AC 2010-1387: ENGINEERING MANAGEMENT IMPROVEMENT PROGRAMS IMPLEMENTED BY MANUFACTURERS TO BECOME MORE COMPETITIVE

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Engineering Management Improvement Programs Implemented by Manufacturers to Become More Competitive

Abstract

In today's competitive global economy, organizations of all sizes from job shops to huge corporations are searching for ways to improve their ability to compete. Actions taken and changes made in the way they do business have made a positive difference. However, that alone may not be enough. Further efforts are needed to enhance quality, increase efficiency, and streamline operations. In response, organizations are implementing established or traditional improvement programs. This is a good choice since they have a proven record of accomplishment. However, which ones are actually being used to make organizations more competitive? To answer that question a study was undertaken in 2008 into one fundamental type of job shop; the American tool and die shops that fabricate molds, dies, and tools essential to manufacturing. Numerous improvement programs are available ranging in cost, time, and personnel to implement. Since many tool shops have limited resources, the choices for implementation are usually restricted. Regardless of the type of improvement program selected, the objectives are always to enhance quality, increase efficiency, and streamline operations. As a result, knowledge about the most frequently used programs must be included in the engineering and management courses associated with the engineering and engineering technology curriculum. The findings indicate that they are using ISO 9000, continuous improvement, lean manufacturing, and other programs to become more competitive. However, no one program was the magic cure for all of them. In order to meet this challenge, engineering and engineering technology courses were revised to utilize the results from this study in the preparation of graduates for engineering management positions in electrical, computer, mechanical, manufacturing, and construction careers.

Introduction

"Job shops … are the unsung heroes and backbone of U.S. industry" (Bozzone[4], 2002). Typically, they encompass contract, build-to-order, and custom manufacturing organizations. Few realize that job shops provide essential services to businesses of all sizes. If job shops were removed from any large company's supplier base, their manufacturing system would likely collapse (Bozzone[4], 2002). Among the many types of job shops, one group that is of particular importance is the American tool and die shops that fabricate molds, dies, and tools vital to the manufacturing process. "Thus, companies that produce them take on significance to the economy beyond their own contribution in employment and spending. Maintaining a strong, domestically based tooling sector is essential to the self-sufficiency of the U.S. manufacturing economy" (Michigan Economic Development Corporation[19], 2005, p. 2).

A healthy American tooling industry is required to ensure the self-sufficiency of the domestic manufacturing sector, which is true for the commercial segment as well as the military industrial complex. This strategic significance sets the tooling industry apart from other small businesses. "At the same time, the vital role job shops play in enabling larger companies to compete successfully in the global economy is generally not well recognized or appreciated" (Bozzone[4], 2002). As a result, the importance of the tooling industry to the entire American manufacturing sector, whether commercial or military, cannot be overstated in terms of impact, capacity, and jobs.

However, global competition is threatening the existence of many tool shops. Some have already gone out of business while others are struggling to survive. They are taking actions and making changes in order to augment or regain their competitive edge. One important way this is being accomplished is through improvement programs. The objectives are often to enhance quality, increase efficiency, and streamline operations. Numerous improvement programs are available ranging in cost, time, and personnel to implement. Since many tool shops have limited resources, the choices for implementation are usually restricted. This raises the question of which improvement programs are being implemented and how successful have they been? An engineering management study (Loendorf[18], 2008) was conducted in 2008 with its main objective to answer these questions in a definitive manner.

Knowledge about the improvement programs most frequently used by manufacturers is a key aspect that must be included in the management courses associated with the engineering and engineering technology curriculum. Exposure to this important information better prepares graduates for the challenges that they will encounter during their real-world engineering and management careers in manufacturing. To meet that objective, various engineering and engineering technology courses have incorporated and are utilizing the results from this study.

Theoretical or Conceptual Support

Many organizations have discovered that total quality management (TQM) actually improves quality, reduces waste, decreases costs, enhances efficiency, and improves productivity while increasing the confidence level of their customers (Besterfield, Besterfield-Michna, Besterfield, & Besterfield-Sacre[3], 2003, p. 13). Escrig, Belén, Llusar, Carlos, and Vicente[11] (2001) found that TQM programs "can generate a wealth of distinctive competencies which partly explain how a competitive advantage can be upheld. The distinctive competencies associated with TQM are responsible for … a positive influence on performance" (p. 937). Rao, Youssef, and Stratton[23] (2004) reported that TQM has the potential to save a failing organization and even improve its competitive position. Agus and Sagir[1] (2001) concluded, "TQM practices have an indirect impact on financial performance mediated by competitive advantage. TQM has a strong effect on competitive advantage which ultimately leads to a more significant impact on financial performance" (p. 1023). Sila and Ebrahimpour[25] (2003) examined and compared the differing critical factors affecting successful TQM implementations in various countries. Vincant and Vincant[28] (1996) concluded that many challenges and choices occur during the strategic management of a TQM program.

A single unified approach to quality management does not really exist; rather there are many variations from which to choose. However, Deming[9, 10] (1982, 1986), Juran[15] (1989), and Crosby[8] (1992) have provided some of the most useful TQM theories during the 20th century. In fact, they have been called "quality advocates" (Summers[27], 2003, p. 28), "total quality pioneers" (Goetsch & Davis[13], 2003, p. 17), and "gurus of total quality management" (Besterfield et al.[3], 2003, pp. 4-5). While their views on quality management and how it should be undertaken differ, they all agree on the importance of customer satisfaction.

The Japanese extended the work of Deming[9, 10], Juran[15], and Crosby[8] into their concept of continual incremental quality improvement called Kaizen. "Kai means change, and zen means good. Kaizen, therefore, means making changes for the better on a continual, never-ending basis" (Goetsch & Davis[13], 2003, p. 694). Every aspect of the organization must be constantly improving; with no exceptions. Included are all of the people, processes, management practices, and products. The condition of good enough does not exist; everything must continually get better. Usually these improvements are easy to identify and can be accomplished without sophisticated techniques or expensive equipment at little or no cost. Besterfield et al.[3] (2003), Chang[5] (2005), Garvin[12] (1988), Goetsch and Davis[13] (2003), and Summers[27] (2003) stated that the procedure focuses on simplification by breaking down complex processes into smaller parts, improving them, and then putting them back together. Kaizen relies heavily on a company culture that encourages suggestions by the workers who constantly try to improve their job or process.

Other contrasting methods to improve quality have also been developed including Six Sigma, QS 9000, quality function deployment (QFD), statistical process control (SPC), along with the Malcolm Baldrige Quality Award. Information on these methods has been written by Besterfield et al.[3] (2003), Chang[5] (2005), Cohen[6] (1995), Goetsch and Davis[13] (2003), Gryna[14] (2001), Khalil[16] (2000), Morse and Babcock[20] (2007), Perez-Wilson[22] (1999), and Summers[27] (2003). All of these methods, when properly applied and managed, have resulted in dramatic quality improvements. However, implementing these approaches typically requires an overhead in terms of manpower, money, and materials that simply cannot be prudently supplied by most tool shops.

By focusing on the customer's perception of value the organization becomes customer centered and has the ability to produce and deliver superior value to their clientele and consistently win in the marketplace. Organizations or individuals will "buy from the firm that they perceive to offer the highest customer delivered value" (Kotler[17], 1994, p. 37). The most effective way to establish customer value is to listen to your existing and potential customer's needs and wants (Compton[7], 1997, p. 238). Frequently customers make this process difficult by not disclosing their real needs and wants and the perception of value can vary greatly from one customer to another.

An organization's greatest strength might well be its ability to rapidly transform new ideas, technologies, and processes into improved or totally new products. Time compression has three critical aspects: "(1) shortened product life cycles; (2) shortened development times; and (3) … decreasing payback periods" (Narayanan[21], 2001, p. 48). The product must also be designed to meet or exceed the customers' expectations in terms of application, performance, features, cost, safety, and dependability (Chang[5], 2005). These characteristics reflect a dilemma between reducing cycle time for the organization and improving the product for the customer.

Cross functional teams are, according to Wild, Wild, and Han[30] (2006), "composed of employees who work at similar levels in different functional departments. They work to develop changes in operations and are well-suited to projects requiring coordination across functions, such as reducing … time" (p. 336). A team of experts is assembled from throughout the organization to attack and resolve a critical issue by collectively using resources from every department or functional area. In this way the problem is now being addressed simultaneously by the entire organization rather than a single department or functional area at a time.

Traditionally little time was spent during the product definition phase, instead considerable time was exhausted throughout the design phase, and even more time was expended redesigning the product. “The key to shortening the overall design time is to better define the product and better document the design process” (Morse & Babcock[20], 2007, p. 221). Concurrent engineering (CE) spends more time initially planning and designing the product in order to avoid later interruptions and speed up the entire process. Concurrent engineering can be “defined as the earliest possible integration of the overall company’s knowledge, resources, and experiences in design, development, marketing, manufacturing, and sales into creating successful new products, with high quality and low cost, while meeting customer expectations” (Compton[7], 1997, p. 271).

Few organizations possess all of the knowledge and other resources required to develop a new technology or product. As a result, organizations are forming alliances. “Economists have provided the term social capital to describe the concept that to achieve innovation requires not only physical capital, human capital, and financing, but also an understanding of how those individuals and institutions work with each other” (Allen[2], 2003, pp. 158-159). “Collaborative arrangements involve two or more firms in which the partners hope to learn and acquire from each other the technologies, products, skills, and knowledge that are not otherwise available” (Narayanan[21], 2001,p. 269).

One production method that has been widely accepted by the tooling industry to increase efficiency is lean manufacturing or “the systematic elimination of waste. As the name implies, lean is focused on cutting ‘fat’ from production activities. Lean has also been applied successfully to administrative and engineering activities” (Santos, Wysk, & Torres[24], 2006, pp. 8-9). The concept is to eliminate anything that does not add value to the product. Waurzyniak[29] (2004) applied this theory to job shops and found that firms that applied lean techniques reaped many benefits including faster throughput, lower costs, and improved quality.

Scope

The target population for this study (Loendorf[18], 2008) included only American tool and die shops. Every State in the Union has some tool shops; however, they are heavily concentrated near the automotive, aerospace, and durable goods industries. They consist of organizations of various sizes ranging from only a few workers to hundreds, primarily privately owned while others are under corporate control. These tool shops either can be independent entities or embedded in much larger organizations. The population of interest was comprised of tool shops ranging from small to large and from private to corporate.

Within the tool shop, the people and their actions hold the most significance for this study. Of particular interest was the management team that may consist of the owner, president, general manager, director, department heads, or other types of supervisors. They were responsible for setting the policy and direction for the organization along with being ultimately accountable for its success or failure. Therefore, information about the operation of the tool shop was gathered from their management team in order to determine how they are changing or transforming the organization to obtain a competitive advantage.

Preferably, every American tool and die shop would receive a survey to complete. However, the time and effort required to do so would be exorbitant, and the results might not reflect much of a difference from those using a much smaller sample. Consequently, a simple random probability design selected tool and die shops for study from an industry wide association of American tool shops, The National Tooling & Machining Association (NTMA). With this method, each tool shop had a known and equal chance of selection (Singleton & Straits[26], 2005). Using this sampling structure, 600 tool and die shops received the survey questionnaire and 94 completed surveys were returned.

Demographics of Tool Shop Respondents

The 94 tool shops that responded to the survey varied in size with over 60% employing 40 or fewer workers and almost 75% employing 60 or less. In terms of annual sales, the 1 to 10 million-dollar range accounted for almost 66% of the responding tool shops. During the past three years over 35% of the tool shops had their sales decline while about 43% saw sales increase. However, the largest single category exceeding 21% had their sales remain roughly the same. Two-thirds of the tool shops did some international business while a third of them had no international business at all. None of the organizations had international sales that accounted for more than 60% of their business. Almost 94% of the responding tool shops have experienced a negative impact on their business from global competition. Slightly more than 6% of the tool shops reported no negative effects but rather a small positive impact or no impact at all. Over 31% of the tool shops were in the stable or steady state mode while 38% were growing and 28% shrinking or contracting. This depicts the critical nature of the problem with almost a third of the tool shops having trouble.

Results

American tool shops have implemented improvement programs in order to become more competitive. Twenty-four established or traditional improvement programs were selected for this study (Loendorf[18], 2008) from focus group input. Table 1 shows those programs either considered, planned for partial use, planned for full use, partially applied (or implemented), or fully applied (or implemented) both by percentage and number of selections.

Multiple selections were allowed resulting in all of the programs being selected numerous times. The category receiving the most selections was partially applied closely followed by considered. The column with the least number of selections was planned for full use.

The improvement programs receiving the highest number of total responses were ISO 9000, continuous improvement, lean manufacturing, 5S campaign, Kanban, and Kaizen. These reflect quality enhancing and production upgrading efforts aimed at improving efficiency. Those with the fewest total number of responses were scientific management, Six Sigma, life cycle cost, quality function deployment, and time and motion studies. Four of these programs are typically used at larger organizations while the other two are efficiency programs that the tool shops may not have the time or resources to implement.

Table 1
Improvement Programs Used to Counteract Imported Tools

Improvement program (Number of responses)	Considered % (#)	Planned partial use % (#)	Planned full use % (#)	Partially applied % (#)	Fully applied % (#)
Value chains (19)	31.6 (6)	31.6 (6)	5.3 (1)	21.1 (4)	10.5 (2)
Customer value perception (24)	12.5 (3)	37.5 (9)	8.3 (2)	25.0 (6)	16.7 (4)
Cross functional teams (25)	20.0 (5)	28.0 (7)	0.0 (0)	32.0 (8)	20.0 (5)
Concurrent engineering (20)	35.0 (7)	15.0 (3)	0.0 (0)	40.0 (8)	10.0 (2)
Collaborative engineering (21)	33.3 (7)	14.3 (3)	9.5 (2)	28.6 (6)	14.3 (3)
Life cycle cost (15)	71.4 (10)	14.3 (3)	0.0 (0)	7.1 (1)	7.1 (1)
Continuous improvement (45)	11.1 (5)	6.7 (3)	8.9 (4)	40.0 (18)	33.3 (15)
Quality circles (22)	27.3 (6)	0.0 (0)	13.6 (3)	31.8 (7)	27.3 (6)
ISO 9000 (50)	10.0 (5)	10.0 (5)	10.0 (5)	12.0 (6)	58.0 (29)
Just-in-time (JIT) (24)	33.3 (8)	8.3 (2)	8.3 (2)	25.0 (6)	25.0 (6)
Kaizen (27)	33.3 (9)	14.8 (4)	3.7 (1)	40.7 (11)	7.4 (2)
Kanban (28)	32.1 (9)	10.7 (3)	7.1 (2)	42.9 (12)	7.1 (2)
Zero defects (18)	33.3 (6)	11.1 (2)	11.1 (2)	16.7 (3)	27.8 (5)
Lean manufacturing (38)	13.2 (5)	15.8 (6)	7.9 (3)	52.6 (20)	10.5 (4)
QS 9000 (20)	45.0 (9)	5.0 (1)	0.0 (0)	10.0 (2)	40.0 (8)
Six Sigma (13)	61.5 (8)	23.1 (3)	7.7 (1)	7.7 (1)	0.0 (0)
Speed to market (23)	17.4 (4)	13.0 (3)	13.0 (3)	39.1 (9)	17.4 (4)
5S campaign (31)	12.9 (4)	16.1 (5)	16.1 (5)	48.4 (15)	6.5 (2)
Theory of constraints (20)	35.0 (7)	15.0 (3)	15.0 (3)	15.0 (3)	20.0 (4)
Total quality management (17)	29.4 (5)	29.4 (5)	11.8 (2)	17.6 (3)	11.8 (2)
Scientific management (12)	58.3 (7)	8.3 (1)	16.7 (2)	0.0 (0)	16.7 (2)
Time and motion study (16)	43.8 (7)	18.7 (3)	18.7 (3)	18.7 (3)	0.0 (0)
Statistical process control (23)	17.4 (4)	26.1 (6)	4.3 (1)	30.4 (7)	21.8 (5)
Quality function deployment (15)	33.3 (5)	20.0 (3)	13.3 (2)	13.3 (2)	20.0 (3)

Note, Respondents could select multiple improvement programs.

Almost 21% of the total selections were made in the fully applied (implemented) column indicating that many improvement programs are already in use. The most frequently fully implemented improvement programs by percentage were: ISO 9000, QS 9000, continuous improvement, zero defects, and quality circles. Three of these choices are manufacturing related with the other two easily applied to production as would be the case in a tool shop. The next five selections were just-in-time (JIT), statistical process control, cross functional teams, theory of constraints, and quality function deployment. All of these programs had over 20% of their selections in the fully applied column. When viewed in term of the number of selections the order changes somewhat to ISO 9000, continuous improvement, QS 9000, just-in-time (JIT), and quality circles.

The partially applied (implemented) column had the highest number of total selections, just over 28%, revealing the importance of the improvement programs while also signifying that constraints may have limited their full use. Perhaps restrictions due to capital, personnel, and time influenced this alternative. In the partially implemented category, the top selections by percentage were lean manufacturing, 5S campaign, Kanban, Kaizen, and continuous improvement. These improvement programs also reflect an emphasis on upgrading production and quality procedures. These selections were closely followed by concurrent engineering, speed to market, cross functional teams, quality circles, and statistical process control. Over 30% of the selections for each of these improvement programs were in the partially applied column. When arranged by the number of selections the order of these programs changes a little to lean manufacturing, continuous improvement, 5S campaign, Kanban, and Kaizen.

Slightly under 9% of the overall selections were made in the planned for full use column reflecting the lowest number of selections for any column. In terms of planning for full use by percentages time and motion studies, scientific management, 5S campaign, theory of constraints, and quality circles were selected the most. However, these choices all had a much lower percentage of selection than the other four categories. When listed by the number of selections the order is to some extent different with 5S campaign and ISO 9000 tied followed by continuous improvement.

The planned for partial use column accounted for almost 16% of the total selections. The top improvement programs planned for partial use by percentages were customer value perception, value chains, total quality management, cross functional teams, and statistical process control. These selections once again highlight the importance of and focus on quality, efficiency, and customer satisfaction. The order is once again slightly different when listed by number of selections with customer value perception still leading the way followed by cross functional teams. The next three selections lean manufacturing, value chains, and statistical process control were tied. Another tie followed them between ISO 9000, 5S campaign, and total quality management.

The second highest total number of selections, near 27%, was in the considered category suggesting that tool shops are still looking for ways to become more competitive. For those improvement programs being considered life cycle cost, Six Sigma, scientific management, QS 9000, and time and motion studies were most frequently selected by percentage. In this case, the tool shops are considering a variety of improvement programs targeted at different aspects of their business. All are aimed at competitive issues that need to be improved. Over a third of the selections for these five programs were in the considered category. When sorted by the number of selections the sequence shifts slightly to life cycle cost was first followed by a three-way tie between Kaizen, Kanban, and QS9000. They were followed by a tie between just-in-time (JIT) and Six Sigma.

Many of the improvement programs are either being planned or have been applied (implemented) on a partial basis. This indicates that the tool shops have a variety of needs that can only be met by using an assortment of improvement programs. It may also point to other problems that the organization may be facing that would not allow additional resources to be committed to the project.

The impact from the improvement programs that have been partially or fully applied (implemented) is displayed in Table 2.

Table 2
Impact from the Already Implemented Improvement Programs

Implemented improvement program (Number of responses)	Positive impact % (Number)	No impact % (Number)	Negative impact % (Number)
Value chains (11)	63.6 (7)	36.4 (4)	0.0 (0)
Customer value perception (11)	72.7 (8)	27.3 (3)	0.0 (0)
Cross functional teams (14)	85.7 (12)	14.3 (2)	0.0 (0)
Concurrent engineering (12)	58.3 (7)	33.3 (4)	8.3 (1)
Collaborative engineering (12)	66.7 (8)	33.3 (4)	0.0 (0)
Life cycle cost (7)	28.6 (2)	71.4 (5)	0.0 (0)
Continuous improvement (30)	86.7 (26)	6.7 (2)	6.7 (2)
Quality circles (14)	78.6 (11)	21.4 (3)	0.0 (0)
ISO 9000 (38)	65.8 (25)	34.2 (13)	0.0 (0)
Just-in-time (JIT) (14)	50.0 (7)	28.6 (4)	21.4 (3)
Kaizen (14)	64.3 (9)	28.6 (4)	7.1 (1)
Kanban (16)	43.8 (7)	37.5 (6)	18.8 (3)
Zero defects (11)	63.6 (7)	27.3 (3)	9.1 (1)
Lean manufacturing (25)	88.0 (22)	12.0 (3)	0.0 (0)
QS 9000 (11)	45.4 (5)	45.4 (5)	9.1 (1)
Six Sigma (5)	40.0 (2)	60.0 (3)	0.0 (0)
Speed to market (17)	52.9 (9)	29.4 (5)	17.6 (3)
5S campaign (19)	78.9 (15)	21.1 (4)	0.0 (0)
Theory of constraints (12)	58.3 (7)	41.7 (5)	0.0 (0)
Total quality management (11)	45.5 (5)	45.5 (5)	9.1 (1)
Scientific management (7)	28.6 (2)	71.4 (5)	0.0 (0)
Time and motion study (11)	36.4 (4)	54.5 (6)	9.1 (1)
Statistical process control (14)	64.3 (9)	28.6 (4)	7.1 (1)
Quality function deployment (10)	70.0 (7)	30.0 (3)	0.0 (0)

Note, Respondents could select multiple already implemented improvement programs.

More than 64% of the implemented improvement programs had a positive impact, a little more than 30% had no impact, and slightly over 5% had a negative impact. In all but six programs, the positive impact was greater than the no impact and much greater than the negative impact columns. Two of these programs QS 9000 and total quality management had the same number of positive impact and no impact selections. The other four programs scientific management, life cycle cost, time and motion study, and Six Sigma had more no impact selections than positive impact selections. The data indicates that when properly implemented, improvement programs can have a positive impact on the ability of the organization to compete. However, it also indicates that improvement programs are not easy to implement and require support from all levels of the organization.

The programs resulting in the largest positive impact by percentages were lean manufacturing, continuous improvement, cross functional teams, 5S campaigns, and quality circles. When arranged by the total number of selections the order changes a little to continuous improvement, ISO 9000, lean manufacturing, 5S campaign, and cross functional teams. Easily the largest number of selections was given to the first three programs. Together these programs reflect ways to improve manufacturing capability or the quality of the product.

In the no impact category, the top choices by percentages were life cycle cost, scientific management, Six Sigma, time and motion studies, and total quality management. The sequence changes some when listed by the total number of selections to ISO 9000, Kanban, and time and motion studies. These programs all require a commitment of time, personnel, and capital to implement. Inadequate resources may have been assigned to the programs leading to their no impact rating.

Thirteen of the improvement programs had no negative impact at all. This indicated that over half of the improvement programs did no harm and in the majority of cases offered a positive impact. All of the negative impact percentages were significantly lower than the positive impact percentages and much lower than the no impact percentages.

The respondents were given the opportunity to comment on improvement programs they were using along with their impact. They could input what was working for them or what was not working for them along with improvement programs they were either considering or planning to use. These important comments received related to improvement programs and their impact:

1. [We] apply a good amount of the concepts from each but have not fully implemented any one concept itself. Continuous improvement is our company's goal.
2. Many of these relate to larger organizations and may not be cost effective for smaller organizations.
3. There is no impact yet, but positive ones are expected.
4. Quality is a given in the industry that no one is willing to pay for. It is just expected. The improvement will be felt throughout the supply chain when the OEM's include the tool shops in the manufacturability of the part from the beginning, as Honda does.
5. Use of the balanced scorecard approach has resulted in a positive impact for us.
6. We have not received a positive return on investment yet. But we anticipate one in years 2 and 3.
7. The most important thing to understand regarding the American Tooling Industry is one must make a consistent profit.

These comments reflect on partial implementations, the time required before results can be noticed, the cost involved with implementation, and the expectation of positive results. It may take time to see any results from improvement programs as these comments indicate. In addition, for a variety of reasons many programs may be partially rather than fully implemented leading to limited effectiveness.

There is no one dominant solution that can be applied to all American tool shops. Rather a unique solution based on the particular needs and resources of the organization are being used. This is consistent with and reinforces why there are so many ways to improve quality, increase efficiency, and streamline operations as presented in the literature review. However, every tool shop that responded to this survey was actively doing something.

Implementation

During some point in their career, many engineers will become managers. Management expertise is frequently combined with engineering knowledge to solve a variety of business and technical problems by engineering managers. These skills are often used to lead projects, functional departments, and companies in a wide variety of highly technical tasks. Most engineering managers focus on product development, materials management, production processes, and workforce reliability. Management engineers apply engineering principles to the planning and operational management of industrial and manufacturing operations.

The Department of Engineering & Design offers degrees in Electrical Engineering, Computer and Mechanical Engineering Technology, Design, Manufacturing, Applied Technology, and Construction Management. The primary goal is to provide students with the technical background required for successful careers in industry and business. The coursework within each program offers experiences in real-world situations that enhance the preparation of graduates.

Results from this study have already been incorporated into courses that include: Problem Analysis and Design; Machine Tool; Computer-Aided Design; Project Management; Quality Assurance; Engineering Economics; Environmental Engineering; Engineering Ethics, Contracts, and Patents; Industrial Safety Engineering; Computing Systems; Senior Projects; Senior Engineering Capstone; Senior Capstone: Production Laboratory; and Technology in World Civilization; along with the Industrial Internship Program. In addition to textbook knowledge, these courses offer real-world exposure to the field of engineering management along with the skills necessary for graduates to be successful in their chosen career field.

The inclusion of the study's results occurred in numerous aspects of these courses. The textbook readings, lectures, and discussions were modified in order to emphasize the findings from the study. In addition homework assignments, case studies, and real world experiences derived from the study were included as individual or group exercises.

Homework assignments, specific to the material covered in each course, were developed to directly apply improvement programs to what the students were studying. Many of these problems were developed to match actual events that were occurring in the manufacturing and production sector. These exercises provided an immediate avenue for the direct application of the topics under consideration.

Case studies were also developed to put the student into a real-world situation where they have to use what they have learned to resolve the problem or issue. In each case, the students are to apply their knowledge of improvement programs to the assigned projects and case studies; then analyze their effectiveness, suggest improvements, and implement them. Additional case studies were developed from the study's findings and used as an integral part of the lecture and discussion sections of the courses.

A slightly different approach was used to apply the knowledge obtained from this study in the Industrial Internship Program. In this case, the students are asked to examine the improvement programs currently utilized by their employer. Then analyze their effectiveness, recommend changes or enhancements, and if practical implement them. A final report is required that reviews the effectiveness of the improvements made in comparison to what was previously used. This real-world use of the students engineering knowledge has encouraged the managers of these companies to implement new types of improvement programs. The results from these improvement programs have been relayed back to the department by the student's engineering manager in both emails and letters.

These assignments and case studies add a real-world aspect to the student's textbook and classroom studies. The study and application of improvement programs better prepares students for the challenges they will face during their professional careers. In addition, this experience will enhance the ability of their future companies to compete in today's global economy.

Conclusions

When reviewing 24 classical improvement programs (Table 1) the 94 responding tool shops made 566 selections. The number of programs selected by each tool shop ranged from a low of one to a high of eight. Some of the tool shops have already considered, planned, or applied all of the choices. ISO 9000 led all selections by sheer number as would be expected in a manufacturing environment. ISO 9000 was the most frequently fully implemented program followed by continuous improvement and QS 9000. All of the most frequently fully implemented programs were manufacturing or production related. This follows since tool shops are industrial concerns focusing on producing a product and anything that can enhance that capability improves their ability to compete. Lean manufacturing was the top choice for partial implementation. Few selections were under the planned for full use category while selections highlighting quality, efficiency, and customer satisfaction led the planned for partial use responses. Improvement programs under consideration all dealt with competitive issues that needed enhancement. However, it included only planned or partial implementations of most programs.

The impact from the already partially or fully implemented improvement programs was largely positive (Table 2). The negative impact percentages were small indicating that the majority of tool shops received no harmful results from their implementation. By the total number of selections continuous improvement, ISO 9000, and lean manufacturing returned the most positive impact. Seventeen of the 24 programs received a positive impact percentage of 50% or more. Most frequently selected, as having no impact by percentages were life cycle cost and scientific management. Just-in-time, Kanban, and speed to market had the highest percentages of negative impact. However, improper preparation or poor implementation could have skewed the results.

Important comments from the respondents concerned already implemented improvement programs. They emphasized that the impact from these improvement programs take time, many of these programs target larger organizations, and partial implementation may be the norm. Perhaps the most pointed comment was that "tool shops must make a consistent profit no matter what they do."

Combining all of these conclusions, actions have been taken by the American tooling industry to improve quality (even though it is a given today), increase efficiency (with new machines and technologies), and streamline operations (by cutting costs, and speeding up processes) to enhance its competitive position. More changes and actions to enhance manufacturing capabilities and financial controls occurred than with traditional improvement programs. This is understandable since the results are immediate and easily monitored. Traditional improvement programs take more time, perhaps even years, for results and many tool shops cannot wait, they need to see and obtain the results now. New machines and technologies are automating processes streamlining operations and cutting costs while offering a rapid return on investment for American tool shops.

The findings from this study have been utilized to enhance and focus the educational experience for engineering and engineering technology students on the management aspects of engineering. Added emphasis on the improvement programs successfully being used by manufacturers has been included in many engineering courses. It is also stressed that total implementations of improvement programs are not always necessary, but partial implementations spotlighting specific areas of concern are also very effective. The overall goal is to graduate engineers that are prepared to face the engineering management challenges of a continually changing manufacturing environment.

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