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Design and Development of a Target-Costing Model for Machining

Ameet Kokatnur

**Thesis submitted to the
College of Engineering and Mineral Resources
at West Virginia University
in partial fulfillment of the requirements for the degree of**

**Master of Science
in
Industrial Engineering**

Bhaskaran Gopalakrishnan, Ph.D., Chair.

Jack Byrd Jr., Ph.D.

Robert Creese, Ph.D.

Department of Industrial and Management Systems Engineering

Morgantown, West Virginia

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ABSTRACT

In today's intensely competitive and highly volatile business environment, consistent development of low cost and high quality products meeting the functionality requirements is a key to a company's survival. Companies continuously strive to reduce the costs while still producing quality products to stay ahead in the competition. Many companies have turned to target costing to achieve this objective. Target costing is a structured approach to determine the cost at which a proposed product, meeting the quality and functionality requirements, must be produced in order to generate the desired profits. It subtracts the desired profit margin from the company's selling price to establish the manufacturing cost of the product. Extensive literature review revealed that companies in automotive, electronic and process industries have reaped the benefits of target costing. However target costing approach has not been applied in the machining industry, but other techniques based on Geometric Programming, Goal Programming, and Lagrange Multiplier have been proposed for application in this industry. These models follow a forward approach, by first selecting a set of machining parameters, and then determining the machining cost. Hence in this study we have developed an algorithm to apply the concepts of target costing, which is a backward approach that selects the machining parameters based on the required machining costs, and is therefore more suitable for practical applications in process improvement and cost reduction. A target costing model was developed for turning operation and was successfully validated using practical data.

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CHAPTER 1

INTRODUCTION

1.1 Need For Target-costing

In an era of intensely competitive and ever changing business environment, consistent development of low cost and high quality products meeting the functionality requirements is a key to a company's survival. Companies continuously look forward to cut down costs while still producing quality products and stay ahead in the competition. Many companies have adopted a process known as target-costing for controlling both manufacturing and non-manufacturing costs. The following example illustrates the role played by target-costing in redesigning and reengineering the business process of one of the largest camera manufacturer.

In the 1980s, five Japanese companies dominated the world's 35mm camera market: Asahi Pentax, Canon, Minolta, Nikon and Olympus. Olympus was the third major player with 10% market share. There were two major types of 35mm cameras: Single Lens Reflex (SLR) and Lens Shutter (LS) or compact cameras. SLR cameras allowed the photographer to see exactly what a picture would look like before it was taken. Because of this feature SLR cameras rapidly gained a dominant share of the professional photographic market. Compact cameras, as suggested by their name, were smaller than SLR cameras. They were relatively unsophisticated and posed little challenge to the SLR market. However as advances in electronic control systems allowed auto-focus and automatic exposure features to be added at relatively low prices, the compact camera began to be viewed as a serious alternative to SLR cameras. Sales of SLR cameras

plummeted. The shift in consumer preference to compact cameras adversely affected Olympus in particular, because the company historically had relied heavily on SLR sales and had failed to develop a leadership position in the compact camera arena. In the mid-1980s, Olympus' camera business began to lose money and by 1987 Olympus suffered considerable losses. Top management reacted to the losses by introducing an ambitious three-year program to "reconstruct" the camera business. At the core of this program were three objectives: first, to recapture lost market share; second, to dramatically improve product quality; and third, to reduce production costs via an aggressive set of cost reduction programs. At the heart of the cost reduction program was the company's target-costing system (Cooper & Slagmulder 1999).

1.2 Target-costing Methodology

The first step in determining the target cost of a product is to establish the selling price and the company's desired profit margin for a product. The desired profit is subtracted from the selling price to determine the product-level target cost. The product-level target cost is then decomposed to component-level so that the purchase price of the components can be determined. This also enables in making "make vs buy" decisions. The critical factor that distinguishes target-costing is the intensity with which the cardinal rule is applied: the target cost can never be exceeded (Cooper & Slagmulder 1999). By setting the target cost in this way, the company assures itself that when the product's target cost and the market price are realized, the product will generate its anticipated returns. If the actual cost exceeds its target cost, actions must be taken to reduce the product manufacturing cost. Manufacturing costs can be reduced by taking different actions.

One option to achieve the target cost is to reengineer the manufacturing process. Manufacturing is a very broad term consisting of different processes like casting, forging, machining, bending, drawing, extrusion etc that strive to impart the desired shape to a work-piece. The next section gives an overview about machining operation.

1.3 Target-costing In Machining

Machining is one of the major manufacturing processes. It aims to generate the shape of a work-piece from a solid body or improve the tolerances and surface finish of a previously formed work-piece. A very high percentage of parts used in the automotive industry, aircraft industry, pumps, turbines etc have machined components forming a major part of the final product. Machining cost therefore forms a significant portion of the total cost of the final product. The machining cost depends upon the machining process, cutting tools, labor, type of machine, material and several other factors and hence significant cost reduction can be obtained by proper design and selection of these parameters. Different machining operations such as turning, milling, drilling, tapping and grinding are widely used, of which the turning operation and the cost of turning will be the focus of this research. Subsequent sections will be dedicated to an overview of the turning operation and its associated costs, and the application of target-costing in machining for the turning operation

1.4 Turning

Turning is probably the most widely used of all the machining processes. It is a continuous machining process governed by various parameters. The work-piece is held

in the chuck that rotates and a single point cutting tool is used to remove the metal from the work-piece. Different parameters which govern the turning process are cutting speed, feed depth of cut, tool life, tool angles and so on. The cost per piece in turning can be divided into two components: machine time cost and tool cost. The total machine time cost can be subdivided into feeding cost, rapid traverse cost, tool-changing cost, loading/unloading cost and setup cost. The total tool cost is made up of tool depreciation cost, tool re-sharpening cost, re-brazing cost, carbide insert cost and grinding wheel cost. Some components of the total tool cost may be zero depending upon the type of tool selected.

1.5 Primary Variables In Turning

The primary variables in turning operation are cutting speed, the feed and the depth of cut. The product of these three variables results in the metal removal rate, and generally a high metal removal rate is desirable. However, the tool costs and tool changing costs increase as the three variables increase, so there is an optimal set of parameter levels for the three variables. The general situation is to first select the depth of cut, then the feed and finally the cutting speed [7]. The depth of cut is determined by the part dimensions, machine power and also the surface finish requirements. The feed is mainly controlled by surface finish requirements or machine power and the cutting speed is controlled by the economical or production requirements.

1.5.1 Cutting Speed

The cutting speed is the rate at which the workpiece surface moves past the cutting edge of the tool. It is expressed in surface feet per minute or meters per second and denoted by “V” in various machining calculations.

1.5.2 Feed

The feed rate is defined as the displacement of the tool along the workpiece in the direction of the feed motion. It is expressed inches per minute denoted by “F” or inches per revolution denoted by “ f_r ”.

1.5.3 Depth Of Cut

The depth of cut is defined as the undeformed chip thickness. It is the distance between the surface of material formed by the previous cut to the new workpiece surface. It is measured in inches or millimeters and is denoted by “d”.

All three variables depend upon the cutting tool material, workpiece material, cutting fluids if used, the machining capabilities and the surface finish desired. These variables are important for determining the machining times as well as for estimating the power requirements.

1.6 Notations Used In The Target-costing Algorithm

a	approach of tool to work-piece; in
e	over-travel of tool past work-piece; in
L	length of work-piece; in

ID	initial diameter of work-piece; in
D_{fin}	final diameter of workpiece; in
D	Average diameter of workpiece; in
f_r	feed per revolution; in/rev
V	cutting speed; sfpm
d	depth of cut; in
N_l	batch size
R	rapid traverse rate of tool; in/min
t_L	time to load and unload work-piece; min
t_c	time to change tool; min
t_0	time to setup machine tool for operation; min
t_s	time to re-sharpen the tool; min
t_b	time to re-braze the carbide tip; min
C_p	purchase cost of tool shank; \$
K_2	number of parts machined after which the carbide tip is re-brazed.
C_w	cost of grinding wheel for re-sharpening the tool;\$ /tool.
G	labor + overhead on tool grinder; \$/min
P	labor + overhead on brazing machine; \$/min
M	labor + overhead on lathe; \$/min
C_c	purchase cost carbide insert; \$
K_3	number of parts machined after which the carbide insert is discarded.
T	tool life in minutes

Mp	Material Price
Wt	Weight of material
Mc	Material cost
rewc	Rework cost
ubs	updated batch size
rew-rate	rework rate
no_parts_reworked	number of parts reworked.

1.7 Machining Cost

The machining cost comprises of costs associated with the machine time, cutting tools, work-piece material and costs associated with rejection and rework. The total machine time cost and the total tool costs can be divided into their respective components.

1.7.1 Feeding Cost

Feeding time is the time during which the tool actually cuts the metal. The feeding cost is calculated as the feeding time multiplied by the labor and overhead cost.

$$\text{Feeding Cost} = M [(D \times (L + a + e)) / (3.82 \times f_r \times V)]$$

1.7.2 Rapid Traverse cost

When the tool finishes the cut and clears the work-piece, it comes back rapidly to the start point. The time taken for this motion is called rapid traverse time and the cost associated with this time is called rapid traverse cost. It is given as:

$$\text{Rapid Traverse Cost} = M [(a + L + e) / R]$$

1.7.3 Loading/Unloading Cost

The time taken to load and unload the work-piece on the lathe is called loading/unloading time. The cost associated with this time is called loading/unloading cost, given as:

$$\text{Loading/Unloading Cost} = M \times t_L$$

1.7.4 Setup Cost

Before actually starting the machining operation, the machine has to be setup for the operation. Work-holding device like a chuck has to be loaded. The cutting tool has to be held in the tool holder and the line of cutting has to be adjusted. The time required for such activities is called setup time. The cost of setting up the machine is called setup cost. It is a one-time cost for a batch. It is given as :

$$\text{Setup Cost} = M (t_0 / N_L)$$

1.7.5 Tool Changing Cost

Whenever the tool breaks during machining a part, it has to be replaced and the new tool has to be readjusted in the tool holder. The time required to change the tool and readjust it in the tool holder is called tool change time. The cost associated with the tool changing time is called tool change cost which is given as:

$$\text{Tool Change Cost} = M [(D \times L \times t_c) / (3.82 \times f_r \times V \times T)]$$

1.7.6 Re-Sharpening Cost

This component of tool cost depends upon the number of times the tool fails. Every time a tool fails i.e. the cutting edge becomes blunt or the cutting edge breaks, it has to be re-

sharpened. The cost associated with re-sharpening the tool is called the re-sharpening cost. If carbide inserts are used, this component is zero as carbide inserts are not re-sharpened. The re-sharpening cost is given as:

$$\text{Re-sharpening Cost} = [(D \times L)/(3.82 \times f_r \times V \times T)] \times (G \times t_s)$$

1.7.7 Re-Brazing Cost

This cost is associated with tools wherein a carbide tip is brazed to a carbon steel shank. The shank can be any other low cost material with good toughness. This is the cost incurred in re-brazing the insert on to the shank. This component of cost does not depend upon the number of times the tool fails. It can be assumed that the carbide tip is re-brazed after a fixed number of parts are machined.

$$\text{Re-brazing Cost} = (P \times t_b)/K_2$$

1.7.8 Carbide Insert Cost

This is the cost of the carbide insert per part machined. It can be assumed that the insert is discarded after a certain number of parts are machined.

$$\text{Carbide Insert Cost} = C_c/K_3$$

1.7.9 Grinding Wheel Cost

Whenever the edge of the cutting tool breaks or becomes blunt, it has to be re-sharpened to be used again. The cutting tools are re-sharpened on a tool and cutter grinder. Hence the cost of the grinding wheel for each tool re-sharpened has to be incorporated in the total tool cost.

$$\text{Grinding Wheel Cost} = [(D \times L) / (3.82 \times f_r \times V \times T)] \times C_w$$

1.7.10 Material Cost

The amount of dollars spent on the material to make a part is the material cost per part.

The material cost is given by the expression:

$$Mc = (Wt) \times (Mp)$$

1.7.11 Rework Cost

After machining, parts are subjected to a quality check where some parts may be rejected due to non-conformance of quality or design specifications. These parts are either rejected or reworked. The cost associated with reworking the parts to meet the specifications is called rework cost. This rework cost is spread over the entire batch.

$$\text{Rework Cost} = (\text{Number of parts reworked} \times \text{Rework rate}) / \text{updated batch size.}$$

1.8 Need For Research

Since the turning cost is comprised of many cost components, there is a huge opportunity for cost reduction through process improvement. Much of the research work done in machining economics area is based on forward approach wherein the process parameters are determined and cost is calculated for this set of parameters. This is the optimum cost. If there arises a situation where the machining cost of a product has to be cut down, to achieve a target cost so that the product realizes its desired profit, the machining process plan has to be changed or a new process plan has to be developed. The machining parameters, cutting tool, the raw material, labor or even the machine may have to be

changed and all alternatives have to be assessed to obtain the target cost. Several trials have to be carried out with different combinations of tools, cutting parameters, labor and machine to achieve this objective. The general procedure is as shown in Figure 1.

On the other hand if there existed a structured approach to obtain a good set of feasible process parameters, which could satisfy the target cost, it could result in considerable saving of time and resources. This emphasizes the need to develop a structured target-costing model to obtain a good process plan that realizes the target cost.

Many researchers have reported cases where target-costing has been applied during the early stages of product development. This concept has been seldom applied at later stages of product life cycle. According to Shank & Fisher [21], target-costing seems to be applied mostly at the early stages of product development, but the target-costing principle can also be applied at a later stage of the product life cycle. They report a case, which shows how a paper mill reaped the benefits by applying target-costing in manufacturing and regained market share. Extensive literature review revealed that this concept has not been applied in the machining arena.

A need was felt to analyze the machining operations, and hence an attempt is made in this study to apply the concept of target-costing in machining in general and turning in particular. The study reveals a structured approach to achieve the target cost in turning. The turning operation was selected, as it is one of the most widely used machining operations.

1.9 Research Objectives

1. Apply the concept of target-costing in machining.

2. Develop a target-costing model for turning operation to determine the machining process parameters and obtain the target cost.
3. Verify and validate the model over a range of cutting tools, labor and machines.
4. Develop a software program to handle the complexity of the iterative process.
5. Sensitivity Analysis of the system.

1.10 Assumptions

1. Taylor's extended tool life equation $VT^n f^m d^p = C$ to determine the optimum cutting speed and feed rate for specific machining conditions.
2. Geometric programming model for determining optimum cutting speed and feed for a given depth of cut and cutting tool.
3. Availability of organizational databases of tools, labor and machines.
4. Tools database consists of tool life constant and exponents for different tools.
5. Machine database consists of rapid traverse rates for different machines.
6. Labor database consists of setup times, loading and unloading times and tool changing times for different categories of labor.
7. Carbide insert is discarded after a certain number of parts are machined.
8. The tool shank is discarded after a certain number of parts are machined.

1.11 System Diagram

The current and the proposed system diagrams are shown in Figure 1 and Figure 2 respectively. The current system diagram shows an unstructured approach to cost reduction. Several trials are conducted and various parameters are tweaked to reduce the

machining cost, based on the experience and expertise of the person handling the problem. In such cases trade offs between two or more outcomes are often given more importance. Since the problem solving technique is based upon the “feel” of the person, the result obtained may not give the desired results or considerable efforts may be required to achieve the target cost. This type of approach is common on shop floor where the operator may increase or decrease the speed of the machine depending upon the workload.

Figure 2 shows a structured approach to cost reduction to meet the target cost. The user inputs the current process and the program calculates the unit cost for the process. The user then inputs the target cost in the form of percentage reduction in the unit cost required. The current process unit cost is compared to the target cost and if the target is reached, the program ends. If the target cost is not achieved, the target-costing algorithm examines different alternatives based upon their relative importance and their potential to achieve the target cost. The program ends after achieving the target cost or after all alternatives are examined.

FIGURE 1. UNSTRUCTURED APPROACH TO ACHIEVE TARGET COST

FIGURE 2. STRUCTURED APPROACH TO ACHIEVE TARGET COST

1.12 Conclusion

Target-costing philosophy is widely used for achieving cost reduction during the design and development of a new product or the cost reduction of an existing product by combining various techniques like value engineering, quality function deployment or simple functionality analysis. This enables a company to generate more profits by reducing the manufacturing cost or reduce the product price to increase market share. This research aims at exploring the benefits of target-costing in turning operation.

CHAPTER 2

LITERATURE REVIEW

In competitive markets, prices of the product are decided by the market. Large number of competitors can offer similar products at keen prices and consumers will expect greater value for their money. Hence it is the job of the producer to sell their products at a price that the market expects and is prepared to pay. To ensure the continuing survival and growth, the company needs to make a financial return on the products sold. They must be made at a cost that meets the market's expectations on price and make a profit. Many companies have turned to target-costing to achieve these objectives.

2.1 Target-costing History

Target-costing has a history of more than 40 years in Japanese industry. In 1959 Toyota invented target-costing as it has developed in Japan. Although many manufacturers in Japan use target-costing, the system used at Toyota Motor Corporation is the oldest and considered by many the most technically advanced. While the idea of systematic cost reduction had existed at Toyota since it was founded, the process was first codified in the mid-1960s, when the firm set itself the objective of producing a \$1000 car [5].

2.2 Target-costing Definitions

Target-costing (*Genkakikaku* in Japanese) is defined in many ways, but its goal is cost reduction. It is a system to support the cost reduction process in the development and

designing phase of an entirely new model, a full model change or a minor model change [16]. Target-costing is not actually a form of costing. Rather it is a comprehensive program to reduce costs [12]. It is a process for ensuring that products and services are designed such that the company can sell them cheaply and still makes a fair profit [31]. Target-costing is a strategic cost management concept for reducing cost over the entire life cycle of a product [11]. Target-costing is a structured approach to determine the cost at which a proposed product with specified functionality and quality must be produced in order to generate the desired level of profitability over its life cycle at its anticipated selling price [5]. Accordingly target-costing has multiple objectives of cost reduction, quality assurance, timely introduction of new products into the market and product development to attract customers.

2.3 Approach To Target-costing

Different authors present varied ways to achieve the target cost. Target-costing can be achieved by taking various types of actions. The first category includes those actions that achieve target costs by increasing production. The second category of actions includes those that decrease the product's fixed or variable costs by increasing some other component of cost. Finally, the third category of actions includes those that reduce the product's variable or fixed costs [31]. Target-costing projects can pursue the routes of total cost management, cost cutting and cost shifting to reach their goals [1].

2.4 Target-costing In Industry

Target-costing has been successfully applied in process industries as well as in assembly industries. It produces much better results when combined with simultaneous engineering. Target cost management together with simultaneous engineering helps generate unique ideas for product development and cost reduction [26]. Nissan Motor Corporation's approach to total cost control entails a strategic approach, utilizing target-costing principles [3]. At Lucent Technologies, target-costing has been applied on both existing and new products ranging from business telephones, to wireless mini-cells and more. The phrase "Set the target; achieve the target; maintain the target" is used at Lucent Technologies to summarize target-costing [5]. Motor Division, Goldstar Company Ltd., in South Korea uses target-costing in conjunction with value engineering to obtain the target costs of the final products [24]. Target-costing has been adopted by many successful market leaders such as Mercedes, Kodak, Boeing, Chrysler and Goodyear [6], [18], [12] and [26].

2.5 Machining Economics

The machining economics problem, with respect to the turning operation has been investigated to no end. Considerable research has been done to determine the constrained machining parameters. Taylor [28] focused on investigating the efficient range of machining parameters through experimental studies; over a period of 26 years, he conducted numerous experiments at Midvale Steel Company to achieve metal cutting efficiency. Ever since, many mathematical models have been developed to determine the optimum cutting conditions for either single pass or multi-pass turning. Extensive

literature review revealed that Geometric Programming [18], [29] and [30]; Lagrange multiplier [2]; a combination of linear and geometric programming [8]; and Goal programming [9] and [23] were some of the optimization techniques used by researchers in this area. An analytical approach to select machining parameters for turning with constraints was developed by Gopalakrishnan and Al-Khayyal [10] based on geometric programming; F.P. Tan and R. C. Creese [25] developed a generalized multi-pass machining model based on sequential linearization optimization. Variable flow stress machining theory has been used to predict cutting forces and stress to check process constraints depending upon which, optimum cutting conditions have been determined [14]. A knowledge-based expert system has been developed to automate the process planning functions and determine the machining parameters by R. V. Narang and G. W. Fischer [17].

The main objective of these process planning systems has been either to minimize the cost or to maximize the production rate. Some authors have also considered a combination of three criteria simultaneously: minimum unit production cost, minimum unit production time and minimum number of passes [15]. The objective function to minimize the machining cost has traditionally consisted of cutting costs and tool costs. Some researchers have also considered including the “other” costs such as in-process inventory costs and penalty costs for not meeting the demand [21], non-productive costs of loading, unloading and inspection [20], and costs due to loss of quality when the quality characteristic of the part deviates from its target value [13], even though they may not be directly related to machining economics. All these models strive to select an optimum set of machining parameters, which are then utilized to obtain the machining

cost. These models follow a forward approach; by first selecting a set of machining parameters, and then determining the machining cost.

2.6 Conclusion

In this chapter, the target-costing history and its development were discussed. Various definitions of target-costing as proposed by different authors and industry leaders and its applications in industry were cited. Some methods of achieving the target cost were stated. The later part of the chapter was dedicated to the machining economics problem. Various methods of achieving the optimum cutting conditions and machining cost as published by several authors were mentioned.

CHAPTER 3

SYSTEM DEVELOPMENT

3.1 Design And Development Of The Algorithm

The algorithm developed in the present study was designed after reviewing the turning process and the associated costs. The machining cost comprises of costs pertaining to the machine time, cutting tools, work-piece material and costs associated with rejection and rework. The total machine time cost and the total tool costs can be divided into their respective components. Depending upon the cutting parameters selected, the percentage of each cost component in the unit cost changes. Hence the reduction in the highest cost component will have the largest effect in reducing the unit cost of the product. The algorithm was developed based on the “Pareto Principle” where the causes of a problem are arranged in descending order of severity and efforts are directed at resolving the cause with highest effect first. The cost components are arranged according to their percentages in the unit cost from highest to lowest and the cost component with highest percentage is targeted for reduction. The algorithm takes the current process and the current costs as a base case and then tries to make improvements in the process thereby reducing the cost components. It is shown graphically in Figures 3 to 12. A Geometric Programming model [9] was used to calculate optimum cutting speed, and feed for a given depth of cut and cutting tool, thus satisfying the surface finish, and machine power constraints.

The algorithm tries to minimize the cost components with maximum contribution to the unit cost in a sequential order after arranging the cost components in decreasing order and

the component with maximum contribution is targeted for reduction. The parameters involved in the calculation of that cost component are replaced with values either from the database or from the user input. The unit cost is calculated and compared with the target cost. If the target cost is reached, the algorithm stops and shows the results. Otherwise, the process is repeated until all the combinations from the database are exhausted or there is no scope for any further improvements.

Different cutting tools are analyzed for reduction in feeding cost and different machines are examined to reduce the rapid traverse cost. If these combinations do not result in satisfying the target cost, the user is prompted to improve some other parameters based on which the unit cost is recalculated.

3.2 Geometric Programming Model Background

The geometric programming model developed by Gopalakrishnan and Al-Khayyal was used in the development of this algorithm. The setting of the machine parameters in turning operation determines the cost of the machining process. The rate and cost of production depend on the cutting speed, feed and the depth of cut. The depth of cut is usually fixed for a particular pass in turning operation and in this case the cutting speed and the feed are the only variables in the minimization of the production cost or the maximization of production rate. The major constraints affecting the turning process are related to the required surface finish of the product being machined, and the maximum power, which the machine tool can provide for the operation. The geometric programming model developed by Gopalakrishnan and Al-Khayyal uses Taylor's

extended tool life equation, $VT^n f^m d^p = C$ to determine the costs due to losses in tool life, and due to the time incurred in removing a defective tool and replacing it.

In the above equation, T is the tool life in minutes, V is the cutting speed in inches/minute, f is the feed in inches/rev, and m, n, p, C are constants based on the tool material and workpiece material.

3.3 Geometric Programming Model Nomenclature

HPmax	maximum horse power available
Sfmax	surface finish acceptable
Cm	coefficient in machine power constraint
Cs	coefficient in surface finish constraint
n,m,p	coefficients in tool life equation
b,c,e	exponents in machine power constraint
g,h,i	exponents in surface finish constraint

3.4 The Algorithm

The algorithm shown in a graphical format in figure 3 is described in the following seven steps.

1. Read the current process and calculate current unit cost.
2. Calculate the target cost based on the percentage reduction required.
3. Select the first cutting tool from the database and calculate the unit cost. If the target cost is reached, then go to step 6. If the target cost is not reached and the new unit cost is less than the current unit cost, then retain the new cutting tool, else reject it.

Select the next cutting tool and repeat the process till target cost is reached or all cutting tools are explored.

4. Sort the cost components in descending order. If the highest cost component is rapid traverse cost, then chose the first machine from the database and calculate the new unit cost. If the target cost is reached, then go to step 6. If the target cost is not reached and the new unit cost is less than the current unit cost, then accept the new machine else reject it. Repeat the process till target cost is reached or all machines are explored.
5. If the highest cost component in step 4 is not rapid traverse cost, then prompt the user for improvements. If the target cost is reached, then go to step 6, else prompt user for further improvements till all options are explored.
6. If target cost is reached then print, “ Target cost achieved” else print, “Target cost could not be achieved”.
7. Show the details of the process.

Figure 3 shows the program logic, which epitomizes the algorithm. The program acquires the current process details from the user and calculates the unit cost of machining. The user is then prompted to enter a target percentage reduction based upon which the target cost is calculated. The program then selects the highest cost component for cost reduction and prompts the user to enter the percentage improvement that could be achieved in the factors affecting that cost component, so that the unit cost of the product can be reduced to meet the target cost. The user can enter “0” if improvements are practically infeasible. The unit machining cost is recalculated and compared to the target cost. The program stops further calculations if the target cost is reached; else the next highest cost

component is selected for cost reduction and the process is repeated. After the target-costing process is completed the program enables the user to view the information in graphical as well as tabular format. The graphical format shows the user, the number of iterations required to achieve the target cost and how the cost varied between iterations. The tabular format gives the details of the changes that occurred between iterations.

3.5 Scope Of The Target-costing Program

The program is interactive in nature and elicits responses from the user. It presumes that the user has knowledge about the process and knows the feasibility of performing the improvements suggested to achieve the target cost. The program arranges the cost components sequentially from highest to lowest and prompts the user to improve upon the factors affecting these cost components. If improvements cannot be made for some factors, the user can enter “0” when prompted. The user also has to understand that the improvements suggested by the program involve implementation costs to bring about necessary process changes. Deciding whether the cost component can be reduced or not and its implementation cost depends upon the user and is out of scope of this program and this research work.

When the target-costing program prompts the user to enter percentage by which the setup time can be reduced, it assumes that the user knows if and how the reduction can be made, what changes are required in the process to bring about this improvement and has a fair idea about the cost involved in performing the improvement. The user has to perform a cost benefit analysis about the improvement in setup time and the monetary gain achieved. This program prioritizes the cost components and provides the user with

opportunities to direct resources towards those cost components that have a high effect on the unit cost of the product. The program does not suggest what is required to implement the changes in the process parameters and their implementation costs as this is outside the scope of this research work.

The program comprises of a main program and consists of modules for each cost component, which will be discussed in the upcoming pages.

FIGURE 3. PROGRAM LOGIC

FIGURE 4. FEEDING COST MODULE

Figure 4 shows the feeding cost module. The feeding cost depends upon the cutting speed, feed rate, depth of cut and the tool life, which are dependent upon the selection of the cutting tool. Hence this module tries to reduce the feeding cost by examining different cutting tools and selecting the one that gives the minimum feeding cost. The unit cost is calculated and compared to the target cost after each cutting tool selection. If the target cost is not reached and all the tools are examined, the program retains the tool that gives the minimum cost and transfers the logic to the next module.

FIGURE 5. RAPID TRAVERSE COST MODULE

The rapid traverse cost module is shown in figure 5. The rapid traverse rate is dependent upon the machine and therefore this module tries to reduce the rapid traverse cost by examining different machines and selecting the one that gives the minimum rapid traverse cost. The unit cost is calculated and compared to the target cost after each iteration till the target cost is reached or till all machines are examined. If the target cost is not reached and all the machines are examined, the program retains the machine that gives the minimum cost and transfers the logic to the next module.

FIGURE 6. SETUP COST MODULE

FIGURE 7. LOADING AND UNLOADING COST MODULE

FIGURE 8. REBRAZING COST MODULE

FIGURE 9. RESHARPENING COST MODULE

FIGURE 10. CARBIDE INSERT COST MODULE

FIGURE 11. MATERIAL COST MODULE

FIGURE 12. REWORK COST MODULE

3.6 Code Development

The user interface was developed using Microsoft Visual Basic version 6.0. Visual Basic is an object oriented programming language, which is used to design the user interface. The various objects are forms, textboxes, list-boxes, labels, grids and many others. Forms are the basic objects or the background on which various controls such as text boxes, buttons, list-boxes, labels etc are arranged. A source code or a program to perform specific tasks then ties up these controls. The tasks may be simply reading an input or performing a calculation or showing an output. The user interface consists 7 forms and a module. A module is a program space consisting of subprograms, subroutines and variable declarations that are called by the main programs repeatedly. The input screen shown in figure 13 allows the user to enter the data for the current process. This data consists of the design requirements for the product, the machining parameters and constraints on machine power and surface finish. The program checks if all the data was entered and prompts the user if any data fields are left blank. The second input screen shown in figure 14 prompts the user to select the cutting tool and its related parameters for the current process. The program then calculates the unit cost and the current process output screen in figure 15 details the cost components. It also provides the user with an option to enter the percentage reduction required in the unit cost. This percentage reduction is required to calculate the target cost. After determining the target cost, the cost component contribution screen in Figure 16 arranges the cost components of the current process according to their contribution to the unit cost starting from highest to lowest. It also shows the percentage contribution of each cost component. After clicking on the “Achieve Target Cost” button, the algorithm is called which prompts the user for

improvements in the current process. A note is displayed suggesting the user if the target cost was achieved or not. Figure 17 shows a comparison between the cost components before and after the target-costing process. The program also allows the user to see the variation of the unit cost for different iterations in a graphical format as shown in figure 18.

3.7 Database Design

The information pertaining to different work materials, cutting tools, machines and labor are stored in a database. The database, which is designed in Microsoft Access, forms the back end and the user interface forms the front end. The database is in the form of tables and the tables consist of several fields and records. The columns are called fields and the rows are referred to as records. A table consisting of several machines will have a record for each machine and each record will have several fields. Each field may represent a particular characteristic for a machine.

The database in this model consists of several tables for different material conditions.

Table 1 shows data for a cold drawn material condition.

Table 1: Database table for Cold Drawn Material Condition

ID	Condition	Hardness	C	m	n	p	Type	Cost	dmax	G	Cw	ts	Lrb	tb	k2	k3
11	Cold Drawn	175 - 200	120	0.25	0.29	0.35	HSS	2	0.1	30	0.5	15	0	0	0	0
12	Cold Drawn	175 - 200	140	0.27	0.31	0.4	Carbide tip	3	0.3	30	0.5	15	30	15	50	0
13	Cold Drawn	175 - 200	160	0.29	0.35	0.43	Carbide insert	4	0.5	0	0	0	0	0	0	4

The table consists the hardness of the material, different tools that can be used for machining this material, tool life coefficient and the tool life exponents for each tool and material combination. The table consists of other data like cost of the tool, labor and overhead on the tool grinder, cost of grinding wheel for re-sharpening the tool, tool re-sharpening time. A brazed tip carbide tool also has other data like re-brazing time and labor and overhead for brazing the carbide tip. The database consists of similar tables for different material conditions.

The database also consists of a machine table which contains the type of machine, the labor and overhead for each machine, the rapid traverse rate, maximum horse power available, exponents and coefficients in machine power and surface finish constraint and the tool handling times for each machine.

The database can be easily updated by inserting new information in the tables. The information entered in the database will have a significant effect on the results. Hence the database should be updated with realistic values in order to prevent inaccurate results.

3.8 Conclusion

The design and development of the target-costing algorithm was presented in this chapter. The steps involved in developing the algorithm were discussed and an analogy was made to the Pareto principle. The algorithm and the programming logic were elucidated in detail with the help of flowcharts. The later part of the chapter was dedicated to the development of the user interface using Microsoft Visual Basic programming language and the database design in Microsoft Access.

CHAPTER 4

SYSTEM BEHAVIOR ANALYSIS

This chapter analyses the dynamics of the target-costing model and its application to turning process. The turning process consists of numerous parameters that are interrelated and the turning cost depends upon the selection of these parameters. The turning cost is made up of components like machine time cost, tool cost and material cost. The selection of process parameters affects the cost components and hence the turning cost. Since the process parameters are interdependent and their selection is a complex process, they have to be selected such that they meet the target cost. The target-costing model uses a structured approach to select these process parameters to comply with the target cost. The program is very interactive and elicits responses from the user. The path taken to achieve the target cost depends upon the behavior of all the parameters involved in the machining process. The system behavior will be explained with the help of an example.

The values of the tool life exponents, exponents in surface finish and horsepower constraint, and other coefficients used to verify the model were taken from the examples published by Gopalakrishnan *et al.*

The target-costing program starts with an input screen. The input parameters are categorized into four types. The first category is design parameters, which consist data like initial diameter, final diameter, work material, batch size, material condition and hardness, acceptable surface finish and the material price. These parameters are design requirements except the batch size and the material price, and hence cannot be changed. The batch size and the material price though are not design requirements and hence can be varied to achieve cost improvements. The second type of input requirement is

machining parameters. This consists of machine related data like labor and overhead rate, tool-handling times, rejection rate and rapid traverse rate of the machine. These parameters are machine dependent and hence vary with the type of machine. The third category of input data consists of exponents and coefficients of the geometric programming model. Since the geometric programming model forms the part of the target-costing model, these parameters are required to be furnished by the user. The last category of input data is related to the cutting tools. The target-costing program consists of a tools base, which has three different types of cutting tools: high speed steel (HSS), brazed carbide tip and carbide insert. HSS is the lowest quality cutting tool in comparison to the other two. The cutting speeds at which it can be used are lower than the tools with carbide tip or carbide insert. It possesses lower hot hardness and hence cannot be used for machining applications where very high heat is generated. But its main advantage is low cost and hence can be used for low cost machining applications. The cutting edge can be ground repeatedly and hence it may prove economical in some cases. The brazed carbide tip cutting tool consists of a carbide tip that is brazed to a mild steel shank. This type of tool can achieve higher cutting speeds and the cutting edge can be machined to regain its sharpness. The carbide insert cutting tool consists of a carbide insert that is screwed in place on a tool holder. The carbide insert has more than one cutting edge and generally has a higher tool life compared to HSS or a brazed tip tool. When one edge breaks, the orientation of the insert is changed to expose a fresh cutting edge. It can be used at very high cutting speeds and possesses good hot hardness.

The first input screen is shown in Figure 13. This is the first step in the target-costing model. The input data is as shown.

Work-piece Parameters:

Initial Diameter	6 inches
Final Diameter	5 inches
Batch Size	250
Material Condition	Hot Rolled or Annealed
Hardness	100 – 125 BHn

Machining Parameters:

d	0.1 inches
M	60 \$/hr
t_0	25 minutes
t_{ch}	5 minutes
t_l	1 minute
R	60 inches/min
Rejection	10 %
Rework	10 %
Rework Rate	30 \$/hr

Current Process

Work-piece Parameters

Initial Diameter	<input type="text" value="6"/>	inches	Final Diameter	<input type="text" value="5"/>	inches
Initial Length	<input type="text" value="8"/>	inches	Final Length	<input type="text" value="8"/>	inches
Batch Size	<input type="text" value="250"/>		Density of Matl	<input type="text" value="7.85"/>	gm/cc
Condition	<input type="text" value="Hot Rolled or Annealed"/>				
Hardness	<input type="text" value="100 - 125"/>		Material Price	<input type="text" value="440"/>	\$/ton

Machining Parameters

Depth of Cut	<input type="text" value=".1"/>	inches	Setup Time	<input type="text" value="25"/>	min
Rapid Tr. Rate	<input type="text" value="60"/>	in/min	Tool Change Time	<input type="text" value="5"/>	min
Load/Unload Time	<input type="text" value="1"/>	min	Approach	<input type="text" value=".3"/>	inches
Labor Rate	<input type="text" value="60"/>	\$/hr	Overtravel	<input type="text" value=".3"/>	inches
Rejection Rate	<input type="text" value="10"/>	%	Rework	<input type="text" value="10"/>	%
Rework Rate	<input type="text" value="30"/>	\$/hr			

Maximum

Machine Power Available

Surface Finish Acceptable

Exponents In Machine Power

b

c

e

Exponents in Surface Finish

g

h

i

Coefficients

Machine Power Constraint

Surface Finish Constraint

FIGURE 13. INPUT SCREEN 1

As described in the previous section, this screen has three parts. The user is required to enter all the information in the text boxes. The material condition and hardness can be selected from the drop down list. The user is also required to enter information related to the maximum horsepower available and the exponents and coefficients in the machine power and surface finish constraint. If the information is incomplete, the program gives a message on the screen that a particular data point is missing and instructs the user to enter data in that particular text box. Once all the information is complete, the user clicks on the “next” button to invoke the second input screen, which is shown in Figure 14.

Tool Parameters

Type Of Tool

☐ HSS

☐ Carbide Tip

☒ Carbide Insert

Carbide Insert Cost \$/insert

Exponents in Tool Life Equation

m

n

p

Number of Times Indexed

Tool Life Constant

FIGURE 14. INPUT SCREEN 2

The second step in the target-costing process is tool selection. The second input screen allows the user to enter information about the cutting tool being used for the current process. The user selects a cutting tool from the three options and enters values for exponents in tool life equation, cost of the cutting tool and tool life constant. If the selected cutting tool is HSS then the user is prompted for labor and overhead on the tool grinder. The user also has to enter the labor and overhead for brazing if the cutting tool selected is a brazed carbide tip.

The tool data is as shown.

Cutting Tool Carbide Insert

Cost of Tool 3 \$/insert

Number of edges 4

C (Tool life constant) 250

After entering all the information the user then clicks on “calculate” button. This screen invokes the third screen, which is shown in Figure 15. This screen details the cost components in turning operation. All the cost components discussed in chapter 1 are displayed on the screen, which enables the user to see the breakdown of the total cost of turning operation. The screen also shows the unit cost for turning that product. The model uses the equations shown in chapter 1 to calculate the cost components and the unit cost.

At the bottom of the screen the program asks the user to enter the target cost in the form of percentage reduction in the unit cost. This percentage has to be realistic and the user has to have fair knowledge of the amount of cost reduction that is feasible with the available machines, labor and tools.

Feeding cost	<input type="text" value="4.97"/>	\$	Rebrazing cost	<input type="text" value="0.00"/>	\$
Rapid traverse cost	<input type="text" value="0.72"/>	\$	Resharpening cost	<input type="text" value="0.00"/>	\$
Setup cost	<input type="text" value="0.10"/>	\$	Carbide insert cost	<input type="text" value="0.25"/>	\$
Tool changing cost	<input type="text" value="0.09"/>	\$	Grinding cost	<input type="text" value="0.00"/>	\$
Loading/Unloading cost	<input type="text" value="1.00"/>	\$	Total tool cost	<input type="text" value="0.25"/>	\$
Total Machine Time Cost	<input type="text" value="6.87"/>	\$	Material cost	<input type="text" value="12.80"/>	\$
Rework Cost	<input type="text" value="0.31"/>	\$			
Total Cost	<input type="text" value="5643.88"/>	\$	Unit cost	<input type="text" value="22.58"/>	\$
What is the percentage reduction in unit cost required			<input type="text" value="10"/>	%	
			<input type="button" value="Back"/>	<input type="button" value="Next"/>	

FIGURE 15. CURRENT PROCESS OUTPUT

After entering the percentage reduction required, the user then clicks on the “Next” button to bring up the screen shown in Figure 16. This screen shows the contribution of different cost components towards the unit cost and also the target cost. This user can recognize those cost components that have a major effect on the unit cost and hence identify those process parameters that are critical. The target-costing algorithm is designed in such a way that cost components with higher contributions are targeted first for improvement. The user clicks on “Achieve Target Cost” button to invoke the target-costing algorithm, which tries to achieve a unit cost that is less than or equal to this target cost. The program identifies the critical parameters for improvement and prompts the user to enter a percentage by which that particular parameter can be improved. The program continues till the target cost is reached or all selected parameters are examined.

Major Cost Components in the Current Process

Cost Component	Value	Percentage	Unit
Feeding Cost	4.97	22.00	% of Unit Cost
Material Cost	12.80	56.67	% of Unit Cost
Loading and Unloading Cost	1.00	4.43	% of Unit Cost
Rapid Traverse Cost	0.72	3.17	% of Unit Cost
Rework Cost	0.31	1.38	% of Unit Cost
Carbide Insert Cost	0.25	1.09	% of Unit Cost
Setup Cost	0.10	0.44	% of Unit Cost
Tool Changing Cost	0.09	0.40	% of Unit Cost
Grabrazing Cost	0.00	0.00	% of Unit Cost

Target Cost: 20.32 \$

The Target Cost has been reached. Please press Next to see the new cost component.

Back Achieve Target Cost Next

FIGURE 16. COST COMPONENT CONTRIBUTION

A message is displayed on the screen informing the user if the algorithm was successful in achieving the target cost. The user then clicks the “Next” button to invoke the screen shown in Figure 17. This screen shows a comparison between the cost components, the unit cost and the total cost, before and after the target costing process. The unit turning cost for the base case was \$22.58 and a cost reduction of 10% was desired in this unit cost. Based upon this reduction the target cost was calculated to be \$20.32.

	Before		After			Before		After	
Feeding cost	4.97	\$	3.39	\$	Rebrazing cost	0	\$	0.00	\$
Rapid traverse cost	0.72	\$	0.14	\$	Resharpening cost	0	\$	0.00	\$
Setup cost	0.1	\$	0.10	\$	Carbide insert cost	0.25	\$	0.59	\$
Tool changing cost	0.09	\$	0.81	\$	Grinding cost	0	\$	0.00	\$
Loading/Unloading cost	1	\$	1.00	\$	Total tool cost	0.25	\$	0.59	\$
Total Machine Time Cost	6.87	\$	5.44	\$	Material cost	12.8	\$	11.52	\$
Rework Cost	0.31	\$	0.31	\$					
Total Cost	5,643.88	\$	4982.23	\$	Unit cost	22.58	\$	19.93	\$
<div>Back</div> <div>Graphs</div>									

FIGURE 17. COST COMPONENTS BEFORE AND AFTER TARGET-COSTING

The unit cost after the target-costing process was \$19.93, which was less than the target cost of \$20.32. This cost reduction was achieved after four iterations as shown in Figure

18. The steps described in section 3.1 are applied sequentially to achieve the target cost.

The following section shows the calculations for each iteration.

FIGURE 18. VARIATION OF UNIT COST OVER FOUR ITERATIONS

4.1 Base Case

The cutting speed and the feed per revolution were calculated to be

$$V = 878.97 \text{ feet per minute}$$

$$f_r = 0.0014 \text{ inches per revolution}$$

$$\begin{aligned} \text{Tool Life } T &= C / (f_r^m d^p v)^{1/n} \\ &= 250 / (0.0014^{0.25} 0.1^{0.3} 878.87)^{1/0.19} \\ &= 60.35 \text{ minutes.} \end{aligned}$$

$$\begin{aligned} \text{Number of passes} &= ((ID - D_{fin})/2) / \text{depth of cut} \\ &= ((6 - 5) / 2) / 0.1 \end{aligned}$$

$$= 5.$$

$$\begin{aligned}\text{Rapid Traverse Cost} &= M [(a + L + e)/R] \\ &= 60 [(0.3 + 8 + 0.3) / 60] \\ &= \$ 0.72\end{aligned}$$

$$\begin{aligned}\text{Feeding Cost} &= M [(D \times (L + a + e))/(3.82 \times f_r \times V)] \\ &= 60 [(D \times (8 + 0.3 + 0.3)) / 3.82 \times 0.0014 \times 878.87]\end{aligned}$$

Since D is average diameter, its value changes after every pass. The feeding cost was calculated for each pass and the total feeding cost was \$ 4.97.

$$\begin{aligned}\text{Loading/Unloading Cost} &= M \times t_L \\ &= (60 \times 1)/60 \\ &= \$1\end{aligned}$$

$$\begin{aligned}\text{Setup Cost} &= M (t_0 / N_L) \\ &= 60 (25 / 60) / 250 \\ &= \$0.1\end{aligned}$$

$$\begin{aligned}\text{Tool Change Cost} &= M [(ID \times L \times t_c)/(3.82 \times f_r \times V \times T/60)] \\ &= 60 [(6 \times 8 \times 5)/(3.82 \times 0.0014 \times 878.87 \times 60.35/60)] \\ &= \$0.009\end{aligned}$$

$$\text{Re-sharpening Cost} = [(ID \times L)/(3.82 \times f_r \times V \times T)] \times (G \times t_s)$$

As the cutting tool was carbide insert, there was no re-sharpening cost as the carbide insert cannot be re-sharpened. The insert has to be indexed if it breaks.

$$\text{Re-brazing Cost} = (P \times t_b)/K_2$$

Since the cutting tool for the base case was a carbide insert, there was no re-brazing cost, as a carbide insert cutting tool cannot be brazed.

$$\begin{aligned}
 \text{Carbide Insert Cost} &= (C_c/T) \times \text{total cutting time} \\
 &= (3 / 60.35) \times 4.97 \\
 &= \$0.25
 \end{aligned}$$

$$\text{Grinding Wheel Cost} = [(D \times L)/(3.82 \times f_r \times V \times T)] \times C_w$$

The grinding wheel cost was zero as the tool was carbide insert.

$$\begin{aligned}
 \text{Material Cost} &= (W_t) \times (M_p) \\
 &= 0.029 \times 440 \\
 &= \$12.80
 \end{aligned}$$

$$\begin{aligned}
 \text{Rework Cost} &= (\text{Number of parts reworked} \times \text{Rework rate}) / \text{updated batch size} \\
 &= (2.9 \times 30)/279 \\
 &= \$0.31
 \end{aligned}$$

$$\begin{aligned}
 \text{Total Machine Time Cost} &= \text{Feeding Cost} + \text{Rapid Traverse Cost} + \text{Setup Cost} + \\
 &\quad \text{Loading/Unloading Cost} + \text{Tool Changing Cost} \\
 &= 4.97 + 0.72 + 0.1 + 1 + 0.009 \\
 &= \$6.87
 \end{aligned}$$

$$\begin{aligned}
 \text{Total Tool Cost} &= \text{Carbide Insert Cost} + \text{Re-brazing Cost} + \text{Re-sharpening} \\
 &\quad \text{Cost} + \text{Grinding Wheel Cost} \\
 &= 0.25 + 0.00 + 0.00 + 0.00 \\
 &= \$0.25
 \end{aligned}$$

$$\begin{aligned}
 \text{Total Cost} &= \text{ubs} \times (\text{Total Machine Time Cost} + \text{Total Tool Cost} + \\
 &\quad \text{Material Cost} + \text{Rework Cost}) \\
 &= 279 \times (6.87 + 0.25 + 12.80 + 0.31) \\
 &= \$5643.88
 \end{aligned}$$

$$\begin{aligned}
 \text{Unit Cost} &= \text{Total Cost} / N_i \\
 &= 5643 / 250 \\
 &= \$22.58
 \end{aligned}$$

A 10% reduction was desired in the unit cost based upon which the target cost was calculated to be \$20.32.

4.2 Iteration 1: HSS Cutting Tool

The cutting tool was changed from carbide insert to HSS. The notion behind this change is that the cost of HSS cutting tool is less than carbide insert. The following parameters changed from the base case.

Table 2: Change in Data between Base Case and Iteration 1.

Parameter	Base Case	Iteration 1
Cutting Tool	Carbide Insert	HSS
Cost Of Cutting Tool	\$3.00	\$2.00
C	250	150
N	0.19	0.29
P	0.30	0.35

As seen from the table above the cost of HSS cutting tool was less than carbide insert cutting tool. Also the tool life coefficient was significantly lower than that of the carbide insert. The results obtained after the cutting tool was changed from carbide insert to HSS are shown in Table 3 and are compared to the results of the base case. The unit cost increased by 49% from \$22.58 to \$33.71. The increase in unit cost was due to the

increased machine time cost and tool cost. The rework cost did not change because the rework rate and the rejection rate remained constant. The number of parts rejected and the number of parts reworked also did not change resulting in the updated batch size of 279, which was equal to the updated batch size in the base case.

The amount of material required is influenced by the updated batch size. The updated batch size depends upon the rework and rejection rate and hence 279 parts have to be machined in order to produce 250 acceptable parts. Since the updated batch size did not change the material cost remained constant at \$12.80.

The unit cost increased by 49% even though the cost of cutting tool decreased by 33.33%. This signifies that by reducing only the cost of the cutting tool, the unit cost of machining cannot be reduced. There are other parameters involved in the process that have to be analyzed. Nevertheless the selection of the right cutting tool is still an important step in obtaining the desired machining cost. HSS was rejected and the next cutting tool, brazed carbide tip was selected for analysis in the second iteration, the results of which are shown in the next section.

Table 3: Comparison of Results between Base Case and Iteration 1.

Parameter	Base: Carbide Insert	Iteration 1: HSS Cutting Tool
D	0.1 inches	0.1 inches
V	878.97 feet per minute	652.36 feet per minute
fr	0.0014 inches per rev.	0.0084 inches per rev.
Number Of Passes	5	5
Updated Batch Size	279	279
Feeding Time	4.97 minutes	10.51 minutes
Feeding Cost	\$4.97	\$10.51
Rapid Traverse Cost	\$0.72	\$0.72
Setup Cost	\$0.10	\$0.10
Load/Unload Cost	\$1.00	\$1.00
Tool Changing Cost	\$0.009	\$1.84
Total Machine Time Cost	\$6.87	\$14.16
Re-sharpening Cost	\$0.00	\$2.76
Re-brazing Cost	\$0.00	\$0.00
Carbide Insert Cost	\$0.25	\$0.00
Grinding Wheel Cost	\$0.00	\$0.18
Total Tool Cost	\$0.25	\$2.94
Material Cost	\$12.80	\$12.80
Rework Cost	\$0.31	\$0.31
Total Cost	\$5643.88	\$8428.59
Unit Cost	\$22.58	\$33.71

4.3 Iteration 2: Brazed Carbide Tip Cutting Tool

The target-costing algorithm was not able to achieve the target cost of \$20.32 by changing the cutting tool from carbide insert to HSS. Instead the unit cost increased by 49% from \$22.58 to \$33.71 due to which HSS was rejected and the original carbide insert was retained. The algorithm is designed such that it analyzes all the available cutting tools sequentially. Hence the next cutting tool examined was a brazed carbide tip tool. The results obtained with brazed carbide tip cutting tool are shown in Table 4 and are compared to the initial carbide insert.

As can be seen from Table 4, the brazed carbide tip cutting tool yielded a unit turning cost of \$34.42, which was 52.4% more than the unit cost of current process using a carbide insert cutting tool. This increase was more than the increase in unit cost using HSS cutting tool. By comparing to iteration 1 where HSS cutting tool was used, it can be seen that the total machine time cost decreased by \$0.78 but the total tool cost increased by \$1.41 resulting in a net increase of \$0.63. This increase in cost applies to 279 parts. Hence the effective unit cost for a batch size of 250 increased by \$0.71 when the cutting tool was changed from HSS to brazed carbide tip. The brazed carbide tip cutting tool was rejected, as it was not successful in lowering the unit cost below \$22.58. The algorithm then analyzes the next cutting tool in the database.

Table 4: Comparison of Results between Base Case and Iteration 2.

Parameter	Base: Carbide Insert	Iteration 2: Brazed Carbide Tip
D	0.1 inches	0.3 inches
V	878.97 feet per minute	617.51 feet per minute
fr	0.0014 inches per rev.	0.0059 inches per rev.
Number Of Passes	5	3
Updated Batch Size	279	279
Feeding Time	4.97 minutes	9.17 minutes
Feeding Cost	\$4.97	\$9.17
Rapid Traverse Cost	\$0.72	\$0.43
Setup Cost	\$0.10	\$0.10
Load/Unload Cost	\$1.00	\$1.00
Tool Changing Cost	\$0.009	\$2.68
Total Machine Time Cost	\$6.87	\$13.38
Re-sharpening Cost	\$0.00	\$4.02
Re-brazing Cost	\$0.00	\$0.08
Carbide Insert Cost	\$0.25	\$0.00
Grinding Wheel Cost	\$0.00	\$0.27
Total Tool Cost	\$0.25	\$4.35
Material Cost	\$12.80	\$12.80
Rework Cost	\$0.31	\$0.31
Total Cost	\$5643.88	\$8605.39
Unit Cost	\$22.58	\$34.42

4.4 Iteration 3: Carbide Insert II

The database consists of three types of cutting tools with different characteristics and costs. The target-costing algorithm analyzed the first two cutting tools and rejected them, as they were not successful in achieving the target cost. The current process unit cost was \$22.58 and the target cost was \$20.32. After rejecting HSS and brazed carbide tip cutting tools, the target-costing algorithm selected carbide insert type cutting tool. The carbide insert cutting tool selected was different from the original carbide insert and hence it is referred as carbide insert II. The results of this iteration are shown in Table 5.

The application of carbide insert II cutting tool resulted in unit turning cost of \$21.36, which was lower than the current process unit cost by \$1.22. This reduction in the unit cost was mainly due to the decrease in feeding cost by 32% over the current process feeding cost even though the tool changing cost increased. It can be seen from the Table 5 that the cutting speed decreased and the feed per revolution increased. Hence each pass is completed at a faster rate. The number of passes were reduced from 5 to 1 because carbide insert II achieved a higher depth of cut of 0.5 inches compared to 0.1 inches that the original carbide insert achieved. The number of passes also influences the rapid traverse cost as the machine had to travel rapidly only once compared to 5 times in the current process. Since the unit cost was less than the current process unit cost, the target-costing algorithm replaced the original carbide insert cutting tool by the carbide insert II cutting tool. But the target cost of \$20.32 or less was still not achieved. Since all the cutting tools were examined, the target-costing algorithm focused on the parameters influencing the highest cost component.

Table 5: Comparison of Results between Base Case and Iteration 3.

Parameter	Base: Carbide Insert	Iteration 2: Carbide Insert II
D	0.1 inches	0.5 inches
V	878.97 feet per minute	632.87 feet per minute
Fr	0.0014 inches per rev.	0.0054 inches per rev.
Number Of Passes	5	1
Updated Batch Size	279	279
Feeding Time	4.97 minutes	3.38 minutes
Feeding Cost	\$4.97	\$3.38
Rapid Traverse Cost	\$0.72	\$0.14
Setup Cost	\$0.10	\$0.10
Load/Unload Cost	\$1.00	\$1.00
Tool Changing Cost	\$0.009	\$0.8
Total Machine Time Cost	\$6.87	\$5.44
Re-sharpening Cost	\$0.00	\$0.00
Re-brazing Cost	\$0.00	\$0.00
Carbide Insert Cost	\$0.25	\$0.60
Grinding Wheel Cost	\$0.00	\$0.00
Total Tool Cost	\$0.25	\$0.60
Material Cost	\$12.80	\$12.80
Rework Cost	\$0.31	\$0.31
Total Cost	\$5643.88	\$5339.24
Unit Cost	\$22.58	\$21.36

4.5 Iteration 4: Material Cost Reduction

The material cost of \$12.80 was 56.67% of the current process unit cost and was the highest cost component in the unit cost. The basis of the target-costing algorithm is to focus on the cost components that have high contribution towards the unit cost starting from highest to lowest. The parameters that affect the material cost are material price and weight of material. The rework and rejection rate were not changed and hence 279 parts were required to be machined to achieve a batch of 250 acceptable parts. As a result the weight of material remained constant. The only parameter affecting the material cost was material price. The material price was reduced by 10%. The total machine time cost and the tool cost did not change, as the material price did not affect those cost components. The material cost decreased by 10% from \$12.80 to \$11.52 resulting in a unit cost of \$19.93 which was lower than the target cost of \$20.32. Since the target cost was reached, the algorithm did not resume any further iterations.

4.6 Conclusion

The target-costing program is very interactive and depends upon the type of response given by the user. All cost components are sequentially analyzed for reduction from highest to lowest after all cutting tools in the database are examined. When the program prompts the user to enter a percentage by which a certain factor can be reduced, the user should enter a percentage that could be achieved practically. The algorithm is based on the assumption that the user has good knowledge of the turning process. The information provided to the program influences its behavior. A sensitivity analysis was performed over five parameters and the results are shown in the appendix A.

CHAPTER 5

SYSTEM VALIDATION

The system validation forms the final part of this research work. It was deemed necessary to validate the model to test its suitability to practical conditions. The data was obtained from *De Vall Brothers Inc.* in Morgantown, WV. The results are discussed in the upcoming sections.

5.1 Data

Work-piece Parameters:

Part	Thermowell Pin
Initial Diameter	2 inches
Final Diameter	1.5 inches
Length	8 inches
Batch Size	4
Material	4140 Heat Treated
Hardness	25 – 250 BHn
Material Price	\$1800/ton

Machining Parameters:

d	0.12 inches
M	60 \$/hr
t ₀	15 minutes
t _{ch}	0.11 minutes
t _i	0.25 minute

R	120 inches/min
Rejection	0 %
Rework	0 %
Rework Rate	0 \$/hr
Cutting Tool	Carbide Insert
Cost of Tool	9 \$/insert
Number of edges	6
C (Tool life constant)	250

Machine Parameters:

Machine Capacity	20 HP
Surface Finish	32 micro inches

The manufacturing cost per part determined by the target-costing model was \$14.40, which was very close to the actual manufacturing cost of \$15 per part. The higher actual manufacturing cost is due to the chamfering operation performed on the ends of the pin, which is not considered in the model. The tool life data and the different exponents in the horsepower and surface finish constraint were not available and hence the data discussed in the previous sections was used. Several trials were conducted to determine the percentage cost reduction that could be achieved by the model. The model successfully achieved a target cost of \$14.11, which was a cost reduction of 2% and \$13.98 or a cost reduction of 2.9%.

5.2 Case 1: 2% Cost Reduction

The details for this case are as follows:

Current Process Unit Cost \$14.40

Desired Cost Reduction 2%

Target Cost \$14.11

Achieved Cost \$14.04

Iterations 5

The iterations are explained in table 43.

Table 6. System Validation Case 1: 2% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	14.40	21.85	Cutting tool was changed from carbide insert to hss.
2	14.40	22.46	Hss was replaced by carbide tip cutting tool.
3	14.40	14.48	Carbide tip was replaced by carbide insert.
4	14.40	14.19	Purchase price of material was reduced by 3%.
5	14.19	14.04	Setup time was reduced by 3%.

The material cost contributed 40% towards the unit cost and the setup cost was the second highest with 26% contribution. The material price was \$1800/ton and hence was the highest cost component. The setup time was 15 minutes, which was low, compared to the hypothetical examples, but was absorbed by a very small batch size compared to the batch size of 250 in the previous examples. This emphasizes the necessity of having a large batch size to offset the effect of high setup time. The target-costing process is shown in Figure 28. All the tools were examined and carbide insert was finally selected.

A further reduction in material price and setup time by 3% each was required to achieve the required target cost.

FIGURE 19. VALIDATION EXAMPLE 1

5.3 Case 2: 2.9% Cost Reduction

The details for this case are as follows:

Current Process Unit Cost \$14.40

Desired Cost Reduction 2.9%

Target Cost \$13.98

Achieved Cost \$13.98

Iterations 10

The iterations are explained in table 44.

Table 7. System Validation Case 2: 2.9% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	14.40	21.85	Cutting tool was changed from carbide insert to hss.
2	14.40	22.46	Hss was replaced by carbide tip cutting tool.
3	14.40	14.48	Carbide tip was replaced by carbide insert.
4	14.40	14.19	Purchase price of material was reduced by 3%.
5	14.19	14.04	Setup time was reduced by 3%.
6	14.04	14.01	Machine with rapid traverse rate 40 inches/min selected.
7	14.01	20.69	Machine with rapid traverse rate 50 inches/min selected.
8	14.01	20.28	Machine with rapid traverse rate 60 inches/min selected.
9	14.01	18.55	Loading and Unloading time was reduced by 10%.
10	14.01	13.98	Cost of carbide insert was reduced by 5%.

Since the target cost was lower compared to the previous case, more improvements were necessary. The percentage reduction in material price, setup time and the carbide insert

cost show more realistic values, which can be achieved in the real world. The results are shown in table 44 and Figure 29.

FIGURE 20. VALIDATION EXAMPLE 2

During iterations 7, 8 and nine, different machines were evaluated to reduce the rapid traverse cost. The machines with lower rapid traverse rate had lower labor, but the higher unit cost is justified by higher handling times.

5.4 Conclusion

The system validation formed the most important part of this research work. Two real life examples were solved using the target-costing model, the process and results of which were presented in this chapter. The model provided good results as illustrated by the examples and the accuracy of the results could be improved by populating the databases with more realistic and practical data. The examples also demonstrated that the material cost and the setup time constituted the major portion of the unit cost, which is consistent with real life applications. The examples provided in this chapter and the earlier chapters suggest that the effect of high setup time can be offset by larger batch sizes.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

The field of target-costing is emerging fast as the solution to future product development and cost reduction. Target-Costing, Value Chain Analysis, Value Chain Improvement, Quality Function Deployment etc are different names which try to achieve the same objective: to produce a product at the lowest cost with all the required features with adherence to quality conformance and aesthetics. All the above mentioned are different techniques of process improvement but try to achieve the same objective. Target-costing has been widely applied in product development and process improvement by companies such as Toyota Motor Corporation, Nissan Motor Corporation, Boeing, Chrysler, Kodak, Lucent Technologies, Sony Corporation, and many others. Target-costing can be applied in the design of a new product as well as improvement of an existing process.

Machining is one of the most widely used manufacturing operations and hence there is a huge potential for cost reduction using the target-costing technique. In this research, a target-costing model was developed for turning operation, which uses a structured approach to reduce the machining costs. The user interface was designed in Microsoft Visual Basic and the database was developed using Microsoft Access. The model was tested using real time data and the results obtained were comparable to the actual values. This model can be utilized as a starting point in the development of an integrated target-costing system for all machining operations.

6.2 Future Work

The target-costing model was developed for the turning operation to evaluate its feasibility. Since the tests produced good results, this model can be further enhanced to incorporate more machining operations like milling, drilling, grinding, tapping and other finishing operations. The user can be given more choices regarding the materials and their respective hardness. By incorporating all machining operations, a good process planning system can be developed which can be used very well for instructional purposes. The program can also be made smart by incorporating user input data analysis feature, which screens the user input data before using it in the program.

Features such as implementation costs and opportunity costs can be incorporated to enhance the model and its usefulness.

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APPENDIX

APPENDIX A

Sensitivity Analysis Tables

Table A1. Labor rates and associated non-productive times.

Case	Labor Rate	Setup Time	Tool Changing Time	Load/Unload Time
1	60	25	5	1
2	50	30	8	3
3	40	35	12	5

Table A2. Target Costing Summary for Labor and Overhead Rate \$60/hr.

Trial	CPUC \$	Reduction %	Target \$	Achieved \$	Iterations
1	22.58	10	20.32	19.93	4
2	22.58	12	19.87	19.82	5
3	22.58	13	19.64	19.55	12

Table A3. Target Costing Iteration Summary for 10% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.58	33.72	Cutting tool was changed from carbide insert to hss.
2	22.58	34.42	Hss was replaced by carbide tip cutting tool.
3	22.58	21.36	Carbide tip was replaced by carbide insert.
4	21.36	19.93	Purchase price of material was reduced by 10%.

Table A4. Target Costing Iteration Summary for 12% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.58	33.72	Cutting tool was changed from carbide insert to hss.
2	22.58	34.42	Hss was replaced by carbide tip cutting tool.
3	22.58	21.36	Carbide tip was replaced by carbide insert.
4	21.36	19.93	Purchase price of material was reduced by 10%.
5	19.93	19.82	Loading and Unloading time was reduced by 10%.

Table A5. Target Costing Iteration Summary for 13% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.58	33.72	Cutting tool was changed from carbide insert to hss.
2	22.58	34.42	Hss was replaced by carbide tip cutting tool.
3	22.58	21.36	Carbide tip was replaced by carbide insert.
4	21.36	19.93	Purchase price of material was reduced by 10%.
5	19.93	19.82	Loading and Unloading time was reduced by 10%.
6	19.82	21.81	Machine with rapid traverse rate 40 inches/min selected.
7	19.82	21.4	Machine with rapid traverse rate 50 inches/min selected.
8	19.82	19.93	Machine with rapid traverse rate 60 inches/min selected.
9	19.82	19.89	Rework rate was reduced by 10%
10	19.82	19.75	Cost of carbide insert was reduced by 10%
11	19.75	19.74	Setup time was reduced by 10%
12	19.74	19.55	Tool changing time was reduced by 10%

Figure A1. Target Costing Iteration Summary for 13% Cost Reduction

Table A11. Target Costing Summary for Batch Size 500 Units

Trial	CPUC \$	Reduction %	Target \$	Achieved \$	Iterations
1	22.47	10	20.22	19.83	4
2	22.47	12	19.77	19.72	5
3	22.47	13	19.55	19.47	11

Table A12. Target Costing Iteration Summary for 10% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.47	33.6	Cutting tool was changed from carbide insert to hss.
2	22.47	34.3	Hss was replaced by carbide tip cutting tool.
3	22.47	21.26	Carbide tip was replaced by carbide insert.
4	21.26	19.83	Purchase price of material was reduced by 10%.

Table A13. Target Costing Iteration Summary for 12% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.47	33.6	Cutting tool was changed from carbide insert to hss.
2	22.47	34.3	Hss was replaced by carbide tip cutting tool.
3	22.47	21.26	Carbide tip was replaced by carbide insert.
4	21.26	19.83	Purchase price of material was reduced by 10%.
5	19.83	19.72	Loading and Unloading time was reduced by 10%.

Table A14. Target Costing Iteration Summary for 13% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.47	33.6	Cutting tool was changed from carbide insert to hss.
2	22.47	34.3	Hss was replaced by carbide tip cutting tool.
3	22.47	21.26	Carbide tip was replaced by carbide insert.
4	21.26	19.83	Purchase price of material was reduced by 10%.
5	19.83	19.72	Loading and Unloading time was reduced by 10%.
6	19.72	21.71	Machine with rapid traverse rate 40 inches/min selected.
7	19.72	21.3	Machine with rapid traverse rate 50 inches/min selected.
8	19.72	19.83	Machine with rapid traverse rate 60 inches/min selected.
9	19.72	19.8	Rework rate was reduced by 10%.
10	19.72	19.66	Cost of carbide insert was reduced by 10%.
11	19.66	19.47	Tool changing time was reduced by 10%.

Figure A2. Target Costing Iteration Summary for 13% Cost Reduction

Table A19. Target Costing Summary for Material Condition Hot Rolled and Annealed and Hardness 125 – 150 BHn.

Trial	CPUC \$	Reduction %	Target \$	Achieved \$	Iterations
1	22.58	10	20.32	20.27	10
2	22.58	11	20.10	20.05	12
3	22.58	13	19.87	20.05	13

Table A20. Target Costing Iteration Summary for 10% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.58	36	Cutting tool was changed from carbide insert to hss.
2	22.58	36.5	Hss was replaced by carbide tip cutting tool.
3	22.58	21.89	Carbide tip was replaced by carbide insert.
4	21.89	20.46	Purchase price of material was reduced by 10%.
5	20.46	20.35	Loading and unloading time was reduced by 10%.
6	20.35	22.26	Machine with rapid traverse rate 40 inches/min selected.
7	20.35	21.91	Machine with rapid traverse rate 50 inches/min selected.
8	20.35	20.46	Machine with rapid traverse rate 60 inches/min selected.
9	20.35	20.42	Rework rate was reduced by 10%.
10	20.35	20.27	Cost of carbide insert was reduced by 10%.

Figure A3. Target Cost Achieved in 10 iterations

Table A21. Target Costing Iteration Summary for 12% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.58	36	Cutting tool was changed from carbide insert to hss.
2	22.58	36.5	Hss was replaced by carbide tip cutting tool.
3	22.58	21.89	Carbide tip was replaced by carbide insert.
4	21.89	20.46	Purchase price of material was reduced by 10%.
5	20.46	20.35	Loading and unloading time was reduced by 10%.
6	20.35	22.26	Machine with rapid traverse rate 40 inches/min selected.
7	20.35	21.91	Machine with rapid traverse rate 50 inches/min selected.
8	20.35	20.46	Machine with rapid traverse rate 60 inches/min selected.
9	20.35	20.42	Rework rate was reduced by 10%.
10	20.35	20.27	Cost of carbide insert was reduced by 10%.
11	20.27	20.25	Setup time was reduced by 10%.
12	20.25	20.05	Tool changing time was reduced by 10%.

Table A22. Target Costing Iteration Summary for 13% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	22.58	36	Cutting tool was changed from carbide insert to hss.
2	22.58	36.5	Hss was replaced by carbide tip cutting tool.
3	22.58	21.89	Carbide tip was replaced by carbide insert.
4	21.89	20.46	Purchase price of material was reduced by 10%.
5	20.46	20.35	Loading and unloading time was reduced by 10%.
6	20.35	22.26	Machine with rapid traverse rate 40 inches/min selected.
7	20.35	21.91	Machine with rapid traverse rate 50 inches/min selected.
8	20.35	20.46	Machine with rapid traverse rate 60 inches/min selected.
9	20.35	20.42	Rework rate was reduced by 10%.
10	20.35	20.27	Cost of carbide insert was reduced by 10%.
11	20.27	20.25	Setup time was reduced by 10%.
12	20.25	20.05	Tool changing time was reduced by 10%.
13	20.05	20.05	Resharpening time was reduced by 10%.

Table A27. Target Costing Summary for Percentage Rejection 5%.

Trial	CPUC \$	Reduction %	Target \$	Achieved \$	Iterations
1	21.2	10	19.08	18.7	4
2	21.2	12	18.66	18.59	5
3	21.2	13	18.44	18.35	12

Table A28. Target Costing Iteration Summary for 10% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	21.2	31.74	Cutting tool was changed from carbide insert to hss.
2	21.2	32.41	Hss was replaced by carbide tip cutting tool.
3	21.2	20.05	Carbide tip was replaced by carbide insert.
4	20.05	18.7	Purchase price of material was reduced by 10%.

Table A29. Target Costing Iteration Summary for 12% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	21.2	31.74	Cutting tool was changed from carbide insert to hss.
2	21.2	32.41	Hss was replaced by carbide tip cutting tool.
3	21.2	20.05	Carbide tip was replaced by carbide insert.
4	20.05	18.7	Purchase price of material was reduced by 10%.
5	18.7	18.59	Loading and unloading time was reduced by 10%.

Figure A4. Target Cost Achieved in 5 Iterations

Table A30. Target Costing Iteration Summary for 13% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	21.2	31.74	Cutting tool was changed from carbide insert to hss.
2	21.2	32.41	Hss was replaced by carbide tip cutting tool.
3	21.2	20.05	Carbide tip was replaced by carbide insert.
4	20.05	18.7	Purchase price of material was reduced by 10%.
5	18.7	18.59	Loading and unloading time was reduced by 10%.
6	18.59	20.47	Machine with rapid traverse rate 40 inches/min selected.
7	18.59	20.09	Machine with rapid traverse rate 50 inches/min selected.
8	18.59	18.7	Machine with rapid traverse rate 60 inches/min selected.
9	18.59	18.56	Cost of carbide insert was reduced by 10%.
10	18.56	18.54	Rework rate was reduced by 10%.
11	18.54	18.53	Setup time was reduced by 10%.
12	18.53	18.35	Tool changing time was reduced by 10%.

Table A39. Target Costing Summary for Material Price \$200/ton

Trial	CPUC \$	Reduction %	Target \$	Achieved \$	Iterations
1	16.41	10	14.77	22.72	4
2	16.41	13	14.28	22.6	5
3	16.41	14	14.11	14.00	12

Table A40. Target Costing Iteration Summary for 10% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	16.41	27.55	Cutting tool was changed from carbide insert to hss.
2	16.41	28.25	Hss was replaced by carbide tip cutting tool.
3	16.41	15.19	Carbide tip was replaced by carbide insert.
4	15.19	14.38	Purchase price of material was reduced by 10%.

Figure A5. Target Cost Achieved in 4 Iterations

Table A41. Target Costing Iteration Summary for 13% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	16.41	27.55	Cutting tool was changed from carbide insert to hss.
2	16.41	28.25	Hss was replaced by carbide tip cutting tool.
3	16.41	15.19	Carbide tip was replaced by carbide insert.
4	15.19	14.38	Purchase price of material was reduced by 10%.
5	14.38	14.27	Loading and unloading time was reduced by 10%.

Table A42. Target Costing Iteration Summary for 14% Cost Reduction

It. No.	Unit Cost	Achieved	Description
1	16.41	27.55	Cutting tool was changed from carbide insert to hss.
2	16.41	28.25	Hss was replaced by carbide tip cutting tool.
3	16.41	15.19	Carbide tip was replaced by carbide insert.
4	15.19	14.38	Purchase price of material was reduced by 10%.
5	14.38	14.27	Loading and unloading time was reduced by 10%.
6	14.27	16.26	Machine with rapid traverse rate 40 inches/min selected.
7	14.27	15.85	Machine with rapid traverse rate 50 inches/min selected.
8	14.27	14.38	Machine with rapid traverse rate 60 inches/min selected.
9	14.27	14.34	Rework rate was reduced by 10%.
10	14.27	14.2	Cost of carbide insert was reduced by 10%.
11	14.2	14.19	Setup time was reduced by 10%.
12	14.19	14.00	Tool changing time was reduced by 10%.

APPENDIX B

Program to Control the Input Form 1

```
Dim flag As Integer
Private Sub Command1_Click()
Form8.Show
End Sub

Private Sub conditionlist_MouseUp(Button As Integer, Shift As Integer, X As Single, Y
As Single)
For i = 0 To conditionlist.ListIndex
    Select Case (i)
    Case 0
        hardnesslist.Clear
        hardnesslist.AddItem ("100 - 125")
        hardnesslist.AddItem ("125 - 150")
    Case 1
        hardnesslist.Clear
        hardnesslist.AddItem ("150 - 175")
        hardnesslist.AddItem ("175 - 200")
    Case 2
        hardnesslist.Clear
        hardnesslist.AddItem ("200 - 225")
        hardnesslist.AddItem ("225 - 250")
    Case 3
        hardnesslist.Clear
        hardnesslist.AddItem ("250 - 275")
        hardnesslist.AddItem ("275 - 300")
    End Select
Next i
End Sub

Private Sub Form_Load()
flag = 0
For i = 0 To 3
    Select Case (i)
    Case 0
        conditionlist.AddItem ("Hot Rolled or Annealed")
    Case 1
        conditionlist.AddItem ("Cold Drawn")
    Case 2
        conditionlist.AddItem ("Hot Rolled Nor, Ann or CD")
    Case 3
        conditionlist.AddItem ("Quenched and Temp")
    End Select
Next i
End Sub
```

```

End Select
Next i
conditionlist.Selected(0) = False
End Sub

```

```

Private Sub nextform1_Click()
ID = Val(IDtext.Text)
L = Val(ILtext.Text)
Dfin = Val(FDtext.Text)
NI = Val(Bstext.Text)
den = Val(dentext.Text)
matl_price = Val(mptext.Text)
d = Val(doctext.Text)
r = Val(rapidtext.Text)
tl = Val(loadtext.Text)
M = Val(machhrtext.Text)
t0 = Val(setuptext.Text)
tc = Val(tchtext.Text)
a = Val(apptext.Text)
e = Val(overtext.Text)
rejectionrate = (Val(rejectiontext.Text)) / 100
per_rework = Val(reworktext.Text)
reworkrate = Val(reworkratetext.Text)
SF = Val(SFmaxtext.Text)
HP = Val(HPmaxtext.Text)
matl_cond = conditionlist.Text
matl_hard = hardnesslist.Text
var = hardnesslist.ListIndex
If (IDtext.Text = "" Or FDtext.Text = "" Or Fltext.Text = "" Or ILtext.Text = "" Or _
dentext.Text = "" Or Bstext.Text = "" Or mptext.Text = "" Or doctext.Text = "" Or _
rapidtext.Text = "" Or loadtext.Text = "" Or machhrtext.Text = "" Or _
rejectiontext.Text = "" Or reworkratetext.Text = "" Or reworktext.Text = "" Or _
overtext.Text = "" Or apptext.Text = "" Or tchtext.Text = "" Or _
setuptext.Text = "" Or HPmaxtext.Text = "" Or SFmaxtext.Text = "" Or _
btext.Text = "" Or ctext.Text = "" Or etext.Text = "" Or _
gtext.Text = "" Or htext.Text = "" Or itext.Text = "" Or Cmttext.Text = "" Or _
Cstext.Text = "") Then
MsgBox "Some data is missing. Please fill in all the data"
Exit Sub
End If
conditionlist.Refresh
If conditionlist.Selected(0) = True Or conditionlist.Selected(1) = True _
Or conditionlist.Selected(2) = True Or conditionlist.Selected(3) = True Then
If hardnesslist.Selected(0) = True Or hardnesslist.Selected(1) = True Then
flag = 1

```

```
Else
    MsgBox " Please select the material hardness"
End If
Else
    MsgBox " Please select the material condition"
End If
If flag = 1 Then
    Form2.Show
    Form1.Hide

End If
End Sub
```

APPENDIX C

Program to Control the Input Form 2

```
Dim D1, D2, D3, D4 As Double
Dim X1, X2, X3, X5, X6, X7, X8, X9, X10, X11, X12, X13 As Double
Dim flag As Integer

Private Sub backform2_Click()
Form1.Show
Form2.Hide
resultsform2.Enabled = False
calculate.Enabled = True
End Sub
Private Sub calculate_Click()
flag = 0
If ((hss.Value = False) And (carbideip.Value = False) And (carbideinsert.Value = False))
Then
MsgBox " Please Select the Tool Type"
Exit Sub
End If
If (mtext.Text = "" Or ntext.Text = "" Or ptext.Text = "") Then
MsgBox " Please enter all Tool Life Exponents "
Exit Sub
End If
If hss.Value = True Then
If Gwctext.Text = "" Or Tstext.Text = "" Or Lrgtext.Text = "" Or _
toolprice.Text = "" Or Toollifeconsttext.Text = "" Then
MsgBox "Please fill in all data"
Else
flag = 1
End If
ElseIf carbideip.Value = True Then
If Gwctext.Text = "" Or Tstext.Text = "" Or Lrgtext.Text = "" Or _
toolprice.Text = "" Or Lrbtext.Text = "" Or k2text.Text = "" Or _
Toollifeconsttext.Text = "" Then
MsgBox "Please fill in all data"
Else
flag = 1
End If
ElseIf carbideinsert.Value = True Then
If Cictext.Text = "" Or k3text.Text = "" Or Toollifeconsttext.Text = "" Then
MsgBox "Please fill in all data"
Else
```

```

    flag = 1
End If
End If
If flag = 1 Then
X1 = Val(Form1.btext.Text)
X2 = Val(Form1.ctext.Text)
X3 = Val(Form1.etxt.Text)
X4 = Val(Form1.gtext.Text)
X5 = Val(Form1.htext.Text)
X6 = Val(Form1.itext.Text)
X7 = Val(mtext.Text)
X8 = Val(ntext.Text)
X9 = Val(ptext.Text)
X10 = Val(Form1.Cstext.Text)
X11 = Val(Form1.Cmtext.Text)
D3 = 0
D4 = (1 - X7) / (X5 - X4 * X7)
D2 = (X8 * (X5 - X4)) / (X5 - X4 * X7)
D1 = 1 - D2
Csdash = X10 * (Val(Form1.doctext.Text) ^ X6) / SF
Cmdash = X11 * (Val(Form1.doctext.Text) ^ X3) / HP
C1dash = (3.14 * ID * L * M) / (12 * 60)
X12 = (C1dash * (d ^ (X9 / X8))) / (Val(Toollifeconsttext.Text) ^ (1 / X8))
If (hss.Value = True Or carbidetip.Value = True) Then
X13 = ((M * tc / 60) + Val(toolprice.Text)) * 60 / M
Else
X13 = ((M * tc / 60) + Val(Cictext.Text)) * 60 / M
End If
C2dash = X12 * X13
    If (D2 >= 0 And D2 <= 1 And D4 >= 0) Then
        Dual_D2 = D2
    Else
        Dual_D2 = "Not feasible"
    End If
    If (D2 >= 0 And D2 <= 1 And D4 >= 0) Then
        Dual_D4 = D4
    Else
        Dual_D4 = "Not feasible"
    End If

fr = (Csdash ^ (1 / (X7 * X4 - X5))) * (C1dash * (1 - D1) / (C2dash * D1)) ^ (X8 * X4 /
(X7 * X4 - X5))
v = 1 / (Csdash * (fr ^ X5)) ^ (1 / X4)

If (Dual_D2 = "Not feasible" Or Dual_D4 = "Not feasible") Then
    z1 = "not feasible" ' case 1

```

```

Else
    z1 = "ok"
End If
If z1 = "not feasible" Then
    D4 = 0
    D3 = X1 / X9
    If (D2 >= 0 And D2 <= 1 And D3 >= 0) Then
        Dual_D2 = "ok"
    Else
        Dual_D2 = " not feasible"
    End If
    If (D2 >= 0 And D2 <= 1 And D3 >= 0) Then
        Dual_D4 = "ok"
    Else
        Dual_D4 = " not feasible"
    End If
    If (Dual_D2 = "not feasible" Or Dual_D4 = " not feasible") Then
        z2 = "not feasible" ' case 2
    Else
        z2 = "ok"
    End If
    fr = (Cmdash ^ (1 / (X7 * X1 - X2))) * (C1dash * (1 - D1) / (C2dash * D1)) ^ (X8 *
X1 / (X7 * X1 - X2))
    v = 1 / (Cmdash * (fr ^ X2)) ^ (1 / X1)
End If
If (z1 = "not feasible" And z2 = "not feasible") Then ' case 1 and case 2 are not feasible
v = Exp((X5 * Log(Cmdash) - X2 * Log(Csdash)) / (X4 * X2 - X1 * X5))
fr = Exp((X1 * Log(Csdash) - X4 * Log(Cmdash)) / (X4 * X2 - X1 * X5))
End If
If hss.Value = True Then
    G = Lrgtext.Text
    Cw = Gwctext.Text
    ts = Tstext.Text
    tooltype1 = "hss"
ElseIf carbidetip.Value = True Then
    k2 = k2text.Text
    Lrb = Lrbtext.Text
    tb = Tbtext.Text
    G = Lrgtext.Text
    Cw = Gwctext.Text
    ts = Tstext.Text
    tooltype1 = "carbide tip"
Else
    'carbideinsert.Value = True Then
    Cost = Cictext.Text
    k3 = k3text.Text

```



```

tooltype1 = "carbide insert"
End If
m1 = Val(mtext.Text)
n = Val(ntext.Text)
p = Val(ptext.Text)
C = Val(Toollifeconsttext.Text)
T = Toollife(v, fr, d, m1, n, p, C, tooltype1, k3)
Call feeding(d, rejectionrate, M, v, fr)
feedcost = Fc
rtc = (a + L + e) * No_passes(d) * M / (r * 60)
stc = setup(t0, M)
tcc = Tool_change(fr, v, T, tc, M)
lcc = tl * M / 60
tmtc = feedcost + rtc + stc + tcc + lcc
rsc = Resharpening(fr, v, T, G, ts, k2, tooltype1)
grc = Grinding(frnew, vnew, T, Cwnew, tooltype1)
rbc = Rebrazing(Lrb, tb, k2, tooltype1)
cic = Carbide(Cost, Ft, T, tooltype1)
rwc = reworkcost()
Form3.feedcost = Format(Fc, "####0.00")
Form3.rtc = Format(rtc, "####0.00")
Form3.stc = Format(stc, "####0.00")
Form3.tcc = Format(tcc, "####0.00")
Form3.lc = Format(lcc, "####0.00")
Form3.tmtc = Format(tmtc, "####0.00")
Form3.rwc = Format(rwc, "####0.00")
toolcost = rbc + rsc + cic + grc
matlcost = Material(matl_price, den)
totalcost = ubs * (tmtc + toolcost + matlcost + rwc)
unitcost = totalcost / NI
Form3.rbc = Format(rbc, "####0.00")
Form3.rsc = Format(rsc, "####0.00")
Form3.cic = Format(cic, "##,##0.00")
Form3.grc = Format(grc, "####0.00")
Form3.toolcost = Format(toolcost, "####0.00")
Form3.matlcost = Format(matlcost, "####0.00")
Form3.totalcost = Format(totalcost, "####0.00")
Form3.unitcost = Format(unitcost, "####0.00")
calculate.Enabled = False
resultsform2.Enabled = True
Else
Exit Sub
End If
End Sub

Private Sub hss_Click()

```

```

lrglabel.Visible = True
Lrgtext.Visible = True
gwclabel.Visible = True
Gwctext.Visible = True
tslabel.Visible = True
Tstext.Visible = True
tblabel.Visible = False
Tbtext.Visible = False
lrblabel.Visible = False
Lrbtext.Visible = False
ciclable.Visible = False
Cicctext.Visible = False
k2label.Visible = False
k2text.Visible = False
k3label.Visible = False
k3text.Visible = False
Tclabel.Visible = True
toolprice.Visible = True
Label6.Visible = True
Label5.Visible = False
Label2.Visible = False
Label3.Visible = True
Label4.Visible = True
Label7.Visible = False
Label8.Visible = True
End Sub
Private Sub carbidetip_Click()
lrglabel.Visible = True
Lrgtext.Visible = True
gwclabel.Visible = True
Gwctext.Visible = True
tslabel.Visible = True
Tstext.Visible = True
tblabel.Visible = True
Tbtext.Visible = True
lrblabel.Visible = True
Lrbtext.Visible = True
k2label.Visible = True
k2text.Visible = True
k3label.Visible = False
k3text.Visible = False
ciclable.Visible = False
Cicctext.Visible = False
Tclabel.Visible = True
toolprice.Visible = True
Label6.Visible = True

```

```
Label5.Visible = False
Label2.Visible = True
Label3.Visible = True
Label4.Visible = True
Label7.Visible = True
Label8.Visible = True
End Sub
```

```
Private Sub carbideinsert_Click()
lrglabel.Visible = False
Lrgtext.Visible = False
gwclabel.Visible = False
Gwctext.Visible = False
tslabel.Visible = False
Tstext.Visible = False
tblabel.Visible = False
Tbtext.Visible = False
lrblabel.Visible = False
Lrbtext.Visible = False
ciclable.Visible = True
Cictext.Visible = True
k2label.Visible = False
k2text.Visible = False
k3label.Visible = True
k3text.Visible = True
Tclabel.Visible = False
toolprice.Visible = False
Label5.Visible = True
Label6.Visible = False
Label2.Visible = False
Label3.Visible = False
Label4.Visible = False
Label7.Visible = False
Label8.Visible = False
End Sub
```

```
Private Sub resultsform2_Click()
Form2.Hide
Form3.Show
End Sub
```

APPENDIX D

Program to Control Form 3

```
Dim cn As Connection
```

```
Dim rs As Recordset
```

```
Private Sub Command1_Click()
```

```
    If targettext.Text = "" Then
```

```
        MsgBox " Please enter the Percentage Reduction Required"
```

```
        Exit Sub
```

```
    End If
```

```
    Call sort
```

```
    Form4.Text1 = Format(Arr1(0), "##,##0.00")
```

```
    Form4.Text2 = Format(Arr1(1), "##,##0.00")
```

```
    Form4.Text3 = Format(Arr1(2), "##,##0.00")
```

```
    Form4.Text4 = Format(Arr1(3), "##,##0.00")
```

```
    Form4.Text5 = Format(Arr1(4), "##,##0.00")
```

```
    Form4.Text7 = Format(Arr1(5), "##,##0.00")
```

```
    Form4.Text8 = Format(Arr1(6), "##,##0.00")
```

```
    Form4.Text9 = Format(Arr1(7), "##,##0.00")
```

```
    Form4.Text10 = Format(Arr1(8), "##,##0.00")
```

```
    Form4.Label2.Caption = Arr2(0)
```

```
    Form4.Label3.Caption = Arr2(1)
```

```
    Form4.Label4.Caption = Arr2(2)
```

```
    Form4.Label5.Caption = Arr2(3)
```

```
    Form4.Label6.Caption = Arr2(4)
```

```
    Form4.Label19.Caption = Arr2(5)
```

```
    Form4.Label20.Caption = Arr2(6)
```

```
    Form4.Label21.Caption = Arr2(7)
```

```
    Form4.Label22.Caption = Arr2(8)
```

```
    Form4.Label8.Caption = Format(Val(Arr1(0) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label9.Caption = Format(Val(Arr1(1) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label10.Caption = Format(Val(Arr1(2) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label11.Caption = Format(Val(Arr1(3) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label12.Caption = Format(Val(Arr1(4) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label23.Caption = Format(Val(Arr1(5) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label24.Caption = Format(Val(Arr1(6) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label25.Caption = Format(Val(Arr1(7) / unitcost.Text) * 100, "##,##0.00")
```

```
    Form4.Label26.Caption = Format(Val(Arr1(8) / unitcost.Text) * 100, "##,##0.00")
```

```
    targetcost = Val(unitcost.Text) * (1 - (Val(targettext.Text) / 100))
```

```
    Form4.Text6.Text = Format(targetcost, "##,##0.00")
```

```
    Form4.Show
```

```
    Form3.Hide
```

End Sub

```
Private Sub Command2_Click()  
Form3.Hide  
Form2.Show  
End Sub
```

APPENDIX E

Program to Control Form 4

```
Private Sub Achieve_Click()
Dim con As New ADODB.Connection
Dim cmd As New ADODB.Command
Dim rs As New ADODB.Recordset
Dim unitcost1 As Single
con.Open "Provider=Microsoft.Jet.OLEDB.4.0;" & _
"Data Source= C:\Documents and Settings\ameet\My
Documents\research\vbcode\target.mdb;" & _
"User Id=Admin;" & _
"Password"
unitcost1 = 1000
Achieve.Enabled = False
For j = 0 To 10
'Select Case (Arr2(j))
'-----
'Case "Feeding Cost"
'stri = "select * from tools where Condition = '" & matl_cond & "' and Hardness = '" &
matl_hard & "'"
'stri = "select * from HRA1 "
'rs.Open "select * from tools where Condition = '" & matl_cond & "' and Hardness = '" &
matl_hard & "'", con, adOpenStatic, adLockPessimistic
If matl_cond = "Hot Rolled or Annealed" And matl_hard = "100 - 125" Then
    rs.Open "select * from HRAlo ", con, adOpenStatic, adLockPessimistic
End If
If matl_cond = "Hot Rolled or Annealed" And matl_hard = "125 - 150" Then
    rs.Open "select * from HRAhi ", con, adOpenStatic, adLockPessimistic
End If
If matl_cond = "Cold Drawn" And matl_hard = "150 - 175" Then
    rs.Open "select * from CDlo ", con, adOpenStatic, adLockPessimistic
End If
If matl_cond = "Cold Drawn" And matl_hard = "175 - 200" Then
    rs.Open "select * from CDhi ", con, adOpenStatic, adLockPessimistic
End If
If matl_cond = "Hot Rolled Nor, Ann or CD" And matl_hard = "200 - 225" Then
    rs.Open "select * from HRNACDlo ", con, adOpenStatic, adLockPessimistic
End If
If matl_cond = "Hot Rolled Nor, Ann or CD" And matl_hard = "225 - 250" Then
    rs.Open "select * from HRNACDhi ", con, adOpenStatic, adLockPessimistic
End If
If matl_cond = "Quenched and Temp" And matl_hard = "250 - 275" Then
    rs.Open "select * from QTlo ", con, adOpenStatic, adLockPessimistic
```

```

End If
If matl_cond = "Quenched and Temp" And matl_hard = "275 - 300" Then
    rs.Open "select * from QThi ", con, adOpenStatic, adLockPessimistic
End If
rs.Move (Start)
Do While Not rs.EOF
    d22 = rs("dmax")
    m2 = rs("m")
    n2 = rs("n")
    p2 = rs("p")
    C2 = rs("C")
    Cost2 = rs("cost")
    tooltype2 = rs("type")
    G2 = rs("G")
    Cw2 = rs("Cw")
    ts2 = rs("ts")
    Lrb2 = rs("Lrb")
    tb2 = rs("tb")
    k22 = rs("k2")
    k32 = rs("k3")
    Call calculate(d22, m2, n2, p2, C2, Cost2, M, tooltype2, G2, Cw2, ts2, Lrb2, tb2, k22,
    k32, r, tc, tl, t0)
    If (unitcost < unitcost1) Then
        If (unitcost < Val(Form3.unitcost.Text)) Then
            d = d22
            m1 = m2
            n = n2
            p = p2
            C = C2
            tooltype1 = tooltype2
            k2 = k22
            k3 = k32
            tb = tb2
            ts = ts2
            G = G2
            Cost = Cost2
            Cw = Cw2
            Lrb = Lrb2
            unitcost1 = unitcost
        End If
    End If
    If (unitcost <= targetcost) Then
        Exit Do
    End If
    rs.MoveNext
Loop

```

```

rs.Close
'If (unitcost <= targetcost) Then
'targetlabel.Visible = True
'  Exit For
'End If
'-----
'Call sort
For j = 1 To 10
If (unitcost <= targetcost) Then
  Exit For
End If
Select Case (Arr2(j))
'-----
Case "Rapid Traverse Cost"
mcexplore = yes
rs.Open "select * from machine ", con, adOpenForwardOnly, adLockReadOnly
Do While Not rs.EOF
M3 = rs("Machinehourrate")
r3 = rs("Rapidtraverserate")
t03 = rs("Settime")
tl3 = rs("Loadunloadtime")
tc3 = rs("Toolchtime")
mctype3 = rs("Name")
Call calculate(d, m1, n, p, C, Cost, M3, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r3, tc3, tl3,
t03)
If (unitcost < unitcost1) Then
  If (unitcost < Val(Form3.unitcost.Text)) Then
    M = M3
    r = r3
    t0 = t03
    tl = tl3
    tc = tc3
    mctype = mctype3
    unitcost1 = unitcost
  End If
End If
If (unitcost <= targetcost) Then
  Exit Do
End If
rs.MoveNext
Loop
rs.Close
If (unitcost <= targetcost) Then
'targetlabel.Visible = True
  Exit For
End If

```



```

'-----
Case "Setup Cost"
response = InputBox("Can you reduce the Setup time? Please enter the percentage")
t0 = t0 * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
'targetlabel.Visible = True
Exit For
End If

'-----
Case "Loading and Unloading Cost"
response = InputBox("Can you reduce the Loading and Unloading Time? Please enter the percentage")
tl = tl * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
'targetlabel.Visible = True
Exit For
End If

'-----
Case "Tool Changing Cost"
response = InputBox("Can you reduce the Tool Changing Time? Please enter the percentage")
tc = tc * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
'targetlabel.Visible = True
Exit For
End If

'-----
Case "Rebrazing Cost"
response = InputBox("Can you reduce the Rebrazing Time? Please enter the percentage")
tb = tb * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
'targetlabel.Visible = True
Exit For
End If

'-----
Case "Resharpening Cost"
response = InputBox("Can you reduce the Resharpening Time? Please enter the percentage")
ts = ts * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then

```

```

'targetlabel.Visible = True
    Exit For
End If
'-----

Case "Carbide Insert Cost"
response = InputBox("Can you reduce the Cost per carbide insert? Please enter the
percentage")
Cost = Cost * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
    'targetlabel.Visible = True
    Exit For
End If
'-----

Case "Material Cost"
response = InputBox("Can you reduce the Material Price? Please enter the percentage",
"Material_Cost", 0)
matl_price = matl_price * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
    'targetlabel.Visible = True
    Exit For
End If
'-----

Case "Rework Cost"
response = InputBox("Can you reduce the Rework Rate? Please enter the percentage",
"Material_Cost", 0)
reworkrate = reworkrate * ((100 - Val(response)) / 100)
Call calculate(d, m1, n, p, C, Cost, M, tooltype1, G, Cw, ts, Lrb, tb, k2, k3, r, tc, tl, t0)
If (unitcost <= targetcost) Then
    'targetlabel.Visible = True
    Exit For
End If
'-----

End Select
Next j
'=====
=====
If (unitcost <= targetcost) Then
    targetlabel.Visible = True
Else
    Notarget.Visible = True
End If
con.Close
Set con = Nothing
If (unitcost > targetcost) Then

```

```

' Label17.Visible = True
Else
    Command2.Enabled = True
End If
End Sub

```

```

Private Sub Command1_Click()
Form4.Hide
Form3.Show
Achieve.Enabled = True
targetlabel.Visible = False
Notarget.Visible = False
End Sub

```

```

Private Sub Command2_Click()
Form5.feedcostgt = Format(feedcost, "####0.00")
Form5.rtctgt = Format(rtc, "####0.00")
Form5.stctgt = Format(stc, "####0.00")
Form5.tectgt = Format(tcc, "####0.00")
Form5.lctgt = Format(lcc, "####0.00")
Form5.tmtctgt = Format(tmtc, "####0.00")
Form5.rsectgt = Format(rsc, "####0.00")
Form5.rbctgt = Format(rbc, "####0.00")
Form5.grctgt = Format(grc, "####0.00")
Form5.cictgt = Format(cic, "####0.00")
Form5.toolcostgt = Format(toolcost, "####0.00")
Form5.matlcostgt = Format(matlcost, "####0.00")
Form5.reworktgt = Format(rwc, "####0.00")
Form5.totalcostgt = Format(totalcost, "####0.00")
Form5.unitcostgt = Format(unitcost, "####0.00")
Form5.fcpre = Val(Form3.feedcost)
Form5.stcpre = Val(Form3.stc)
Form5.rtcpre = Val(Form3.rtc)
Form5.tccpre = Val(Form3.tcc)
Form5.lccpre = Val(Form3.lc)
Form5.rbcpre = Val(Form3.rbc)
Form5.grcpre = Val(Form3.grc)
Form5.cicpre = Val(Form3.cic)
Form5.rscpre = Val(Form3.rsc)
Form5.tmtcpre = Val(Form3.tmtc)
Form5.reworkpre = Val(Form3.rwc)
Form5.toolcostpre = Val(Form3.toolcost)
Form5.matlcostpre = Val(Form3.matlcost)
Form5.unitcostpre = Val(Form3.unitcost)
Form5.totalcostpre = Format(Val(Form3.totalcost.Text), "##,##0.00")
Form4.Hide

```

```
Form5.Show  
End Sub
```

APPENDIX F

Program to Control Form 5

```
Private Sub Command1_Click()  
Form4.Show  
Form5.Hide  
End Sub
```

```
Private Sub Command2_Click()  
Form6.Show  
Unload Me  
End Sub
```

APPENDIX G

Program to Control Form 6

```
Private Sub Command1_Click()  
Dim i As Integer  
Dim Xaxis As Object  
Show  
MSChart1.Column = 1  
MSChart1.RowCount = Module1.count      'Number of X Values  
For i = 0 To Module1.count - 1  
    MSChart1.Row = i + 1      'X Coordinate  
    MSChart1.Data = unit(i)  
    MSChart1.RowLabel = i + 1  
    MSChart1.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Iterations"  
    MSChart1.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Unit Cost ($)"  
Next i  
For i = 0 To 10  
    Select Case (i)  
    Case 0  
        List1.AddItem ("Feeding Cost")  
    Case 1  
        List1.AddItem ("Rapid Traverse Cost")  
    Case 2  
        List1.AddItem ("Load/Unload Cost")  
    Case 3  
        List1.AddItem ("Tool Change Cost")  
    Case 4  
        List1.AddItem ("Setup Cost")  
    Case 5  
        List1.AddItem ("Rebrazing Cost")  
    Case 6  
        List1.AddItem ("Resharpening Cost")  
    Case 7  
        List1.AddItem ("Carbide Insert Cost")  
    Case 8  
        List1.AddItem ("Grinding Cost")  
    Case 9  
        List1.AddItem ("Material Cost")  
    Case 10  
        List1.AddItem ("Rework Cost")  
    End Select  
Next i  
End Sub
```

```

Private Sub Command2_Click()
num = 0
Form7.MSFlexGrid1.Col = 0 ' Setting the column number = 0
'=====Naming the Rows in the
Grid=====
Form7.MSFlexGrid1.Row = 1
Form7.MSFlexGrid1.CellWidth = 10
Form7.MSFlexGrid1.AllowUserResizing = flexResizeColumns
Form7.MSFlexGrid1.Text = "Cutting Speed"
Form7.MSFlexGrid1.Row = 2
Form7.MSFlexGrid1.Text = "Feed"
Form7.MSFlexGrid1.Row = 3
Form7.MSFlexGrid1.Text = "Depth of Cut"
Form7.MSFlexGrid1.Row = 4
Form7.MSFlexGrid1.Text = "Tool Life"
Form7.MSFlexGrid1.Row = 5
Form7.MSFlexGrid1.Text = "Machine Hour Rate"
Form7.MSFlexGrid1.Row = 6
Form7.MSFlexGrid1.Text = "Number of Passes"
Form7.MSFlexGrid1.Row = 7
Form7.MSFlexGrid1.Text = "Rapid Traverse Rate"
Form7.MSFlexGrid1.Row = 8
Form7.MSFlexGrid1.Text = "Setup Time"
Form7.MSFlexGrid1.Row = 9
Form7.MSFlexGrid1.Text = "Tool Change Time"
Form7.MSFlexGrid1.Row = 10
Form7.MSFlexGrid1.Text = "Load/Unload Time"
Form7.MSFlexGrid1.Row = 11
Form7.MSFlexGrid1.Text = "Rebrazing Time"
Form7.MSFlexGrid1.Row = 12
Form7.MSFlexGrid1.Text = "Resharpening Time"
Form7.MSFlexGrid1.Row = 13
Form7.MSFlexGrid1.Text = "Unit Cost"
Form7.MSFlexGrid1.Row = 14
Form7.MSFlexGrid1.Text = "Feeding Cost"
Form7.MSFlexGrid1.Row = 15
Form7.MSFlexGrid1.Text = "Setup Cost"
Form7.MSFlexGrid1.Row = 16
Form7.MSFlexGrid1.Text = "Rapid Traverse Cost"
Form7.MSFlexGrid1.Row = 17
Form7.MSFlexGrid1.Text = "Resharpening Cost"
Form7.MSFlexGrid1.Row = 18
Form7.MSFlexGrid1.Text = "Rebrazing Cost"
Form7.MSFlexGrid1.Row = 19
Form7.MSFlexGrid1.Text = "Carbide Insert Cost"
Form7.MSFlexGrid1.Row = 20

```

```

Form7.MSFlexGrid1.Text = "Grinding Cost"
Form7.MSFlexGrid1.Row = 21
Form7.MSFlexGrid1.Text = "Load/Unload Cost"
Form7.MSFlexGrid1.Row = 22
Form7.MSFlexGrid1.Text = "Tool Change Cost"
Form7.MSFlexGrid1.Row = 23
Form7.MSFlexGrid1.Text = "Rework Cost"
Form7.MSFlexGrid1.Row = 24
Form7.MSFlexGrid1.Text = "Tool Type"
Form7.MSFlexGrid1.Row = 0
For i = 1 To Module1.count
    Form7.MSFlexGrid1.Col = i
    Form7.MSFlexGrid1.Text = "Iter" & i
Next i
For j = 1 To Module1.count
    Form7.MSFlexGrid1.Col = j
    For i = 1 To 24
        'k = i + 1
        Form7.MSFlexGrid1.Row = i
        Select Case (i)
            Case 1
                Form7.MSFlexGrid1.Text = speed(num)
            Case 2
                Form7.MSFlexGrid1.Text = feed(num)
            Case 3
                Form7.MSFlexGrid1.Text = depth(num + 1)
            Case 4
                Form7.MSFlexGrid1.Text = life(num + 1)
            Case 5
                Form7.MSFlexGrid1.Text = mc_hr_rate(num + 1)
            Case 6
                Form7.MSFlexGrid1.Text = passes(num + 1)
            Case 7
                Form7.MSFlexGrid1.Text = rapidrate(num)
            Case 8
                Form7.MSFlexGrid1.Text = setuptime(num + 1)
            Case 9
                Form7.MSFlexGrid1.Text = toolchangetime(num + 1)
            Case 10
                Form7.MSFlexGrid1.Text = loadunloadtime(num)
            Case 11
                Form7.MSFlexGrid1.Text = rebtime(num)
            Case 12
                Form7.MSFlexGrid1.Text = restime(num + 1)
            Case 13
                Form7.MSFlexGrid1.Text = unit(num)
        End Select
    Next i
Next j

```



```

Case 14
    Form7.MSFlexGrid1.Text = feedingcost(num)
Case 15
    Form7.MSFlexGrid1.Text = setupcost(num)
Case 16
    Form7.MSFlexGrid1.Text = rapidcost(num)
Case 17
    Form7.MSFlexGrid1.Text = rescost(num)
Case 18
    Form7.MSFlexGrid1.Text = rebcost(num)
Case 19
    Form7.MSFlexGrid1.Text = carbidecost(num)
Case 20
    Form7.MSFlexGrid1.Text = grindcost(num)
Case 21
    Form7.MSFlexGrid1.Text = loadcost(num)
Case 22
    Form7.MSFlexGrid1.Text = toolchcost(num)
Case 23
    Form7.MSFlexGrid1.Text = rew(num)
Case 24
    Form7.MSFlexGrid1.Text = tool_type(num + 1)
End Select
Next i
num = num + 1
Next j
Unload Me
Form7.Show
End Sub

Private Sub Command3_Click()
Dim flag As Integer
flag = 0
If List1.Selected(0) = True Or List1.Selected(1) = True _
Or List1.Selected(2) = True Or List1.Selected(3) = True Or List1.Selected(4) = True _
Or List1.Selected(5) = True Or List1.Selected(6) = True Or List1.Selected(7) = True _
Or List1.Selected(8) = True Or List1.Selected(9) = True Or List1.Selected(10) = True
Then
flag = 1
Else
    MsgBox " Please select the Cost Component and the Parameter"
    Exit Sub
End If
MSChart2.Column = 1
MSChart2.RowCount = Module1.count
Select Case (List1.ListIndex)

```

	FEED	COST
Case 0		
Select Case (List2.ListIndex)		
Case 0		
For i = 0 To Module1.count - 1		
MSChart2.Row = i + 1 'X Coordinate		
MSChart2.Data = feedingcost(i)		
MSChart2.RowLabel = feed(i)		
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "feed (inches/rev)"		
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "feeding Cost (\$)"		
Next i		
Case 1		
For i = 0 To Module1.count - 1		
MSChart2.Row = i + 1 'X Coordinate		
MSChart2.Data = feedingcost(i)		
MSChart2.RowLabel = speed(i)		
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "speed (SFPM)"		
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "feeding Cost (\$)"		
Next i		
Case 2		
For i = 0 To Module1.count - 1		
MSChart2.Row = i + 1 'X Coordinate		
MSChart2.Data = feedingcost(i)		
MSChart2.RowLabel = depth(i + 1)		
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "depth of cut (inches)"		
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "feeding Cost (\$)"		
Next i		
Case 3		
For i = 0 To Module1.count - 1		
MSChart2.Row = i + 1 'X Coordinate		
MSChart2.Data = feedingcost(i)		
MSChart2.RowLabel = passes(i + 1)		
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Number of Passes"		
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "feeding Cost (\$)"		
Next i		
Case 4		
For i = 0 To Module1.count - 1		
MSChart2.Row = i + 1 'X Coordinate		
MSChart2.Data = feedingcost(i)		
MSChart2.RowLabel = mc_hr_rate(i)		
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Machine Hour Rate (\$/hr)"		
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "feeding Cost (\$)"		
Next i		
End Select		

```

===== RAPID TRAVERSE COST
=====
Case 1
  Select Case (List2.ListIndex)
Case 0
  For i = 0 To Module1.count - 1
    MSChart2.Row = i + 1 'X Coordinate
    MSChart2.Data = rapidcost(i)
    MSChart2.RowLabel = rapidrate(i)
    MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Rapid Traverse Rate
(inches/min)"
    MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rapid Traverse Cost
($)"
  Next i
Case 1
  For i = 0 To Module1.count - 1
    MSChart2.Row = i + 1 'X Coordinate
    MSChart2.Data = rapidcost(i)
    MSChart2.RowLabel = mc_hr_rate(i)
    MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Machine Hour Rate
($/hr)"
    MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rapid Traverse Cost
($)"
  Next i
Case 2
  For i = 0 To Module1.count - 1
    MSChart2.Row = i + 1 'X Coordinate
    MSChart2.Data = rapidcost(i)
    MSChart2.RowLabel = passes(i + 1)
    MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Number of Passes"
    MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rapid Traverse Cost
($)"
  Next i
End Select
===== LOAD UNLOAD COST
=====
Case 2
  Select Case (List2.ListIndex)
Case 0
  For i = 0 To Module1.count - 1
    MSChart2.Row = i + 1 'X Coordinate
    MSChart2.Data = loadcost(i)
    MSChart2.RowLabel = loadunloadtime(i)
    MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Loading/Unloading
Time (min)"

```

```

        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Loading/Unloading
Cost ($)"
    Next i
    Case 1
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = loadcost(i)
        MSChart2.RowLabel = mc_hr_rate(i)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Machine Hour Rate
($/hr)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Loading/Unloading
Cost ($)"
    Next i
    End Select
'=====
'                                TOOL                CHANGE                COST
'=====
    Case 3
    Select Case (List2.ListIndex)
    Case 0
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = toolchcost(i)
        MSChart2.RowLabel = toolchangetime(i)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Tool Change time
(min)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Tool Change Cost
($)"
    Next i
    Case 1
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = toolchcost(i)
        MSChart2.RowLabel = feed(i)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "feed (inches/rev)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Tool Change Cost ($)"
    Next i
    Case 2
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = toolchcost(i)
        MSChart2.RowLabel = speed(i)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "speed (SFPM)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Tool Change Cost ($)"
    Next i
    Case 3
    For i = 0 To Module1.count - 1

```

```

        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = toolchcost(i)
        MSChart2.RowLabel = life(i + 1)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Tool Life (min)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Tool Change Cost ($)"
    Next i
Case 4
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = toolchcost(i)
        MSChart2.RowLabel = mc_hr_rate(i)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Machine Hour Rate
($/hr)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Tool Change Cost
($)"
    Next i
End Select
'=====                SETUP                COST
=====

Case 4
    Select Case (List2.ListIndex)
    Case 0
        For i = 0 To Module1.count - 1
            MSChart2.Row = i + 1 'X Coordinate
            MSChart2.Data = setupcost(i)
            MSChart2.RowLabel = setuptime(i)
            MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Setup Time (min)"
            MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Setup Cost ($)"
        Next i
    Case 1
        For i = 0 To Module1.count - 1
            MSChart2.Row = i + 1 'X Coordinate
            MSChart2.Data = setupcost(i)
            MSChart2.RowLabel = mc_hr_rate(i)
            MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Machine Hour Rate
($/hr)"
            MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Setup Cost v"
        Next i
    End Select
'=====                REBRAZING                COST
=====

Case 5
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = rebcost(i)
        MSChart2.RowLabel = rebtime(i)

```

```

MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Rebrazing Time
(min)"
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rebrazing Cost ($)"
Next i
'===== RESHARPENING COST
=====
Case 6
Select Case (List2.ListIndex)
Case 0
For i = 0 To Module1.count - 1
MSChart2.Row = i + 1 'X Coordinate
MSChart2.Data = rescost(i)
MSChart2.RowLabel = restime(i + 1)
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Resharpening Time
(min)"
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Resharpening Cost
($)"
Next i
Case 1
For i = 0 To Module1.count - 1
MSChart2.Row = i + 1 'X Coordinate
MSChart2.Data = rescost(i)
MSChart2.RowLabel = feed(i)
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "feed (inches/rev)"
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Resharpening Cost
($)"
Next i
Case 2
For i = 0 To Module1.count - 1
MSChart2.Row = i + 1 'X Coordinate
MSChart2.Data = rescost(i)
MSChart2.RowLabel = speed(i)
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "speed (SFPM)"
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Resharpening Cost
($)"
Next i
Case 3
For i = 0 To Module1.count - 1
MSChart2.Row = i + 1 'X Coordinate
MSChart2.Data = rescost(i)
MSChart2.RowLabel = life(i + 1)
MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Tool Life (min)"
MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Resharpening Cost
($)"
Next i
End Select

```

'=====	CARBIDE	INSERT	COST
--------	---------	--------	------

Case 7

Select Case (List2.ListIndex)

Case 0

For i = 0 To Module1.count - 1

MSChart2.Row = i + 1 'X Coordinate

MSChart2.Data = carbidecost(i)

MSChart2.RowLabel = feedtime(i)

MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Feeding Time (min)"

MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Carbide Insert Cost

(\$)"

Next i

Case 1

For i = 0 To Module1.count - 1

MSChart2.Row = i + 1 'X Coordinate

MSChart2.Data = carbidecost(i)

MSChart2.RowLabel = life(i + 1)

MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Tool Life (min)"

MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Carbide Insert Cost

(\$)"

Next i

End Select

'=====	GRINDING	COST
--------	----------	------

Case 8

Select Case (List2.ListIndex)

Case 0

For i = 0 To Module1.count - 1

MSChart2.Row = i + 1 'X Coordinate

MSChart2.Data = grindcost(i)

MSChart2.RowLabel = feed(i)

MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "feed (inches/rev)"

MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Grinding Cost (\$)"

Next i

Case 1

For i = 0 To Module1.count - 1

MSChart2.Row = i + 1 'X Coordinate

MSChart2.Data = grindcost(i)

MSChart2.RowLabel = speed(i)

MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "speed (SFPM)"

MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Grinding Cost (\$)"

Next i

Case 2

```

    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = grindcost(i)
        MSChart2.RowLabel = life(i + 1)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Tool Life (min)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Grinding Cost ($)"
    Next i
End Select
'=====
=====
Case 9
    For i = 0 To Module1.count - 1
        MSChart2.Row = i + 1 'X Coordinate
        MSChart2.Data = materialcost(i)
        MSChart2.RowLabel = matprice(i + 1)
        MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Material Price ($/tonne)"
        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Material Cost ($)"
    Next i

'=====
=====
Case 10
    Select Case (List2.ListIndex)
        Case 0
            For i = 0 To Module1.count - 1
                MSChart2.Row = i + 1 'X Coordinate
                MSChart2.Data = rew(i)
                MSChart2.RowLabel = rewper(i)
                MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Percentage Rework"
                MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rework Cost ($)"
            Next i
        Case 1
            For i = 0 To Module1.count - 1
                MSChart2.Row = i + 1 'X Coordinate
                MSChart2.Data = rew(i)
                MSChart2.RowLabel = rewrate(i)
                MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Rework Rate"
                MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rework Cost ($)"
            Next i
        Case 2
            For i = 0 To Module1.count - 1
                MSChart2.Row = i + 1 'X Coordinate
                MSChart2.Data = rew(i)
                MSChart2.RowLabel = rewquant(i)
                MSChart2.Plot.Axis(VtChAxisIdX, 1).AxisTitle.Text = "Rework Quantity"
            Next i
    End Select

```



```

        MSChart2.Plot.Axis(VtChAxisIdY, 1).AxisTitle.Text = "Rework Cost ($)"
    Next i
End Select

'=====
=====

End Select
'End If
End Sub

Private Sub Command4_Click()
Form5.Show
Form6.Hide
End Sub

Private Sub List1_MouseUp(Button As Integer, Shift As Integer, X As Single, Y As
Single)
For i = 0 To List1.ListIndex
    Select Case (i)
    Case 0
        List2.Clear
        List2.AddItem ("Feed Per Rev")
        List2.AddItem ("Cutting Speed")
        List2.AddItem ("Depth of Cut")
        List2.AddItem ("No of Passes")
        List2.AddItem ("Machine Hour Rate")
    Case 1
        List2.Clear
        List2.AddItem ("Rapid Traverse Rate")
        List2.AddItem ("Machine Hour Rate")
        List2.AddItem ("No of Passes")
        List2.AddItem ("Tool Approach")
        List2.AddItem ("Tool Overtravel")
    Case 2
        List2.Clear
        List2.AddItem ("Load/Unload Time")
        List2.AddItem ("Machine Hour Rate")
    Case 3
        List2.Clear
        List2.AddItem ("Tool Change Time")
        List2.AddItem ("Feed Per Rev")
        List2.AddItem ("Cutting Speed")
        List2.AddItem ("Tool Life")
        List2.AddItem ("Machine Hour Rate")
    Case 4
        List2.Clear

```

```

        List2.AddItem ("Setup Time")
        List2.AddItem ("Machine Hour Rate")
    Case 5
        List2.Clear
        List2.AddItem ("Rebrazing Time")
        List2.AddItem ("Brazing Labor Rate")
        List2.AddItem ("Rebrazing Frequency")
    Case 6
        List2.Clear
        List2.AddItem ("Resharpening Time")
        List2.AddItem ("Feed Per Rev")
        List2.AddItem ("Cutting Speed")
        List2.AddItem ("Tool Life")
        List2.AddItem ("Grinding Labor Rate")
    Case 7
        List2.Clear
        List2.AddItem ("Feeding Time")
        List2.AddItem ("Tool Life")
    Case 8
        List2.Clear
        List2.AddItem ("Feed Per Rev")
        List2.AddItem ("Cutting Speed")
        List2.AddItem ("Tool Life")
    Case 9
        List2.Clear
        List2.AddItem ("Material Price")

    Case 10
        List2.Clear
        List2.AddItem ("Percentage Rework")
        List2.AddItem ("Rework Rate")
        List2.AddItem ("Rework Quantity")
    End Select
Next i
End Sub

```

APPENDIX I

Program to Control Form 7

```
Private Sub Command1_Click()  
Unload Me  
End  
End Sub
```

```
Private Sub Command2_Click()  
Form7.Hide  
Form6.Show  
End Sub
```

APPENDIX H

Module containing Subprograms

Public ID As Single, L As Single, Dfin As Single, targetcost As Single
Public den As Single, matl_price As Single, fr As Single, v As Single
Public d As Single, r As Single, tl As Single, M As Single, t0 As Single
Public tc As Single, a As Single, e As Single, rejectionrate As Single, per_rework As Single
Public G As Single, p As Single, Cw As Single, Cost As Single, tb As Single, reworkrate As Single
Public ts As Single, m1 As Single, n As Single, C As Single, Lrb As Single
Public k2 As Integer, k3 As Integer, ub As Integer, Nl As Integer, count As Integer
Public T As Single, Ft As Single, Fc As Single, time_tool_fails As Single
Public X1 As Double, X2 As Double, X3 As Double, X4 As Double, X5 As Double, X6 As Double
Public X10 As Double, X11 As Double, X12 As Double, X13 As Double
Public Arr1(11) As Single, Arr2(11) As String, typenew As String
Public m2 As Single, n2 As Single, p2 As Single, C2 As Single, Cost As Single
Public dnew As Single, unitcost As Single, frnew As Single, vnew As Single, Mnew As Single
Public D1 As Single, D2 As Single, D3 As Single, D4 As Single, m1new As Single
Public feedcost As Single, rtc As Single, stc As Single, lcc As Single, tcc As Single
Public tmtc As Single, rbc As Single, grc As Single, rsc As Single, cic As Single
Public totalcost As Single, matlcost As Single, toolcost As Single
Public tooltype1 As String, tooltype2 As String, mcexplore As String
Public SF As Double, HP As Double, life(20) As Double, rwc As Double
Public unit(20) As Double, depth(20) As Double, speed(20) As Double, feed(20) As Double
Public feedingcost(20) As Double, passes(20) As Integer, rapidcost(20) As Double
Public rescost(20) As Double, rebcost(20) As Double, carbidecost(20) As Double
Public grindcost(20) As Double, loadcost(20) As Double, toolchcost(20) As Double
Public setupcost(20) As Double, rapidrate(20) As Double, setuptime(20) As Double
Public toolchangetime(20) As Double, reptime(20) As Double, restime(20) As Double
Public loadunloadtime(20) As Double, rew(20) As Double, mc_hr_rate(20) As Double
Public matl_cond As String, matl_hard As String, var As Integer, tool_type(40) As String
Public brazingrate(20) As Single, grindingrate(20) As Single, feedtime(20) As Single
Public matprice(20) As Single, rewquant(20) As Single, rewper(20) As Single
Public rewrate(20) As Single, materialcost(20) As Double

Public Sub feeding(dnew, rejectionrate, Mnew, vnew, frnew)
Dim Dmax(12) As Double
Dim Dmin(12) As Double
Dim Dav(12) As Double

```

Dim feed_time(12) As Double
Dim feed_cost(12) As Double
Dim i As Integer, n As Integer
Static i1
n = No_passes(dnew)
ubs = Round(NI / (1 - rejectionrate)) + 1
Fc = 0
Ft = 0
For i = 1 To n
    If (i = 1) Then
        Dmax(i) = ID
        Dmin(i) = Dmax(i) - (dnew * 2)
        Dav(i) = (Dmax(i) + Dmin(i)) / 2
    Else
        Dmax(i) = Dmin(i - 1)
        Dmin(i) = Dmax(i) - (dnew * 2)
        If (Dmin(i) < Dfin) Then
            Dmin(i) = Dfin
        End If
        Dav(i) = (Dmax(i) + Dmin(i)) / 2
    End If
    feed_time(i) = (Dav(i) * L) / (3.82 * frnew * vnew)
    feed_cost(i) = (Mnew / 60) * (Dav(i) * L) / (3.82 * frnew * vnew)
Next
For i = 1 To n
    Ft = Ft + feed_time(i)
    Fc = Fc + feed_cost(i)
Next
depth(i1) = dnew
depth(i1) = Round(depth(i1), 2)
passes(i1) = n
mc_hr_rate(i1) = Mnew
feedtime(i1) = Ft
i1 = i1 + 1
End Sub
Public Function setup(t0new, Mnew)
Static i2
setup = (t0new / NI) * Mnew / 60
setuptime(i2) = t0new
i2 = i2 + 1
End Function
Public Function No_passes(dnew) As Integer
Dim max_matl As Single
max_matl = (ID - Dfin) / 2
If ((max_matl * 100) Mod (dnew * 100) > 0 And (max_matl * 100) Mod (dnew * 100)
<= 50) Then

```

```

No_passes = Round(max_matl / dnew) + 1
Else
No_passes = Round(max_matl / dnew)
End If
End Function
Public Function Tool_change(frnew, vnew, T, tcnew, Mnew)
Static i3
Tool_change = (ID * L * tcnew * Mnew) / (3.82 * vnew * frnew * T * 60)
toolchangetime(i3) = tcnew
i3 = i3 + 1
End Function
Public Function Rebrazing(Lrbnew, tbnew, k2new, typenew)
Static i4
If (typenew <> "carbide tip") Then
    Rebrazing = 0
Else
    Rebrazing = (Lrbnew * tbnew) / (k2new * 60)
End If
reptime(i4) = tbnew
i4 = i4 + 1
End Function

Public Function Resharpening(frnew, vnew, T, Gnew, tsnew, k2new, typenew)
Static i5
time_tool_fails = (ID * L) / (3.82 * frnew * vnew * T)
If (typenew = "carbide insert") Then
    Resharpening = 0
Else
    Resharpening = time_tool_fails * Gnew * tsnew / 60
End If
restime(i5) = tsnew
i5 = i5 + 1
End Function

Public Function Carbide(Ccnew, Ft, T, typenew)
Static i6
If (typenew <> "carbide insert") Then
    Carbide = 0
Else
    Carbide = (Ccnew / T) * Ft
End If
carbidecost(i6) = Carbide
i6 = i6 + 1
End Function

Public Function Grinding(frnew, vnew, T, Cw, typenew)

```

```

'Static i6
If (typenew = "carbide insert") Then
    Grinding = 0
Else
    Grinding = time_tool_fails * Cw
End If
'grindcost(i6) = Grinding
'i6 = i6 + 1
End Function

```

```

Public Function Material(matl_price, den)
Static i7
Dim vol As Single, wt As Single
vol = (3.14 * (ID / 2) ^ 2) * L * 16.38706
wt = vol * den * 0.000001
Material = wt * matl_price
matprice(i7) = matl_price
'materialcost(i7) = Material
matprice(i7) = Round(matprice(i7), 2)
'materialcost(i7) = Round(Material(i7), 2)
i7 = i7 + 1
End Function

```

```

Public Function Toollife(vnew, frnew, dnew, m1new, nnew, pnew, Cnew, typenew,
k3new)
Static i11
If (typenew <> "carbide insert") Then
    Toollife = (Cnew / ((frnew ^ m1new) * (dnew ^ pnew) * vnew)) ^ (1 / nnew)
Else
    Toollife = ((Cnew / ((frnew ^ m1new) * (dnew ^ pnew) * vnew)) ^ (1 / nnew)) * k3new
End If
life(i11) = Toollife
tool_type(i11) = typenew
life(i11) = Round(life(i11), 2)
i11 = i11 + 1
End Function

```

```

Public Sub optimum(X7, X8, X9, C2, Costnew, dnew, Mnew)
Static i8
X1 = Val(Form1.btext.Text)
X2 = Val(Form1.ctext.Text)
X3 = Val(Form1.etxt.Text)
X4 = Val(Form1.gtext.Text)
X5 = Val(Form1.htext.Text)

```

```

X6 = Val(Form1.itext.Text)
X10 = Val(Form1.Cstext.Text)
X11 = Val(Form1.Cmtext.Text)
D3 = 0
D4 = (1 - X7) / (X5 - X4 * X7)
D2 = (X8 * (X5 - X4)) / (X5 - X4 * X7)
D1 = 1 - D2
Csdash = X10 * (dnew ^ X6) / Form1.SFmaxtext.Text
Cmdash = X11 * (dnew ^ X3) / Form1.HPmaxtext.Text
C1dash = (3.14 * ID * L * Mnew) / (12 * 60)
X12 = (C1dash * (dnew ^ (X9 / X8))) / (C2 ^ (1 / X8))
X13 = ((Mnew * tc / 60) + Costnew) * 60 / Mnew
C2dash = X12 * X13
If (D2 >= 0 And D2 <= 1 And D4 >= 0) Then
    Dual_D2 = D2
Else
    Dual_D2 = "Not feasible"
End If
If (D2 >= 0 And D2 <= 1 And D4 >= 0) Then
    Dual_D4 = D4
Else
    Dual_D4 = "Not feasible"
End If
frnew = (Csdash ^ (1 / (X7 * X4 - X5))) * (C1dash * (1 - D1) / (C2dash * D1)) ^ (X8 *
X4 / (X7 * X4 - X5))
vnew = 1 / (Csdash * (frnew ^ X5)) ^ (1 / X4)
If (Dual_D2 = "Not feasible" Or Dual_D4 = "Not feasible") Then
    z1 = "not feasible" ' case 1
Else
    z1 = "ok"
End If
If z1 = "not feasible" Then
    D4 = 0
    D3 = X1 / X9
    If (D2 >= 0 And D2 <= 1 And D3 >= 0) Then
        Dual_D2 = "ok"
    Else
        Dual_D2 = " not feasible"
    End If
    If (D2 >= 0 And D2 <= 1 And D3 >= 0) Then
        Dual_D4 = "ok"
    Else
        Dual_D4 = " not feasible"
    End If
    If (Dual_D2 = "not feasible" Or Dual_D4 = " not feasible") Then
        z2 = "not feasible" ' case 2

```



```

Else
    z2 = "ok"
End If
End If
If (z1 = "not feasible" And z2 = "not feasible") Then
vnew = Exp((X5 * Log(Cmdash) - X2 * Log(Csdash)) / (X4 * X2 - X1 * X5))
frnew = Exp((X1 * Log(Csdash) - X4 * Log(Cmdash)) / (X4 * X2 - X1 * X5))
End If
speed(i8) = vnew
speed(i8) = Round(speed(i8), 2)
feed(i8) = frnew
feed(i8) = Round(feed(i8), 4)
i8 = i8 + 1
End Sub
Public Function reworkcost()
Static i10
no_parts_reworked = (ubs - Nl) * (per_rework / 100)
reworkcost = (no_parts_reworked * reworkrate) / ubs
'rew(i10) = reworkcost
rewrate(i10) = reworkrate
rewquant(i10) = no_parts_reworked
rewper(i10) = per_rework
'rew(i10) = Round(rew(i10), 2)
rewrate(i10) = Round(rewrate(i10), 2)
rewquant(i10) = Round(rewquant(i10), 2)
rewper(i10) = Round(rewper(i10), 2)
i10 = i10 + 1
End Function
Public Sub sort()
Dim Per(5) As Single
Dim i As Integer, j As Integer
Dim tempA As Single, tempB As String
Arr1(0) = feedcost
Arr1(1) = rtc
Arr1(2) = stc
Arr1(3) = tcc
Arr1(4) = lcc
Arr1(5) = rbc
Arr1(6) = rsc
Arr1(7) = cic
Arr1(8) = grc
Arr1(9) = matlcost
Arr1(10) = rwc
Arr2(0) = "Feeding Cost"
Arr2(1) = "Rapid Traverse Cost"
Arr2(2) = "Setup Cost"

```

```

Arr2(3) = "Tool Changing Cost"
Arr2(4) = "Loading and Unloading Cost"
Arr2(5) = "Rabrazing Cost"
Arr2(6) = "Resharpening Cost"
Arr2(7) = "Carbide Insert Cost"
Arr2(8) = "Grinding Wheel Cost"
Arr2(9) = "Material Cost"
Arr2(10) = "Rework Cost"
For i = 0 To 10
    For j = 1 To 10
        If (Arr1(j) < Arr1(j + 1)) Then
            tempA = Arr1(j)
            Arr1(j) = Arr1(j + 1)
            Arr1(j + 1) = tempA
            tempB = Arr2(j)
            Arr2(j) = Arr2(j + 1)
            Arr2(j + 1) = tempB
        End If
    Next j
Next i
End Sub

Public Sub calculate(dnew, m1new, nnew, pnew, Cnew, Costnew, Mnew, typenew,
Gnew, Cwnew, tsnew, Lrbnew, tbnew, k2new, k3new, rnew, tcnew, tlnew, t0new)
Static i9
Call optimum(m1new, nnew, pnew, Cnew, Costnew, dnew, Mnew)
T = Toollife(vnew, frnew, dnew, m1new, nnew, pnew, Cnew, typenew, k3new)
Call feeding(dnew, rejectionrate, Mnew, vnew, frnew)
feedcost = Fc
rtc = (a + L + e) * No_passes(dnew) * Mnew / (rnew * 60)
stc = setup(t0new, Mnew)
tcc = Tool_change(frnew, vnew, T, tcnew, Mnew)
lcc = tlnew * Mnew / 60
tmte = feedcost + rtc + stc + tcc + lcc
If (typenew = "hss") Then
    rsc = Resharpening(frnew, vnew, T, Gnew, tsnew, k2new, typenew)
    grc = Grinding(frnew, vnew, T, Cwnew, typenew)
    cic = 0
ElseIf (typenew = "carbide tip") Then
    rsc = Resharpening(frnew, vnew, T, Gnew, tsnew, k2new, typenew)
    rbc = Rebrazing(Lrbnew, tbnew, k2new, typenew)
    grc = Grinding(frnew, vnew, T, Cwnew, typenew)
    cic = 0
Else
    rsc = 0
    grc = 0
    rbc = 0

```

```

    cic = Carbide(Costnew, Ft, T, typenew)
End If
'tmtc = feedcost + rtc + stc + tcc + lcc
toolcost = rbc + rsc + cic + grc
matlcost = Material(matl_price, den)
rwc = reworkcost()
totalcost = ubs * (tmtc + toolcost + matlcost + rwc)
unitcost = totalcost / NI
unit(i9) = unitcost
feedingcost(i9) = feedcost
rapidcost(i9) = rtc
setupcost(i9) = stc
toolchcost(i9) = tcc
loadcost(i9) = lcc
rescost(i9) = rsc
rebcost(i9) = rbc
grindcost(i9) = grc
carbidecost(i9) = cic
materialcost(i9) = matlcost
rew(i9) = rwc
rapidrate(i9) = rnew
loadunloadtime(i9) = tlnew
loadunloadtime(i9) = Round(loadunloadtime(i9), 2)
unit(i9) = Round(unit(i9), 2)
feedingcost(i9) = Round(feedingcost(i9), 2)
rapidcost(i9) = Round(rapidcost(i9), 2)
setupcost(i9) = Round(setupcost(i9), 2)
toolchcost(i9) = Round(toolchcost(i9), 2)
loadcost(i9) = Round(loadcost(i9), 2)
rescost(i9) = Round(rescost(i9), 2)
rebcost(i9) = Round(rebcost(i9), 2)
grindcost(i9) = Round(grindcost(i9), 2)
carbidecost(i9) = Round(carbidecost(i9), 2)
materialcost(i9) = Round(materialcost(i9), 2)
rew(i9) = Round(rew(i9), 2)
feedtime(i9) = Round(feedtime(i9), 2)
i9 = i9 + 1
count = i9
End Sub

```