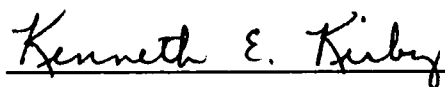


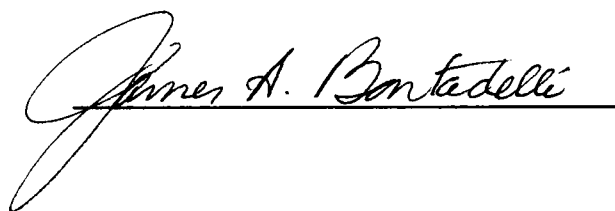
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TRIAD PERFORMANCE ANALYSIS

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

Christopher Lewis Whaley

December, 1994

Dedication

This thesis is dedicated to the One who
makes all things possible, God.

Without Him, there can be no life
or reason to live.

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Abstract

Businesses have begun to see the need to provide cost efficient, high quality products with an emphasis on reducing the time it takes to deliver these goods. To accomplish these goals, superior management decisions must be based upon information from multiple dimensions. Currently, the impact that a decision in the product or process development procedure has is not fully considered in cost, quality, and time, yet managers must be able to account for the results in these three domains. Unfortunately, there has been a deficiency in the use of multiple dimensions in the decision making process due to the lack of practice in this area.

Triad Performance Analysis is developed to meet this need. This activity-based methodology provides a complete breakdown of a design process. A superior process, containing only value added activities, is outlined that serves as a benchmark to improve the current process with in terms of cost, quality, and time. Using activity-based costing, quality measurements, and time studies, values for the cost, quality level, and time required for an activity can be tracked for the actual process and the superior process. Comparisons can be made, which leads to better focus for improvement programs so that the process can be modified to better mirror the superior process. These analyses lead to quantitative performance indicators that can be used to make decisions and then monitor the results.

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Chapter 1

Introduction

In order for managers to make timely and accurate decisions in today's rapidly changing business environment, it is imperative that they have access to information to determine the strategic profitability of a product. The availability of this information, complicated by advances in manufacturing processes and customer demands, has been found lacking when conventional systems are used to evaluate a product's life-cycle. This has lead to the development of activity-based cost accounting, management of quality, and the emergence of time as the new competitive edge in manufacturing. Triad Performance Analysis (TPA) allows a business to see how a product or service delivery process affects cost, quality, and time.

Problem Statement

Many managers have found it difficult to examine the areas of cost, quality, and time simultaneously. The amount of effort required to concentrate on a single element is often sufficient to use all of the resources available for documentation and improvement efforts. Businesses see the use of multiple dimensions as being too complicated for process decisions, so they concentrate on the dimension they see as most valuable to their particular industry. One

example of this is the trucking industry, which once concentrated on the speed of transport as the primary competitive dimension. Now, speed of delivery may be a subordinate factor to package handling in order to provide less damaging services. In addition to this, this industry has seen a decrease in profit margins, making the reduction in costs a necessity to remain competitive and financially viable (interview with Thompson, July 29, 1994).

Thus, there is a need for a methodology that considers all three performance dimensions so that managers examine the basic processes more thoroughly. If only one or two dimensions are examined, change in the other dimension(s) might be undetected and negate the positive influence of a decision. In addition to monitoring the three dimensions, the improvement process itself must strive to improve performance in all the dimensions, and any trade-offs must be explicitly evaluated.

The Changing Environment

As time progresses, the role of the manager and the management techniques used continue to change. In the early 20th century, manufacturing organizations were primarily interested in reducing the cost of producing a product. In response, Taylor, who is referred to as the father of scientific management, developed and used the concept of time and motion studies to develop work standards (Ishikawa, 1985, p. 25). These standards were used to reduce the cost of putting a product together by controlling worker actions.

Once these methods had taken hold in various industries, it was time for a new competitive dimension to come forth. The middle of the century saw the advent of quality and continuous improvement as major factors in production. This interest was furthered by the work of Deming in statistical analysis and his Plan-Do-Check-Act cycle (Imai, 1986, pp. 10-11). These ideas were adopted by world class manufacturing firms and are still focus points for businesses today.

For a while, it seemed that businesses had a good hold on product design and production. However, during the last few decades, there has been an evolution in the way that manufacturing performs it's part of the business function. Concepts like cellular manufacturing and just-in-time production have been implemented as improved operating strategies (Heizer and Render, 1993, p. 557). At the same time, businesses have become much more customer oriented. As a result of these changes, the systems used to monitor and control the costs and quality involved were not modified to properly represent these changes. In addition, the time dimension is being adopted by many companies as part of their competitive strategy. Satisfying the customer does not only apply to quality and cost but also to how quickly a company can react to changes in market demands (Freedman, 1993, p. 70).

Case in Point: Concurrent Engineering

A common technique used current product development efforts is concurrent engineering. A design team manager faced with the decision of whether to implement concurrent engineering or continue using sequential engineering can reach several conclusions depending on which domain is focussed on. Engineering person-hours needed in a project may not be changed by much regardless of which engineering method is used, since the same time must be spent to develop designs regardless of when in the product development cycle they are completed. Thus, the cost of engineering labor may remain approximately the same. However, there would need to be significant capital investments made in order to facilitate the use of concurrent engineering techniques. This would include upgrades for computer systems to allow engineering teams to be networked together, alteration of office layout to co-locate teams, and increased spending for worker education. Thus, by looking at the direct costs alone, a manager may decide to continue the development process as usual.

Considering quality, concurrent engineering methodology would reduce the amount of redesign necessary since engineers would be working together with other disciplines on a proactive basis. For example, manufacturing engineers can point out design features that would be difficult to produce before design engineers have completed designs on them. However, this may result in a lack of creativity on the part of design engineers and could result in a less

desirable product in terms of customer expectations. Looking at quality issues alone, a manager may be undecided on whether to use concurrent engineering or not..

When the time domain is examined, the total engineering hours may not be affected by much, but the total time the project takes will be greatly reduced. This quicker design and development process will allow the company's product to get to the market quicker, thus helping to gain more market share. Based on the time considerations only, a manager would probably want to use concurrent engineering techniques.

Attempts at integrating multiple dimensions in the decision making process often end up with one dimension being concentrated on, with other parameters being devalued. If a manager is being pressured by his director to lower his or her budget, decisions made will concentrate on the cost dimension, even though other information may be considered. Since a large part of the overall information content can be lost by this, decisions are made with partial information. In this case, a manager may not have realized that the increased revenue from being first to market with their new product would more than cover any additional expenses incurred in using concurrent engineering techniques. Thus, the need for a methodology that incorporates cost, quality, and time would be valuable in forcing managers to think in "3-D".

Attempts at integrating the three dimensions entail normalizing values of performance parameters onto a single scale. Information content from each

separate dimension is lost as the performance of each domain is combined into a single value. In order to do this, the normalized values must be weighted, and this introduces an element of favoring one dimension over another.

Objective

A published multidimensional approach to evaluating product delivery system performance from a time, cost and quality perspective was not found in the literature search. By keeping each domain performance parameter separate, instead of combining them into a single value, each dimension can be unweighted thus preventing bias from clouding the information content of the values. Techniques that incorporate multiple dimensions often consider manufacturing processes and not the design decisions that drive the requirements that they must meet. Consequently, the need exists for a tool that can be used to reliably assess the state of product development processes and determine what steps need to be taken to improve their performance.

To meet this goal, it is necessary to combine time based assessment models, superior product and process models, activity-based management, quality measurements, and concurrent engineering techniques to result in an integrated methodology. Customer focus must always be maintained by including customer input when designing the superior process that will be used as a benchmark for the current process. This methodology will allow companies to systematically assess and enhance their product delivery system.

Summary of Paper

A roadmap of the study is now described. Chapter 2 is a literature review that looks at the three dimensions and examines five current techniques that in some ways meet the needs shown in Chapter 1. However, all of the methods fail to meet the final objective.

Chapter 3 details the conceptual design of TPA. By examining the strengths and deficiencies of the techniques in the literature review, these ideas can be incorporated into a more encompassing strategy for the development of TPA. Each of the primary components are detailed, and their effect on the total methodology is made clear.

Chapter 4 extends the framework from the conceptual design and details the methodology in a ten-step process that is TPA. Chapter 5 presents an example application of TPA, showing how each step is performed using numerical data.

Chapter 6, drawing from the experience of Chapter 5, lists the conclusions and recommendations on TPA. This includes not only the benefits of TPA but also the future improvements that will be made to the TPA methodology. In addition, an outline is given for the use of computer software to automate many of the calculations and summaries necessary in an activity analysis.

Chapter 2

Literature Review

The number of methodologies dealing with activity-based costing, quality improvement programs, and time reduction strategies on an individual basis are now common. Each of these has been developed to deal with the changes taking place in the fields of cost, quality, and time. For the majority of these, each individual dimension is examined separately. However, a few methodologies have been successful in fostering improvement in more than one of the primary dimensions of cost, quality, and time. These comprehensive strategies are examined to insure that TPA includes the best of what is currently available while avoiding any problems that have developed from their use.

Cost

One of the areas in costs that changes have affected the most is the amount of direct-labor hours used in producing a product. While direct-labor once accounted for nearly half the costs of producing an item, this currently accounts for less than a quarter of the total costs of the product (with values of 8 to 12 percent of total cost not uncommon) (Berliner and Brimson, 1988, p. 25). Indirect costs, such as documentation, engineering work, and depreciation

of equipment, have risen to as much as half the total costs (Huthwaite, 1989, p. 44). Traditional cost accounting systems assign costs on unit-based measurements, which is quite accurate with regards to direct-labor and materials' costs. Thus traditional cost accounting systems are adequate in tracking costs when direct costs account for the majority of expenses. However, as indirect costs replace the direct costs as being the most substantial, the accuracy of conventional cost allocation systems begins to degrade. This is primarily due to the fact that indirect costs are not consumed on a per-unit basis like direct-labor, and thus any estimates based on these measurements would be misleading (Cooper and Kaplan, 1991, pp. 267-268). The advent of activity-based cost accounting (ABC) has allowed companies the opportunity to accurately reflect how much they spend for each activity and better track the costs associated with a product development process. Since processes can be broken down into activities that are assigned to different cost drivers, the necessity for unit-based measurements for accuracy is removed..

Quality

Recently quality has been the major competitive dimension, with companies implementing new programs in efforts to improve their quality level as delivered to their customers. The concept of the cost of quality has allowed companies to quantify the costs associated with their quality programs in the areas such as appraisal, prevention, and internal and external failure (Juran,

1974, pp. 5:3-6). While these categories can help in planning and proceeding with quality programs, they often overlook how to improve the quality levels. Other recent advances in the quality area include the concept of customer-defined quality, which holds out the old thought that "the customer is always right." Tools such as quality function deployment help businesses to translate these customer values into manufacturing goals . Despite these trends, there has been a lack in the ability of companies to track quality in the same frame as activity analysis. Many quality parameters are given in terms of final product characteristics, such as number of surface blemishes, but they lack methods to tie these values in with strategic goals of the company (Green, 1993, p. 33). In addition, most companies do not have the ability to see how individual activity quality levels affect the entire process. By identifying quality terms on an activity basis like ABC does with costs, it is easier to see not only where quality problems exist, but how they affect the process as a whole. Each activity can be assigned a quantifiable measure of quality, and these measures can be tracked and compared throughout the entire process.

Time

Only recently have companies come to fully appreciate the value that time can add to a product's profitability. Product life-cycles have been shortened due to rapid changes in technology and consumer desires. Companies must be better able to estimate and understand the components of

the total life-cycle of a product. Since 70 to 90 percent of all costs related to a product are committed during the product design and development stage of the life-cycle, it is imperative that this area be the starting point of any effort to track and control product costs (Huthwaite, 1989, p. 46). This leads to the need to clearly define cost drivers not only in putting the pieces of a product together, but in how the product is designed in the first place. Current trends in concurrent engineering and design for manufacture give a greater impetus to the reduction of life-cycles and the ability of a company to link costs with design decisions early in the product life-cycle (DeGarmo, et al., 1993, p. 33). The ability to incorporate the value of time into a process can help prevent mistakes in decision making caused when managers choose low cost solutions without consideration for the effects of time. Companies that can deliver what the customer wants (with regards to cost and quality) the quickest will be able to realize greater initial market share. It may be better to spend more money to get a product out faster than to choose a less expensive alternative yet slower design process. These decisions must be made in reference to quantifiable parameters and not to subjective reactions.

Process Value Analysis

Process Value Analysis (PVA) is one of the earliest uses of ABC in conjunction with value analysis, in an attempt to combine the domains of cost and quality. The dimension of time was not included as a primary analysis area

in PVA. In spite of this, the method was proclaimed as "the most powerful analysis method financial managers can use to analyze a company's cost structure" (Beischel, 1990, p. 54). PVA begins by preparing a flowchart for each manufacturing process step, which includes the average time the product or part remains at each step. Then each step is examined and classified as either value added (from the customer's point of view) or non-value added. Next, department costs are applied to manufacturing process steps. This is most easily done with ABC, which can be used to assign more accurate cost figures to specific process activities. The result is a description of the manufacturing process in terms of the cost of value and non-value added steps. Managers can then make better informed decisions with regards to manufacturing procedures or product mixes, which will lead to improved performance (Beischel, 1990, p. 57). PVA thus formed the basis of using ABC and activity analysis to lead to improvement of processes. One drawback to PVA is that there is no inherent focus on continuous improvement. While providing information on costs of various activities and whether they are value or non-value added, it does not help in formulating better ways to perform activities. In addition, while a value judgement is made for each step, there is not a specific provision for evaluating at what quality level each value-added step is operating at.

Attribute Based Costing

Recent work by Walker (1993, p. 65) has opened the eyes of many that ABC is useful not only in costing manufacturing processes, but also in the design and development phases of a product's life cycle. Attribute Based Costing or ABCII integrates quality data directly with cost data. Once again, the time domain is not included as a primary area of concern. Product attributes that customers value are analyzed through methods like quality function deployment and conjoint analysis. This data can then be used with ABC data to show how the cost of incorporating or improving a specific attribute could lead to improved customer utility and thus a greater perception of customer value. Designers will have the information they need to develop products with consideration to not only what customers desire, but to what is cost effective to do in order to provide those attributes. This work has shown a link between three major components of a product delivery system: the quality of the product, the cost of the product, and actual design of the product. Unfortunately, ABCII does not account for the time involved in designing a product or how this affects the process as a whole. Although it is possible to develop the "best" widget given enough time, competitors who are able to get their less than perfect widget into the marketplace first will have the benefit of a greater initial market share which will be difficult to regain once lost.

Real-Time Cost Management

Another drawback that PVA and ABCII encounter, as well as many conventional costing methods, is that financial reports may be produced weeks after the events they detail take place. It becomes difficult to track contributing events that may have occurred to affect the cost figures for a certain period. This makes precise action to correct or improve a process difficult at best (Dragoo and Letendre, 1994, p. 11). To combat this time lag between when an activity is performed and when the true cost of the activity is revealed, a method to provide this data without delay was needed. Real-time cost management (RTCM) was developed to provide the costing techniques to yield almost instantaneous information on product costs. Thus, RTCM focusses on the cost and time dimensions, and gives quality cursory treatment. RTCM links real-time process control information with data from business systems such as purchasing and inventory to provide product costs on-line as the product is put together. ABC provides the backbone of the financial information. Just as control charts can be used to monitor how process changes affect quality levels, RTCM allows managers and operators to see how costs fluctuate in a changing manufacturing environment. Cost variances can be observed and their root causes determined so that corrective action can be applied immediately instead of two weeks after the production of the product in question. However, RTCM is more like a monitoring program instead of an improvement program. While it allows users to see the impact of their

decisions, it does not suggest better ways to perform their activities. So, although it is more proactive than PVA, it also has the same weakness in that it does not have intrinsic improvement goals in its methodology.

Workforce Activity-Based Management

Perhaps the most inclusive methodology developed and implemented so far has been Workforce Activity-Based Management (WABM). This technique begins by assigning groups of employees who work together into work teams. Through the use of visual aids like storyboards, the team develops a visual list of all the jobs and activities that they perform. This can be used to help formulate ABC systems to evaluate cost information as well as helping the team to focus on certain activities and measures of performance. Teams must come up with the performance measurements for the cost, time, and quality of their activities and are responsible for monitoring and improving these measurements. For example, the final assembly team for an automobile manufacturer selected the assembly cost per vehicle, the part per million defects in assembly, and the assembly lead time per vehicle as their performance measurements (Turney, 1993, p. 30). Thus, all three dimensions are emphasized, and each person can see how the work they do can impact the overall performance of the entire system. However, WABM does not have an explicit improvement plan, just a focus to meet the goals specified by the work team. Companies must be careful to monitor group activities to insure

that they are compatible with the overall strategic goals of the company. While specific quality goals or cost figures can be set, there is not a focus on strategic planning that ensures the changes will benefit the entire process

Efficient Consumer Response

The grocery industry has recently begun emphasizing a strategy referred to as Efficient Consumer Response (ECR). This strategy can be applied to any industry and embodies the goals of all the methods previously discussed. The most important focus is on providing the customer with better value through better quality, better assortments, and better delivery service with less cost. It relies on accurate and timely information from sources like ABC and inventory systems to support better decision making. ECR seeks to define consistent performance measurements and reward systems that focus on the process as a whole. ECR stresses the maximization of value added steps to make sure "the right product is available at the right time" (Freedman, 1993, p. 70).

Unfortunately, ECR is a strategy only and is not a distinct methodology to reach the goals specified. In essence, the goals expressed in ECR are the same goals that TPA is designed to meet. The primary distinction is that TPA takes steps to accomplish the goals, while ECR merely points them out.

Chapter 3

Conceptual Design

The objective defines the areas that TPA must focus on, so the tools already available for those areas are integrated with TPA. Activity analysis techniques exist so that activities can not only have costs assigned to them but to label them as value or non-value added as well. Quality assessments have evolved to a point where they can be used to determine product quality before the first prototype comes off a production line. Time based management incorporates everything from basic time and motion studies to concurrent engineering techniques used to reduce product development times. The strengths of the techniques examined in Chapter 2 must also be incorporated into the TPA methodology. All three dimensions can be analyzed at the same time to assess the current standing of an organization. That information can be used to develop a plan for improvements by comparing the current process performance with a superior process consisting of only value added activities

Activity Analysis Techniques

Determining accurate cost figures on an activity basis has been one of the most common uses of activity analysis. By breaking a process down into activities, such as "drill a one inch hole in center of plate", the cost of

performing that single activity can be evaluated. A bill of activities can be developed, showing the indirect activities that support a primary activity. For drilling a hole, the indirect activities might include the paper work necessary to order drill bits and the design time used in deciding where to drill the hole. These activity cost figures can be added together to give a total cost for a process without regards as to whether the cost is direct or indirect. In looking at the profitability of a product, a dollar spent on direct costs has the same effect as a dollar spend on indirect costs, even though one may be more difficult to change than the other. More accurate total cost figures can be generated for each process, leading to better decisions with regards to a product's profitability.

While this is an important step in understanding the full cost of a processes, it is not the only use of activity analysis. With the process broken down into activities, a judgement can be made as to whether each activity adds value or not to the to the final product for the customer. The non-value added activities must be identified and then eliminated. This will reduce the cost and time spent in a process while improving the quality level of the process.

Quality Assessment Tools

It is important that concerns about quality issues be addressed from the beginning of a product development process. Quality must be designed into the product, and manufacturing must be able to put together a quality product.

One of the primary tools used to define quality in a product is quality function deployment (QFD). By determining exactly how a customer defines a quality product, the subjective observations of customers can be turned into objective design and manufacturing goals. Through QFD, for example, a car company could learn that the customer values doors that are easy to open. This would result in determining specific values for the force needed to open the door that would be considered easy by the customer. Thus, customer desires can be turned into quantitative goals for design and manufacturing.

Once the quality goals are identified for a product, it is important that these are monitored throughout the process. For the design process, quality can be measured based upon the number of re-designs necessary or on the accuracy of drawings produced. Statistical process control techniques can be used in manufacturing to track the quality levels in each process. These levels can be used to evaluate how well the process is achieving the goals set for the process. Changes in quality levels can be used to determine cause and effect relationships in the process, which can lead to improvement of the process.

Time Based Management

Although performing processes faster has been a goal in many companies, the full effects of time based management have only recently been investigated. Individual activities are studied to reduce the time they require to perform their duties. In addition, processes as a whole have been evaluated to

determine the best progression of individual activities. As a result, many techniques have emerged to reduce not only the time spent on each activity but also to reduce the time spent on the process as a whole.

One of the primary techniques used to reduce the time spent on a single activity is cycle time reduction. By looking at the components of the cycle time for an activity, the slowest part of the activity can be found. For example, a process may have an actual run time of ten minutes but have a set-up time of three hours. The large size of set-up time in relation to the run time makes the cost involved in change-overs prohibitive. By reducing the set-up time, through a method such as single minute exchange of dies, the activity will proceed more quickly and will be more flexible in terms of being able to change to another product without significant time loss. In many cases, simple time and motion studies can lead to significant reductions in time spent on a single task.

One of the most popular methods of reducing total process time is concurrent engineering. By performing several steps in the design process simultaneously, the overall time spent on the process is shortened since steps are occurring nearly simultaneously instead of sequentially. In addition, problems are noted sooner than if a traditional design process had been used, once again reducing the calendar time spent on the process. Even though some steps in the design process must proceed others, such as a piece being drawn before it can be manufactured, the use of rapid prototyping can allow designs to be evaluated before any manufacturing processes are designed.

The use of techniques such as the ones discussed above shows that the old adage "time is money" is more accurate than once thought. By performing a task or process faster than anyone else, a product can reach the market more quickly. The increase in initial market share can have a significant impact on the financial success of a product.

Superior Process Modeling

The goal of any process is for it to perform in the most efficient manner at the desired quality level. This goal can be achieved by what is defined as the superior process. The superior process contains only value added activities at their optimum levels of cost, quality, and time. This is the benchmark that is used to evaluate the performance level of the current process. While Wilson and Kennedy have developed a generic superior process model to serve as a template, each user must develop a custom superior process to fit their particular industry requirements (Stahl and Bounds, 1991, pp. 428-477). The superior process represents the most efficient way the process can proceed by eliminating non-value added activities and optimizing the remaining activities in terms of cost, quality, and time.

The development of the superior process comes from several areas. The basic format comes from the use of concurrent engineering and meeting customer expectations. Early in the process, techniques like QFD are used to assess customer needs in a qualitative manner. Nearly simultaneously, design

and manufacturing engineers begin evaluating the methods and technologies they will use in the final design of their systems. As the product development process advances, the components are rigorously tested to ensure that they meet customer needs in terms of functionality as well as performance. Creative thinking on the part of engineers, marketing personnel, and line workers can lead to the development of new methods of performing activities. Similar processes can be benchmarked to determine not only how others perform a process but how well they do it. The end result is a superior process that represents the best possible way of performing the separate activities to complete the total process.

Three-Dimensional Improvement Program

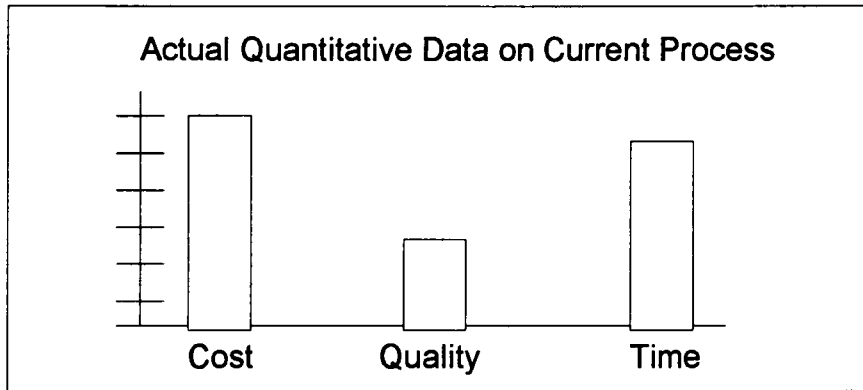
With the tools available in each dimension presented, they must all be combined into a single methodology for ease of use. These will form the basis of TPA. Activity-based analysis is the primary tool used in TPA, and the benefits of PVA and ABCII are integrated here. Each activity performed in a process would be examined in the realms of cost, quality, and time. The level of activities examined will primarily depend on the detail provided by the cost accounting system in use. The cost per activity can be arrived at through activity-based costing. Quality levels can be set through the use of QFD and can then be measured with a performance indicator such as defects per million. The time is measured as the actual time spent on performing the activity.

When completed simultaneously, these studies would constitute the current standing of the processes in the organization. Each domain performance parameter is kept separate, instead of normalizing them into a single value, so that each dimension is not given subjective weighting.

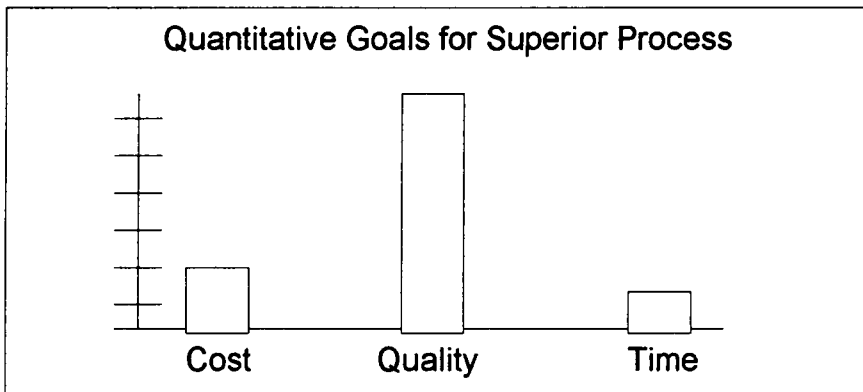
Then, by combinations of benchmarking, developing superior models, and creative thinking, a superior process can be generated. This superior process contains only value added steps being performed in the most efficient manner. It serves as the goal that the entire organization should strive to achieve (see Figure 1). The gaps between the existing process and the superior model will identify the areas that need to be improved the most. As done in WABM, this information can be used to provide guidance as to how this desired outcome can be attained. The goal is to reduce the gaps between the existing and the superior processes in all three dimensions simultaneously. The need and benefit of gaining competitive advantage in only two dimensions is expressed by Senge (1990, p.65):

For years . . . American manufacturers thought they had to choose between low cost and high quality. 'Higher quality products cost more to manufacture,' they thought. 'They take longer to assemble, require more expensive materials and components, and entail more extensive quality controls.' What they didn't consider was all the ways the increasing quality and lowering costs could go hand in hand, over time. What they didn't consider was how basic improvements in work processes could eliminate costs, increase customer loyalty, and reduce advertising and sales promotion costs. They didn't realize that they could have both goals, if they were willing to wait for one while they focused on the other.

Evaluate Current Process



Develop Superior Process to Use as a Benchmark



Improve Process to Strive for Superior Process

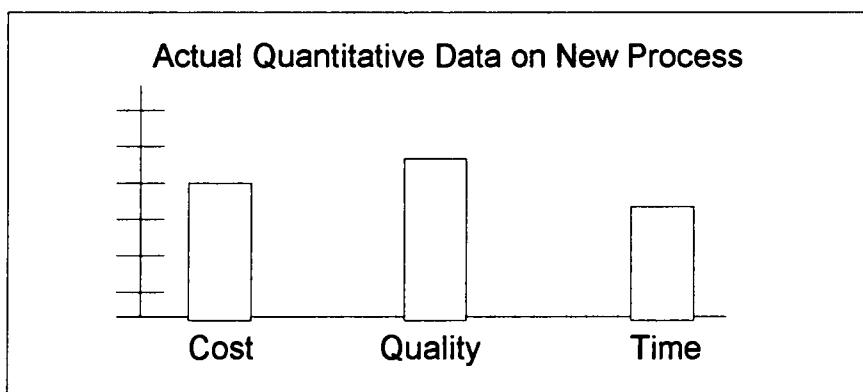


Figure 1: Conceptual Design of TPA

When time is included in the Senge's analysis, an even greater benefit can be seen in reducing costs, improving quality, and being able to do so in less time than is currently required.

By using the techniques from each dimension in a single unified methodology, the benefits of all three can be realized simultaneously. Each dimension is treated equally in the analysis, without one taking precedence over another. This prevents decision makers from forming a prejudice against one dimension over another. For example, reducing costs does not always mean that lower quality levels will result. By not weighting the three dimensions' values and normalizing them onto a single scale, the information is kept as unbiased as possible. Any trade-offs that must be made between the three dimensions can now be made with the help of quantitative information that comes from the analysis process.

Chapter 4

Methodology

Triad Performance Analysis can be summarized in a ten step methodology (see Figure 2). This methodology incorporates the elements of the conceptual design while reflecting the research established by previous methods (see Figure 3). Certain steps of this analysis, adhering to the principles that TPA is based upon, can be performed concurrently with other steps. For example, depending on the resources available for the study, one group can develop flowcharts and performance variables for the existing process while another group does the same for the superior process.

Step One: Flowcharting the Current Process

Before any improvement or benchmarking program can begin, it is mandatory that the existing process be known and understood. This can not be a simplified representation of how the process is supposed to be performed, but it must be a detailed examination of how every activity involved is currently done. An activity must be described as a verb and a noun. For example, "drilling an alignment hole" is a possible activity. The flowcharting process should be the responsibility of a facilitator, someone who is familiar with the process but is not intimately involved in the actual activities. As the facilitator

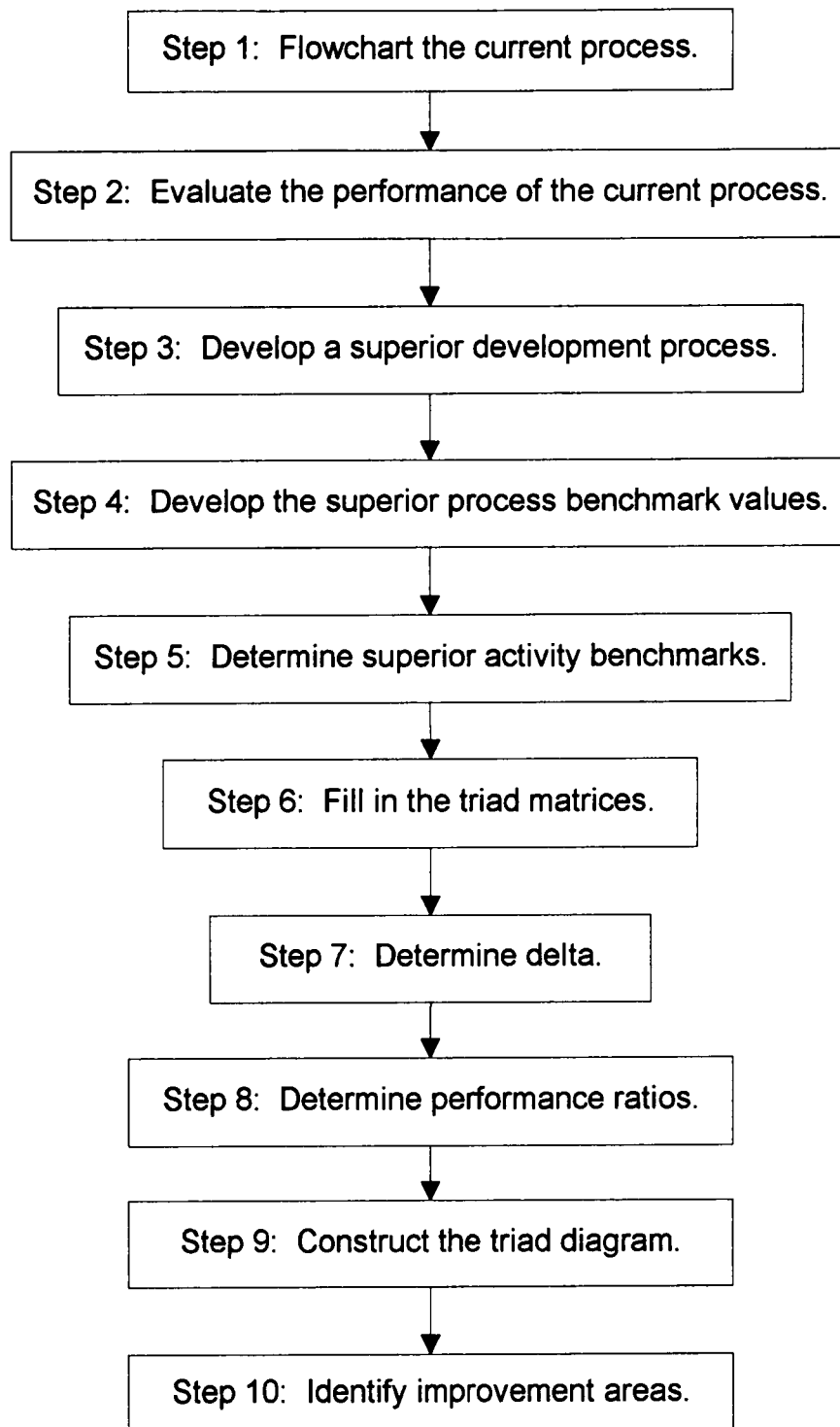


Figure 2: The Tens Steps for TPA

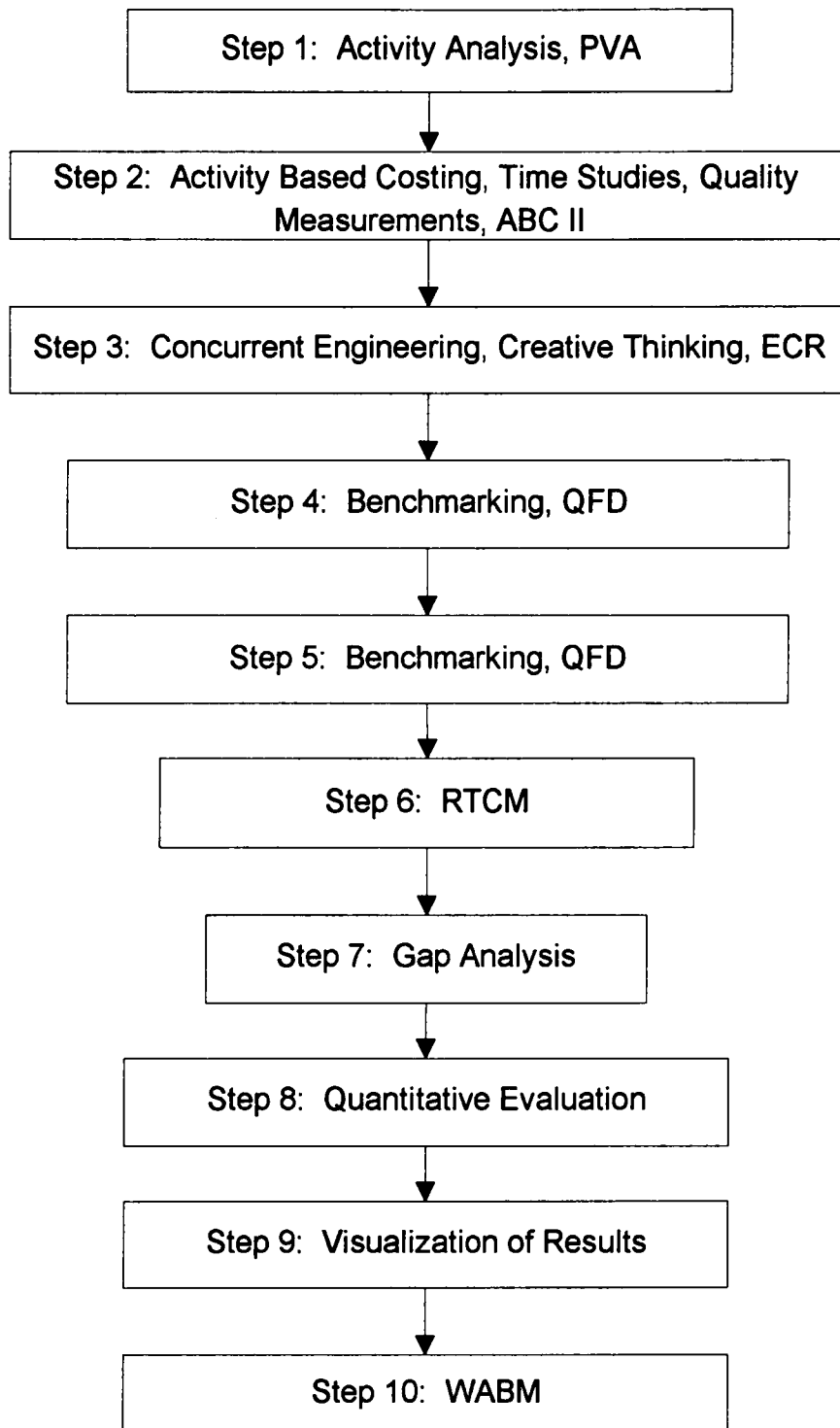


Figure 3: Conceptual Factors in TPA Methodology

interviews workers and observes the activities being performed, he or she may notice activities that are performed by the workers that would not have recorded had the workers had the sole responsibility of flowcharting the process.

The level of detail this part of the study is done at will depend on how detailed of an analysis is desired. The greater amount of detail will allow better tracking of even small activities, but this could quickly inundate the facilitator as well as the cost accounting system. If "drilling an alignment hole" is a simple process, this may be the farthest that the activity level is broken down. On the other hand, if drilling the alignment hole requires a new drill bit set-up, the use of a tap, and a follow-up quality check, more detail may be needed to differentiate these other activities. This decision is best made by upper management, with input from the accounting system and the facilitator in order to get as detailed as possible without overwhelming the systems involved.

Step Two: Evaluating the Performance of the Current Process

Cost, quality, and time performance data must be determined for each activity identified in Step One. Cost information will come primarily from ABC systems, with historical data used as needed. The result will be the cost of performing the particular activity. Quality performance data will be in units that provide the most information about the quality level of the activity. These units include traditional part per million or percent defective values as well as more customer oriented values such as the service level provided. Conventional

time studies can be used to determine the average amount of time it takes to perform an activity, whether in seconds or months. Performance for the entire process can be determined by examining all the activities performed in the process.

Each activity's three performance indicators are entered into its triad data block (see Figure 4). The triad data block is located adjacent to the activity it represents on the flowchart. Several guidelines are to be used in evaluating the process's total performance, and the same guidelines must be applied to the superior model developed in Step Three.

Guideline 1

A decision, shown in a flowchart as a diamond shape, does not consume any resources and thus does not have a triad data block assigned to it. This assumes any information gathering that occurs to facilitate the decision is shown as a separate previous activity.

Guideline 2

If a decision block forces a loop to occur, the loop activity's values include the cost, quality, and time measures of the entire loop cycle. Since the steps have already been performed once before the decision, the loop activity's values are not necessarily the summation of the performance values of the activities included in the loop. Thus, the triad data block that goes with the loop activity indicates the total cost, quality, and time values that occur to get back to the decision step that forced the loop originally.

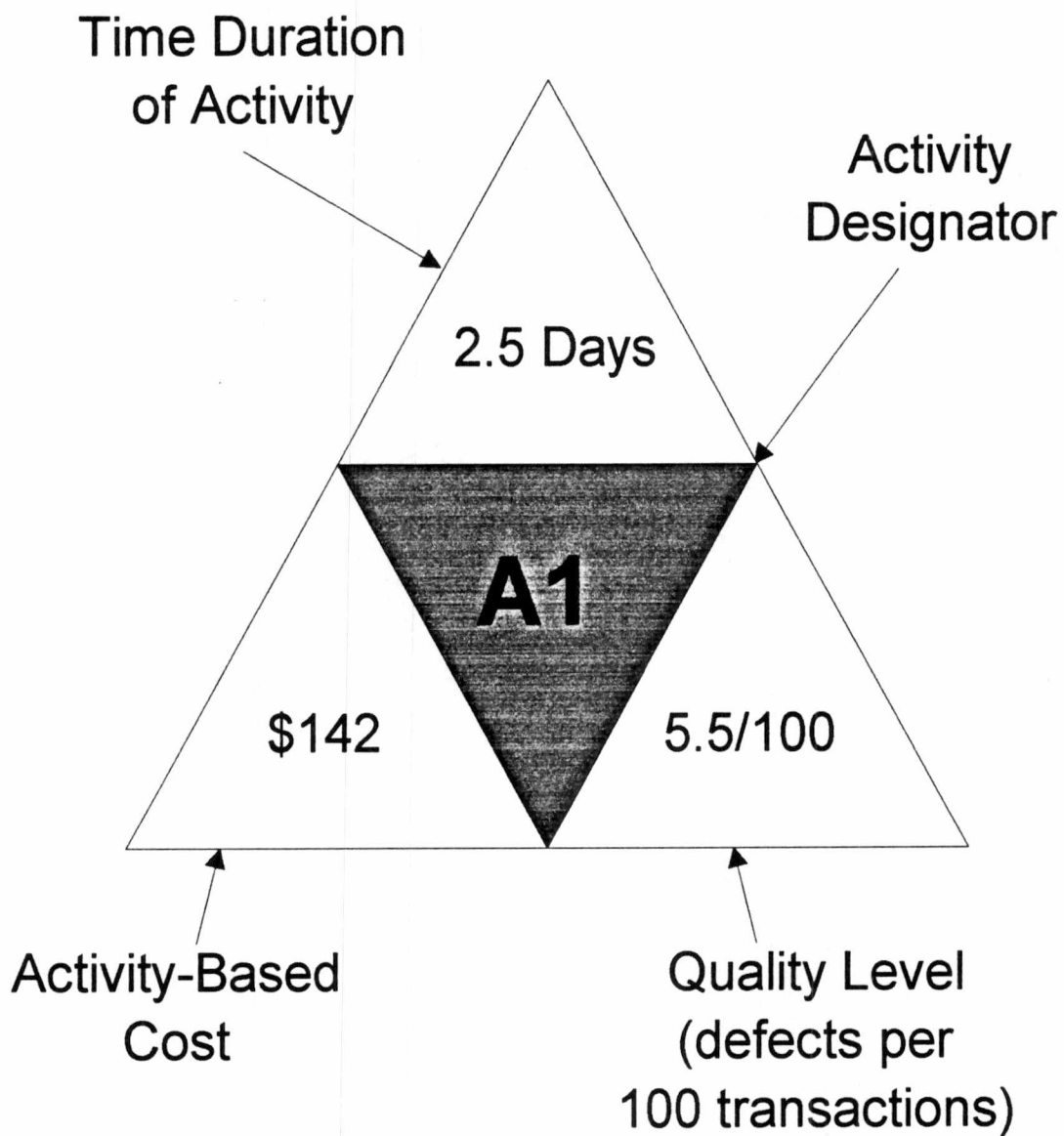


Figure 4: Triad Data Block

Guideline 3

Each loop is assumed to occur once for the purposes of determining the performance results of the entire process. This guideline can be modified if other information is available that sets the number of times a loop is to be performed in a process, but it must be applied uniformly to the current process as well as the superior process.

Step Three: Developing a Superior Development Process

The primary objective of this step is to develop the superior process that will serve as the benchmark for the current process. The result is a development process that focusses on cutting time and cost to design a product while ensuring the quality level that the customer requires. The generic superior process, discussed in Chapter 3, will serve as a template with each user developing a custom process to fit their particular industry requirements. Benchmarking of competitors and others with similar processes can be valuable in determining what the superior process will be like. The superior process should incorporate the use of quality function deployment, concurrent engineering, multidisciplinary teams, and traditional work methods studies. This list is limited only by the creativity of the users. The final superior process will represent the most efficient way that the design process can occur by eliminating non-value added activities and optimizing the necessary activities in terms of cost, quality, and time parameters.

Quality Function Deployment

In order to make a successful product, customer expectations must be understood and incorporated into the product. One of the tools that can accomplish this is quality function deployment (QFD). By taking customer values and translating them into design and manufacturing terms, companies are able to incorporate these goals into their product from the earliest stages of the development process. While mostly used in the early stages of a development process, QFD is also useful later on to track changes in customer requirements and to help predict future demands.

Concurrent Engineering

There is a two-fold purpose in the use of concurrent engineering (CE). The first is to reduce the time spent during the initial design, since manufacturing engineers are designing the manufacturing processes at nearly the same time as the product engineers are designing the item. This lessens the time lag between when something is designed and when its manufacturing process is ready to produce it. The second reward of CE is that the number of design modifications are minimized since problems in making a part can be spotted sooner by manufacturing engineers and can then be re-designed quickly.

Multidisciplinary Teams

The concept of using multidisciplinary teams complements the use of concurrent engineering. By putting people representing such diverse areas as design, manufacturing, marketing, and quality together in a team environment,

communication between all these functions is greatly enhanced. By giving the team complete responsibility for a product, a greater impetus is seen to succeed since those involved know that they will be accountable for the results, whether good or bad. These factors lead not only to time savings in the development process but also to a more robust final product.

Work Methods Studies

Perhaps one of the more powerful tools available to improve necessary activities is the study of work methods. This can be used to improve anything from the way a part drawing is released for manufacturing to the stamping process used to make the part. The primary benefit of these studies is the discovery and elimination of non-value added activities taking place in a process, as well as the improvement of the performance of value-added activities.

Step Four: Developing the Superior Process Benchmark Values

With the superior process being defined, it is necessary to have some quantitative means to compare it to the current process. This is done by determining the cumulative cost, quality, and time for the superior process through traditional benchmarking techniques. Since it is not feasible to benchmark each individual activity involved in the superior process, this study will limit itself to groups of activities or processes. For example, it is relatively easy to determine how long another company takes to process an order, but it

may not be possible to find out how long their secretary takes to type in an order.

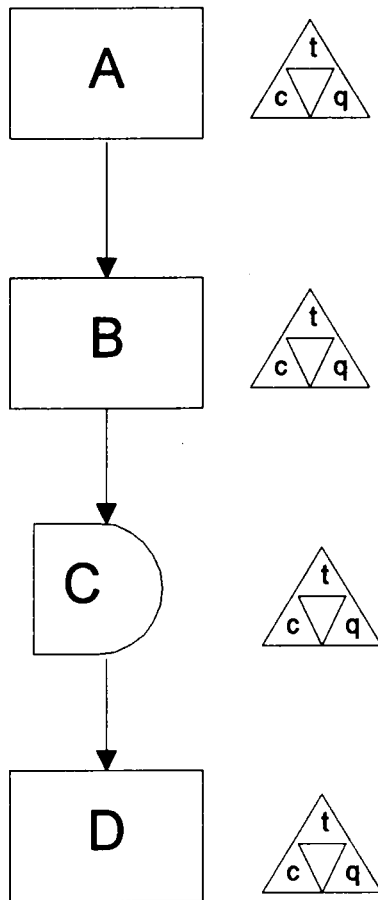
Since this is a superior model, not only can competitor's systems be investigated to develop benchmarks, but customer's expectations can be used as well. Since the goal is to provide the best services available, imitation of competitors is not enough. By targeting product attributes above customer expectations, companies will "delight" their customers with ever-increasing levels of performance (Gilbert and Nelson, 1991, p. 52).

Step Five: Determining Superior Activity Benchmarks

In order to be able to compare the current process with the superior process on an activity level, the overall superior benchmarks determined in step four must be broken down to the activity level. By experience and the knowledge gained in earlier steps, the total benchmark values for cost, quality, and time for each part of the superior process can be allocated to the individual activities. In addition, the existing process can be used as a guide in determining how values should be allocated in the superior process. The proper division of the total benchmark value into its component parts is vital to preserve the accuracy of the analysis, since it is performed at the activity level.

Each activity's three performance indicators are entered into its triad data block, as was done for the current process in step two. Figure 5 shows how the current process and the superior process can be charted side by side to visually illustrate the difference in the two processes. One primary difference

Existing Process



Superior Process

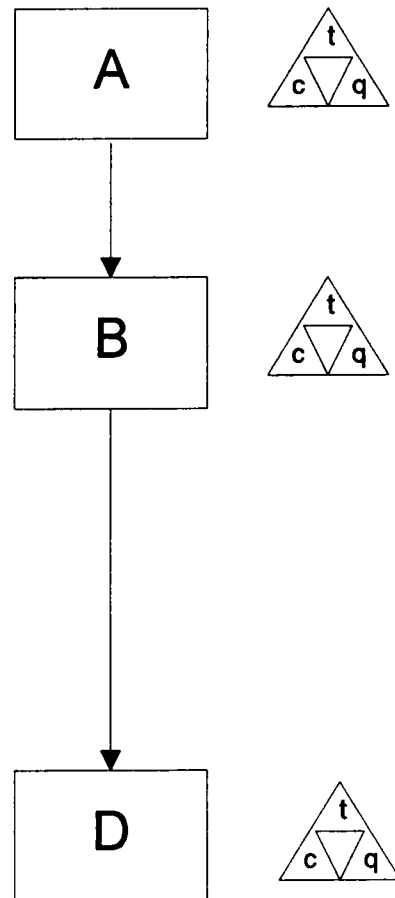


Figure 5: Process Flows With Data Triad Blocks

observed here is the lack of non-value added activity C in the superior process.

Users must be careful in selecting these superior benchmarks. If they are set too high, users can become discouraged with the lack of headway. If set too low, superior benchmarks may lull users into a false sense of security with regards to the performance of their process. To prevent this, a group of people outside the direct sphere of influence of the project should be used to monitor the selection of superior benchmarks. This should include representation from upper management.

Step Six: Filling In The Triad Matrices

The triad matrices (see Figure 6) incorporate the information from each activity's triad data block for the current as well as the superior process. Each dimension (cost, quality, and time) has its own matrix, identifying the activity and the value of the dimension for both processes. The first column of numbers represents the current process levels, the second indicates the superior process levels. If an activity is not performed in the superior process that is performed in the current process, the superior activity values are assumed to be zero. The other columns are described in following steps.

At the bottom of each matrix is a summary of the entire process. For the quality matrix, the units used to describe the cumulative quality level of the process will depend on the type of statistics used to measure the quality level. If using defect ratios, for example, the total would be expressed as a cumulative yield, or the product of all the activity quality ratios.

TIME					
Activity	Actual	Superior	Delta	PR	Triad Value
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					
K					
TOTAL					
Project Time					

COST					
Activity	Actual	Superior	Delta	PR	Triad Value
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					
K					
TOTAL					

QUALITY					
Activity	Actual	Superior	Delta	PR	Triad Value
A					
B					
C					
D					
E					
F					
G					
H					
I					
J					
K					
Cumulative Yield (Triad Value Only)					

Figure 6: Time, Cost, and Quality Matrices

The time matrix has two totals that are both important to examine. The first is the total time spent on the project, expressed in units such as person-hours. This would represent the amount of time spent to complete each activity separately, and it would not generally reflect time savings due to concurrent engineering. The second total, referred to as project time, indicates the amount of time it takes from the beginning of the process to the end. If two steps are being done simultaneously, only the one with the longest activity time would be counted for project time, since this is measured in units such as calendar days..

Step Seven: Determining Delta

The third column of figures in the matrices represents the absolute difference in the current process and the superior process. The superior values are simply subtracted from the current values for each activity. This will determine the absolute amount of cost, quality, and time the actual process is from the superior process for each activity. The magnitude of the delta values will indicate the areas where the greatest amounts of improvement are needed. This also represents a quantitative value of how improvements in these activities can have an impact. Negative values should not occur, since the superior process should meet or exceed the current process. Values of delta of zero indicate that the current process and the superior process match in performance.

Step Eight: Determining Performance Ratios

Performance ratios (PR) are another way to look at the quantitative differences in the current and the superior processes, and they are calculated by dividing the current value by the superior value. The PR indicates the factor that the current process is performing to with regards to the superior process level. A PR of one implies a delta of zero, which signifies that the current process and the superior process are operating at the same level. If the superior process has a value of zero, indicating a non-value added activity that is not needed in the superior process, the PR is left blank. Values for PR that are greater than one indicate areas that need improvement.

Step Nine: Constructing the Triad Diagram

The triad diagram is a valuable tool that TPA creates. It is a visual representation of the difference in the current process and the superior process (see Figure 7). The triad diagram is constructed from the values in the last column of the triad matrices, the triad value. The triad value is the inverse of the PR expressed as a percentage, which indicates the percentage of the superior process level that the current process is working at. A value of 100% shows that the superior process and the current process are at the same level. The lower the triad value, the more improvement that is needed. For activities that do not exist in the superior model but are in the current process, the triad value is considered zero percent.

The triad values can be plotted for each individual activity or for the total

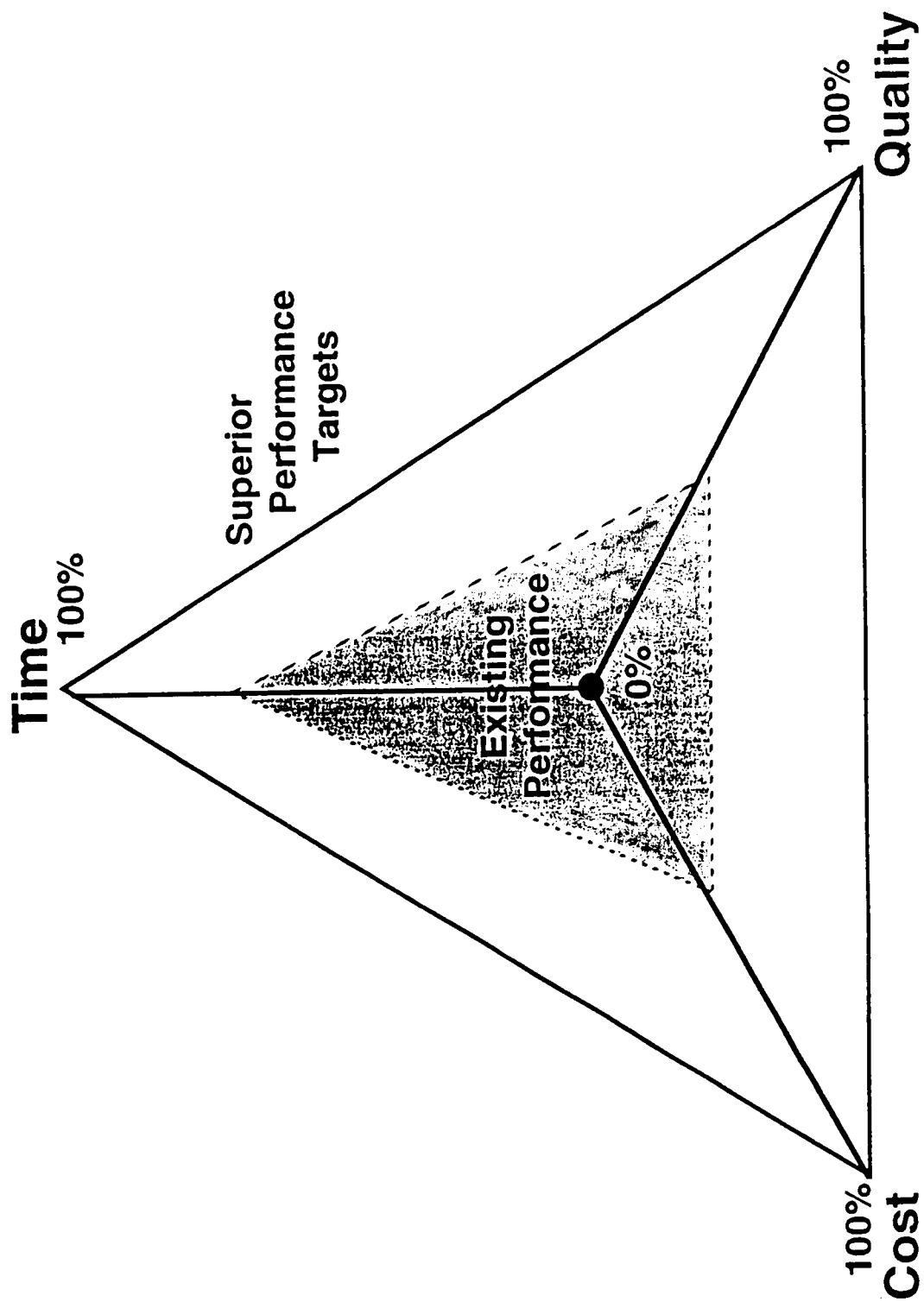


Figure 7: The Triad Diagram

process. The outer triangle symbolizes the performance of the superior process, or triad values of 100%. The center of the triangle is the origin, or 0%, with each leg of the triangle representing one of the dimensions of cost, quality, and time. With the triad values plotted for a particular activity or entire process, all three dimensions can be seen simultaneously. With a glance, it can easily be seen which dimension(s) needs the most improvement by the size of the gap between the current process triangle and the superior triangle. The graph also prevents users from only looking at a single dimension to base decisions on, since all three dimensions are shown at once.

Step Ten: Identification of Improvement Areas

The triad diagram, along with information from the matrices, will help identify improvement areas as the activities with the largest delta values or lowest triad values. Having this information will also allow the user to quantify the results of any improvements in the process on an activity level by tracking the performance before and after improvement efforts. When the process is modified, the triad values will change. The new triad values can then be plotted on top of the old triad values to see how the modifications affected all three dimensions. The triangles can be shaded to emphasize the qualitative differences in the processes, which can be used to justify further improvements in these areas.

Summary of TPA

TPA is based on developing a superior process to compare a current process to on an activity level. This requires the ability to obtain cost, quality, and time data on an activity level. The comparison is done on all three dimensions simultaneously, with the results giving qualitative and graphical representations of how far away a process is away from it's ideal values. The analysis itself is limited in it's usefulness unless used in a improvement program designed to revise the current process into the superior process. TPA can be used to monitor the progress of the improvement program, and can itself be improved upon as processes change.

Chapter 5

Case Study

Description of Process

This case study is based on a medium-sized company located in East Tennessee that designs and manufactures large water purification units. The particular process analyzed is the design phase of their product delivery system. The current process is flowcharted to fulfill the first step of TPA (see Figure 8). A manufacturing engineer starts the process by opening a work order, which allows the project engineer to begin the initial design by giving the project to a design engineer. The design engineer and a designer complete the calculations required and produce any drawings that are needed. This information is then verified by a checker, and the design is finally approved for release to manufacturing or purchasing. While the flowchart is being developed, measurements are taken to determine the current performance of the process, which is the second step in the analysis. A bill of activities is developed for each step in the process to facilitate allocation of costs within the costing system (see Figure 9 for a representative bill of activities). By the completion of these two steps, management should have a clear picture of the current process and its performance. This knowledge can be used to help in the formulation of the superior process, which is the next step in TPA.

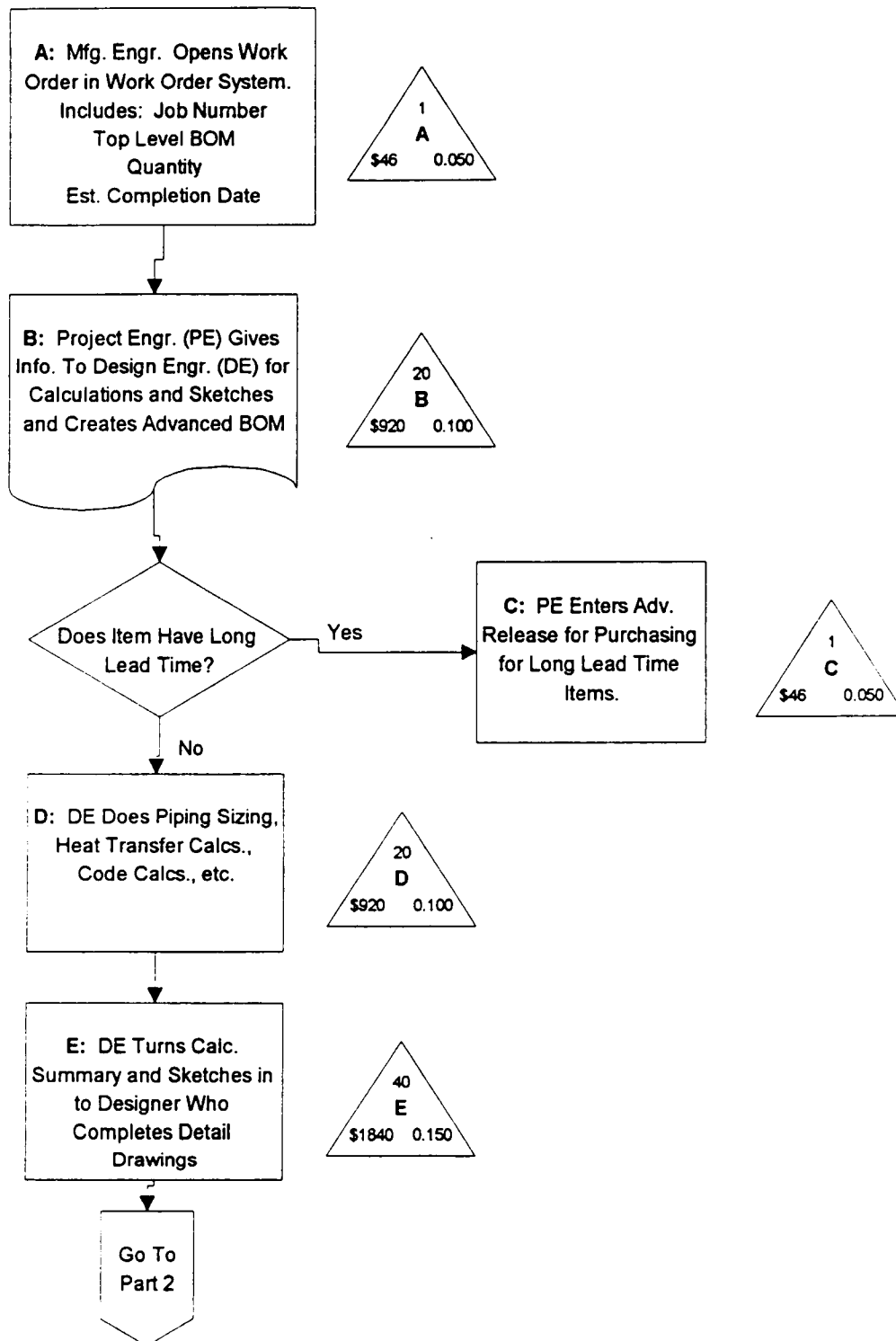


Figure 8: Current Process

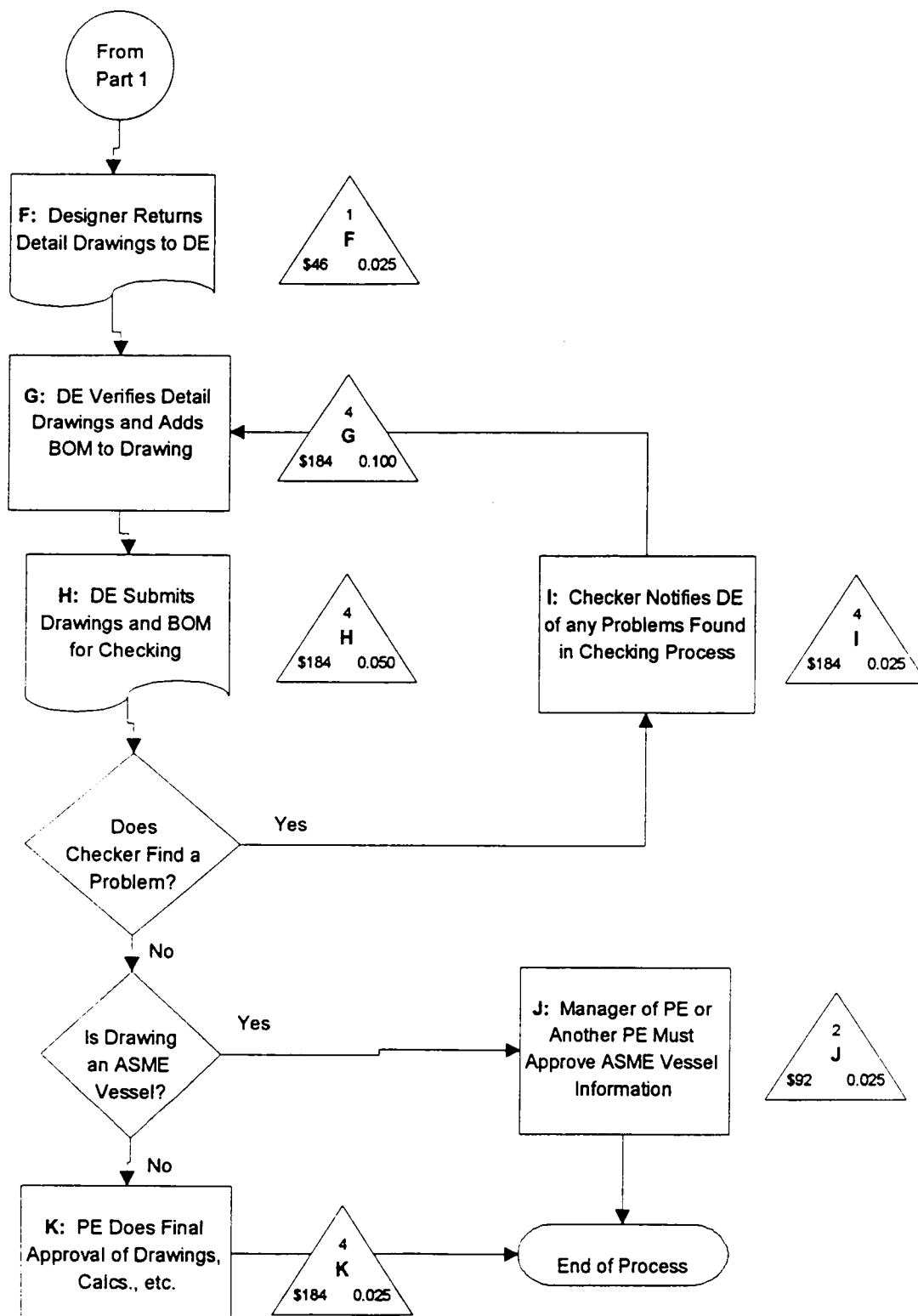


Figure 8 (Continued)

A: Manufacturing Engineer (ME) Opens Work Order in Work Order System

Paperwork is filed by secretary

Secretary receives information

Information is sorted by project

Completed information is forwarded to manufacturing engineer

ME inputs information into work order system

ME receives information from secretary

ME determines scheduling information for project

Information is entered into the work order system

Computer systems updates all related files

B: Project Engineer (PE) Gives Information to Design Engineer for Calculations

PE assigns project to a specific design engineer

PE accesses open project files from computer system

PE examines available time of design engineers

PE matches a particular project with a specific design engineer

PE turns project over to a design engineer

PE writes work assignment order (WAO) to assign the project

WAO and related files are given to the design engineer

Figure 9: Sample Bill of Activities for the Current Process

The Superior Process

The superior process accomplishes the end result as the current process, but does so quicker, cheaper, and with better quality. Each individual activity as well as the process as a whole are examined to determine better ways to perform the process. This could include the use of concurrent engineering, expanding communication systems, and employee training. Examination of similar processes can provide other suggestions. The flowchart of the superior process is the final product of the third step of the analysis (see Figure 10).

For the fourth and fifth steps, performance values for the three dimensions must be developed and allocated on the activity level used in the flowchart. Benchmarking is done on competitors as well as similar operations in other fields to develop target values for each activity. The process as a whole is also studied, with three steps (D, E, and G) being done concurrently and step F being eliminated as non-value added. It is important to remember that the superior model is the goal of what is to be achieved and has not yet been implemented.

The Triad Data Block

Each activity has a triad data block associated with it, indicating the time, cost, and quality factor for each activity. In the case of the current process, this data was obtained by studying the current activities and represents the operations of the company at the present time. For the superior process, these

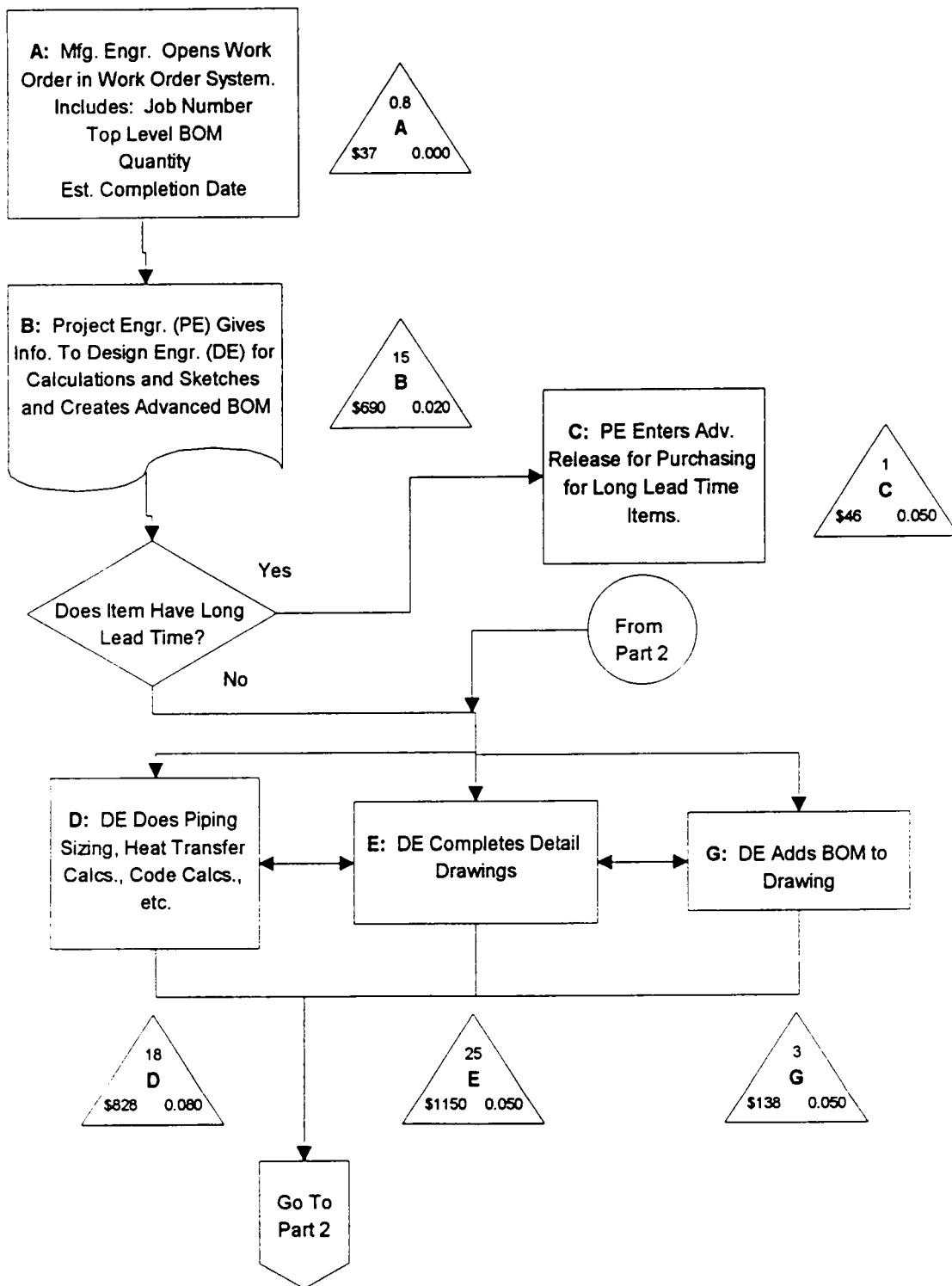


Figure 10: Superior Process

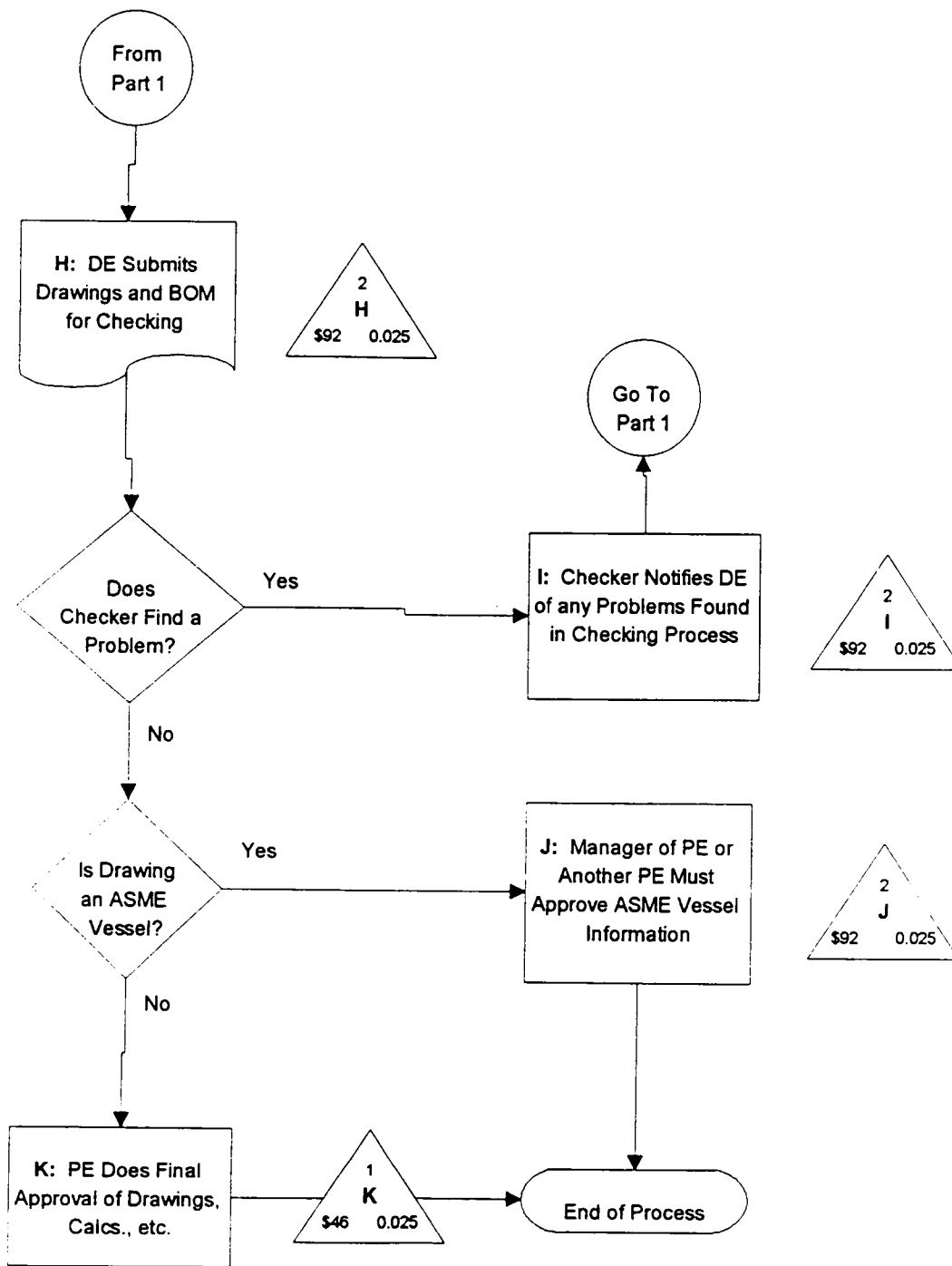


Figure 10 (Continued)

values are based on the benchmarking done and on goals set by the company. For both processes, the time data are based on person-days, or 8 hours of a single person's work time. Since an activity-based accounting system is not currently in place at this company, the cost figures represent the rate charged for engineering services at the company (\$46 per hour). While the actual cost involved in certain activities may be affected by more than the labor rate for engineering work, this approximation is close enough to show the impact of TPA. Quality is defined here as the defect ratio per 100 transactions.

Conventions

To form the increment between the two processes, several conventions must be applied. The first is that decision blocks do not consume any resources. Any information gathering done to make a decision is included in the previous step. The decision itself is considered instantaneous, with no cost or quality associated with it. Second, for calculating project time, it is assumed that each loop is completely entirely once. Lastly, each loop activity includes the time required to pass back through to the decision point again. For example, a decision occurs after activity H. If a problem is found by the checker, a loop is initiated. This leads to activity I, which has a time of 4 person-days. These four days include the time needed to go back through activities G and H and to return to the decision point again. Based on the second convention, the process is then continued on to the next decision.

Triad Performance Analysis

The actual analysis of the data begins with the sixth step. The information from each triad data block in both flowcharts are put into the triad matrices (see Figure 11). For the time matrix, two total lines are shown. The first total is the number of person-days required for the project. The project time total represents the calendar days required to complete the project. This total reveals the time savings primarily due to performing activities concurrently. The first set of TPA information compares the current operations with the superior process. The seventh step, determining delta, is simply the mathematical difference in the superior values from the actual values for each activity. The performance ratios are evaluated in the eighth step. For time and cost, this value is simply the actual value divided by the superior value. In the case where the superior value is zero, such as the superior time for activity F, this field is left blank since the ratio is undefined. For the quality measurements, the performance ratio can not be calculated due to the nature of the statistical data and this column is left blank.

The ninth step visually represents the analysis with the triad diagram (see Figure 12), which gives a representation of where the greatest gaps are between the current process and the superior process. The total triad value for the process is the total superior value divided by the total actual value expressed as a percentage. This represents what amount of the superior process that the current process is achieving. For project time and cost, the

TIME (8-hour person-days)

Activity	Actual	Superior	Delta	PR	Triad Value
A	1	0.8	0.2	1.25	80%
B	20	15	5	1.33	75%
C	1	1	0	1.00	100%
D	20	18	2	1.11	90%
E	40	25	15	1.60	63%
F	1	0	1		0%
G	4	3	1	1.33	75%
H	4	2	2	2.00	50%
I	4	2	2	2.00	50%
J	2	2	0	1.00	100%
K	4	1	3	4.00	25%
TOTAL	101	69.8	31.2	1.45	69%
Project Time	101	48.8	52.2	2.07	48%

(Project Time in Calendar Days)

COST (\$)

Activity	Actual	Superior	Delta	PR	Triad Value
A	\$46	\$37	\$9	1.25	80%
B	\$920	\$690	\$230	1.33	75%
C	\$46	\$46	\$0	1.00	100%
D	\$920	\$828	\$92	1.11	90%
E	\$1,840	\$1,150	\$690	1.60	63%
F	\$46	\$0	\$46		0%
G	\$184	\$138	\$46	1.33	75%
H	\$184	\$92	\$92	2.00	50%
I	\$184	\$92	\$92	2.00	50%
J	\$92	\$92	\$0	1.00	100%
K	\$184	\$46	\$138	4.00	25%
TOTAL	\$4,646	\$3,211	\$1,435	1.45	69%

QUALITY (defect ratio per 100 transactions)

Activity	Actual	Superior	Delta	PR	Triad Value
A	0.050	0.000	0.050	*	95%
B	0.100	0.020	0.080		92%
C	0.050	0.050	0.000		100%
D	0.100	0.080	0.020		98%
E	0.150	0.050	0.100		90%
F	0.025	0.000	0.025		98%
G	0.100	0.050	0.050		95%
H	0.050	0.025	0.025		98%
I	0.025	0.025	0.000		100%
J	0.025	0.025	0.000		100%
K	0.025	0.025	0.000		100%
Cumulative Yield (Triad Value Only)					70%

* Due to the nature of this data, the PR can not be calculated. The triad value is (1-Delta) expressed as a percentage. The cumulative yield is the product of the triad values.

Figure 11: Triad Matrices for Original Process

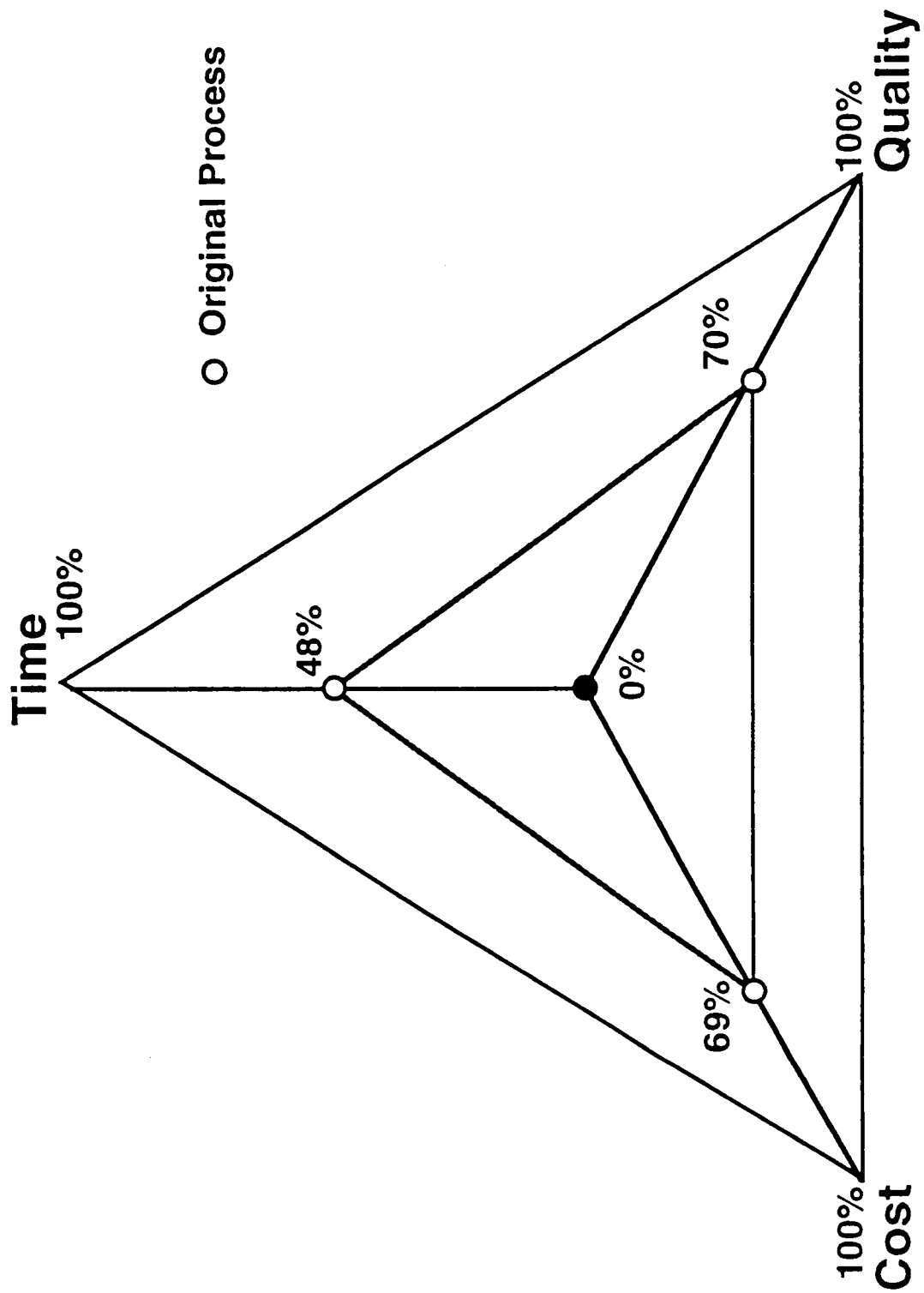


Figure 12: Triad Diagram for the Original Process

triad value is the inverse of the performance ratio expressed as a percentage. For the quality data, since the performance ratio was undefined, the triad value is determined by calculating $(1 - \text{Delta Value})$ expressed as a percentage. The cumulative yield is the product of all the individual triad values, since the data are based on defect ratios. Overall, we see that only 48% of the superior process is being achieved in terms of project time (time when manufacturing engineer opens work order until the time the design process is complete), 69% in terms of cost, and 70% in terms of quality. So, it is clear that a major focus should be on time reduction in general. This begins the tenth step in the analysis, which uses the information gathered to determine where the improvement efforts should focus. In particular, individual activities are selected that should be the focus of study to improve them to the superior levels. Activities H, I, and K are doing very poorly in terms of time and cost when compared to the superior model, so these activities in particular should be targeted for immediate improvement actions.

First Stage of Improvement Efforts

Seeing the need for improvement, the company decides to begin working to achieve the performance of the superior model. A list of improvement actions are developed for consideration of implementation (see Table 1). It is decided that the first stage of improvement should focus on areas that give significant results for relatively little effort. This begins with worker training and education,

Table 1: Improvement Focus Areas

Improvement Code	Improvement Activity
1	Continuous Training And Education
2	Multidisciplinary Teamwork
3	Reduction of Cycle Time
4	Work Method Studies to Improve Current Processes
5	Concurrent Engineering Principles
6	Enhanced Communication
7	Elimination of Non-Value Added Activities
8	Single Person Authority
9	Co-location of teams
10	Comprehensive Information Database
11	Benchmarking

which will form the basis of all further improvements. Since the ease of communication is a major factor in any project, improved communication tools and comprehensive information databases will be made available to all involved. The rest of the improvements decided upon for the first stage are implementing reduction of cycle time techniques and work method studies to improve the performance of individual activities. These are all relatively easy areas to approach for beginning improvement efforts, and thus they are chosen to begin the improvement process.

Each person must learn that they personally can have a tremendous impact on the process as a whole by working to improve their own activities. One major part of worker education involves engineers interacting with engineers from other departments, so that each person knows what is needed from the other. This technique is especially useful where one engineer turns documents over to another engineer for further work. The design engineer, in activity E, gives the designer important calculations such as pipe sizing and heat transfer values for the development of detail drawings. By knowing what the designer needs the most, the design engineer is able to concentrate more on these areas and spend less time on others.

On an individual level, each person becomes responsible for making sure that their job is done correctly, and they become responsible for improvement efforts. For example, Activity A was improved by studying how the manufacturing engineer entered information into the work order system. Since

the top level bill of materials (BOM) remain nearly the same for all orders, a standard BOM is now automatically selected by the system and the engineer simply modifies it to match the current project. Through the use of a work method study and a computer database, this activity was improved to reduce the time, cost, and number of errors in the entire project.

The improvement action causing the most initial investment in this first stage is expanding the computer network to enhance communication and lessen the amount of paperwork. By having each engineer put all their work in the computer network system, any engineer can have access to someone else's work, thus reducing the need to send paper back and forth. In addition, the person using the database would know that this was the current design so there is not a fear of working off outdated drawings or calculations. This facilitates better communication between individuals and reduces time in waiting for someone to get finished to send documents to. Engineers can also post questions and comments in the system for quick notice, enhancing communications even more.

After the changes in the process were given time to take effect, the triad data blocks are re-evaluated, and the information is input into a set of performance matrices to indicate the results of the improvement efforts . Figure 13 shows the new set of matrices, with a code indicating what method was used to improve the activity (see Table 1 for key). A new triad diagram illustrates the results for both the original and the improved process (Figure 14).

TIME (8-hour person-days)						Improvement
Activity	Actual	Superior	Delta	PR	Triad Value	Code(s)
A	0.9	0.8	0.1	1.13	89%	1, 4, 10
B	17	15	2	1.13	88%	3, 10
C	1	1	0	1.00	100%	
D	19	18	1	1.06	95%	6, 10
E	35	25	10	1.40	71%	6
F	1	0	1		0%	
G	3.5	3	0.5	1.17	86%	6
H	3	2	1	1.50	67%	6
I	3	2	1	1.50	67%	6
J	2	2	0	1.00	100%	1,6,10
K	2	1	1	2.00	50%	1, 4, 10
TOTAL	87.4	69.8	17.6	1.25	80%	
Project Time	87.4	48.8	38.6	1.79	56%	

(Project Time in Calendar Days)

COST (\$)						Improvement
Activity	Actual	Superior	Delta	PR	Triad Value	Code(s)
A	\$41	\$37	\$5	1.12	89%	1, 4, 10
B	\$782	\$690	\$92	1.13	88%	3, 10
C	\$46	\$46	\$0	1.00	100%	
D	\$874	\$828	\$46	1.06	95%	6, 10
E	\$1,610	\$1,150	\$460	1.40	71%	6
F	\$46	\$0	\$46		0%	
G	\$161	\$138	\$23	1.17	86%	6
H	\$138	\$92	\$46	1.50	67%	6
I	\$138	\$92	\$46	1.50	67%	6
J	\$92	\$92	\$0	1.00	100%	1,6,10
K	\$92	\$46	\$46	2.00	50%	1, 4, 10
TOTAL	\$4,020	\$3,211	\$810	1.25	80%	

QUALITY (defect ratio per 100 transactions)						Improvement
Activity	Actual	Superior	Delta	PR	Triad Value	Code(s)
A	0.035	0.000	0.035	*	97%	1, 4, 10
B	0.080	0.020	0.060		94%	3, 10
C	0.050	0.050	0.000		100%	
D	0.095	0.080	0.015		99%	6, 10
E	0.125	0.050	0.075		93%	6
F	0.025	0.000	0.025		98%	
G	0.080	0.050	0.030		97%	6
H	0.040	0.025	0.015		99%	6
I	0.025	0.025	0.000		100%	6
J	0.025	0.025	0.000		100%	1,6,10
K	0.025	0.025	0.000		100%	1, 4, 10
Cumulative Yield (Triad Value Only)					77%	

* Due to the nature of this data, the PR can not be calculated. The triad value is (1-Delta) expressed as a percentage. The cumulative yield is the product of the triad values.

Figure 13: Triad Matrices After First Round Improvement Effort

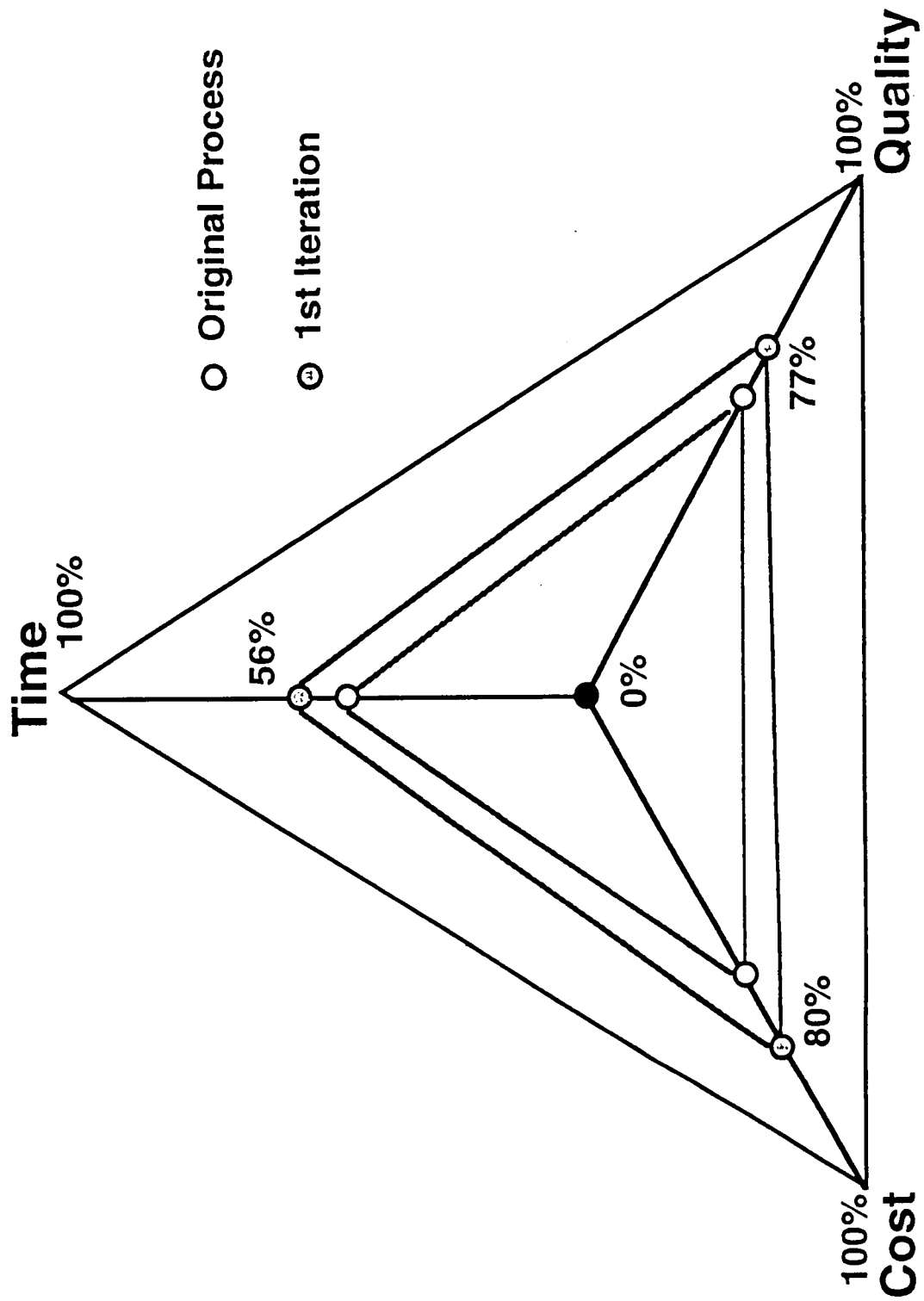


Figure 14: Triad Diagram for the First Iteration

Second Stage of Improvement Efforts

The company, encouraged by the results of the first round of improvement efforts but still seeing the large gap between the superior process and the current process, makes the decision to pursue further improvements. With the foundation for further improvements set in the first stage, the methods to be used in the second phase of improvements are selected. Since these methods include major changes in the way engineering work is done at the company, all personnel involved should be kept well informed of proposed changes. These changes would have been too dramatic to make as a first stage of improvement efforts, but making them in the second stage allows them to build upon the learning done during the first stage. Instead of continuing the traditional sequential design process of a sign-off to the next engineering group, the company decides to use concurrent engineering techniques and teamwork. In addition, the concepts of co-location of people and having a single person responsible for a project are implemented. A non-value added step (F) is eliminated, and benchmarking is used to help improve other areas.

The greatest impact on the process is apparent in activities D through G. The actual process now begins to look like the superior process in that these steps are performed concurrently. Instead of completing all calculations before giving the information to a designer, the designer is eliminated. Through training, the designer is "promoted" to design engineer status and is located with the other design engineers. Working as a team, design engineers perform

activities D, E, and G concurrently since step F can now be eliminated. A single engineer is given overall responsibility over the other personnel on the team for the project. To receive the full benefit of multidisciplinary teamwork, the members of the team include not only design engineers but manufacturing engineers, quality personnel, and even representatives from marketing. These improvements lead to a new set of performance matrices for the process (see Figure 15), as well as another triad diagram (see Figure 16). It may take several months for people to become comfortable with doing work concurrently as opposed to more traditional methods. However, the end results can be quantitatively evaluated from the analysis. Not only has TPA been used to record and track changes in performance values, but it has been instrumental in directing the path for improvements through the superior process.

As the actual process approaches the superior process in performance, it will be necessary to re-evaluate the superior process. New design techniques or changes in the market provide opportunity for improvement that is not reflected in the current superior process. Thus, the superior process can be improved and provide a new set of goals for the process.

Computer simulations can be used to give better analysis results with regards to process changes. However, the six month study that the data is based on provides a good foundation for estimating the results of process changes. Thus, while simulation would have added greater depth to the analysis, the benefit of TPA can clearly be demonstrated without it.

TIME (8-hour person-days)						Improvement
Activity	Actual	Superior	Delta	PR	Triad Value	Code(s)
A	0.9	0.8	0.1	1.13	89%	
B	16	15	1	1.07	94%	9
C	1	1	0	1.00	100%	
D	19	18	1	1.06	95%	5
E	28	25	3	1.12	89%	5, 11
F	0	0	0	1.00	100%	7
G	3	3	0	1.00	100%	5, 8
H	3	2	1	1.50	67%	2
I	2	2	0	1.00	100%	9
J	2	2	0	1.00	100%	
K	2	1	1	2.00	50%	
TOTAL	76.9	69.8	7.1	1.10	91%	
Project Time	54.9	48.8	6.1	1.13	89%	

(Project Time in Calendar Days)

COST (\$)						Improvement
Activity	Actual	Superior	Delta	PR	Triad Value	Code(s)
A	\$41	\$37	\$5	1.12	89%	
B	\$736	\$690	\$46	1.07	94%	9
C	\$46	\$46	\$0	1.00	100%	
D	\$874	\$828	\$46	1.06	95%	5
E	\$1,288	\$1,150	\$138	1.12	89%	5, 11
F	\$0	\$0	\$0	1.00	100%	7
G	\$138	\$138	\$0	1.00	100%	5, 8
H	\$138	\$92	\$46	1.50	67%	2
I	\$92	\$92	\$0	1.00	100%	9
J	\$92	\$92	\$0	1.00	100%	
K	\$92	\$46	\$46	2.00	50%	
TOTAL	\$3,537	\$3,211	\$327	1.10	91%	

QUALITY (defect ratio per 100 transactions)						Improvement
Activity	Actual	Superior	Delta	PR	Triad Value	Code(s)
A	0.035	0.000	0.035	*	97%	
B	0.050	0.020	0.030		97%	9
C	0.050	0.050	0.000		100%	
D	0.090	0.080	0.010		99%	5
E	0.075	0.050	0.025		98%	5, 11
F	0.000	0.000	0.000		100%	7
G	0.070	0.050	0.020		98%	5, 8
H	0.030	0.025	0.005		100%	2
I	0.025	0.025	0.000		100%	9
J	0.025	0.025	0.000		100%	
K	0.025	0.025	0.000		100%	
Cumulative Yield (Triad Value Only)					88%	

* Due to the nature of this data, the PR can not be calculated. The triad value is (1-Delta) expressed as a percentage. The cumulative yield is the product of the triad values.

Figure 15: Triad Matrices After Second Round Improvement Effort

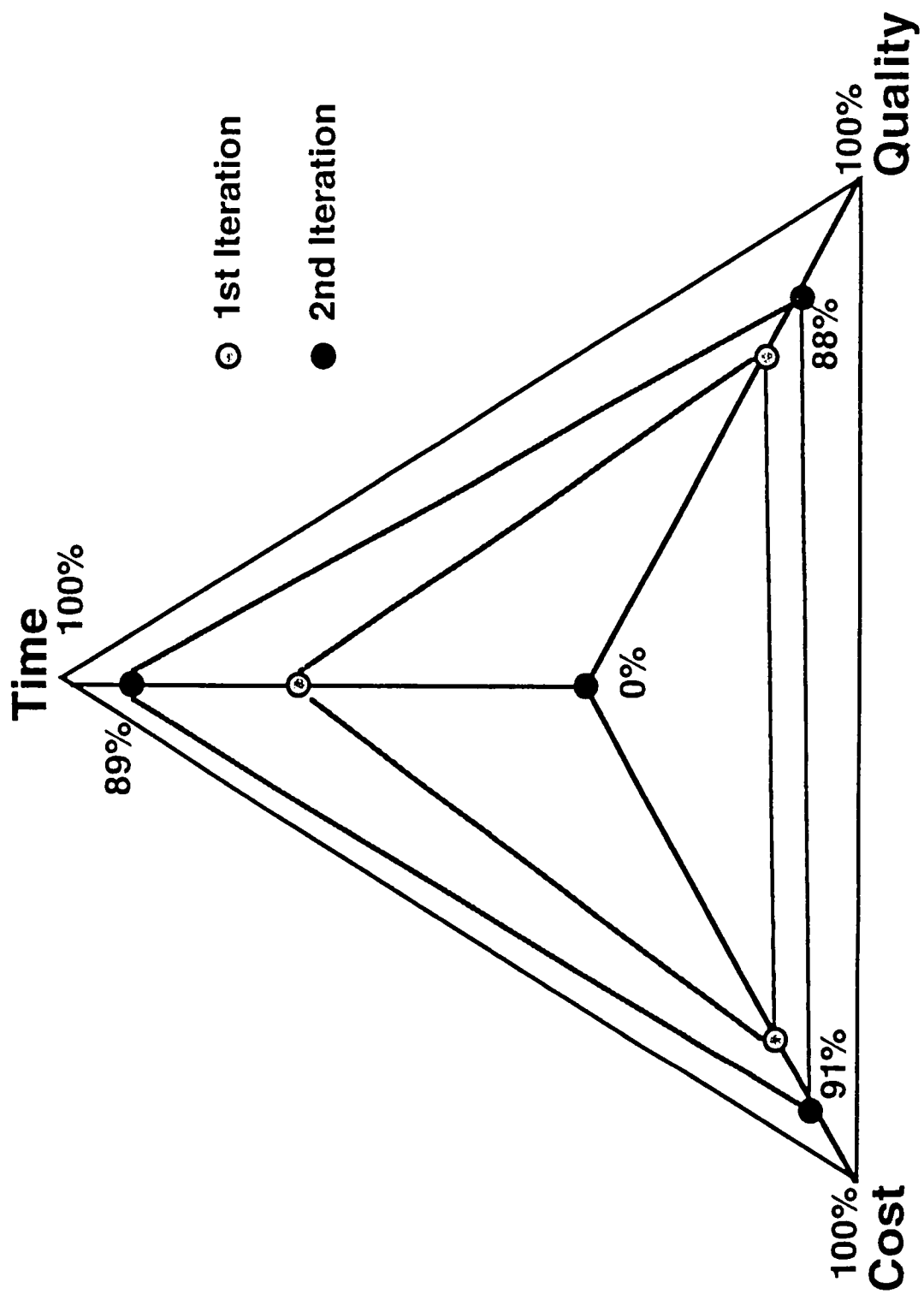


Figure 16: Triad Diagram for the Second Iteration

Results Using Other Methods

To demonstrate how TPA differs from the methodologies presented in the literature review, several of the methodologies will be applied to the case study to see how the results differ. While many have similar steps or utilize the same tools as TPA, none combine the tools to get the maximization of results that have been arrived at by using TPA.

Process Value Analysis (PVA)

PVA begins by flowcharting the current process, with a time value being assigned to each activity. Next, a decision is made as to which activities are value added and which are not. As in the TPA analysis, activity F is determined to be non-value added. Costs are applied to the activities through ABC systems. Thus, the process is now described with a dollar amount of activities that are value added, and a dollar amount of activities that are non-value added. An obvious goal for improvement would be to eliminate the non-value added activity F. PVA divides activities into the two value categories, but it does not establish goals for improvement with regards to value-added activities. It does not make the distinction between a value added activity operating at it's most efficient and a value added activity that needs to be improved upon. Thus, only a small part of the improvements made through TPA would be recognized by PVA. The improvements made by PVA are usually seen on the process level for the manufacturing environment. TPA examines both design and manufacturing on the process and activity levels.

Attribute Based Costing (ABCII)

By integrating quality information from the customer with costing information, ABCII allows the designers to decide which features in a product would be cost efficient to include. The primary benefit of this is that customer requirements will be stated explicitly and the costs known for each activity. Thus, for a particular product, ABCII would be valuable in providing guidance in what features will be valuable to customers. However, it is designed to be used in the design and development stages of a product since this is where most decisions regarding product design can be made. This makes ABCII's usefulness in designing a process or in a manufacturing process limited. In addition, there is no focus on the aspects of time in ABCII. The focus on customer value will improve the product, but not necessarily the process developing the product. In our case study, ABCII would have had little effect on improving the current process.

Workforce Activity Based Management (WABM)

Of all the methods discussed, WABM will come the closest to TPA in performance. By utilizing work teams, flowcharts and performance benchmarks are developed for individual activities. The goals are set in all three dimensions of time, cost, and quality. Although individual activities may be improved upon, the separation of personnel into several work teams prevents a wider analysis of the process as a whole. Thus, major improvements in the way a process is done, such as concurrent engineering, may never be introduced since teams

are only focussed on their particular activities. Many of the changes made in the first stage of improvements of TPA would also be made in WABM, since these were focussed on the activity level. However, the changes in the way the process as a whole was performed, such as concurrent engineering, might have been overlooked by the WABM teams who are examining only a small set of activities.

A summary of the various methods are shown in Table 2. Combining the results for PVA and WABM would approach the performance of TPA. TPA not only meets the best abilities of the other methodologies, it combines and improves upon them. There is improvement of individual activity performance as well as improvement for the process as a whole, and TPA can be used for either the design or manufacturing environment. All three dimensions of time, cost, and quality are examined, with a continuing focus on meeting or exceeding customer expectations. One area that TPA excels in that none of the other methodologies has is a visual representation of the performance levels of the current process, the triad diagram. While each methodology has its own strong points, TPA incorporates the best of all methods into a single analysis.

Table 2: Comparison of Improvement Methodologies

Area of Interest	TPA	PVA	ABCII	WABM
Time Dimension?	YES	YES	NO	YES
Cost Dimension?	YES	YES	YES	YES
Quality Dimension?	YES	YES	YES	YES
Customer Value Analysis?	YES	YES	YES	NO
Individual Activity Improvement?	YES	NO	YES	YES
Total Process Improvement?	YES	YES	NO	NO
Area of Improvements?	BOTH	Manufact.	Design	Manufact.
Visual Representation of Process Performance?	YES	NO	NO	NO

Chapter 6

Conclusion and Remarks

Benefits of TPA

By incorporating the ideas of activity analysis, three-dimensional decision making, and process improvement, TPA meets the need for assessing and improving product delivery systems in all performance dimensions. By using the strength of one another, each of the source methods is better able to perform its own function. While each could be applied separately to a process, applying them together through TPA allows a much greater return on the effort.

Activity Analysis

TPA derives a great deal of its benefits from the use of activity-based analysis. By breaking a process down into discrete activities, it is easier to see and eliminate the non-value added activities by comparison to the superior model. Each individual activity can be examined for improvements within itself. Looking at costs at the activity level make the distinction between direct and indirect costs inconsequential, which helps to focus efforts on the total costs of a process. These costs are also more accurate than ones reported by traditional cost accounting systems. The focus on activities will make sure that the activities are managed instead of the costs alone.

Three-Dimensional Decision Making

By examining the three dimensions of cost, quality, and time simultaneously, TPA allows companies to manage processes in the three major domains of competition. Since process changes will result in changes in multiple dimensions, TPA will force managers to see how their decisions affect all dimensions. This helps managers avoid making single dimension decisions, such as always choosing the lowest cost. The three-dimensional aspect of TPA also gives a competitive advantage to the user. If a single dimension should eventually reach a point where it is no longer a market differentiator, the other two are already being tracked and the process can easily be modified to meet changing demands. In addition, TPA is flexible enough to incorporate new competitive dimensions as they come into use.

Process Improvement

TPA develops metrics for cost, quality, and time for a process and gives the user a baseline to evaluate any future changes against. By looking at the gap between the superior process and the current process, the drive for continuous improvement always has a place to focus its efforts. The triad diagram can be used to quickly evaluate what areas need improvement the most, and the superior process provides a tangible goal. One of the more powerful aspects of TPA is the fact that it looks at improving a process at the activity level, thus improving the process across organizational boundaries.

Future Expansions of TPA

In order to follow the tenets that it endorses, TPA must be able to grow and improve. Areas of future study include improving the type of performance dimensions measured as well as making TPA more user friendly through the use of computer software. There are many avenues of growth available for TPA to pursue, and a few of these are detailed here.

Composite Performance Index

While being able to see cost, quality, and time as separate indicators is a valuable tool, many managers prefer to see a single measure of process performance. This could be accomplished by an integrated performance index, which would be a single weighted value that incorporates the results of the cost, quality, and time analysis. A method would be required that would be able to accurately weigh the importance and impact of cost, quality, and time to the outcome of the activity or process. Each of these dimensional weight values would then be applied to each performance parameter, and then the parameters would be combined to provide the composite performance index. It is important that this index not be used alone, but in conjunction with the three dimension values. The primary purpose of utilizing three dimensions is to keep as much information available as possible. While this index would cause the differences in the three dimensions to be combined together, it would give the users a single value to evaluate the overall performance of the process.

Another way to be able to combine the performance indicators into a single

value would be to convert quality and time measurements directly into costs. This would allow the user to analyze process performance using the same unit of measure that management is accustomed to: money. This would require knowledge of how time and quality affect the profitability of a product. For example, if a process can generate a product one month before any other group can, what will be the monetary rewards by being the first to market? How will having a defect rate of only 1 part per million increase the cost of quality while decreasing the cost of processing product returns? The ability of companies to carry this analysis down to an activity level is questionable. If inaccurate relationships between quality and time with cost were to be used, the true significance of these parameters could be lost. Even if a single composite index is used, the triad information that it is based upon must be available so that individual results of the three dimensions could be preserved.

Return on Investment Analysis

TPA considers only the costs involved in a process and not the expected monetary benefits. By providing a return on investment analysis, investment decisions regarding major changes in the process can be made with more quantitative input. This would require the ability to see how individual activities affect the profitability of a product, instead of simply changing the cost of operations. This could take the work done in ABCII in the realm of cost and customer requirements and take it to the level of individual activities.

Customer Value as a Performance Parameter

While customer value is examined when the superior model is developed, it is not quantified as a separate performance parameter. By using customer value as such a figure, the degree of value that each activity is contributing to internal or external customers can be evaluated. Comparisons could then be made to the degree of value verses the time, cost, or quality each activity is producing.

Improved Time Analysis

To further pinpoint causes for waste and opportunities for improvement, the activity time can be subdivided into it's major categories. The five categories utilized in time-based analysis are run time, setup time, down time, move time, and inspection and rework time. Another approach would be to simply identify the value added and non-value added time components within each activity to determine the proportion of these values with respect to the entire process.

Software Development

Timely application of TPA requires the use of computer systems. Everything from tracking cost figures to drawing flowcharts are best done using computer software. Unfortunately, no single program exists that incorporates the broad range of tools needed to implement TPA. A single piece of software could be designed such that any user could easily develop, implement and track their company's or work group's triad performance. This would include

step by step assistance with implementing TPA, integration with other programs to facilitate electronic data interchange, and even on-line systems to provide instant feedback on performance measurements.

A real time system can be developed that would take actual process data for nearly instantaneous evaluations of the process. Time, cost, and quality values can be automatically input to the database from other on-line systems for analysis. For example, the system takes note when an activity begins. It can tally the time and cost to finish the activity and can evaluate the quality level that the activity was performed at. This goes directly into the master database and is used to produce the results for the entire process. This also gives instant feedback to the worker for quick improvements.

In addition, application modules to this generic algorithm could be developed that would provide valuable insight unique to the application area. For example, one application module valuable for design and development processes would be one that evaluates the relationships of market introduction time and revenue potential in a market life cycle as a function of design cycle time, cost and quality. Simulations, included in the software, could then be conducted to optimize each parameter for the desired outcome.

Conclusion

The strive for continuous improvement has been expanding from cutting costs to improving quality to reducing the time to market. Triad Performance Analysis allows companies to embrace all three of these dimensions in a single comprehensive strategy. By utilizing the best tools available, such as quality function deployment, concurrent engineering, and activity-based costing, TPA forms a robust methodology that has the flexibility to be used in nearly any industry at whatever level is needed. It is not simply a measurement program, but an inclusive improvement methodology. The usefulness of TPA is limited only by the amount of effort that management is willing to expend in developing and maintaining the information necessary to perform the analysis. In order to be ready to compete at a world class level in today's markets, companies must be able to implement all-encompassing improvement programs that make sure that one competitive dimension is not sacrificed for another. The use of TPA will provide companies with the ability to not only monitor their progress in all dimensions, but to also give an impetus to the improvement of their processes.

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Vita

Christopher Lewis Whaley was born in Knoxville, Tennessee on October 17, 1970. Going to school in the Halls area of East Tennessee, he was graduated from Halls High School in May of 1988. He began his search for higher knowledge at the University of Tennessee at Knoxville in the fall of that year. Four years and many thousands of dollars later, he received the degree of Bachelor of Science in Aerospace Engineering. During this time he took the grueling Fundamentals of Engineering examination and was certified as an Engineer-In-Training by the Tennessee State Board of Architectural and Engineering Examiners. Not knowing when to quit, he began working on his Master of Science in Industrial Engineering. During this time he had the opportunity to act as a graduate assistant in engineering economy classes and was elected to membership in Tau Beta Pi. With the completion of his thesis, he was awarded his master's degree in December of 1994.

About the same time he began work on his master's degree, Mr. Whaley joined his local volunteer fire department. His interest grew to cover not only basic firefighting but areas such as arson investigation and SCUBA rescue. He finally got a real job as a pricing manager at Carolina Freight Carriers Corporation, located in the big city of Cherryville, North Carolina.