Title: Development of a TQM Performance Measurement System for Use in Architecture and Engineering Firms

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Abstract: This study identifies a performance measurement system for a small Architecture and Engineering (A&E) firm planning to embark on a Total Quality Management program. Data from interviews with several A&E firms regarding their TQM efforts indicated that over 70% of the firms used client performance surveys as measures, while more than 25% used no measurement systems at all. The conclusion is: A&E firms can and should, implement measures of design efficiency and customer satisfaction.

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Table of Contents

Introduction

The purpose of this project is to evaluate performance measurement systems used by Architecture and Engineering (A&E) firms as part of a Total Quality Management (TQM) Program.

A&E companies provide professional design services for all types of facilities. The work includes an integration of the work of up to eight engineering different disciplines to meet the specific requirements for a given user. In certain industries the required systems are very complex. For A&E's no two projects are alike. However, many of the same work processes carry over from one project to the next.

The motivation in selecting this topic is to apply the findings at SJO Consulting Engineers. Eric Mische is employed by SJO, where the management team is currently considering the implementation of a TQM Program. SJO is an A&E firm with 40 employees and serves industrial and government clients. Background information about SJO is presented in Appendix A.

Measurement is a key component of any TQM program. Manufacturing companies have made use of Statistical Process Control (SPC) to improve their work processes based on the output measures of products flowing through their factories. However, in professional services, developing performance measures is more challenging due to variation between projects

quality program, and if so, who was the best person to talk to about the measurement system being used.

A copy of the interview questions is presented in Appendix C. These were faxed to the interviewees prior to the interview. The objective of these interviews was to determine what measures were being used in practice and identify the relative success of those measures. The responses to the questions and the follow-up questions are included in Appendix C.

To statistically validate the conclusions of this paper more interviews are required. These would have been completed if more time was available for the project. However, the interviews do provide valuable information about performance measures being used by A&E firms as a part of their TQM programs. Summaries of the main findings from each interview are presented in Appendix B.

Literature Search

We identified over 100 possibly pertinent article titles from searching ABI/Inform and UMI CD-ROM databases at Portland State University and Tektronix, Inc. for combined topics such as design, engineering, service, measurement and TQM. After reviewing the available abstracts, we eliminated those that would not provide any applicable data. We were forced to eliminate other journal titles due to unavailability or the time constraint of waiting for them through inter-library channels. Eventually, we narrowed our search to about 30 articles which were used within the project.

ensure continuous improvement [1]. It is an accepted tenet of TQM that quality doesn't improve unless you measure it [2]. This measurement of quality is not restricted to product output from a manufacturing process. TQM is applicable to other industries and operations as well. Evaluation and measurement can be used to determine the current status of a process, product or service and also to monitor the direction and trends of process output to determine the effect of improvement efforts [3]. Once directions and trends are determined, efforts can be directed to controlling the root causes of process variation [4].

There are two basic quality measurement systems that should be in place and accessible to all levels of the company:

- Process improvement and rework indices,

and

- Customer and client feedback analysis.

The results of the interviews indicated A&E firms were most likely to measure customer feedback. The results of the types of measures used are shown in Figure 1.

We found the results of our interviews to be surprising with respect to the number of firms using detailed performance measurement. Over one quarter of the companies had no performance measurement system connected to the TQM program. This can result in significant problems. For example, how is a company to know if changes they are making will result in the desired improvements? One of the firms interviewed, Engineering Science, found that approximately 75% of their recommended quality initiatives did not

result in any significant process improvements. This was discovered in part from their use of detailed performance measures. The problem is quality initiatives all cost the company money to maintain, if they add no value they should be eliminated. Measurement systems aid in this evaluation. It is not enough to only embrace the new management philosophies and commitment to new organizational values in TQM. Results must be measured.

Employees should be involved in developing the measurement systems, to ensure the information and analysis generated has meaning for them [5]. This will also help give people some ownership of the system and reduce their natural resistance to change. For example, the Oregon Department of Transportation (ODOT) administration chose the main categories for the performance measurement system. Team members then selected the performance metrics for their own individual units.

While an effective set of measures will help indicate how well the TQM process is working, firms must be careful not to go overboard and simply measure everything, creating mountains of paperwork of little value. The overhead cost of each measure must be considered. The measure needs to be carefully thought out and balanced against the overall goals of the organization [6]. At ODOT, the Roadway Design unit initially used eleven different measurements to analyze the process of creating construction drawings. From the weights assigned to each measure it is evident only 45% (5 of 11) of the measures are the most important, as they make up 86% of the overall performance rating. This is shown in Figure 2. ODOT is currently in the process of modifying these measurements to simplify the system. A detailed copy of the ODOT measurements is contained in Appendix E.

One of the interviewees, Dave Stone, from Practice Management Associates, who provide business consulting services to A&E's, commented he was not sure "wholesale TQM", the complete commitment to a full blown TQM program, was a good fit with design firms. In his experience he has not seen any true success stories. While he agrees there are many good points to quality management, he is not sure A&E's need to go to the same program level as manufacturers to achieve positive results.

What to Measure

Deciding what to measure is no trivial task. The measurements must be specific, not general. For example, measures of overall process efficiency may degrade over time. But what was the specific problem? It is best to measure the process efficiency drivers, the numbers of change orders and drawing errors, for example. When one of these indicators changes for the worse, process efficiency will go down, but we can now identify a specific area to work on [4]. Measures must be easily understood and well defined to all affected employees. And of course, improvements in measured categories must translate to improvements in the bottom line. The best course is to use the strategic business objectives set up for the organization to establish quality goals and productivity metrics [9]. Defining the measurements in this fashion can help identify what to measure. There are a variety of categories that can be measured in any firm, quality, productivity, safety, people issues and customer satisfaction to name a few [10].

numbered scoring system they use. Refer to Appendix D for copies of two consultant performance evaluations. It is interesting to note that Harris Group has another survey to evaluate their clients on how well they performed during the project. The Brown and Caldwell performance evaluation is at the other end of the spectrum. It is short and to the point. The type of survey to be used depends on the firm's management philosophy and the expectations of the clients they serve. The exact form of the survey is not as important as taking the basic step of openly asking the client to evaluate your performance so you can better serve them and then communicating that information to the staff.

Measuring customer feedback can produce significant results. Problems are not often noticed until it is too late. However, the frequent use of a performance survey can help identify problems from the client's viewpoint and allow the A&E to take corrective action. For example, Engineering Science was able to take corrective action when a client survey indicated they were not meeting expectations. The survey gave them the opportunity to make adjustments which subsequently resulted in excellent performance evaluations, enabling them to obtain an additional $3 million in repeat business from the client.

Both quantified variables (output rated on a scale of contribution and reliability) and statements of perception (verbal comments that provide favorable or unfavorable opinions about activities) can be included in published survey results [12]. Care must be exercised in presenting data from customer surveys however. Engineers may perceive customer survey information as subjective and not to be taken seriously. Often, in the case of

In the absence of a manufacturing process producing scrap units, waste can be identified in any work process through simple analysis techniques. Work teams can methodically flow chart every work task performed to identify all the task components and separate them into value-added and non-value-added, or waste, elements [10]. Once the work processes have been analyzed and the process steps identified, measurements for the process inputs and efficiency can be developed and applied [14]. Including process customers into the evaluation process helps to establish metrics for process outputs and outcomes that meet the expectations of the downstream processes [15].

The application of the ISO-9001 guidelines provides a framework for this process examination activity. Not just for manufacturing, the ISO-9001 quality standard applies to the design process as well. In service organizations, the product is information and the transfer of knowledge to the customer. It is much harder to define the final quality of this product than for a tangible piece of hardware that can be measured. For this reason, ISO-9001 is rapidly evolving as a client-driven guide for consistency [16]. Some customers are requiring, or at least recommending, that A&E firms begin to use the ISO-9001 guidelines to define and document the company's work processes. This application helps to ensure delivery of services to the promised standards.

All employees must believe it is in their best interest to eliminate waste and must understand and focus on the requirements of both internal and external customers. Everyone must apply the concept of value-added work,

A long term trend of the labor hours required per drawing in a discipline can be used to determine if the firm is able to reduce their design costs from the TQM program. Most firms have used this measure prior to implementing TQM to help determine their fees for a project.

Measures related to cost of construction are often of great importance to the customer. The measure of change orders resulting from design defects can be directly linked to the cost of quality. These can result in the customer having cost overruns.

Quality vs. Productivity

Every year, Organizational Dynamics Incorporated (ODI), a TQM consulting firm, surveys Fortune 500 manufacturers regarding TQM efforts. In 1990, ODI asked corporate executives whether their companies measured a series of 13 quality performance indicators identified in a previous study of Deming Prize winners. This is the prize awarded annually by the Union of Japanese Scientists and Engineers to companies demonstrating exceptional performance in terms of quality strategy, management and execution. The data from the 1990 survey are included in Figure 3.

This philosophy of concentrating on the quality measures instead of productivity is similar to that of CH2M Hill. In their quality program, they focus on the program itself and expect everything else will fall into place.

It is interesting to note that none of the measures in ODI's questionnaire are directly related to productivity or finance. Each indicator relates directly to the amount of effort put into the firm's quality program and the results from that program, measured in customer satisfaction [9].

Costs of Quality / Costs of Non-Conformance

Identification of the costs of quality (or non-conformance to quality) and then tracking these costs was a common practice in several instances we discovered in our literature search. In some cases the system was very complicated and involved large overhead costs in manpower and computer data support [18]. These would not likely be useful in a small A&E firm.

The traditional cost of quality model identifies the principal costs as those of assessment, prevention and failure. There are both internal and external components of failure costs. Rework constitutes the majority of internal costs and external costs are made up primarily of correction of drawing errors during construction and costs of lost sales. A very simple way to view the cost of quality model is to assume that prevention and assessment expenditures affect (reduce) the number of defective units and the number of defective units drives failure costs.

It can be a difficult task to translate the traditional cost of quality definitions used in manufacturing to a service context. The concepts of prevention and detection of defects require a common output, or product, to

measured in the Roadway Design unit which could be easily converted into a cost of quality.

One component of the cost of quality model is the cost of lost sales. This cost can be tremendous as service industry estimates indicate that it can cost five times more to replace a customer than it does to retain one [22]. However, because they are difficult to quantify, these costs are often ignored. Usually, estimates for these costs are sufficient and do not take too much effort for an organization to develop. Placing estimated costs on these items can help to develop a projection of future loss contribution margin due to lost customers and sales [23].

While costs of lost sales may be difficult even to estimate, a substitute measure for a company interested in focusing on this aspect of their business may be to measure repeat or referral business. This simple task could yield an index quantifying the magnitude of customer satisfaction related to return and referral business [2]. One of the metrics used in Harris Group is the percentage of repeat business. Involving customers in post-project reviews and performance surveys may help to identify what factors affect return business [10].

Statistical Process Control

Often thought of as belonging only in the realm of high-volume product manufacturing, Statistical Process Control (SPC) can be applied in a variety of areas within a company, not just on the production line. Richard Gwartney,

Recommendations

Customer Surveys

The most common method for quality performance assessment, and probably the most accurate, is listening to one's customers. Customer feedback and reporting is critical to every business, but particularly in service businesses where there are no hard and sure indicators of internal quality such as a manufacturing line can measure. In addition, an emphasis on customer feedback can help stress the importance of listening to the customer to all employees.

A powerful way of achieving long term improvement in quality is gathering and applying customer feedback. Customer surveys are an effective method of obtaining feedback and measuring customer satisfaction. A good questionnaire should seek the answer to two key concerns, how the company is doing and how it can get better. Also, it should be carefully prepared to avoid as much ambiguity as possible. The customer must have the opportunity to tell the company what they expect. Building a performance measurement system based on findings from customer feedback helps employees view their performance through the eyes of their customers. It also emphasizes improvement in areas most important to the customer. Two cost based examples of customer driven measures discussed in the Analysis are:

different disciplines and industries that the A&E firm works in. See Figure 4 for an example matrix of how this could be illustrated graphically.

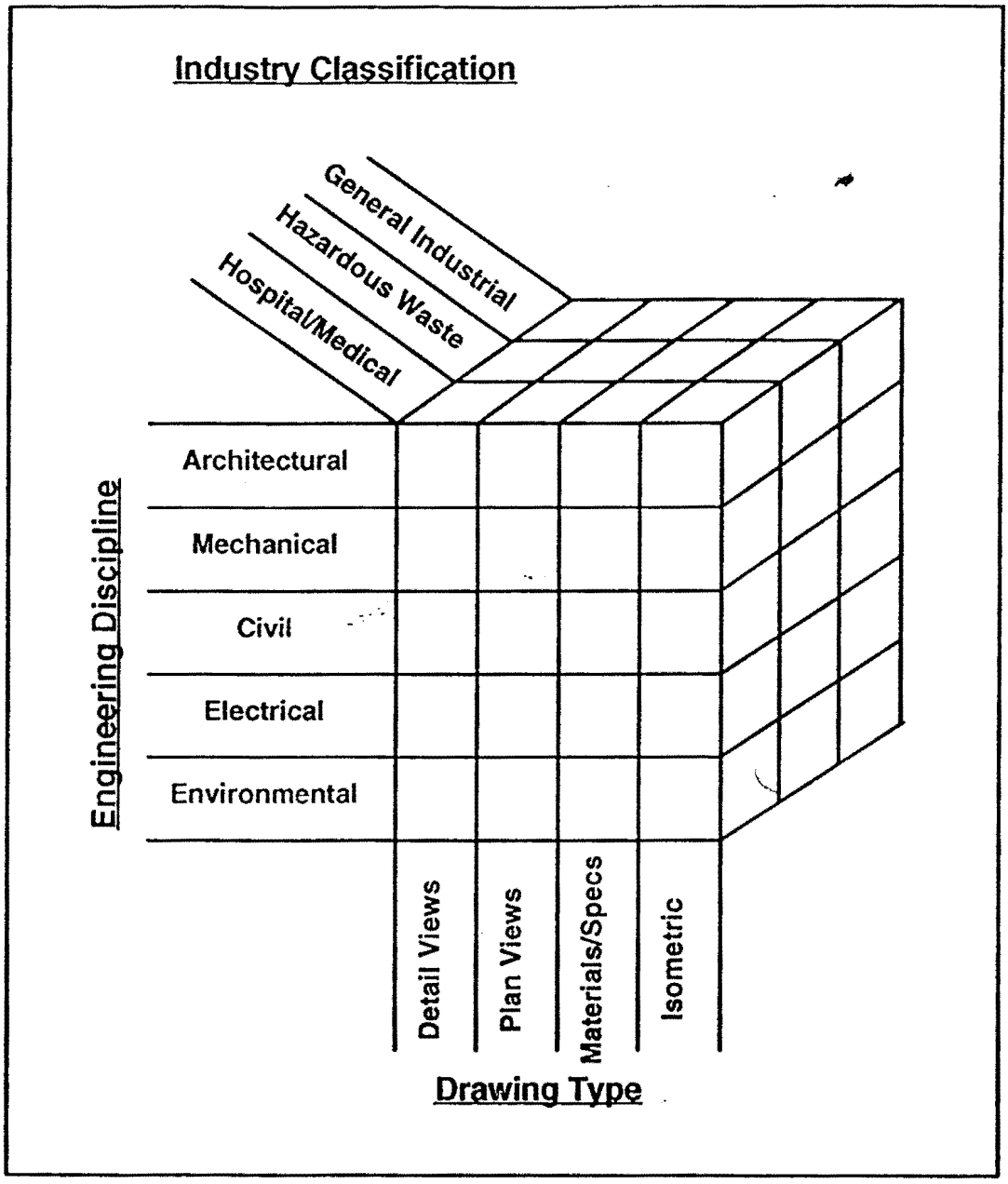

Figure 4

A more structured method for identification of waste in the form of non-value-added activity is accomplished by having work teams related to the process evaluate and flowchart the work process, identifying value-added and non-value-added activity as they go. From this point strategies can be developed by the teams to eliminate or reduce some of the non-value-added activities.

ISO-9001

Previously, we discussed how the application of the ISO-9001 guideline provides a framework to examine work processes. Given the applicability of this standard to design engineering and the growing requirements of consulting engineering clients for ISO-9001 based systems, the International Federation of Consulting Engineers has recommended that every consulting engineering firm should have a formalized quality management system in place including formal monitoring systems that ensure these programs are completely carried out [16]. Quite simply, ISO-9001 is a management system standard that focuses on how an organization provides and consistently delivers quality, whether in product or service. Consistent, good quality cannot tolerate waste in any part of the organization. For this reason, the ISO-9001 framework provides an excellent guide to formalize process management and eliminate waste in the design process.

Implementation of ISO-9001 involves a considerable overhead expense to the A&E firm. Each component of the design process must be fully documented and proceduralized. The documentation must take into account all of the possible design flow paths. This can create a rigid operating

An initial step in measuring design efficiency is to extend the measurement systems that are already in place. As most firms already track the average hours per drawing for bid and quote purposes, we believe capturing this data in greater detail is a good start towards tracking performance. Intermediate design review checklists can help identify how much rework goes into each drawing hour. Tracking the errors and omissions data generated from these reviews can identify the weakest processes and point out ways to improve them.

Careful examination of all work processes to identify and eliminate non-value-added activity is another step that can benefit any firm. Tracking waste process steps and activities that have been eliminated should provide added efficiencies. This activity logically leads into the application of the ISO-9001 quality standard if the company is ready for this step or customers are demanding it.

Remembering that the guiding principle of TQM is understanding customer requirements and executing a business plan to meet those requirements, we must keep the selected measurement process as simple and effective as possible. Measurement is a key component of any TQM program, but it cannot become the program itself.

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Glossary

A&E Firm

Architecture and Engineering (A&E) firms provide professional design services for all types of industries and facilities. Examples of the varied industries A&E's provide design services to are pulp and paper plants, waste water treatment and silicon wafer fabrication. The work normally includes an integration of architectural design as well as civil, chemical, mechanical, electrical, structural, instrumentation, environmental, HVAC, and other engineering disciplines.

ISO-9001

The International Organization for Standardization established the 9000 series of standards in 1987 to document a set of internationally accepted requirements for business quality. Standard ISO-9001 deals specifically with quality assurance in design, development, production, installation and servicing.

SPC

Statistical Process Control (SPC) is data driven, fact based process control. It is the process of gathering data about a process and making adjustments to the process parameters based on data previously gathered. The goal is to effectively reduce the variance in process output by adjusting process inputs to their optimum levels.

environment. However, there are some key benefits of using ISO-9001 properly. One of the main benefits is that it allows for more measurement opportunities since the process is well defined. This lends itself to more analytical treatment of the design process instead of looking at it as a magical creative process which cannot be formally structured. ISO-9001 may become the standard of the future for design firms.

Conclusion

There are several steps that can be taken by nearly any firm interested in applying measurement procedures related to a TQM program. Progress assessment based on performance measures is vital to the success of the quality effort. Management, employees, and customers need to participate in the development of the measurement system. Any A&E firm can, and should, implement measures of design efficiency and customer satisfaction. Implementation of the recommended measures does not require the company to have a full blown TQM program in place. This is especially true for the smaller firm.

The most important metric is to develop some system of formal customer communication and review process. Every firm should develop and apply a customer survey process of some sort. This can take the form of a written survey like one of the two examples in Appendix D, or a combination of the two. In any case, the important concept is openly asking the customer to evaluate the firm's performance and then applying what is learned within the company to make improvements.

As hours-per-drawing data is extracted and compiled over time, the next logical step is to refine the system further and include detailed information on drawing errors from the checking system to more closely track the performance of design teams. A final extension would include an SPC analysis similar to that used by Gwartney on piping isometrics.

Checking Practices

A&E firms that work with the U.S. Government as a customer are familiar with the Redi-Check program review technique required by some Federal agencies. The key element of this method is a set of checklists which allow the reviewers to step through all the items on the checklist and confirm that specifications and design requirements were coordinated between disciplines. Application of the Redi-Check checklists or similar systems at 30%, 60% and 90% of project design completion will help limit the amount of design errors that escape to the customer. But tracking data gathered from the checking process and applying resources to areas that are most error prone will help to improve efficiency and performance in the long run.

From the A&E's perspective, the objective of the Redi-Check or any checking process is to strive to eliminate errors at their source and reduce the amount of rework required. One of the main causes of rework is poor communication between disciplines. Some examples of how the flow of information between disciplines can be improved are by better educating employees on how their work impacts others and by developing structured methods for communicating key inter-discipline design information.

- Variability in construction bids resulting from a given design project
- Change order costs resulting from design defects as a percentage of total project cost.

Surveys need to be conducted often to assure performance is consistent with the client's expectations. They should take place both during the project and after its completion. Management review of the data from these surveys should be aimed at determining the causes for performance lapses and identifying solutions.

Hours per Drawing

A fundamental measure most A&E firms track at some level is the average hours of design time per drawing. This measure shows the average amount of effort required to produce a finished product, including all the rework time that may be involved. Many firms use the number of drawings required for a project as the basis for the project fee estimate, so this average hours measure can be vital for accurate costing. Monitoring the average hours value presents an indicator of the efficiency of the design organization. The trend for this measure can give an indication of the reduction in rework hours that should result from TQM efforts.

Instead of simply tracking the average number of hours for all drawings as an aggregate measure, the system can be enhanced to include some of the various categories every A&E firm deals with. Different drawing types can be considered as well as dividing the drawings into categories defined by the

formerly of RUST International, has developed a solid, technically sound application of SPC to piping drawings and associated drafting activity [24]. The power of statistical methods to monitor and control a work process has been demonstrated by the manufacturing industries within TQM programs for years. This step-by-step approach clearly identifies how an A&E firm can apply the same tools that are used in everyday manufacturing processes in a design shop. The technique can be used to track drawing or specification errors and checker comments. Continuous monitoring of these indicators will identify areas where TQM efforts are successful in reducing rework or areas where training and attention are needed.

One drawback of this paper is that it identifies a methodology that is perhaps beyond the scope of smaller firms, and perhaps even too advanced for larger firms without significant training resources.

The SPC method previously described faces the reality of rework costs and attempts to create a system to manage these costs. Astute project managers recognize that errors and rework cycles, as drawings get corrected and still further errors are discovered and they enter the rework process an additional time, are unavoidable in complex development projects. This real-world phenomenon of the rework cycle must be managed and planned for within a project [25]. When the probability of failure is known (data from an effective drawing based SPC system) and the costs are quantified (data from an accurate cost of quality system), managing this project problem becomes less difficult.

be effective. In one service operation, the "product" was ultimately defined as 100% customer satisfaction [19]. In this way, it was easy to determine which tasks affected the service output quality and their effect on customer service.

In many industries and organizations, failure rates as low as the ones being targeted in high-technology manufacturing industries are not required by customers and may increase service costs to achieve. Once standards of quality that our customers expect have been achieved, anything over and above is a feature that the customers will not want to pay for. Customers will take for granted the quality level they expect and then will turn their attention to, and buy services from, the low-cost producers. Productivity will then become very important again as world-class service providers try to achieve a balance between quality and productivity [20].

The key is to balance the internal prevention and assessment costs with the failure costs. Each operation should select a level of prevention and appraisal costs that minimizes costs of failure: the negative effect on customers. Again, these levels must be competitive within the industry. Assuming that there is some level of failure accepted in the industry, driving costs above the competition in order to achieve an unrealistic level of quality is foolish [21].

If a firm has advanced accounting systems in place that can capture such varied costs as the average rework cost per drawing and the cost of correcting drawing defects during construction, then the cost of quality can be easily estimated. For example, at ODOT, the percent of rework times were

Use of Quantifiable Indicators in Quality Improvement Efforts in Fortune 500 Companies

Does Your Company Track and Report...	No	Yes	Not Sure
Number of Q.I.* Projects Completed?	31%	64%	5%
Management Attendance at Quality Councils?	40%	55%	5%
Number of Q.I. Projects Linked to Strategic Goals?	43%	50%	7%
Number of Quality-Related Standard Operating Procedures?	47%	48%	5%
Percentage of Employees on Q.I. Teams?	42%	52%	6%
Number of Quality Goals Mutually Established by Managers/Employees?	41%	56%	3%
Number of Formal Quality Service Agreements Established with Customers?	46%	48%	6%
Number of Internal Customer-Supplier Agreements?	53%	41%	6%
Percentage of Q.I. Projects Initiated at Suggestion of Customers?	69%	23%	8%
Percentage of Quality Solutions Applying to Multiple Departments/Functions?	68%	25%	7%
Hours of Q.I. Training Per Employee?	57%	38%	5%
Number of Q.I. Teams with Members From More Than One Department?	48%	43%	9%
Customer Complaints?	13%	85%	2%

* Q.I. designates Quality Improvement
Source: ODI Executive Opinion Survey, 1990

Figure 3

From the example of Engineering Science previously noted (see Importance of Measurement in TQM) we can see that this may not always be the case and prudence is warranted. Some level of quantitative measures are necessary for an A&E firm to have a successful quality program.

concentrating on work that directly contributes to fulfilling customer requirements and eliminating tasks that do not add value [17].

Design Firm Performance Measures

From the PSMJ data, a recommended list of performance measures for a design firm might be [13]:

- Average number of defects per sheet of drawings identified during final design reviews
- Total person-hours required per sheet of drawings
- Design cycle-time (compared with projects of similar scope)
- Variability in construction bids resulting from a given design project
- Change order costs resulting from design defects as a percentage of total project cost.

Each of the above measures have their own advantages and disadvantages. The bottom line is that they can provide valuable information to fuel continuous improvement efforts. For example, identifying defects on the final review of a project can be argued as "looking in the rear view mirror," those defects need to be eliminated at their source. This is true in the pure sense of TQM, but is not practical for an A&E firm. Drawings are never perfect and clients are not willing to pay the price for perfection. By tracking these errors firms can focus on improving the processes which have the most problems and can measure the results of those improvement efforts. Our interviews indicated this measure was not used much in practice.

customer input, the subjective, perception based data may yield critical information regarding product features and subtle customer requirements.

Performance Measures

A primary goal in TQM is the identification, quantification and elimination of the waste in work processes. Professional Services Management Journal (PSMJ) data indicates approximately 25-50% of the labor hours spent on A&E projects are spent doing rework [13]. This is a significant resource demand. It is important to note that design is an iterative process, some rework is expected. However firms which can reduce rework can reduce their costs and the time required to complete a project. These factors are of interest to the customer.

Many of the companies interviewed expressed an interest in reducing rework, yet only ODOT had a system in place to measure their current levels of rework. The measurement of rework poses many problems to an A&E firm. First the term "rework" must be defined. What is the difference between rework and the analysis of design options? Secondly the measurement system itself must be developed. Most A&E firms bill based on hours worked by a discipline on a specific task. Rework would need to be tracked separately. It is probable employees would be resistant to classifying hours spent on rework because they want the boss to think they do good quality work.