components and cost drivers in order that cost reductions can be realized. The primary tool used during this cost reduction process is value engineering. The value engineering process will be discussed in more detail in Chapter 3. The target costing procedures generally require that the product design is passed back and forth between design prototyping reviews and value engineering analysis until a final design is evaluated and appraised as having met the desired target cost.

The final step in attaining target costs is the initiation of the actual production activities. Actual production costs are tracked using the standard costs of manufacturing and measured against the target cost figures. Characterized as an effort to reduce standard costs by autonomous improvement efforts, the real challenge of attaining target costs starts with production activities. Production staffs monitor and report on all performance records shortly after production starts. Abnormal events or unexpected costs are investigated in order to ensure that target costs are met. This is when some additional improvements to problems areas can be investigated, solutions tested and potential cost savings identified.

2.3.2. Target Costing Ideology

It should be remembered that the allowable cost that production is striving to meet is in fact top management's dream. Target costs are generally very hard to attain and usually considered to be impossible in the short-run. The goal of target costing is to drive the cost of producing a product down so that the product can be sold for less than a company's competitor. If the process was easy the competitors would already be doing it. The proper use of target costing demands that a concerted and continuous effort be made

in order to obtain the goals of the process. Target costs are attainable, but not without a great deal of effort.

Medium to long-term profit planning must be in place to incorporate target costing. This longer run profitability (as opposed to short term) assessment is crucial because target costs are not usually obtained immediately. Without forward thinking about longer term profit positioning, management may exert pressure to lower costs unrealistically because of short term profit squeezes. Too much of this short term profit pressure has at least two negative consequences. First, there will be a tendency to reject the production of highly profitable products. And second, the intentional lowering of standard costs to appear profitable may be undertaken, when in reality the costs cannot be achieved even in the long run.

In general it is felt that new products must meet certain target profits. If these target profits are not met, then the products are continually redesigned until they meet set target profit goals. This continual redesigning process presumes that the target cost can be reached while still attaining the desired quality and performance by the consumer.

Finally, target costing has for the most part been applied to assembly line or discrete products. By the nature of their short life cycles these products are subjected to many design changes and reconfigurations over relatively short periods of time. Therefore, there is a strong requirement to reduce the product's cost during the design phase of the product life. Conversely, there has been less extensive use of target costing with continuous or process oriented products. However, recent research has indicated that a growing number of process oriented companies are using target costing [16]. Due to the ever increasing variety of components and ingredients that go into making up many process oriented products, target costing is also becoming more important for use during the design and production phases of these products. Target costing techniques have been used successfully in the glass, textile and petroleum manufacturing industries.

2.4. TARGET COSTING CONCEPTS

Within the use of target costing there are a number of management tools and concepts that can assist and further develop the target cost decision making process. Two of these concepts will be further discussed and examined in this report.

As target costing has evolved and developed in the United States, a number of subtle changes have occurred in how it is employed and connected with profit planning. It has recently been suggested that some type of portfolio management should be employed when target costing is being used. Specifically, it is recommended that products should be grouped together in order for a production department to meet its identified target profit [17]. The true value of this portfolio management concept is fully realized in process oriented product manufacturing. Certainly, within the continuous manufacturing industries of textiles and petroleum, a number of sub-products or components are combined in order to minimize the cost of the final product and maximize the potential profits.

In dealing with the examination of process oriented or continuous products in this report, the end product sold to the consumer will be referred to as the product portfolio and the sub-products or ingredients of the portfolio will be referred to as its components.

The portfolio management process suggests that a strategically set target profit for each production period be identified for product portfolios. The profitability of each product portfolio is the focus rather than the profitability of individual components. The desired target profit is obtained by the sharing of individual target profits between components in the same group. The sharing or trade-off made between components will be dependent on where in the life cycle a product is and on the role that a product plays in its present market. In this way, the implementation of long-term strategies can be accomplished through the firm's focus on the profitability of portfolios and the role that

each component plays for the product group. Culp Inc., a textile manufacturer located in North Carolina and a target cost user, suggests that at any given time there will be several products within a portfolio that do not meet the target profit goals for a variety of reasons[18]. During these instances efforts are expended on assuring that the entire group is above target goals and that the portfolio's compensation and standing are based on the entire portfolio's standing. Of course, even though portfolio target costs are being achieved Culp engineers continue to implement improvements on the individual products that may not be obtaining the desired target profit.

Exactly how this portfolio management and the trade-off analogy is to take place is not presented, but a number of reasonable observations and assumptions can be made regardless of whether discrete or continuous products are being considered.

First, it should be assumed that, while target cost and target profit expectations for a given product have been calculated using sound accounting and manufacturing procedures, they are both subject to uncertainty. It would seem likely that periodically, if not frequently, the actual cost for a product or a component would be either above or below the desired target cost due to any number of reasons. Consequently, this fluctuation in target costs will also result in an uncertainty in attaining the identified target profit.

Second, it should be assumed that the potential uncertainties of individual components becomes even more important when components are combined and grouped together into product portfolios. Clearly, in the continuous process industry, management decisions involving target costing results will be improved if the relative risk associated with each product and the manufacturing of each components can somehow be brought into the analysis.

The factors that cause variations in the costing of products can be numerous and should not be assumed to effect all products in a similar manner. A factor that causes a

positive variation for one product may well result in a negative variation for another. More simply, different products could be either positively or negatively correlated or just fluctuate independently of each other. In general, the target costs of a particular component could be exceeded due to increased costs in material, labor or the cost of processing. Target costs could be surpassed due to decreased material costs or new manufacturing technologies. Finally, the variations of the actual costs and profits that a company observes are assumed to follow a normal distribution.

Finally, if target cost techniques have been employed on product portfolio components, the resultant product portfolio will have a target profit and standard deviation values that represent an aggregate of the components. In considering that a continuous product company will have more than one product portfolio that it wishes to manufacture and market the company involved will want to create a mix of product portfolios that could be identified as best meeting their company identified target cost and risk tolerance.

An overview of how target costs can be identified and the tools for completing the target costing process will be examined in Chapter 3. The examination of how uncertainties can be included and addressed in the target costing process will be the subject of Chapter 4.

CHAPTER 3

MANAGEMENT TOOLS USED DURING TARGET COSTING

Although target costing can be identified as a prominent instrument for use within the systems engineering process, there are a multitude of other management and management science tools that can actively contribute to both a target costing and systems engineering cost reduction process. In general, there are two types of product cost reduction tools that are used with target costing. These are tools that are used primarily in the pre-production phases of the product life cycle and tools that are used in the production phase of the life cycle.

3.1. PRODUCTION COST REDUCTION

The primary cost reduction tool used during the production phase of a product's life cycle is Kaizen costing. Although not directly translated into English, "Kaizen" refers to continuous accumulations of small betterment activities rather than massive innovative improvements [19]. It should not be thought of as a discrete instrument, but rather as a whole range of measures and initiatives which have to be adapted to the conditions of the specific production processes and products involved.

By its continuous nature, Kaizen costing is not finished once cost reductions have been identified and implemented. The goal of this cost reduction process is for the product and the overall production process to be continuously examined for additional potential savings throughout the product's life cycle. Finally, it should be noted that Kaizen costing is primarily a bottom-up approach of cost reductions. This is to say that most of the ideas and suggestions for cost reductions come from the production workers who are closest to the production process and product. Given the fact that products have

ever shortening life cycles the amount of effective cost reduction that can be accomplished during the production phase is becoming somewhat limited.

3.2. PRE-PRODUCTION COST REDUCTION

A multitude of cost reduction tools exist for use with the target costing process during the pre-production phases of the product life cycle. A target costing system cannot be implemented successfully without the support of standard costing or budgeting as well as such cost reduction tools as JIT, activity based costing, Total Quality Management (TQM), as well as many others [20]. An overview of two of the more popular tools that support the target costing process is discussed.

3.2.1. Value Engineering

The techniques of value engineering were first developed by General Electric in the 1960's [21]. As the process was first applied, it was aimed at reducing the cost of parts that General Electric purchased. As such the initial use of value engineering was not linked to corporate target profit and target costs as it now is in Japan[22].

The basic idea behind value engineering is that products and services have functions to perform and their value is measured by the ratio of these functions to their cost. In essence cost measures are made by regarding how valuable a part, process or component is to the overall product. The evolving concept of value engineering is similar to good Systems Engineering practice in the sense that they both are:

1. Ideally applied during the development and design phases;
2. Applied to products, their manufacturing processes and the respective means of production; and ,
3. Attempt to increase the value of the whole system[23].

In simple terms, value engineering is the systematic analysis of investigating a product design in order to see where and how that product's design could be changed in order to produce it at a lower price. These changes are implemented with a concern for the total life cycle costs and the requirement to still meet customer needs. As a specific example, value engineering activities for a product could examine the quality of the product's material, the thickness of the material used in the product, the number of parts in its make-up, the coating or painting requirements of the product, etc. Value engineering is the mainstay of the target costing process.

3.2.2. Quality Function Deployment

Recognizing target costing as an iterative process, it benefits from another tool that is able to pass and sort information in a simple and useful manner. One very useful tool which can be used to accomplish this task is the quality function deployment (QFD). The QFD tool allows for the examination of trade-offs between cost and design specifications by compressing diverse information into a small space in a way that it is easily understood. The heart of QFD is a matrix as shown in Figure 3.1.

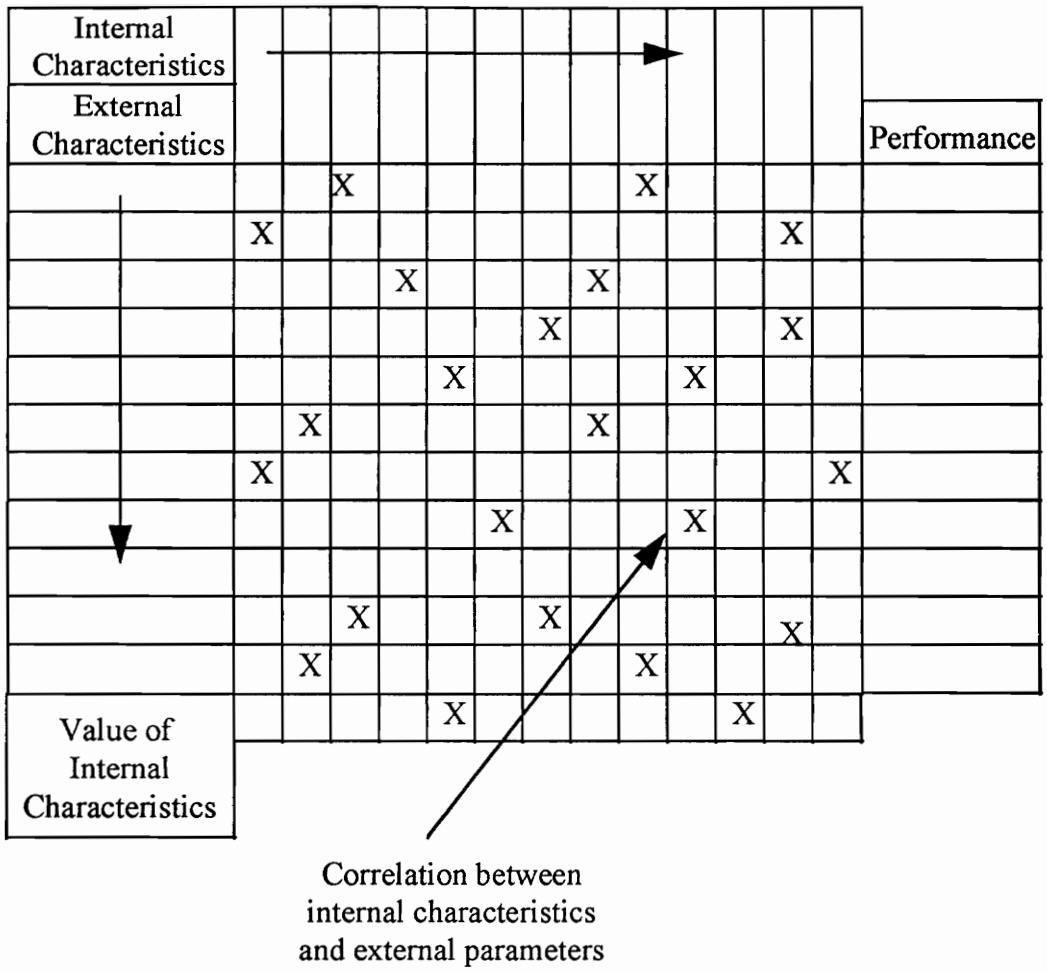


Figure 3.1. Quality Function Deployment Matrix[24].

The vertical sides of the matrix are a statement of the customers requirements and the values that the customer expects and actually receives. The top of the matrix lists the internal characteristics of the product while the bottom represents a measurement of the characteristics, comparing the product with those of the competitors. In this way designers can compare their product with that of a rival, and its performance with that expected by a customer. The matrix also relates a product's internal operation to its functional performance. Once the relationship between the internal and external

characteristics is understood, the trade-offs between cost and design specifications can be made.

In terms of use with target costing, a less critical aspect of design specification or an area where the expectations of the consumer are being exceeded, as identified by the matrix, are potential areas where cost saving could be incorporated.

3.3. COST BREAKDOWN STRUCTURE

A management tool, which is primarily used in Systems Engineering analysis, has a worthwhile target costing application. This tool is the Cost Breakdown Structure (CBS). Although similar to the Work Breakdown Structure (WBS), the CBS is better suited for the application to the analysis and evaluation of product costs used in the target costing process. The WBS generally serves as a program management tool and is most often used for contracting purposes. The basic steps in a life cycle cost analysis, which includes the CBS, are illustrated in Figure 3.2.

In the traditional life cycle costing analysis, CBS is used to provide a mechanism for analyzing the initial cost allocation, cost categorization, and cost monitoring and control. In the target costing application, CBS can provide the framework to link manufacturing processes, functions and activities with resource and cost requirements. It can provide verification of cost drivers and effectively group product components or processes. A typical listing of the major categories of the CBS are illustrated in Figure 3.3. These boxes are further broken down as may be required in order to give a more complete description of cost elements and drivers.

Step	Activity
1	Define the Problem
2	Identify feasible alternatives- configurations to be evaluated through the LCC analysis
3	Design the alternatives in terms of the system requirements
4	Develop cost breakdown structure
5	Develop a cost model that is sensitive to the problem at hand
6	Estimate the appropriate costs for each activity and for each year of the projected life cycle
7	Develop a cost profile
8	Develop a cost summary
9	Accomplish a break-even analysis
10	Identify the high cost contributors
11	Accomplish a sensitivity analysis
12	Accomplish a risk analysis
13	Recommend a preferred approach

Figure 3.2. Basic Steps in a Life Cycle Cost Analysis[25].

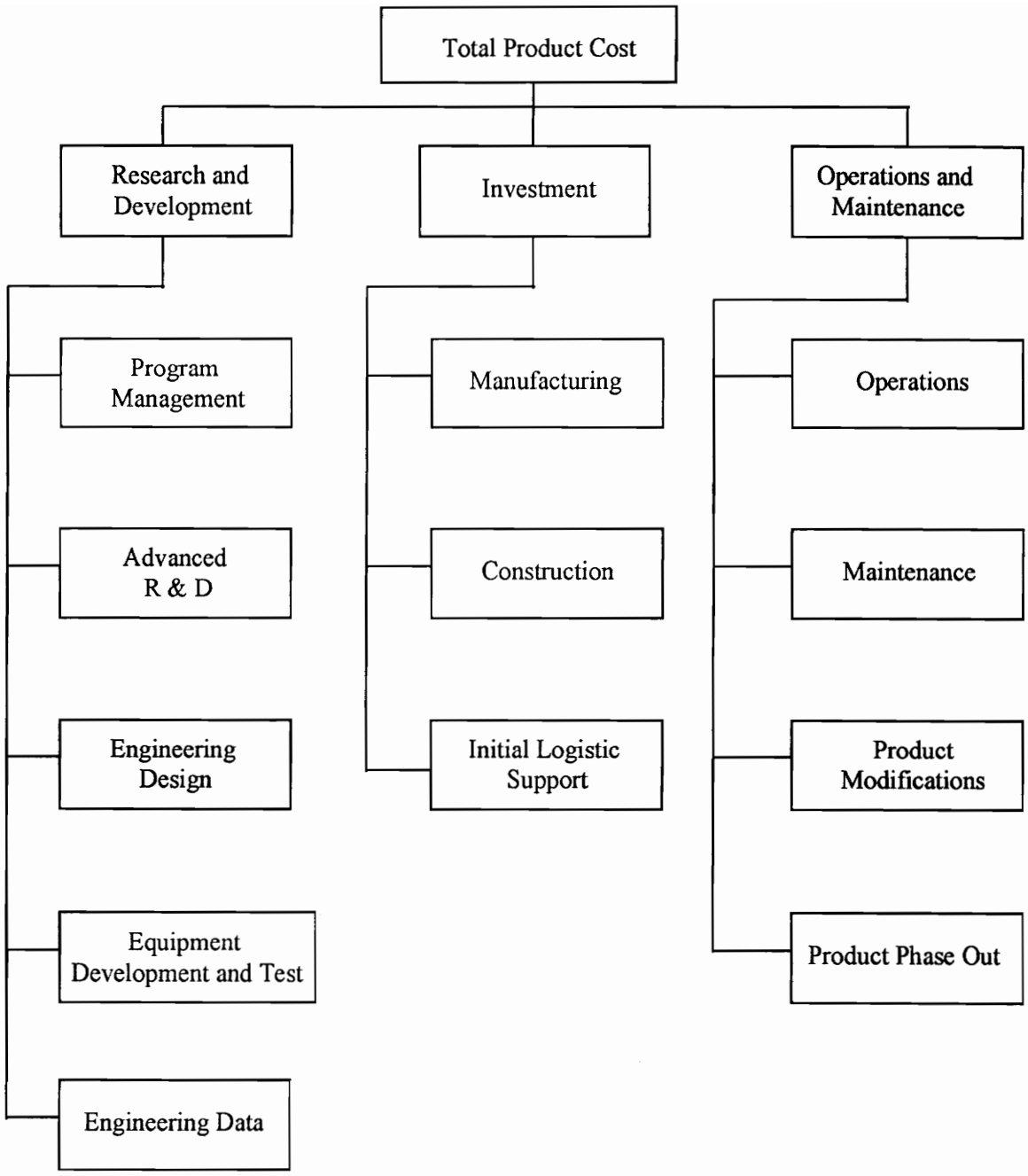


Figure 3.3. Cost Breakdown Structure[26].

Although the CBS is usually tailored and adapted to meet the needs of individual projects and products, each CBS should contain the following characteristics:

1. *All life cycle costs should be considered and identified in the CBS. This includes research and development cost, production and construction cost, operation and system support cost, and retirement and disposal cost.*
2. *Cost categories are generally identified with a significant level of activity or with a major item of material.*
3. *Cost must be broken down to the level necessary to provide management with the visibility required in evaluating various facets of product design and development, production, operational use, and support. Management must be able to identify high cost areas and cause and effect relationships.*
4. *The CBS and the categories defined should be coded in such a manner as to enable the separation of producer costs, supplier costs, and consumer costs in an expeditious manner.*
5. *When related to a particular product or program, the cost structure should be directly compatible with other planning documentation* [27].

The depth and breadth of the CBS will depend on the intended use and purpose of the CBS, but in most instances they must be taken down to a level that ensures that accountability and cost controls can be assured. As a baseline guide, the depth that a CBS is taken to should meet two basic costing goals as listed above. First, it must provide the information necessary for a meaningful and valid analysis of the system or product. And second, it must identify the high cost contributors and cause and effect relationships.

With regards to the target costing process, a properly developed CBS provides design and production engineers with a structured tool that promotes the examination and

analysis of the costs and production processes that contribute to a product's total cost. While there might be an inclination to ignore the operational/ maintenance support and retirement and disposal costs portions of the CBS during target costing they should be included in the overall analysis of cost reduction as they will reflect levels of product quality and identified consumer needs.

3.4. ISECOST

Another cost management tool that can be used to implement the target costing process is ISECOST[28]. ISECOST is a computer based decision support system (DSS) which implements design-to-cost and design-to-price procedures that are based on WBS and CBS framework.

The ISECOST program essentially uses a company's present manufacturing cost data for a proposed product as the baseline input for the design-to-price option of the program. This breakdown of production and manufacturing costs is based on standard costing and the CBS. A management generated target cost for the same product is then compared to the original total manufacturing cost estimate. If the manufacturing data cost is higher than the target cost, the ISECOST program allows for an iterative sequence of reductions to the production and manufacturing costs of the product in order to investigate potential cost reduction areas. A sample printout of an ISECOST worksheet is shown in Figure 3.4. As can be seen the ISECOST DSS allows for variations in the production costs of labor, quality control, material, and the variation of units produced and overhead charged.

Customer:	Aqua Boat Company
Model:	CD X75Y
Part No.:	00681
Parts Req'd:	50
Estimator:	Sam Steward
Date:	21 July 1995

MANUFACTURING COST	CHARGE		
	Hours	Rate	Dollars
A. Factory Labor	34.49	10.54	363.47
B. Planning & Liaison	———	12.0% of A	43.62
C. Quality Control	———	11.0% of A	39.98
D. TOTAL LABOR			447.07
E. Factory Overhead	———	105.0% of D	469.42
F. General & Admin Expense	———	15.0% of D	67.06
G. Production Material	———	———	167.17
H. Outside Manufacture	———	———	28.00
I. SUBTOTAL			1.178.72
J. Packing Costs	———	5.0% of I	58.94
K. Total Direct Charge			1,237.66
L. Other Direct Charge	———	1.0% of K	12.38
M. Facility Rental			0.00
N. Total Manufacturing Cost			1,250.00
O. Profit/Fee @		10.0% of N	125.00
Total Selling Price			1,375.00
Ship Set (Unit) Selling Price			27.50

Figure 3.3. ISECOST Worksheet

The utility of ISECOST is that once the manufacturing data and the target costing goals are entered into the program the user can select any identified single cost element and vary it to the level required to attain target costs. With this computer based decision support system, the evaluation of a cost effective design options can be accomplished quite rapidly. In addition the sensitivity of the product cost to individual cost elements or sales quantities is readily investigated and analyzed.

Although originally designed with the intent of being used on discrete products the program can be used effectively on the components which serve to make up the product portfolio of a process oriented product.

A unique application of ISECOST in terms of its sensitivity capability and uncertainties will be examined further in Chapter 4.

CHAPTER 4

MANUFACTURING UNDER CONDITIONS OF UNCERTAINTY

Risk management and the dealing with uncertainty are topics that are becoming more prevalent in today's business environment. The proliferation of computers and software packages has resulted in literally thousands of middle and upper management personnel attempting to analyze and understand the concepts and applications of risk management.

Although a complete examination of risk and risk management is well beyond the scope of this report, an investigation of risk and uncertainty, as they may be applied to target costing and target profits, will be analyzed.

4.1. MANUFACTURING RISK

Within the field of manufacturing, uncertainties and risks can arise in many different forms and emanate from a variety of sources. As a general overview, the risks that a manufacturing company can encounter are in the form of either economic or manufacturing risk. These types of risks can be categorized as:

1. The uncertainties that relate to the economic status and stability of the country that a company is operating in;
2. The risks that are common to specific industries. Companies involved in auto makers, the service industry and mining operations all face risks and uncertainties that are unique to their industry;

3. The unique risks that are specific to manufacturing plants and processes. These may be influenced by plant location, workers or new technology; and
4. The uncertainties that are unique to a specific product that is being produced. These include such things as manufacturer or consumer quality requirements, the availability of material suppliers, falling selling prices and quantity of sales.

This list is certainly not exhaustive as it does not address many non-manufacturing considerations such as the risk caused by changing consumer trends, market maturity or the political risk that can result from government intervention, but it does present an overview. This report will primarily concentrate on two aspects of risk that are encountered by manufacturing companies. First, this chapter will examine how risk can be incorporated into a company's strategic management and profit planning. Second, the unique and system risk that exists in manufacturing and how diversification reduces risk will be related to target costing in Chapter 5.

4.2. ADDRESSING UNCERTAINTIES AND RISK

Frequently risk and uncertainty in manufacturing are topics that are not investigated as thoroughly as they should be by upper management. Although everyone realizes that there are risks involved in a project or product, management does not always attempt to quantify the potential risks involved and include them in the decision making process. This shortcoming results in decisions being made without the benefit of all the information that may be crucial to making a best alternative decision.

Robichek [29] presents an excellent overview of how uncertainties and risk can be included into a cost-volume-profit (CVP) analysis and aid in a company's strategic

decision making. A review of this examination of risk and uncertainty is presented in the following section.

4.2.1. Cost-Volume-Profit

Often CVP analysis are used by management in order to assist in the decision making process. Frequently the analysis provides management with information that identifies 1) the sales volume needed to obtain a profit (break-even analysis) and 2) the most profitable combination of products to produce and sell. Unfortunately, the failure of management to include simple adjustments for risk and uncertainty can severely limit the usefulness of CVP in the overall analysis.

The following example illustrates the value of this statement. Suppose that a company is considering producing one of two new products. Each product will sell for $10 and has a variable cost of $8. Both products will add $400,000 to the company's fixed costs, and will require no capital investment to the present facilities. From this information the break-even point, in sales, for either products is 200,000 units. Now the only piece of information missing in order for management to make a decision about which product to sell is the expected volume of sales that each product will realize.

If the annual sales for A is expected to be 300,000 units and the sales for B are expected to be 350,000 units, then B is clearly the preferred product to produce.

However, if the expected sales of either product were 300,000 units, is it right to assume that management is indifferent as to which product to produce? The answer is no, unless the sales expectations are certain. If both sales estimates are subject to uncertainty, the decision made by management will be better if the relative risk associated with it can be brought into the analysis.

Although only expected volume of sales was varied in this example, there are four potential areas where a risk analysis could be undertaken. These are 1) the selling price

per unit, 2) the variable cost per unit, 3) the total fixed cost, and 4) the expected sales volume. In most cases, it would seem that relative to the expected sales volume, the cost and selling price are quite certain. Therefore, a preliminary examination of how risk can be dealt with in regards to sales volume will be examined before multi-risk products are examined.

4.2.2. Normal Distribution and CVP Analysis

The Robichek article illustrates how a discrete probability distribution is difficult and cumbersome to apply to a random variable such as sales volume and suggests the use of a continuous distribution. The use of a continuous probability distribution is desirable not only because the calculations will usually be simplified but because the distribution may also be more of a realistic description of the uncertainty aspect of the variables. The normal distribution was selected to deal with the uncertainties in the CVP problem.

In examining the application of a normal distribution, consider a product with a per unit selling price of $3000, fixed cost of $5,800,000 and a variable cost of $1750. The break-even point, in unit sales, is:

$$S = \frac{\$5,800,000}{\$3,000 - \$1,750} = 4,640 \text{ units}$$

Further suppose that the sales manager estimates that the mean expected sales volume will be 5,000 units and also feels that there is roughly a 2/3 chance that the actual sales will be within 400 units of this estimate. These subjective estimates can be expressed as having a mean of E(Q) = 5,000 units and standard deviation of s = 400 units. The approximation for the standard deviation is due to the fact that about 2/3 of the area under a normal curve lies within 1 standard deviation of the mean.

Now using the CVP relationship, the expected profit from the product is:

$$E(Z) = E(Q)\,(P-V) - F = \$450{,}000$$

where $E(Z)$ = expected profit

$E(Q)$ = expected sales

P = price

V = variable cost

F = fixed cost

The standard deviation of the profit (s_Z) is:

$$s_Z = s_Q * \$1{,}250 \text{ contribution per unit}$$

$$= 400 \text{ units} * \$1{,}250$$

$$= \$500{,}000$$

Figure 4.1 is a graphical representation of the relationship between profit level and the probability distribution of the profit level.

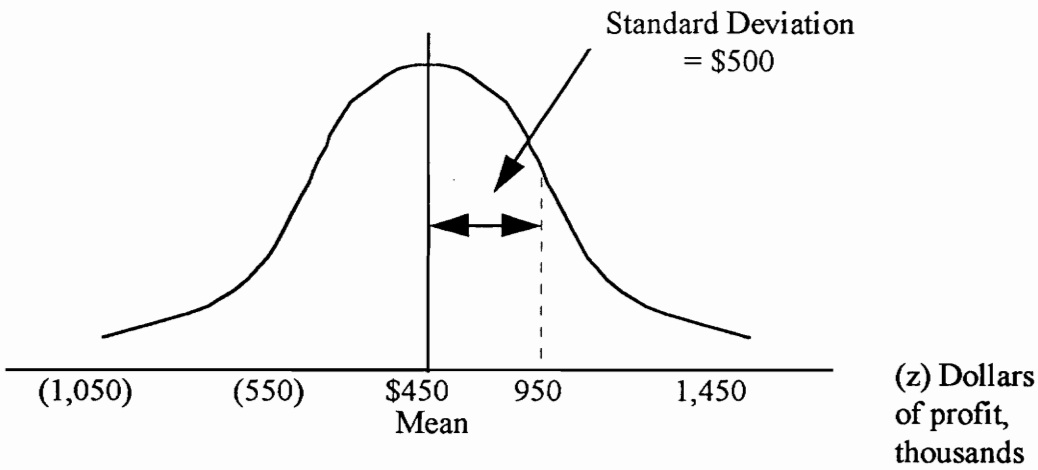


Figure 4.1. Normal Distribution of Expected Profit.

A number of important relationships can now be examined in probabilistic terms. Since the probability distribution of sales quantity is normal with a mean of 5,000 units and a standard deviation of 400 units, the probability distribution of profits will also be normal with a mean of $450,000 and a standard deviation of $500,000.

Now the probability distribution of the expected profit can be used to calculate the probabilities of specific events occurring by using a normal distribution table. For example:

1. The probability of at least breaking even: This is the probability of profits being greater than zero. In this case:

$$Z = X - E(P) / \text{Standard Deviation}$$
$$= (0 - \$450) / \$500$$
$$= -0.9$$

Therefore $P(\text{profit} > 0) = P(Z > -0.9) = 0.816$

2. The probability of profits being greater than $200,000:

$$Z = (\$200 - \$450) / \$500$$
$$= -0.5$$

Therefore $P(\text{profit} > \$200) = P(Z > -0.5) = 0.692$

3. The probability of the loss being greater than $300,000

$$Z = (-\$300 - \$450) / \$500$$
$$= -1.5$$

Therefore $P(\text{profit} < \$300) = P(Z < -1.5) = 0.067$

The question of exactly how this information is used by management is now the issue. A manager can improve his decision making process by using this risk information when trying to decide between the production of this product and any other product. Clearly a decision maker would benefit in his analysis of this product by knowing that:

1. the break-even point in sales is 4,640 units;
2. he expects to sell 5,000 units and achieve a profit of $450,000;
3. the probability of at least reaching the break-even point is 81.6%;
4. the probability of making at least $200,000 profit is 69.2%;
5. the probability of making at least $400,000 profit is 50%;
6. the probability of not breaking-even is 18.4%; and
7. the probability of incurring a $300,000 or greater loss is 6.7%.

In comparing this product with other products, the information given by the probability analysis and the CVP analysis allows management to make a more informed decision. Based on a company's willingness to accept risk a more informed decision can be made regarding alternative products.

4.2.3. Multi-Products and Multi-Variables

The Robichek article continues the examination of risk in the decision making process by comparing the results of three multi-variable products. In the first example profit, Z, was identified as a function of sales volume, Q, while the unit selling price, P, the fixed cost, F, and the variable cost, V were held constant. Now P, F, and V will be treated as random variables with a normal distribution. Using the same initial variables for the CVP analysis and obtaining the expected variation in expected values from the sales manager gives Table 4.1.

Table 4.1. CVP Product with Multi-Variables.

Variable	Expected Value	Standard Deviation
Sales Volume	E(Q') = 5,000 units	$s_{Q'}$ = 400 units
Selling Price	E(P') = $3,000	$s_{P'}$ = $50
Fixed Costs	E(F') = $5,800,000	$s_{F'}$ = $100,000
Variable Costs	E(V') = $1,750	$s_{V'}$ = $75

Therefore, assuming that the random variables are independent and no correlation exists between factors, the expected profit (Z) and standard deviation are:

$$E(Z') = E(Q')[E(P') - E(V')] - E(F')$$

$$= \$450{,}000$$

$$s_{Z'} = \$681{,}500$$

Now, even though the other factors are treated as random variables the expected profit is still $450,000. However, the risk associated with that profit, as measured by the standard deviation has increased to $681,000. The reason for this increase is that the variance that exists in the other factors that make up the profit; fixed and variable cost, etc. will add variability to the profit. The significance of this change can only be judged by the manager

who has to decide between which products to produce and the overall attitude of the firm towards risk.

Finally, a third example is examined where the expected values of the factors remained the same but the variances of the factors were increased as follows: sales increased from 400 to 600 units, selling price from $50 to $125, fixed price from $100,000 to $200,000, and variable price from $75 to $150. A comparison of probabilities for each product are shown in Table 4.2.

Table 4.2. Comparison of Multi-Variable CVP Products.

	Product A	Product B	Product C
Expected Profit ($)	$450,000	$450,000	$450,000
Standard Deviation of Profit ($)	$500,000	$681,500	$1,253,000
Probability of:	-	-	-
at least breaking even	0.816	0.745	0.641
profit at least + $250,000	0.655	0.615	0.564
profit at least + $600,000	0.382	0.413	0.456
loss greater than $300,000	0.067	0.136	0.274

In analyzing the results in Table 4.2 there are a number of noteworthy points. The chances of a least breaking even are greatest with product A and the probability of earning at least $250,000 is highest with product A. However, the probability of earning profits above the expected value of $450,000 are greater for products B and C than for product A. Therefore, if the firm is willing to accept some risk the chances of higher profits are improved with product C over either product A or B. Product C also has the highest chance of incurring a loss. Figure 4.2. shows graphically how the variance of a product increases as the number of variances included in a product are increased and the expected return of the product increases.

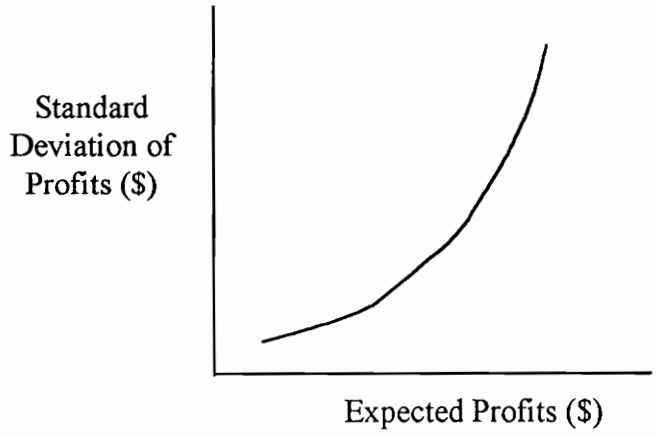


Figure 4.2. Increase of Standard Deviation versus Expected Profits.

The best of these three alternatives cannot be chosen without some indication of management's attitude towards risk and uncertainty or risk tolerance. One thing is certain though. That is, that given the type of uncertainty and risk information that is presented in Table 4.2, any company would be in a better position to make decisions of which alternative to select or which product portfolio to produce. Returning to the illustration of the normal distribution of expected profits, Figure 4.3 shows how the distribution for each of the products listed in Table 4.2 would be represented graphically.

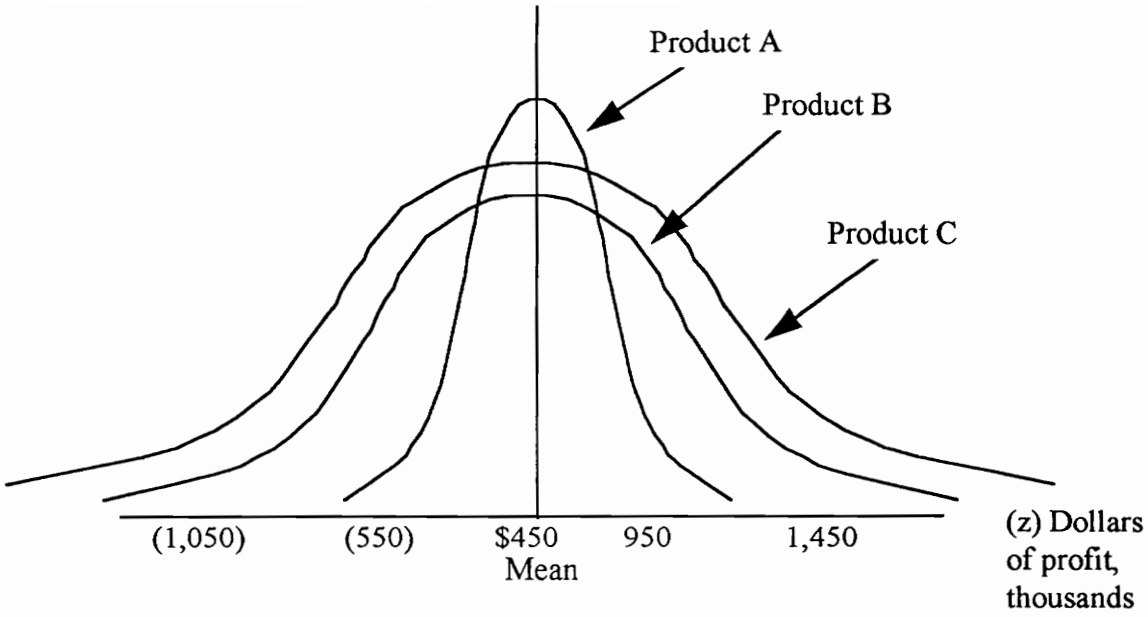


Figure 4.3. Comparison of Expected Profit and Standard Deviation for Products A, B, and C.

Figure 4.3 compares the normal distribution of the three products. Although all three products have an expected return of $450,000, their respective standard deviations results in less certainty about the predicted return and the acceptance of more risk by the company involved as one moves from Product A to B to C.

4.4. UNCERTAINTY IN TARGET PROFITS

With the use of the target costing process, a unique opportunity is provided whereby product uncertainty and risk could be addressed and considered by management. As discussed in Chapter 2, the process of target costing involves: the identification of an ideal selling price, the removal of a profit from that selling price, and then the identification of a target cost for producing a product. An overview of the target costing process is illustrated in Figure 4.4.

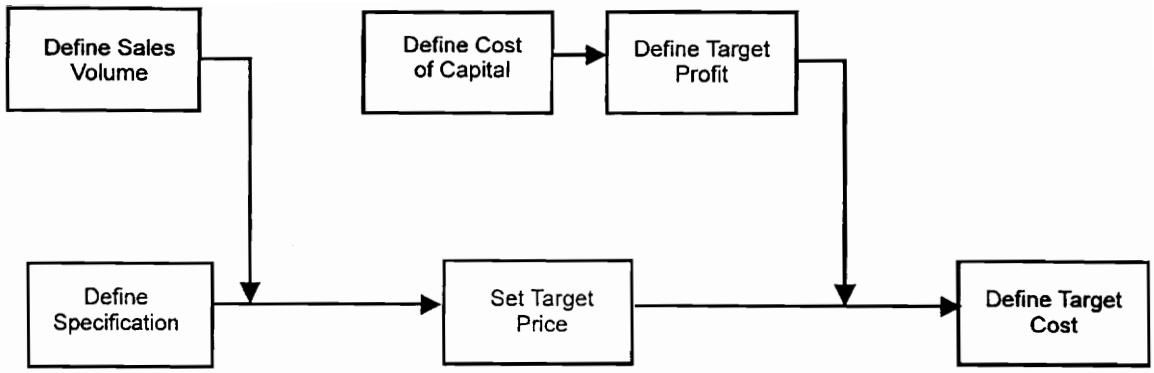


Figure 4.4. Illustration of Target Profit [30].

In the same vein as the Robichek article, the obvious question raised in the target costing process is, "How confident is management about the target cost and target profit once a target selling price has been established?" Given that uncertainties may arise in the cost of the process of manufacturing, the procurement of raw material and the distribution of cost drivers, and selling volume, exactly how certain is management that they will be able to achieve their identified target cost and hence target profit?

In the Robichek report, the CVP analysis was used to identify a total revenue from which costs were subtracted. The variances in the CVP factors could then be examined in order to see where uncertainties existed. When target costing is employed by a company, rather than simply adding a profit margin onto a product cost, an alternative method is used to identify and arrive at an expected target profit. The target profit that a company wishes to realize is subtracted from a selling price and then the company's goal is to obtain the resultant target cost. In the target costing method, the actual target cost that is obtained by a company on any product portfolio could vary. Clearly, target profits could be represented as either a discrete number such as 25 % or as a possible range of expected returns. In this second option, manufacturing managers would be called upon to indicate how confident they felt about obtaining a target cost. This estimate would depend on

current manufacturing conditions, technologies involved and manufacturing processes utilized. In situations with uncertainties in the target cost and profit, the expected profit could be represented as a percentage of selling cost with a level of confidence included. For example, the target profit for a certain product portfolio could be stated as 25 % $\pm$ 5 %.

Recognizing that the process of target costing involves a multitude of factors and cost elements, it would seem likely that each of the components of a process oriented product would have some measure of uncertainty attached to it. Equally, the identified target profit would have an even larger number of factors that combine to create its uncertainties when marketing and sales are considered into the make-up of the overall target profit risk. Considering these facts and the analogy used by Robichek, it would seem appropriate that the target profit of the target costing process should be defined as a random variable and be represented by a continuous distribution. Again, considering the likelihood that both positive and negative deviations could equally occur in the manufacturing process it would seem suitable for the selection of the normal distribution as the distribution to represent the variability of target profits.

Therefore, the same procedures that were suggested and followed for the examination of the CVP uncertainty analysis can be adopted for the target costing process and specifically target profits.

The calculations for expected target profits, variances and standard deviations for products could be based on either historical data or on predictions and standard costing results. The calculations based on alternative predictions will be briefly examined in Chapter 7.

4.3. ISECOST AND UNCERTAINTY IN TARGET COSTING

The validity and feasibility of applying uncertainties to the target costing process is, without a doubt, a worthwhile exercise and a potentially valuable source of information to the strategic decision makers in a company. By completing an assessment of how the costs that make up a product portfolio's target cost could vary, a firm will be in a better position to make decisions on not only which components to select for manufacturing, but also for decisions involving the possible grouping of components into portfolios. The factors of where a component may be in its manufacturing life cycle, and how an increase or decrease of uncertainty will affect target costs and consequently target profits all play a role in the decision making.

While the calculations presented in the Robichek article represented simple changes in one or two cost elements of the product, it is likely that today's management would want the opportunity to investigate the effects of potentially hundreds of cost elements that play a role in target costing. Fortunately, the target costing tool that would seem to easily allow for the original work done by Robichek to be added to target costing would be the ISECOST program. By using the ISECOST program it would seem that literally hundreds of different cost element variations could be investigated and results examined and considered by management. The subjective variations to cost elements that are suggested could be run through the program and the end point extremes of the uncertainty of cost elements and factors established.

In addition to these types of sensitivity analyses being carried out, the ISECOST program could be used to examine and suggest possible correlations between products. For example, in the textile industry the correlation between type of material and ease of manufacture could be quantified by the manufacturer. Other types of relationships could also be examined such as the relationship between the costs of outside manufactured components and in-house labor costs. Although these types of questions may not always

be answered specifically, additional information and a general feeling of their uncertainty could be obtained. A numerical example of ISECOST used to illustrate the development of process oriented product uncertainties is shown in Appendix A.

Even with the additional uncertainty information that is suggested as being available on individual components, the question for management is still exactly how components should be grouped together to form target costed product portfolios and subsequently how multi-product portfolio mixes that meet a company's overall strategic profit plan can be formulated.

Intuitively it would seem that companies might want to group two or three high target profit, high risk components with two or three medium target profit, medium risk products in order to balance out some of the risks involved. This being said, some consideration must be given to the correlation between individual components and how they vary with respect to each other.

Equally, once the components of a product portfolio have been established the company will, undoubtedly, want to compare the predicted returns and risks associated with different portfolios. A company would want to be able to compare the expected return and variance of one product portfolio to that of another product portfolio. For example, assume that a company, which uses target costing, produces two types of glass, one for commercial use and one for residential use. Once the components that make up the glass have been finalized in the design phase, the company can establish a target cost and target profit for each type of glass. If the company has also assigned uncertainties to the production of the glass, either in the form of component uncertainties or as an overall product portfolio uncertainty, and the associated expected returns and risks are different, the company now has to decide how much of each product they will attempt to manufacture and sell. Although there will be a multitude of variables that can and should be considered in reaching a company portfolio mix, strong considerations should be given

to the expected return and risk associated with each portfolio as determined by the expected returns and risks associated with the components of the portfolio. For a target costed product this expected return could be equated to target profit.

These types of decisions with regard to acceptable risk in either components or portfolios must be based on a company's long term profit plan and attitude toward risk or risk tolerance.

It would seem obvious that any portfolio management tool that is used with target costing must reflect the unique characteristics of the target costing process. Specifically, the management tool must attempt to utilize the factors that are the basis for making decisions in the normal target costing process. These factors would include all or any one of the unique target costing concepts of: target cost, target selling price, and target profit.

4.5. FINANCIAL PORTFOLIO ANALYSIS

Traditionally, the term portfolio analysis is used among financial analysts to refer to the appropriate diversification among investment securities to achieve a desired balance between risk and return. The reasoning behind financial portfolio analysis applies equally to product portfolio analysis of process oriented products, although its formal application has always been difficult to implement. The present and growing use of target costing creates an interesting opportunity to utilize a method of financial portfolio analysis on a continuous product portfolio.

In normal financial portfolio management, an investor is attempting to select among independent investments that will maximize the return on his long run initial investment. Generally, the investor reviews the rate of return and risk involved in the investments that he is considering and selects a portfolio that will provide him with a maximum return for his desired level of risk.

On the surface it would seem that this portfolio tool could have an applicable use with target costing. By substituting in the target profit which a company wishes to receive for the desired rate of return that an investor wishes to obtain, it would seem that the financial analysis foundation could be used to manage a product portfolio. The financial process also allows for the product portfolio to integrate the aspect of manufacturing and economic risk into the evaluation. In addition, the financial portfolio analysis system selects products for a portfolio as independent investment opportunities rather than mutually exclusive ones. It is felt that this is very much in line with what happens in the selection of product options by management in attempting to plan and follow its strategic strategy. It should be re-emphasized that the use of a stock investor portfolio analysis is not universally applicable to engineering and manufacturing portfolio situations. The portfolio analysis method that will be further examined was developed by Markowitz [31] in order to consider only long run investments and should not be applied to discrete projects or products. In this sense, the portfolio analysis process would only apply to process oriented or continuous manufactured products. The following section of this chapter describes some of the other work done in the area of corporate finance techniques being used with alternative product selection

In a fashion which is similar to the Culp Inc., management method, efficient portfolio analysis looks at the overall portfolio performance rather than individual product performances. The complete examination of risk, and rate of return as it relates to the use of target costing in the financial portfolio analysis is examined in Chapter 6. An overview of the traditional methods of portfolio management is included as Appendix B for information purposes.

4.6. REVIEW OF CORPORATE FINANCIAL PROCEDURES

A brief overview of how portfolio management has evolved in corporate finance will provide a little more detail on the use of portfolio efficiency and it's management of continuous products.

Markowitz is credited with drawing attention to the common practice of portfolio diversification and showed exactly how an investor can reduce the standard deviation of portfolio returns by choosing stocks that do not move exactly together. But Markowitz did not stop there, he went on to work out the basic principles of portfolio construction by suggesting that rates of return on stocks or portfolios of stocks were correlated. This work effectively integrated the firm's long-run project investment and dividend policies and thereby provided a criterion for selecting future investments.

The Capital Asset Pricing Model (CAPM) continued the development of portfolio management by including the concept of a market security line, which attempts to identify a series of portfolios that maximizes an investor's expected utility between risky and riskless securities, and the creation of a risk assessment, B, for both the investment market and individual stocks.

The CAPM financial decision making process is suitable for use in the selection process of projects and products that are discrete in nature. This is due to the CAPM's ability to consider the risk associated with an individual firm, B, and the risk associated with a particular project. This risk or relative volatility measure is then used as a decision factor for the selection or elimination of projects. An excellent examination of using the CAPM decision model for industrial projects is given by Bussey and Eschenbach [32].

The final financial investment model is called the arbitrage pricing theory (APT). The APT is a completely different type of investment model as it does not attempt to determine which portfolios are efficient, rather it simply assumes that the return on stocks

are dependent on some combination of macroeconomics and "noise" that is unique to the company involved. Once the complete list of factors is identified, they are multiplied together to obtain an expected risk premium factor for consideration. A more complete examination of APT is presented by Brealey and Myers [33]. Due to the fact that the APT incorporates and relies heavily on the practice of selling stocks short, it is felt that it has little practical application to the process of engineering project selection [34].

CHAPTER 5

TARGET COSTING PORTFOLIO MANAGEMENT

The goal of this chapter is to investigate and suggest methods by which target costed product portfolios can be strategically managed. As stated previously, any portfolio management tool that is used with target costed products, ideally, should have a feature or characteristic that takes into effect the unique way in which the products were developed, designed and manufactured. In simple terms this would imply that the portfolio tools must involve at least one of the major decision drivers in the target costing process. These decision drivers are target cost, target profit and target selling price.

If the target costing process is reduced to one involving expected returns (target profits) and the standard deviation about the return (uncertainties in target profits), the examination of target costing and manufacturing uncertainty can be made analogous to that of the stock market investor for the process oriented product case. A stock market investor wishes to maintain a portfolio of stocks that maximizes his expected return while minimizing the risk or uncertainty of this return. In a similar fashion, the continuous manufacturing company wishes to maintain a long run production portfolio that maximizes its target profit, while exposing the company to a minimum of unique product risk. In a sense each company must accept a certain amount of risk, such as industry common risk, that can be viewed as the cost of doing business.

The remainder of this chapter will examine the possible use of target profits and uncertainties in the traditional investors stock portfolios methodology.

5.3. STOCK INVESTMENT PORTFOLIO

Consider the case of a stock investor. The return on an individual stock that an investor hopes to get is expressed as the rate of return 'r' while the risk that he faces on that same investment is expressed as the standard deviation 'σ' on that same return.

When only one stock is owned the investor has a complete understanding of both his potential return and the risk attached with that investment. In the case where he holds two stocks the associated return and risk become slightly more complicated.

Examine the rate of return and risk (standard deviation) associated with two stocks, A and B, as listed in Table 5.1.

Table 5.1. Two Stock Investment Options.

	Stock A	Stock B
Rate of Return r	15 %	21 %
Standard Deviation σ	28 %	42 %
Portion of Money Invested in Each Stock x	0.50	0.50

If the investor created a portfolio with his money split equally between the two stocks, the expected return would be:

$$.50(15\ \%) + .50(21\ \%) = 18\ \%$$

exactly half the sum of the two stocks.

Calculating the expected risk of this new investment portfolio using an equal portion of the standard deviations would give the investor an expected risk of:

$$.50(28\ \%) + .50(42\ \%) = 35\ \%$$

Unfortunately this method is incorrect and would only be correct if the return of the two stocks moved exactly the same to common changes in economic factors. In almost all cases stocks react differently to changes in the economy and other market related factors. In order to calculate the standard deviation of the two stock portfolio the covariance or movement of the stocks relative to each other must be considered. In this examination the covariance of two stocks is expressed as σ_{12}. A more detailed explanation of covariance and the calculation of covariance is demonstrated later in this report.

The correct method for calculating the standard deviation of the two stock portfolio is accomplished as follows:

$$\begin{aligned} \text{Portfolio Variance} &= x_1^2\sigma_1^2 + x_2^2\sigma_2^2 + 2\,(x_1x_2\sigma_{12}) \\ &= .25\,(28)^2 + .25\,(42)^2 + 2(.25\,(470)) \\ &= 872.2 \end{aligned}$$

Therefore the risk $\sigma = 29.5\ \%$

This simple examination of combining two stocks brings out one noteworthy point with respect to dealing with risk. That point is that the expected risk associated with the combining of two stocks was less than might have been expected. Where intuitively it might have been assumed that the risk associated with this two stock portfolio should be

35 % it was actually 29.5%. The reason for this reduction in risk is due to diversification. Simply stated, diversification reduces risk.

5.4. DIVERSIFICATION

The principle of diversification states that some of the riskiness associated with individual assets can be eliminated by forming portfolios. Diversification can eliminate some, but not all, of the risk present. Figure 5.1 illustrates graphically how diversification can reduce unique risk as the size of a stock portfolio increases.

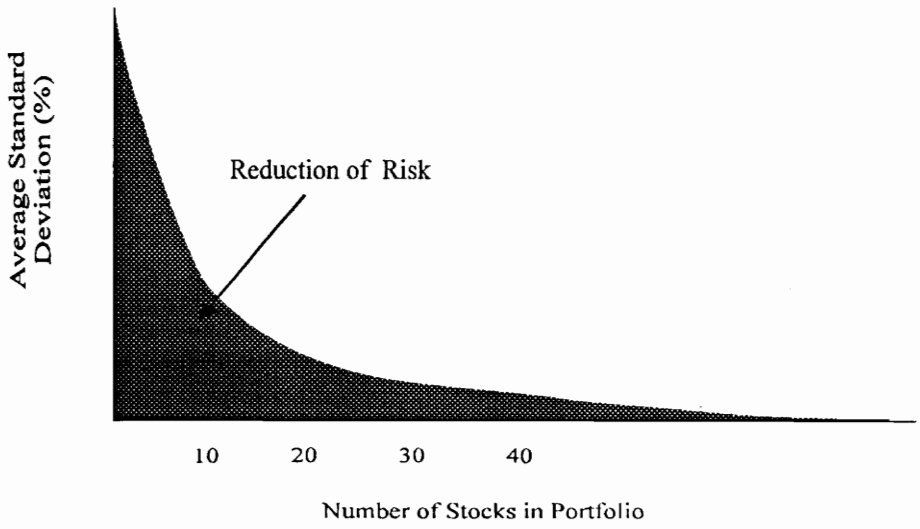


Figure 5.1. Diversification of Risk.

Figure 5.1 shows that the standard deviation or risk decreases as the number assets in the portfolio increases. Once the number of assets in the portfolio gets significantly large the benefit realized by adding one more asset is relatively little.

The amount of risk that can be removed by diversification is called unique risk, while the amount of risk that cannot be removed is called system risk. As the number of items in a portfolio increases, the amount of unique risk decreases. But the system risk represents a minimum amount of risk that cannot be eliminated. Figure 5.3 illustrates the relationship between unique and system risk.

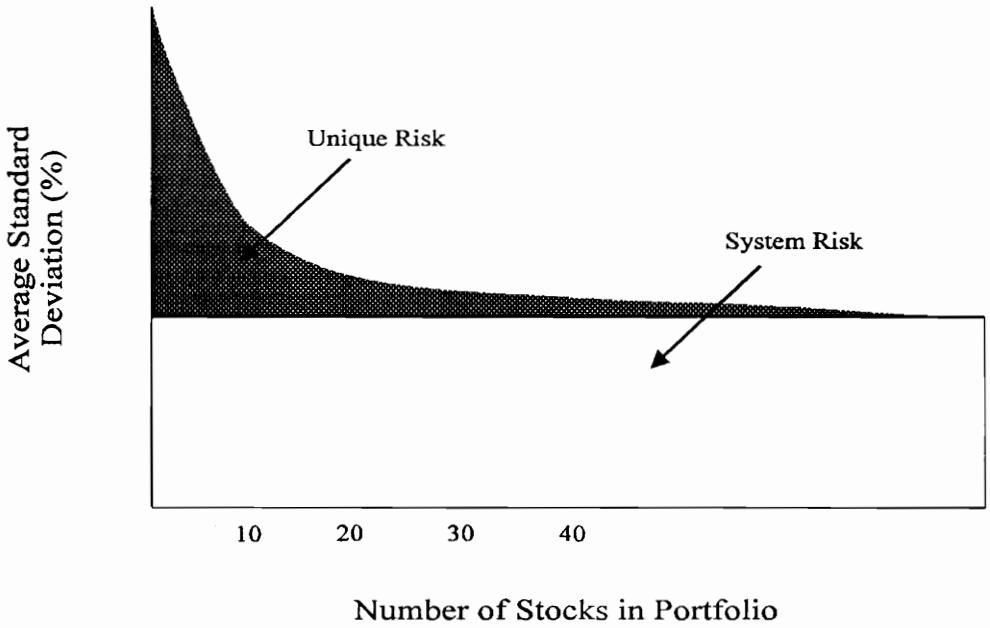


Figure 5.2. Unique and System Risk [32].

System risk is attributable to many factors depending on the composition of the portfolio involved. In the case of stocks, system risk is the uncertainty of the whole stock market and all the other economic factors that sustain the financial and economic markets of the world. In terms of manufacturing, system risk would include such things as simply

being involved in the manufacturing of products and/or the risk associated with being involved with a specific industry. System risk would have an effect on all manufacturing companies to some extent. For example, a company which uses steel as a raw material in their manufacturing process runs the risk of government legislation which makes the production of steel illegal, unless it can be produced without harming the environment. This in turn would make the use of any steel product very cost prohibitive. Although a somewhat unlikely example, it still serves to illustrate a system risk that is associated with all manufacturing companies that use steel as a raw material. The price of raw material presents a risk to manufacturing companies which, in turn, equates to part of the total risk of manufacturing products.

One example of the unique risk faced by manufacturing companies is that one of their products will become obsolete by the introduction of a revolutionary new product. This situation is similar to the changes encountered by the vinyl record producing companies with the introduction of the compact disc. In this case there is a difference drawn between the risk of being involved in the music industry and the risk strictly involved in manufacturing vinyl records.

Based on this information it should be concluded that if a company produces only one product the target cost of that product will fluctuate due to some industry specific risks and events that occur. While a company that produces a wide variety of products will have an overall target cost that could show very little, if any, fluctuation. The result is due to the likelihood that as the target cost of some products increases due to positive industry events, others will decrease due to negative industry events.

The obvious question to be answered now is how many different products must a company have in order to gain the benefit of diversification? Based on Figure 5.2 that answer would seem to lie somewhere between 2 and 20 products. Fortunately, there is another alternative to simply guessing on an arbitrary increase in portfolio size.

Experience with stock market portfolios has demonstrated that the expected returns and standard deviations of a portfolio can be controlled through the percentage of stocks which makeup the portfolio. The process of controlling the relative weights of assets within portfolios, in order to control risk, is referred as to portfolio efficiency.

5.5. PORTFOLIO EFFICIENCY

Now consider the case of two product portfolios that a company is designing to sell, Product A and Product B with information about the products as shown in Table 5.2.

Table 5.2. Two Product Portfolio Mix.

	Product A	Product B
Rate of Return r	15 %	21 %
Standard Deviation σ	28 %	42 %

In considering how much of each product portfolio to produce, the company is faced with three options. These choices are to produce:

1. Product A which gives a low return and low level of risk,
2. Product B which gives a high return and high level of risk, or
3. A combination of Product A and Product B which will give both a return and level of risk somewhere between A and B alone.

Again, the simple case of producing 100% of either product A or B gives known expected results for both rate of return and standard deviation. The results of a 50/50 split were examined with the two stock investment option, but how do the measures of portfolio efficiency change as the mix product A and B are varied? A plot of the expected return and risk that would be achieved for the full range of combinations of the two products is shown in Figure 5.3.

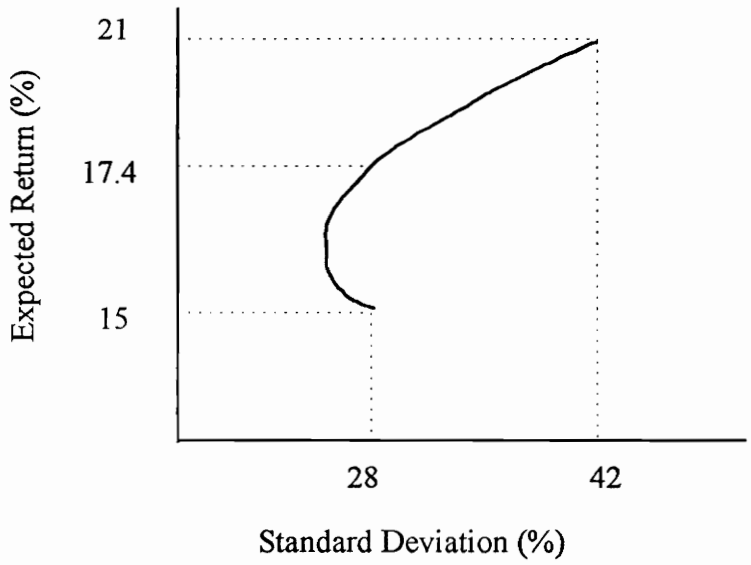


Figure 5.3. Two Product Efficient Portfolio [33].

As indicated by Figure 5.3 the resultant returns and risk involved in a two product portfolio can be quite different than either of the two individual products considered in isolation. The exact return and risk that a company selects is based on their risk tolerance. Consider the product mix portfolio of 60 % Product A and 40 % Product B as highlighted in Figure 5.3. In this case, the product mix portfolio expected return is 17.4 %, which is about 40 % of the way between the expected return of the two products. The standard

deviation 28.1%, which is much less than 40% of the way between the standard deviations on the two products. In fact this 60% Product A, 40% Product B portfolio has about the same risk as a portfolio mix holding only Product A while providing the company with an expected return about 2.5 % higher.

When numerous product portfolios are considered as independent investments and product mixes can be made over a vast range of different proportions, an even wider selection of expected returns and risk portfolios can be obtained. Figure 5.4 illustrates how the multi-product portfolios of expected returns and risk are depicted. In this instance each "X" indicated on the umbrella shape represents the return and risk of a mix of product portfolios. The bottom points of the umbrella represent the return and risk of the individual portfolios. The heavy solid line across the top of the umbrella indicates the efficient or best mix of portfolios. Whether a company is conservative or not, it is assumed that among alternatives with equal expected rates of return companies prefer the product portfolio mix with the smallest risk or variance. Equally, among alternatives with equal variances of returns, companies are assumed to prefer the product portfolio mix with the greatest expected rate of return. These two statements are equivalent to the statement that companies should only consider efficient portfolios. The efficient portfolios are considered to be the best because another product portfolio mix cannot be constructed with a higher expected rate of return and the same variance, or with a lower variance and the same expected rate of return.

As such, efficient portfolios are said to dominate all other inefficient portfolios. This means that:

1. If two product portfolios have the same standard deviation or return rate, the one with the larger expected return is preferred and dominates the other, and

2. If two product portfolios have the same expected return rate, the one with the smaller standard deviation will be preferred and dominates the other.

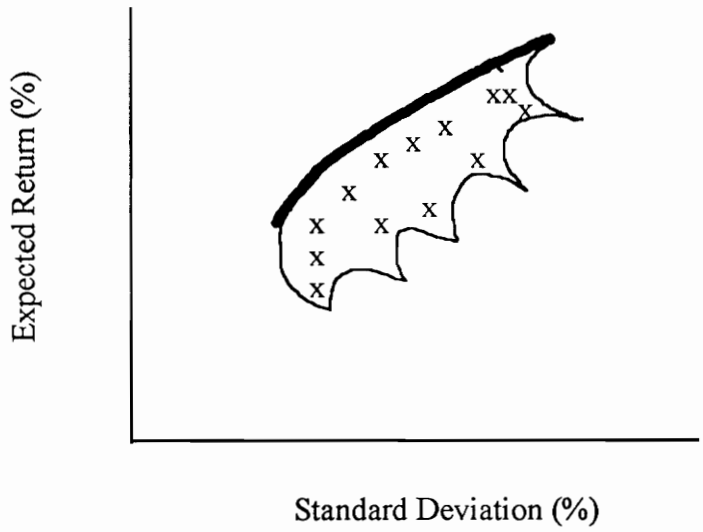
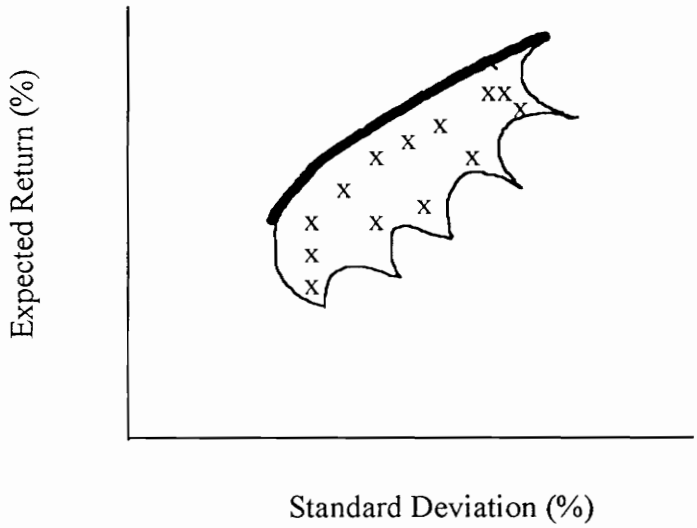


Figure 5.4. Expected Returns of a Multi-Stock Portfolio [34].

Calculating an efficient portfolio for a two product situation is fairly trivial while the determination of a multi-product portfolio would seem to be quite difficult. Fortunately, Markowitz [35] incorporated the use of quadratic programming to make the determination of efficient portfolios relatively easy in all instances.

The use of quadratic programming in order to find efficient portfolios and an illustration how the process relates to the creation of optimizing Target Profit product portfolios will be examined in Chapter 6.

2. If two product portfolios have the same expected return rate, the one with the smaller standard deviation will be preferred and dominates the other.



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The use of quadratic programming in order to find efficient portfolios and an illustration how the process relates to the creation of optimizing Target Profit product portfolios will be examined in Chapter 6.

CHAPTER 6

QUADRATIC PROGRAMMING

Quadratic programming is a unique form of mathematical modeling that has been used within the management science community to examine and optimize non-linear problems. Specifically quadratic programming is concerned with the problem of maximizing a quadratic function subject to linear inequality constraints. The applications of quadratic programming have historically been restricted to the fields of investment portfolio management which is a continual long run investment project and, to a limited extent, the pricing of a firm's product when the demand on that product is a linear function of the product's price.

With respect to industrial manufacturing a direct relationship can be established between the characteristics of a long run investment portfolio and the continuous production seen in a process oriented manufacturing plant.

6.1. INTRODUCTION TO QUADRATIC PROGRAMMING

Mathematical programming problems in general are concerned with the use or allocation of scarce resources, such as labor, materials, machines and capital, in the best possible manner so that costs are minimized or profits are maximized. In this explanation of programming the term "best" implies that there are different choices or a set of alternative actions available for making the decision. The term quadratic programming simply defines a particular class of programming problems that meet specific conditions. A quadratic programming problem is one in which a quadratic objective function is to be optimized. The constraints are assumed to be linear inequalities, and the variables in the problem must be non-negative.

The quadratic programming model is of the general form:

$$\text{Max (or Min)} \quad Z = \sum_{j=1}^{n} c_j x_j + \sum_{i=1}^{n} \sum_{j=1}^{n} d_{ij} x_i x_j$$

$$\text{subject to} \quad \sum_{j=1}^{n} a_{ij} x_j \leq b_i \quad \text{where } i = 1,2,\ldots,m$$

$$x_j \geq 0 \quad \text{where } j = 1,2,\ldots,n$$

and the c_j 's, d_{ij} 's, and a_{ij} 's are known constants.

The model has been used successfully in the studying of manufacturing firms operating in a market characterized by imperfect competition. If a company sells its product in an imperfectly competitive market, its total revenue is assumed to be a quadratic function. If the company buys its resources or raw materials in that same market, and its inputs, outputs and prices are assumed to be non-negative values, the cost of production is a quadratic function. By considering that the demand of a product is a linear function of its price as illustrated in Figure 6.1, a quadratic function can be formed.

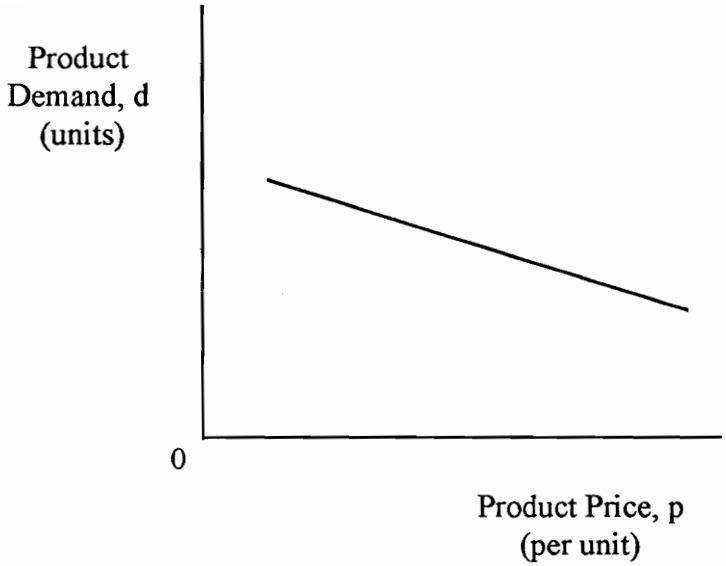

Figure 6.1. Illustration of Linear Product Demand.

For example, suppose demand d, and price p, are related as follows:

$$d = Q - a * p \quad \text{where a and Q are positive constants}$$

Then revenue would be:

$$R = d * p = (Q - a * p)\, p = Q * p - a * p^2 \qquad (6\text{-}1)$$

Note that Equation 6-1 is a quadratic. The optimal solution of this equation can be found using quadratic programming. A graphical representation of Equation 6-1 is shown in Figure 6.2.

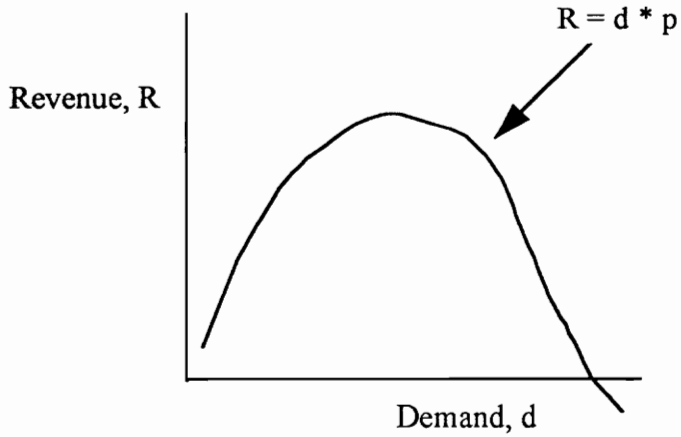

Figure 6.2. Example of Quadratic Equation for Revenue.

The more popular application of quadratic programming involves a continuous investment into the selection of a stock market investment portfolio. The model is one in which a fixed amount of cash is to be allocated for investment into N stocks. Each stock or investment has an expected return associated with it and also a certain amount of variance in that return depending on the movement of the market, national economy, interest rates, etc. The investor wants to maximize the return of his investments, but also wants to give some consideration to the risk or uncertainty involved in each stock considered for inclusion in his investment portfolio.

Historical data on the stock market indicates that the returns on stocks follow a normal distribution that are affected by a multitude of individual factors. Without delving into the world of finance too extensively, the risk or uncertainty on any individual stock can adequately be represented as the variance of return about the mean or expected return. When considering a group of stock investments, the movement either up or down in rate of return of individual stocks, relative to each other, may be similar or dissimilar in fashion. The investments may or may not be independent of each other. This means that the return from various investments may have a tendency to move in the same or opposite

direction in response to common economic factors. This movement, relative to each other, can be measured by the covariance between the investments. When the movement between two stocks is similar the stocks are said to exhibit a high covariance, when the movement is dissimilar they exhibit a low covariance.

6.2. PORTFOLIO FORMULATION

In creating a portfolio formulation for use in a quadratic programming application, consideration must be given to both the dependent and independent aspects of the stocks and the risk involved in a portfolio's make-up.

If X and Y are two random variables, dependent or independent, then the expected value of their sum is the sum of their expectations:

$$E(X + Y) = E(X) + E(Y)$$

So for the investment portfolio case, the model for maximizing the expected value would be:

$$\text{Maximize } Z = \sum_{j=1}^{n} c_j x_j$$

$$\text{subject to } \sum_{j=1}^{n} x_j \leq 1$$

$$x_j \geq 0 \qquad \text{where } J = 1, 2, \ldots n$$

and x_j is the percentage of the available funds invested in the investment j.

The above model is a simple linear programming model because it gives no consideration to the risk or uncertainty involved in the investments. This is where the use

of variance as a measure of risk becomes involved. If the random variables X and Y are independent random variables and a is a constant, then:

$$V(aX) = a^2 V(X) \text{ , and} \qquad (6\text{-}2)$$

$$V(X + Y) = V(X) + V(Y)$$

If X and Y are dependent random variables and a and b are constants, then:

$$V(X + Y) = V(X) + V(Y) + COV(X,Y) + COV(Y,X) \text{ ; and}$$

$$V(aX + bY) = a^2 V(X) + b^2 V(Y) + abCOV(X,Y) + abCOV(Y,X) \qquad (6\text{-}3)$$

where COV (X,Y) is the covariance of X and Y and is equal to the COV (Y,X).

By defining the random variables as:

u_j = the expected return from the investment

$s_{i,i}$ = the variance of the return on investment i

$s_{i,j}$ = the covariance of the return between investment i and j $(i \neq j)$

Suppose the variance of a given investment opportunity is σ_{jj} , and a continuous investment is represented by a percentage x_j of the total amount of money available to invest.

Using Equation 6-2, the variance on the expected return from investment j is $x_j^{\,2}\sigma_{jj}$. The variance of the expected return of N stocks can be determined using Equation 6-3 and would be:

$$V = \sigma_{1,1}\, x_1^2 + \sigma_{2,2}\, x_2^2 + \ldots \sigma_{n,n}\, x_n^2 + \sigma_{1,2}\, x_1 x_2 + \sigma_{1,3}\, x_1 x_3 \ldots$$

$$\ldots + \sigma_{1,n}\, x_1 x_n + \sigma_{2,1}\, x_2 x_1 + \sigma_{n,n-1}\, x_n x_{n-1}$$

or:

$$V = \sum_{j=1}^{n} \sum_{k=1}^{n} \sigma_{i,k}\, x_j\, x_k \qquad (6\text{-}4)$$

Now "ρ" , a risk aversion factor, can be defined such that $0 \leq \rho \leq \infty$. If $\rho = 0$ then the investor has no aversion to risk, and if $\rho = \infty$ the investor has a high aversion to risk. Incorporating risk into Equation 6-4 the model for the variance of N stocks would be:

$$V = \rho \sum_{j=1}^{n} \sum_{k=1}^{n} \sigma_{i,k}\, x_j\, x_k \qquad (6\text{-}5)$$

After combining the two terms of Equations 6-2 and 6-5, a maximization equation is obtained that represents both the return and risk of an investment portfolio.
Equation (6-6) also takes into account both the dependent and independent nature of individual investments. This innovation of combining the risk aspect of investments was first recognized and published by Markowitz as a way to deal with the fluctuation of returns on stocks and bonds [36].

The combined quadratic equation for an investment portfolio is shown in Equation 6-6.

$$\text{Maximize} \quad \Sigma^{n}_{j=1} u_j x_j - \rho \, \Sigma^{n}_{j=1} \Sigma^{n}_{k=1} \sigma_{i,k} x_j x_k \qquad (6\text{-}6)$$

$$\text{subject to} \quad \Sigma^{n}_{j=1} x_j \leq 1$$

$$x_j \geq 0 \qquad \text{for all } j \qquad [37]$$

Therefore, given values for the x_j's and u_j's, an optimal allocation of the investment of money can be made amongst the N stocks as a function of ρ.

6.2.1. Example of Stock Investment Portfolio Maximization

If the average price of three stocks are given as $u_1 = 6$, $u_2 = 8$, and $u_3 = 9$ and the variance and covariance matrix for and between the investments are:

$$V = \begin{vmatrix} \sigma_{11} & \sigma_{12} & \sigma_{13} \\ \sigma_{21} & \sigma_{22} & \sigma_{23} \\ \sigma_{31} & \sigma_{32} & \sigma_{33} \end{vmatrix} = \begin{vmatrix} 8 & 5 & 7 \\ 5 & 16 & 6 \\ 7 & 6 & 30 \end{vmatrix}$$

therefore, using Equation 6-6, the investor should

$$\text{maximize} \quad Z = 6x_1 + 8x_2 + 9x_3 - \rho\,(8x_1^2 + 16x_2^2 + 30x_3^2 + 10x_1x_2 + 14x_1x_3 + 12x_2x_3)$$

$$\text{subject to} \quad x_1 + x_2 + x_3 \leq 1$$

$$x_1, x_2, x_3 \geq 0$$

Using quadratic programming to solve this formulation a series of potential investment portfolios is created that are dependent on the value of ρ selected. The series of optimal allocations for the investor's money, frequently called portfolio weight, generated by quadratic programming software called "Investmaster" is shown in Table 6.1.

Table 6.1. Optimal Allocation of Investments.

ρ	x_1	x_2	x_3	Z
0.5	0.4356	0.3130	0.1358	3.1696
2	0.1359	0.0825	0	0.7379
5	0.0436	0.0313	0.0136	0.3170
10	0.0218	0.0156	0.0068	0.1585

The results serve to illustrate the significance of the parameter ρ in terms of the risk that the investor is willing to accept. As the value of ρ increases, the investor wishes to have less risk in their portfolio and the value of the objective function Z (the return on their investments) decreases. If the investor chooses to disregard the risk, as identified in this model, ρ is set equal to zero and the solution of the objective function is simply $x_3 = 1$. Therefore the investor should place all of their money in investment x_3 and receive a return of 9.

It can be seen that there are an infinite number of values that ρ could be set to but, in each case an optimal allocation or division of investment funds is determined. Unfortunately, the assignment of an acceptable level of risk in this example is seemingly based on a somewhat arbitrary variable of "ρ". This inherently makes the process difficult

to understand, and more importantly, difficult to deal with in terms of manufacturing applications.

A second more useful example of quadratic programming can be examined where the solutions formulated are based on maximizing the rates of returns and minimizing the standard deviations for the formulated portfolios. The process attempts to maximize the efficiency of the portfolios in terms of both return and standard deviation. This type of maximization concept, for return and standard deviation of the return, has more applicability for use with manufacturing processes and the development of an optimizing target profit management tool.

6.2.2. Example of Portfolio Maximization using Returns and Standard Deviations

Previously it was shown how target costing could be modified to develop a desired rate of return for the selling of a product that includes an uncertainty. Once a target profit for a product portfolio is identified, a corresponding risk can also be included in the form of a variance or standard deviation. Consider the case of a company with three different continuous process product portfolios, x_1, x_2, and x_3, to choose from in terms of what to manufacture. The company can produce none, one, two or all three of the product portfolios. The goal of the company is to produce the three products portfolios x_1, x_2, and x_3 in combinations or a mix such that their profit is maximized while the manufacturing risk presented to the company is minimized. Example product portfolio target profits, the standard deviations on those returns, and the covariance for three products are given in Table 6.2.

Table 6.2. Product Rates of Return and Standard Deviations.

Product	Target Profits %	Standard Deviation %	Covariance x_1	x_2	x_3
x1	25.8	43	-	.50	.60
x2	19.5	28	.50	-	.45
x3	22.8	34	.60	.45	-

By using Equation 6-6 a series of potential product portfolio mixes, of x_1, x_2, and x_3, can be derived based on increasing target profits. The use of the quadratic programming algorithm ensures that each mix of portfolio is efficient for a given target profit. As illustrated in Chapter 5, efficient portfolio mixes are efficient to the extent that they provide the lowest standard deviation or risk for a specific return. In manufacturing terms, the portfolio mixes are providing the maximum return on production with the minimum risk of losses through manufacturing production or economic problems.

The series of portfolios for this example was obtained using a microcomputer software program call 'Investmaster'. Investmaster is part of a stand-alone computer package called 'PCF Toolkit'. The PCF Toolkit package is available through the finance textbook "Principles of Corporate Finance" [38]. It is designed for use by financial managers on continuous stock investments. The program requires only the entry of stock rate of returns, standard deviation and stock covariances. These are the same parameters that have been developed by using the target costing process in the continuous manufacturing process. Investmaster can present up to ten different portfolios for review and analysis at one time. The selection of Investmaster was made only out of convenience

of availability as there are many other software programs available for use in portfolio creation and evaluation that would provide the same product portfolios. A sample of the efficient product portfolios generated by Investmaster and detailing the applicable portfolio target profits, standard deviations, and portfolios weights for each product are shown in Table 6.3.

Table 6.3. Optimal Product Sets.

Portfolio Mix Number	Target Profit %	Standard Deviation %	Portfolio Weight x_1	x_2	x_3
1	19.7	27.4	0	94.9	5.1
2	20.3	25.9	0	74.7	25.7
3	21.0	27.9	23.8	76.2	0
4	22.3	30.1	44.9	55.1	0
5	23.0	31	55.6	44.4	0

The results of Table 6.3 show the mix of product portfolios, as a portfolio weight number and the weights across a row sum to one. Now a continuous process oriented manufacturing company can select a mix of product portfolios based strictly on the projected rates of return for the portfolios. By the fact that each product portfolio mix is efficient, management knows that the standard deviation or risk associated with a portfolio

is the lowest possible for the selected target profit. That is to say, these product portfolio mixes dominate all other potential product portfolio mixes.

It is interesting to note that the overall product portfolio mix changes from one containing products x_2 and x_3 to a mix of products containing x_1 and x_2 as the rate of return and level of risk increases. This change in product portfolio mix is due to the interaction of expected return, standard deviation and covariance between the two products. Consider the mix of Portfolio Mix Number 2. It provides a target profit of 20% while containing the two products, x_2 and x_3, with the lower target profits and standard deviations. If management wanted to increase the desired target profit from the 20 % given by Portfolio Mix Number 2 to the 21 % offered by Portfolio Mix Number 3, the most appropriate product mix would be to drop product x_3 and include both the higher target profit and standard deviation of product x_1. Any alternative product mix that management would choose to obtain a target profit of 21% would not have a risk associated with it that is as low as the risk offered by Portfolio Mix Number 3.

6.3. USE OF QUADRATIC PROGRAMMING WITH TARGET COSTING

The use of quadratic programming in the determination of efficient product portfolio mixes provides management with a great deal of useful and effective information that aid in the selection of manufacturing portfolios that are based on target costing and specifically target profits. The microcomputer based software tool for quadratic programming allows the user to quickly and easily create numerous efficient portfolio mixes and present them in ascending target profits for consideration and evaluation. In addition the software program allows for changes and the addition of new products to be made without difficulty.

Finally, the quadratic programming method of creating product portfolios is also ideal for the completion of sensitivity analysis. The use of the computer based quadratic

programming would seem to compliment the sensitivity analysis suggested in Chapter 3 using ISECOST by allowing for the comparison of portfolios with minor changes to either individual product target profits or standard deviations. This benefit encourages management to investigate the potential gains that can be acquired for reinvestment into product or portfolios.

An example of portfolio management for ceramic products using the ISECOST program, used for component uncertainties and Investmaster used to determine a company's product portfolio mix is included as Appendix C.

CHAPTER 7

EXPECTED TARGET PROFIT AND VARIANCES

The inclusion of uncertainties with target costing was reviewed and established in Chapter 4. It was demonstrated how the inclusion of conditions of uncertainty could improve the potential decision making power of management and hopefully result in decisions that reflect a company's true feeling towards risk. The chapter also demonstrated one method of determining the uncertainties that may exist in the cost elements and factors that make up the target costing process.

Chapter 5 and 6 illustrated how these expected returns and uncertainties could be used in quadratic programming to create efficient product portfolios for a company. The quadratic programming algorithm can be used to select from independent continuous product portfolios and determine product mixes that are efficient based on their target profit and uncertainties. The resultant mix identifies not only the products for inclusion by the company, but also the preferred product mix by percentage in order to give the best overall target profit for a given risk tolerance.

The purpose of this chapter is to illustrate an alternative method for the conversion of a target profit for a given product into an expected target profit and uncertainties or variances that can also be used in the quadratic programming algorithm.

7.1. FINDING EXPECTED TARGET PROFITS AND VARIANCES

Chapters 6 and 7 essentially looked at expected rates of return and variances that were based on historical data. As illustrated in Chapter 4, in most cases the use of a product portfolio for target costing will be more concerned about future returns and their probability. In order to use the quadratic programming for the determination of efficient

product portfolio mixes at least three variables must be identified for each product portfolio. These three variables are expected target profit, variance, and the covariance that exists between products. A possible method of calculating these variables, other than using the Robichek example is illustrated in this chapter.

7.1.1. Expected Returns

Consider the case of two products portfolios called Product G and Product B, which have the target profits of 26 % and 19% respectively for the coming year. Based on this limited information it would seem obvious that most companies would want to manufacture and sell Product G. The one consideration that could influence this choice is whether Product G is more risky to produce than Product B. The expected target profit on Product G, although it is predicted to be 26 %, could turn out to be higher or lower due to its uncertainty.

Suppose, during the next year, that the market for Product G experiences rapid growth (equally the example could have considered a technology break-through in manufacturing Product G or a drastic reduction in cost of material from suppliers). In this case, the return on Product G will be 42 %. If the market experiences a rapid decline (alternative examples could have involved environmental concerns, scarce raw materials, import tariffs, etc.) Product G's return will only be 6 %. Recognizing that there may be many factors that could positively or negatively affect future expected returns, these simplified examples allow the general ideas to be demonstrated without laborious computations.

Table 7.1 illustrates the possible returns for Products G and B given that each of the suggested market swings can occur with a 50 % probability. Note that Product B earns a return of 25 % in a market decline and 11 % if there is market growth.

Table 7.1. States of the Market and Product Returns.

State of Market	Probability of Market State	Returns if State Occurs Product G	Product B
Rapid Growth	0.5	42 %	11 %
Rapid Decline	0.5	6	25

Therefore the expected return on Product G is 24 % by:

$$E(R_G) = .50 * 42\ \% + .50 * 6\ \% = 24\ \%$$

and the expected return on Product B is:

$$E(R_B) = .50 * 11\ \% + .50 * 25\ \% = 18\ \%$$

Now consider what happens when the probability of a growing or declining market have unequal probabilities. This time suppose that the growth market will occur with a probability of only 20 % instead of 50 %. Table 7.2 summarizes the expected return calculations for this case.

Table 7.2. Product Returns with Unequal Market Probabilities.

State of Market	Probability of State	Product G Return if Rate Occurs	Product G Product Return if Rate Occurs	Product B Return if Rate Occurs	Product B Product Return if Rate Occurs
Growth	.20	.42	.084	.11	.022
Decline	.80	.06	.048	.25	.20
Expected Return		$E(R_G) =$	13.2 %	$E(R_B) =$	22.2 %

The results show how external factors can affect the expected returns of products. Given the new conditions of a 20 % chance of a growth market and an 80 % chance of a market decline, most managers would select to produce Product B with an expected return of 22.2 %.

This simple example shows how a manager would undertake the calculating of the expected target profit for use in the product portfolio and the quadratic programming efficient portfolio process.

7.1.2. Calculating the Variance

To calculate the variances of the target profits on the two products portfolios, the standard deviation must first be calculated. The squared deviations are then multiplied by the respective probabilities, and then simply added together to get the variance.

For example, in the equal probability outcome case, Product G has an expected return of 24 %. In the next year, Product G will actually have a target profit of

either 42 % or 6 %.

Therefore the deviations would be 42 % - 24 % = 18 % or 6 % - 24 % = -18 %. In this case the variance is:

$$\text{Variance} = \sigma^2 = .50 * (.18)^2 + .50 * (-.18)^2 = .0324$$

The standard deviation is the square root of the variance:

$$\text{Standard Deviation} = \sigma = .18 \text{ or } 18\%$$

Table 7.3 summarizes the results for both products.

Table 7.3. Variances for Equal Probability Case.

	Product G	Product B
Expected Target Profit, E(R)	24 %	19 %
Variance, σ^2	.0324	.0049
Standard Deviation, σ	18 %	7 %

Product G has a higher target profit, but Product B has less risk. With Product G the company could obtain a 42 % target profit, or could obtain a profit of only 6 %.

Notice that the lowest target profit than can be earned with Product B is 11 %. This point can be better investigated using the coefficient of variation.

Although it is often assumed that the product with the higher return has the lower risk, this is not always the case [39]. Therefore, in order to use the standard deviations a measure of the relative risk involved with a product, the standard deviation should be standardized and a calculation of the risk per unit of return examined. This is accomplished by the coefficient of variation, which is defined as the standard deviation divided by the expected return or target profit in this case.

Coefficient of variance = $CV = \sigma / E(R)$

in this case:

Product G: $CV = 18\,\% / 24\,\% = 0.75$

Product B: $CV = 7\% / 19\,\% = 0.36$

Now the exact cost of risk in terms of expected return can be examined for each product. Clearly, Product G has more risk associated with its unit of expected return than Product B. This measure is quite often used as a guide measure of the relative riskiness of a portfolio or product and can be useful when two portfolios are being compared.

Returning to the situation of unequal probabilities the product variances are calculated in the same fashion and are shown in Table 7.4.

Table 7.4. Variances of Unequal Probability Case.

State of Market	Probability of State	Return Deviation from Expected	Squared Deviation	Probability and Squared Deviation Product
Product G				
Growth	.20	.42 - .132 = .288	.0829	.0166
Decline	.80	.06 - .132 = .072	.00518	.00041
Product B				
Growth	.20	.11 - .222 = -.112	.0125	.0025
Decline	.80	.27 - .222 = .048	.0023	.00184

The new expected profits and variability for the two products:

Table 7.5. Summary of Expected Profits and Variances.

	Product G	Product B
Expected Target Profit, E(R)	13.2 %	23.8 %
Variance , σ^2	.017	.0043
Standard Deviation, σ	13 %	6.5 %

Again, the standard deviation for Product B is considerably lower than that of Product G. This indicates that, based on the information used in this example, the risk involved in Product B is much lower than the risk involved in Product G.

7.1.3. Calculating the Covariance

The last step required in preparing product data for use in the quadratic programming algorithm is the calculation of the covariances. As stated previously the covariance is a measure of how the products "covary" with respect to each other. The calculation of the covariance between two products can be accomplished in two ways.

Generally, in the case of investment stocks, the covariance can be found using the correlation coefficient. The correlation coefficient for stocks is based on over 50 years of historical data [40]. The movement of stocks has been recorded and the movement of stocks relative to each other has been established. This movement has formed the basis which is required to establish a correlation coefficient. Therefore the covariance between stocks can simply be found by multiplying the correlation coefficient by the standard deviation of each stock.

In the case of continuous manufacturing products no such historical data exists, but the covariance can be found quite easily. The covariance of two product portfolios can be defined as the variance of the expected values of the two products [41]. Expressed as a formula is would be:

Covariance between product 1 and 2 $= \sigma_{12}$

$$= \sum_{j=1}^{n} (r_{1_j} - r_1) * (r_{2_j} - r_2) * P_j \qquad (7\text{-}1)$$

where r_{1_j} and r_{2_j} represents the actual return

and r_1 and r_2 represent the expected return

The parentheses represent the deviation of a product's return from its expected value under the jth factor, and P_j is the probability of the jth factor occurring.

Returning to the situation involving product portfolios G and B and the equal probability situation, the covariance would be calculated as follows:

Covariance of Products G and B,

$$\sigma_{GB} = (42 - 26) * (11 - 18) * 0.5 + (6 - 26) * (25 - 18) * 0.5$$

$$\sigma_{GB} = -126$$

A similar exercise could be followed in order to calculate the covariance when the outcome probabilities for the two products are not equal. The magnitude and sign, either positive or negative, of the covariance is significant as a rule of thumb measure of the relationship between the two products.

If the returns on Products G and B tend to move in a like direction as a result of one factor, the terms in the parentheses will both be positive or both be negative, and hence the product of the parentheses of Equation 7.1 will be positive. If the returns move counter to each other, the products of the parentheses of Equation 7.1 will tend to be negative. However, if the two product portfolios vary randomly, then the product of the parentheses of Equation 7.1 will sometimes be positive and sometimes negative, and the sum of the products will be close to zero because the positives and negatives will tend to cancel out. Therefore, if the product portfolios tend to move in like directions, their covariance will be positive. If they tend to move counter to one another, their covariance will be negative. Finally, if they tend to fluctuate randomly, their covariance could be either positive or negative but in either case it will be close to zero.

If the target profit on either Product G or B is highly uncertain, then it will have a high standard deviation and the absolute size of the covariance will be large. However, if one or both of the target profits are large but the returns tend to fluctuate randomly then the covariance will be small.

If either product portfolios, G or B, has a standard deviation of zero, and therefore no risk or variance, then the covariance will be zero. Similarly if one of the product portfolios has a very low risk of production then its deviations will tend to be small and will hold down the size of the covariance.

In this case, the covariance is large and negative, indicating that the two product portfolios have a negative correlation in the way that they react to similar factors. This negative correlation means to say that as the target profit of one product portfolio goes up the target profit of the other goes down. As a general statement these two products would be ideal to potentially mix together in a company product portfolio as they tend to balance out each other's target cost and profit deviations.

7.2. USE OF PORTFOLIO ANALYSIS

Regardless of whether the method presented in this chapter or the method presented in Chapter 4 using ISECOST is used, once the determination of the expected target profits and variances for a group of products is completed the quadratic programming algorithm can be used as illustrated in Appendix C. The use of the quadratic program produces a series of efficient portfolios for management to choose between. The factors that go into the selection of expected outcomes can be numerous if not unlimited. The majority of such decisions will depend on the strategic plans and goals of either the strategic business unit or company involved.

The factors that were identified in Appendix B, for the industry attractiveness-business strength matrix would serve as a good basis for the consideration of what might influence the future of both a company and individual product.

These would include such things as:

- market size and growth rate
- the intensity of competition
- seasonally and cyclical influences
- projected industry profitability
- technological requirements
- entry and exit barriers
- capital requirements
- social, legal and environmental influences

The use of the Cost Breakdown Structure and ISECOST costing tool are proven methods for the identification and evaluation of the costs that contribute to the total cost of a product.

Clearly, the process of calculating the required expected target profits, and variances could become a very labor intensive process if there were a large number of products or if a large number of potential portfolios were being considered. If a company were to consider using this optimization of target profits as a means of portfolio management, there should be consideration given to creation of a software program that would readily calculate the required expected returns and variances with the appropriate inputs.

CHAPTER 8

CONCLUSIONS AND RECOMMENDATIONS

This chapter provides a summary and overview of the conclusions drawn in the report. Also included are a number of recommendations dealing with the continuation of the ideas put forth in this report as possible topics for continuing work in efficient product portfolios.

8.1. SUMMARY AND CONCLUSIONS

In recognizing that the world is becoming a borderless global market place, the competition between companies and competitors is growing stronger and fiercer. To be competitive a company must know the needs of the consumer and guide all of their efforts to winning that customer over with their product. Part of this desire to please the customer is being realized in both the quality and selling price of the product. As part of an emerging trend towards Systems Engineering a growing number of companies are placing more emphasis on the design and development phases of the product life cycle where changes and cost savings can be made in a product's design without giving up quality. Target costing is a process that is used by some companies as a cost management tool that enables them to review and analyze production and life cycle costs.

This report has examined target costing with the intent of suggesting ways that the process can be enhanced and made more effective for a process oriented company.

First, this report examined the inclusion of uncertainties in the target costing process. While the addressing of uncertainties in manufacturing is not new, there are a number of relatively new tools that can aid in the determination and consideration of uncertainty and risk, especially when combined with the concept of target costing. The

use of ISECOST has been demonstrated to provide easily obtained additional information and knowledge about the target costing process to management.

Second, the emergence of target costing amongst process oriented companies has made the use of product portfolio management, through the use of expected target profits and variances, a realistic goal. The unique application of portfolio management by target profits for process oriented products has been shown to be similar to investment management and offers a new optimization alternative to companies. In using product portfolio management a company is forced to review and address the uncertainties in its forecasts and consider the factors that could either positively or negatively effect its future.

It is felt that the goal of the report was successfully met in terms of examining the inclusion of uncertainties in the target costing process and demonstrating the application of efficient portfolio analysis for use with process oriented target costed products.

8.2. RECOMMENDATIONS

The emergence of target costing in the process oriented or continuous product industry has provided the springboard by which the use portfolio analysis could be investigated.

In the area of Systems Engineering, research could be done into the use and effects of target costing on the design for economic feasibility aspect of Life Cycle Cost analysis. This could include the use of the ISECOST and Investmaster software as economic decision aids during the design phase.

In the area of efficient portfolio analysis it is recommended that research be continued as follows:

1. First, a field study be undertaken to investigate the real-life distribution and variances of target costed products. Recognizing that target costs and

target profits can vary, further investigation could be completed with a company using the target costing process into uncertainty of these variables. The results of this investigation could either verify the use of a normal distribution for target costing data or identify an alternative distribution that should be employed.

2. Second, a micro-computer software package be developed for the calculation of the expected target profit, variance and covariance of products or components. This simple tool will allow for the utilization of product efficient portfolios by many companies who otherwise would not have the time and manpower available to compute the numerous variables required to enter into a quadratic programming algorithm.

3. Third, it is recommended that a larger more involved software package be developed for the considerations of the factors that influence and impact on target profit. By incorporating the economic and industrial factors that have been introduced in the industry attractiveness - business strength matrix a computer based Decision Support System (DSS) or Expert System (ES) could be developed. The DSS or ES tool will enable companies to select their own target profit factors in accordance with their long range plans. In essence the software would become a computer based strategy tool where a company could examine the "what ifs" of industry and national trends via on-line data.

4. Finally, it is recommended that a company that is currently using target costing be approached and presented with the concept of utilizing the product portfolio analysis tool of efficient portfolio management.

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APPENDIX A

ILLUSTRATION OF THE USE OF ISECOST FOR UNCERTAINTY IN PRODUCTS

As stated in Chapter 4 the ISECOST software program can be used to conduct quick overviews of how uncertainties can be incorporated into the target costing process. The use of the ISECOST program is an iterative process that can establish a series of both Design to Cost and Design to Price printouts that can be used to form the basis for a normally distributed set of target costs and target profits.

A.1. PRODUCT CONSIDERATION

The use of ceramics have be selected for two primary reasons. First, they are a process oriented product that are produced from large batches of raw materials. In this sense, ceramics meets the criteria of continuous production for the application of product portfolio efficiency as stipulated in Chapter 4. Second, the ceramics industry is undergoing a tremendous change as the availability of raw material is predicted to be a major problem in the future. As such, the industry as a whole have been actively searching for ways to improve on both their costing and processing techniques.

A more detailed explanation of the ceramic industry is given in Appendix C, but for the use of ISECOST in this appendix, one of the main components of white ceramics, Kaolin, will be examined.

Kaolin is a clay based material that contributes between 20 % to 60 % of the total solids of ceramic whitewares. Often called "plastic clay" it is a fine-grained, highly plastic clay comprised of a mixture of kaolinitic, quartz and micaceous minerals. In general, kaolin materials are mined from open pit mine operations and then processed in order to achieve a desired quality level. The preparation of kaolin involves shredding, blending,

drying and grinding. Blending is the single most important processing aid to the kaolin producer, but throughout the production and processing operation rigorous quality control measures must be applied to ensure final product uniformity.

In 1987, US prices ranged from a low of $23 for shredded kaolin to $110 per short ton bagged, FOB delivery plant, for specially selected airfloated clays.

A.2. ISECOST

The ISECOST software program allows for the calculation of product Design to Cost criteria and the examination of cost factors, which contribute to the overall cost of the products, on an iterative selection process. The software requires that the Design to Price data for a product be entered into the program and then the user can manipulate any of the identified cost factors in order to examine how Design to Cost applications can be investigated.

In this examination the changing of the Profit/Fee is the area that will be examined. The manipulation of the Profit percentage is similar to the variation of target profit in the target costing process.

Consider the production and purchasing of kaolin by a ceramic manufacturer for use in the manufacturing of a ceramic product. The example uses a ceramic manufacturing company called, Porcelain Ceramics Inc., and their potential use of kaolin. A sample run of Design to Price application has been completed for a quantity of 50 tons of kaolin. Of importance is the final cost of the product, listed as total manufacturing, the profit/fee, and the unit selling price.

In the use of ISECOST in this report the goal is to hold the selling price of a product constant and allow the profit/fee rate to fluctuate. This can be considered equal to a company that has fixed their target cost and now is trying to reduce their drifting cost

and obtain their identified target profit. In this application of the ISECOST program the selling price will be held relatively constant while the profit/ fee will be varied.

The Figures A.1, A.2, A.3 (included at the end of this appendix) are sample printouts illustrating how the ISECOST program can be used to facilitate the target costing process. Each example demonstrates how the program can be especially useful if costing uncertainties are being investigated. In the second and third example the initial cost of material and outside manufacturing cost were allowed to vary while the selling price was held relatively constant. The selling price for each example is set at approximately $66.77.

Table A.1 detailed the change of both the target cost, target profit and selling price involved in the use of kaolin.

Table A.1. Results of Varying Profit Using ISECOST.

Run	Target Cost ($)	Target Profit (%)	Selling Price ($)
A1	2,896.17	17.0	67.77
A2	2,997.90	9.0	67.81
A3	3,110.34	13.0	67.75

Using this data and the uncertainty calculations demonstrated in Chapter 7, the following predicted target profits and standard deviations can be derived. Using an equal probability of either event occurring the expected target profit would be:

$$E(TP) = (.5 * .9\%) + (.5 * .13\%) = 11.0\%$$

and the variance would equal

$$\text{Var}(\sigma^2) = 0.5(.17 - .13)^2 + 0.5(.17 - .09)^2 = .0040$$

$$\text{Standard Deviation} = \sigma = .063 \quad \text{or } 6.3\ \%$$

Therefore given the information in this example, kaolin should be considered to be a component of ceramics that would cause a considerable amount of concern amongst some manufacturer due to its relatively low contribution to target profit and the relatively high risk associated with it.

The true contribution of this one component cannot be determined in isolation. Only when all the components of a product portfolio are considered can a complete assessment be properly made. This type of overall assessment will be examined in Appendix C.

Customer:	Porcelain Ceramics Inc.
Model:	Kaolin
Part No.:	K-0001\A
Parts Req'd:	50
Estimator:	Sam Steward
Date:	21 July 1995

MANUFACTURING COST	CHARGE		
	Hours	Rate	Dollars
A. Factory Labor	25.00	15.5	387.50
B. Planning & Liaison	———	11.5% of A	44.56
C. Quality Control	———	14.5% of A	56.19
D. TOTAL LABOR			488.25
E. Factory Overhead	———	103.0% of D	502.90
F. General & Admin Expense	———	13.0% of D	63.47
G. Production Material	———	———	1,350.00
H. Outside Manufacture	———	———	300.00
I. SUBTOTAL			2,704.62
J. Packing Costs	———	5.50% of I	148.75
K. Total Direct Charge			2,853.37
L. Other Direct Charge	———	1.50% of K	42.80
M. Facility Rental			0.00
N. Total Manufacturing Cost			2,896.17
O. Profit/Fee @		17.0% of N	492.23
Total Selling Price			3,388.40
Ship Set (Unit) Selling Price		$	67.77

Figure A.1. Initial ISECOST Prediction for Kaolin.

Customer:	Porcelain Ceramics Inc.
Model:	Kaolin
Part No.:	K-0001\A
Parts Req'd:	50
Estimator:	Sam Steward
Date:	21 July 1995

MANUFACTURING COST	CHARGE		
	Hours	Rate	Dollars
A. Factory Labor	25.00	15.5	387.50
B. Planning & Liaison	———	11.5% of A	44.56
C. Quality Control	———	14.5% of A	56.19
D. TOTAL LABOR			488.25
E. Factory Overhead	———	103.0% of D	502.90
F. General & Admin Expense	———	13.0% of D	63.47
G. Production Material	———	———	1,550.00
H. Outside Manufacture	———	———	300.00
I. SUBTOTAL			2,904.62
J. Packing Costs	———	5.50% of I	159.75
K. Total Direct Charge			3,064.37
L. Other Direct Charge	———	1.50% of K	45.97
M. Facility Rental			0.00
N. Total Manufacturing Cost			3,110.34
O. Profit/Fee @		9.0% of N	279.93
Total Selling Price			3,390.27
Ship Set (Unit) Selling Price		$	67.81

Figure A.2. ISECOST for Kaolin with Increased Raw Material Cost.

Customer:	Porcelain Ceramics Inc.
Model:	Kaolin
Part No.:	K-0001\A
Parts Req'd:	50
Estimator:	Sam Steward
Date:	21 July 1995

MANUFACTURING COST	CHARGE		
	Hours	Rate	Dollars
A. Factory Labor	25.00	15.5	387.50
B. Planning & Liaison	———	11.5% of A	44.56
C. Quality Control	———	14.5% of A	56.19
D. TOTAL LABOR			488.25
E. Factory Overhead	———	103.0% of D	502.90
F. General & Admin Expense	———	13.0% of D	63.47
G. Production Material	———	———	1,350.00
H. Outside Manufacture	———	———	395.00
I. SUBTOTAL			2,799.62
J. Packing Costs	———	5.50% of I	153.98
K. Total Direct Charge			2,953.60
L. Other Direct Charge	———	1.50% of K	44.30
M. Facility Rental			0.00
N. Total Manufacturing Cost			2,997.90
O. Profit/Fee @		13.0% of N	389.73
Total Selling Price			3,387.63
Ship Set (Unit) Selling Price		$	67.75

Figure A.3. ISECOST for Kaolin with Increased Outside Manufacturing Cost.

APPENDIX B

PRODUCT PORTFOLIO MANAGEMENT

Business strategy and planning for multi-product and multi-market companies is a very complex problem. A firm may have hundreds or even thousands of products serving similar markets with widely differing potentials. Some of these products may be in a strong position relative to competitors and others may be in weak positions.

Regardless of their individual potential, the company may establish an individual strategy for each product that they produce and market. Within any industry there may be numerous other companies that will be competing for market share with their own strategies. In each case, the organization involved wishes to allocate its limited financial resources amongst their products in order to achieve the best performance possible.

B.1. BUSINESS UNITS AND PORTFOLIOS

Often, large diversified firms manage these complex multi-product problems by breaking down the organization into independent profit centers called "business units". The strategies for individual business units, like individual products, are then managed separately. Individual business unit strategies are adjusted independently in order to meet the corporate financial performance targets and plans.

The advantage that a multi-business unit, multi-product company has over an undivided company is that it can channel its resources into the most productive units. Corporate headquarters maintains control of these decisions through the use of an integrated strategic plan. In this way the organization can ensure that the sequence and timing of resource transfers will match the changing potential of products. For example, a firm may decide to slow down the growth of a paper business unit in order to direct money toward the expansion of its light aircraft business unit. The consequences of

such integrated planning may result in the sub-optimization of one business unit, in order to optimize the overall performance of the firm [44].

The product portfolio approach is quite similar to the strategic business unit approach but is generally handled by management personnel one level lower. At this level management is asked to make product decisions which would include such things as production forecasts, buy or manufacture decisions, and the contracting of suppliers. In the same way that a very large company is divided up into smaller more easily directed groups of smaller companies, the products of a company or business unit can be grouped into portfolios for ease of management and control. The make-up of a portfolio can be simple or very complex. Theoretically a portfolio could be made up of an individual product, a product line, a market segment, a business unit, or even a division. In practice though, a portfolio or grouping is usually chosen which can have meaningful strategic value to the company. This means that portfolios are formed for levels at which plans are drawn-up and implemented, and where strategic decisions can be made essentially independently of strategic decisions in other portfolios. Consequently, for these reasons, the composition of a portfolio is usually recognized as being a grouping of related products. For example it is more likely that a portfolio and analysis would be made for color photocopiers than for photocopiers as a whole. Equally, these decisions would encompass all color copiers rather than focus on any particular size or model [45].

Once a portfolio has been formed, the goal of portfolio management is to determine what exactly should happen with each product in the portfolio. Each product should be examined on an individual basis in order to determine what the unique opportunity for it is and what is required to promote it. As an overview, the goal of portfolio management should be to determine which products represent investment opportunities, which should supply investment funds, and which should be considered

for elimination from the portfolio. The objective is to get the best overall performance from the portfolio, and thus generate cash flow for the company.

B.2. PORTFOLIO MANAGEMENT METHODS

The most commonly employed methods for evaluating and analyzing product portfolios are the use of business portfolio matrices. A business portfolio matrix is a two-dimensional display comparing the strategic positions of each business a company is in or can be made for each product in a portfolio. Matrices are constructed using any pair of strategic position indicators. The most common indicators are industry growth rate, market share, long-term industry attractiveness, competitive strength of a business, and stage of product/market evolution. Usually one dimension of the matrix relates to the attractiveness of the industry environment and the other to the strength of a business within the industry.

There are three types of matrices that are most commonly used in managing portfolios; the growth-share matrix, the industry attractiveness-business strength matrix and the industry life-cycle matrix.

B.2.1. Growth-Share Matrix

The first business portfolio matrix to receive wide use was a four square grid devised by the Boston Consulting Group [46]. The matrix is formed using industry growth rate and relative market share as the axes. Each business unit in a corporation or product in a portfolio appears as a circle on the matrix. The area of the circle is scaled to represent the percent of revenue it contributes to the overall portfolio.

A grid is formed on the matrix by dividing the axes into high and low assessments of the industry growth rates and relative market share. The industry growth rate was divided by drawing a line at a point which represented about twice the growth rate of the GNP plus a nominal inflation rate. Portfolios that showed a growth

rate faster than the overall economy should end up in the high-growth cells. Portfolios with slower growth rates would be placed in the low-growth cells. Low-growth products generally represent markets that are mature, aging, stagnant or declining.

Relative market share is the ratio of a business's or product's market share to the market share held by the largest rival firm in the industry. Market share is measured in unit volume and not dollars. For example, if a business has a 15 % market share of the industries total unit volume and the largest company in the industry holds 30 % of the market share, its relative market share is 0.5. If the business has a market-leading share of 40 % and its largest rival has 30 %, its relative market share is 1.33. Therefore it can be seen that only the businesses that are market share leaders will have relative market shares greater than 1.0. Businesses that trail market leaders will have ratios less than 1.0. Figure 5.1 shows an example of a product portfolio growth-share matrix with a number of products.

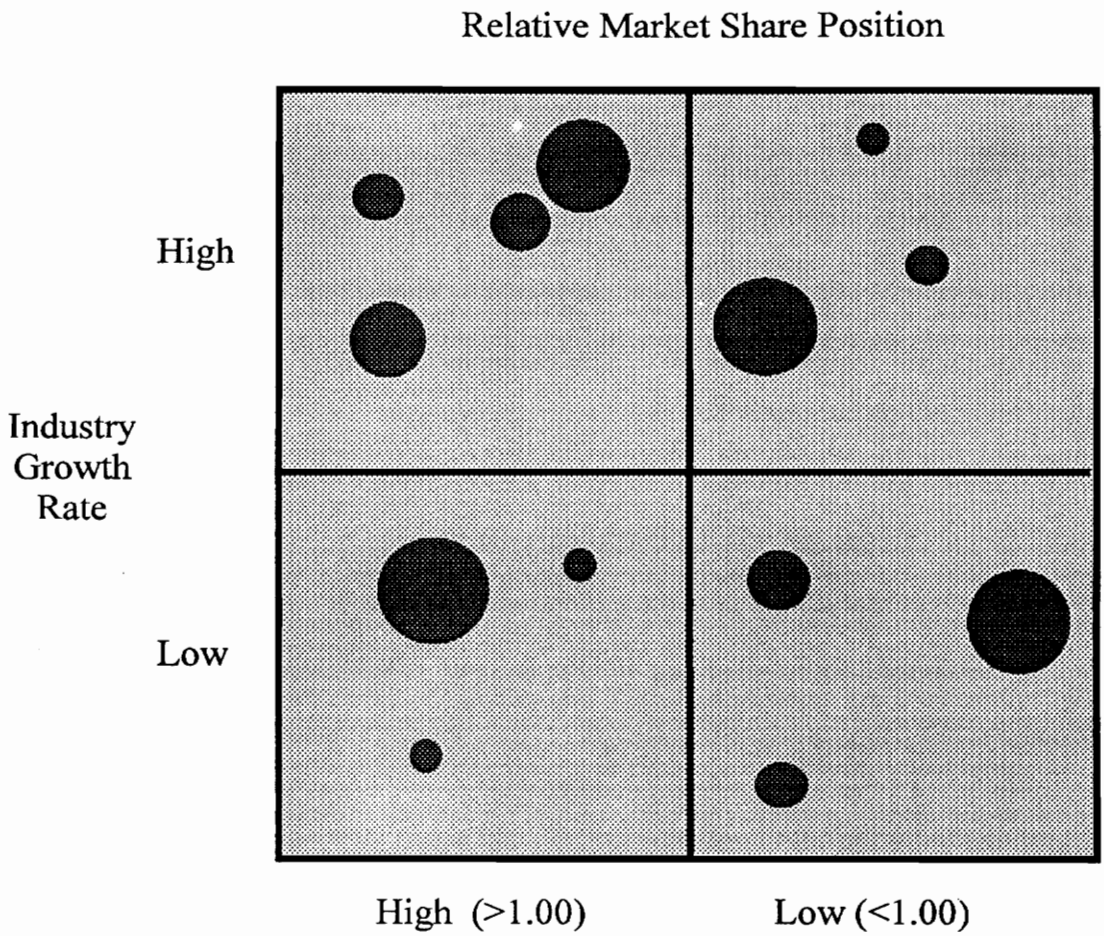

Figure B.1. The Growth-Share Matrix [47].

Although a simple to use system for the analysis of product portfolios, the growth-share matrix does have its limitations. First, because it is almost impossible for a company or firm to control the market growth, this portfolio analysis reduces to one of determining a market share strategy for each product. As a four cell matrix of high or low classifications, the process hides the fact that many products are average performers. There is also a general feeling that although the position of a product or portfolio may be adequately determined, the matrix process gives no concrete direction of what must be done to move from an undesirable position to a desirable one. Finally, there is a great deal of information that is not captured in the growth-share matrix that should be reviewed before making strategic product decisions. These would be such

things as barriers to entry, technological changes, social and legal issues, management capabilities and product promotions.

B.2.2. Industry Attractiveness-Business Strength Matrix

An alternative to the growth-share matrix which avoids a number of its short comings is the industry attractiveness-business strength matrix developed by General Electric [50]. The GE method employs a nine-cell matrix which analyzes products on the two dimensional attributes of industry attractiveness and business strength. An illustration of the matrix is shown in Figure B.3.

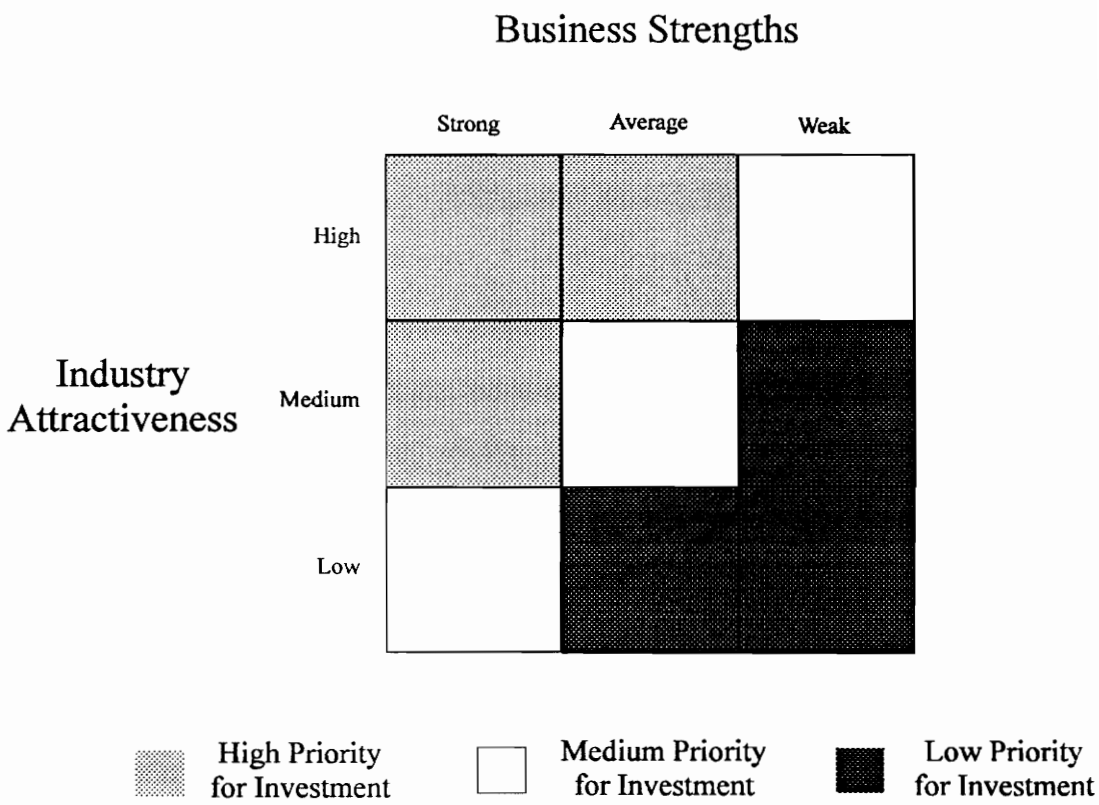

Figure B.3. The Industry Attractiveness - Business Strength Matrix [51].

The two axes measures are composites of several factors as opposed to simply one factor. The criteria for determining long-term industry attractiveness includes:

- market size and growth rate
- the intensity of competition
- seasonally and cyclical influences
- projected industry profitability
- technological requirements
- entry and exit barriers
- capital requirements
- social, legal and environmental influences

To arrive at one quantitative measure of the long-term industry attractiveness, the chosen factors are assigned weights based on their importance to management. The sum of the weights must add up to 1.0. Then the rating that each product in the portfolio (rating is given between 1 to 5) is multiplied by the factor's weight. The sum of the weighted ratings gives a figure which represents the portfolio's long term attractiveness.

The quantitative measure of business strength is obtained using the same approach as for the industry attractiveness. The factors used to assess business strength include such things as:

- adequacy of technical know-how
- knowledge of customers and products
- desirable core competencies
- profitability relative to competitors
- relative cost position
- caliber of management
- market share
- ability to match rival firms on product quality

Again, once the position has been identified along both the axes where a product or portfolio should be located, a circle representing the size of the revenue that a product commands is placed at the intersection of the axes measures. The attractiveness of the product is described by where, of the three different areas, it is located. A product located in the upper three left hand squares is deemed to have a high overall

attractiveness and should be a priority for investment. A product located in the lower three right hand squares is deemed to have a low overall attractiveness and should have a low priority for investment. The three remaining squares on the diagonal possess medium attractiveness and should have a medium priority for investment.

The industry attractiveness-business strength matrix clearly provides more information than the market-share matrix but also has a number of weaknesses. In a similar fashion as the market-share matrix, the industry attractiveness matrix provides no real guidance on the required business strategy to move from one position on the matrix to another. It does not take into account the future changes which may occur in an industry, for instance, when an industry may take off. Finally, the industry attractiveness matrix must be custom built for each industry that is examined according to the factors and parameters that are identified as important. Although this flexibility has advantages, it presents problems when comparisons are to be made across portfolios and strategic business units.

B.2.3. Life-Cycle Matrix

The least common of the three portfolio management tools, the life-cycle matrix is designed to identify a developing winner business or portfolio. The matrix uses a 15 cell matrix where business units or portfolios are plotted based on stage of industry evolution and strength of competitive position. An illustration of a life-cycle matrix is shown in Figure 5.4. In the life-cycle matrix the area of the circles reflect the overall size of the industry involved. The power of the life-cycle matrix is in the story it tells about the distribution of portfolio across the stages of an industry's evolution.

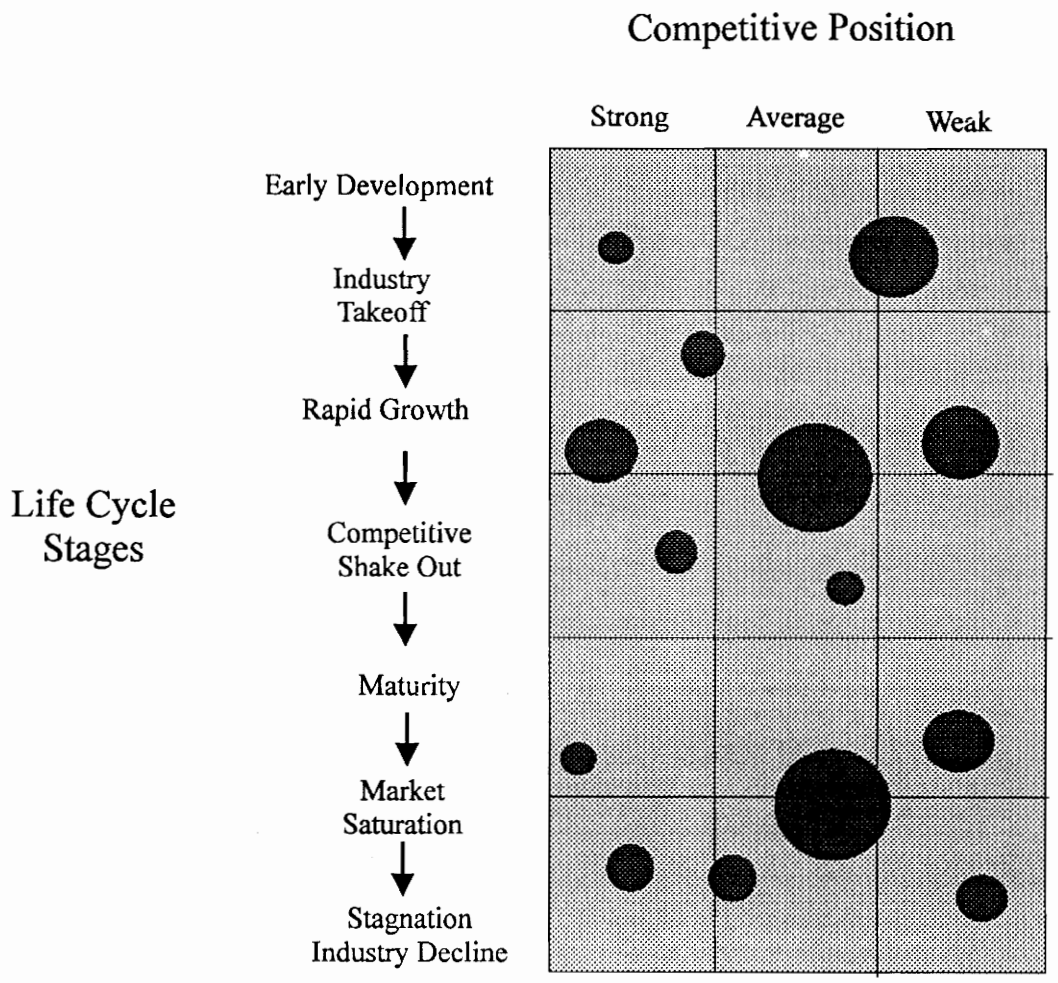

Figure B.4. The Life Cycle Matrix [52].

B.3. APPLICABILITY TO TARGET COSTING

From this abbreviated review of the three most popular matrix portfolio management techniques, it would seem clear that they are not compatible with the concepts of target costing and its possible portfolio management requirements. Individually the matrices exhibit no unique or special characteristics that would make it superior relative to meeting the goals and objectives of target costing.

APPENDIX C

USE OF INVESTMASTER ON CERAMIC PRODUCTS AND PORTFOLIOS

An example of how the INVESTMASTER software might be used to create a company product portfolio mix will be illustrated using the manufacturing of ceramic products. The premise of the example will be that a company, which uses target costing as a cost control process, can choose between the production of four different types of ceramic materials. By using the INVESTMASTER quadratic programming algorithm the company can perform two functions that assist in the use of target costing under conditions of uncertainty. These two tasks are: 1) to identify the product portfolio expected target profit and standard deviation based on the components of the product, and 2) determine an efficient mix of ceramic products such that the company can control their overall target profit and risk tolerance by optimizing the mix of product portfolios.

C.1. BACKGROUND ON THE CERAMIC INDUSTRY

Ceramic raw materials are classified functionally as aggregates, plasticizers, binders, fluxes, and modifiers. Traditional ceramic components were largely derived from the elements most common in the earth's crust: oxygen, silicon, aluminum, iron and so forth, but modern ceramics draw upon nearly every element. Although oxides remain most common other useful compounds include carbides, nitrides, borides, sulfides and fluorides.

Much of the art of the ceramic technologist has always lain in the compounding of raw materials into batches. The formulas, traditionally jealously guarded secrets, involve selection of raw material that confer the desired working characteristics and responses to heat treatment, yielding the sought-for character and properties. The clay

must be selected and apportioned among the kaolins and ball clays for workability, fusibility, fired color and other requirements.

The major processing done in the manufacturing of ceramics are:

1. particle bonding and packing;
2. the forming process, consisting of plastic forming, slip casting, pressing and fusion casting; and,
3. heat treatment.

The typical body compositions of white ceramics, by percentage of total solids, are shown in Table C.1.

Table C.1. Percentage of Solid Bodies in White Ceramics [53].

Whiteware Type	Kaolin	Ball Clay	Flux	Quartz
Earthenware	25	25	15	35
Porcelain	60	10	15	15
Bone China	25	-	25	-
Vitreous-china	20-30	20-30	15-25	30-40
Electric Porcelain	20	30	30	20
Wall tiles	20	30	-	30-35

The future trends in the manufacturing of ceramics are a major concern within the ceramic industry because of the present predictions on the scarcity of raw materials in the future. Table C.2 compares how the present cost of manufacturing ceramics are expected to change in the future.

Table C.2. Manufacturing Cost of Ceramic Components[54].

	Today	Future
Raw Material	15%	50-60%
Mixing, Shaping	15%	10-15%
Firing	15%	15-20%
Finishing	5%	5%
Rejection	50%	5-10%

C.2. USE OF INVESTMASTER

The first step in the use of INVESTMASTER software is in the determination of the expected target profit and standard deviation of a product portfolio. Consider the product portfolio of earthenware which has a component make-up, target profit and standard deviation as given in Table C.3.

Table C.3. Data for Earthenware.

Component	Percentage by Weight	Target Profit %	Standard Deviation %
Kaolin	25	11	6.3
Ball Clay	25	15	9.0
Flux	15	16	6.8
Quartz	35	19	7.4

The INVESTMASTER software allows for the determination of a portfolio's target profit and standard deviation based on specified portions or weights of the components. Using the data given in Table C.3 the following product portfolio composition is identified as having a predicted portfolio target profit of 15.5 % and a standard deviation of 6.8 %.

Once a portfolio target profit and standard deviation for each product portfolio is identified, the INVESTMASTER software can be used to establish an efficient mixes of product portfolios that meet a company's overall long term profits and risk tolerance. Consider a company whose product portfolios, target costs, standard deviations and covariances are shown in Table C.4 and Table C.5.

Table C.4. Target Profits and Standard Deviations for Product Portfolios.

Whiteware Type	Target Profit %	Standard Deviation %
Earthenware	15	7
Porcelain	17	6
Bone China	17	5
Wall Tiles	18	12

Table C.5. Covariances for Product Portfolios.

	Earthenware	Porcelain	Bone China	Wall Tiles
Earthenware	1	-	-	-
Porcelain	.45	1	-	-
Bone China	.45	.9	1	
Wall Tiles	.8	.45	.35	1

Using the INVESTMASTER software a list of possible efficient mixes of product portfolios are identified in Table C.6.

Table C.6. List of Efficient Product Portfolio Mixes.

Target Profit %	16.3	16.8	17.2	17.7
Standard Deviation %	5.5	5.7	6.4	10
Portfolio Weights:				
Earthenware	33.33	11.11	1.0	5.5
Porcelain	66.67	88.89	76.0	17.0
Bone China	-	-	-	-
Wall Tiles	-	-	23.0	77.5

The selection of a specific mix of product portfolios will depend on a company's long term profit planning and on the exact level of risk that they wish to assume. This is especially noteworthy in comparing the last two columns of Table C.6. In the second last column a company can obtain a target profit of just slightly better than 17% with a standard deviation of 6.5%, but if the same company wishes to obtain a target profit of over 17.5% then they must accept a standard on this return of 10%.

VITA

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He received a Bachelor of Engineering degree from the Royal Military College of Canada in Kingston, Ontario in 1980. He also received a Masters of Science in Engineering Science from the Naval Postgraduate School in Monterey, California in 1986.

Kevin was born in Toronto, Ontario. He is married to Suzanne and they have one son, Tobin.