An Evaluation of Continuous Improvement Methodologies and Performance

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ABSTRACT

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Continuous Improvement (CI) can be described as a culture of sustained improvement targeting the elimination of waste in all systems and processes of an organization. Organizations face fierce competition, and in order to enhance their reach in today's markets, they need to maintain a low cost of quality, reduce waste, trim their production lines, and speed up manufacturing. Over the past few decades, comprehensive methodologies that include tools to help firms achieve CI in a systematic fashion have evolved. Not all CI methodologies are applicable to every organization: one may suit a particular organization better than others, and in what respects is not always clear, as no detailed research has been conducted in this area. This thesis therefore concentrates on describing and comparing CI methodologies. It starts with tracing the history and evolution of CI, from the earliest initiatives to modern CI programs, to hybrid methodologies that have developed in recent years. Modern CI trends are studied, and a comprehensive study of the various CI methodologies that are available on the market is undertaken, including Lean Manufacturing, Six Sigma, Balanced Scorecard, and Lean Six Sigma, and a newer methodology known as Achieving Competitive Excellence (ACE^{TM}). Furthermore, a computer-based model has been developed to help organizations select the best CI methodology to implement in order to best achieve their goals.

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I also thank my parents and my friends who have helped and supported me during my Master's study.

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1. INTRODUCTION

1.1 Continuous Improvement

Continuous Improvement (CI) is a philosophy that Deming described simply as "Improvement initiatives that increase successes and reduce failures" (Jergensen, 2000). Another definition of CI is "a company-wide process of focused and continuous incremental innovation" (Bessant and Caffyn, 1994). Yet others view CI as either as an offshoot of existing quality initiatives like Total Quality Management (TQM) or as a completely new approach towards enhancing creativity and achieving competitive excellence in today's market (Oakland, 1999; Caffyn, 1997; Gallagher et al., 1997). Kossoff (1993) states that "total quality is defined as the unrelenting pursuit of CI which is realized by accessing and utilizing the concerted knowledge and experience of managers and employees at all levels".

CI, also known as the Japanese term *kaizen*, can be defined more generally as a culture of sustained improvement targeting the elimination of waste in all systems and processes of an organization. It involves everyone in an organization working together to make improvements without necessarily making huge capital investments. CI can occur through evolutionary improvement, in which case improvements are incremental, or through radical changes that take place as a result of an innovative idea or new technology. Often, major improvements take place over time as a result of numerous incremental improvements. Improvement on any scale is achieved through the use of a number of tools and techniques dedicated to searching for sources of problems, waste, and variation, and finding ways to minimize them.

Organizations today are increasingly competing for market share, and in order to enhance their reach in today's markets, they need to maintain a low cost of quality, reduce waste, trim their production lines, and speed up manufacturing. Much of this can be achieved by implementing CI methodologies. The major CI initiatives are Six Sigma, Lean Production, TQM, Balanced Scorecard, Lean Sigma, Reengineering, Quick Response Manufacturing and a new methodology developed by Pratt & Whitney Canada called Achieving Competitive Excellence (ACE™). In this thesis, the focus will be on Six Sigma, Lean, Lean Six Sigma, Balanced Scorecard, and ACE™.

CI methodologies have evolved from traditional manufacturing focused systems that concentrate more on the production line to reduce waste and improve the product quality, into hybrid methodologies that focus on all aspects of an organization, whether service or manufacturing. Modern CI methodologies (also called CI programs or tools) target a wide range of aspects of the organization and offer various benefits. Not all are applicable to every organization: the one that suits a particular organization better than others, and in what respects, is not always clear, as no detailed research has been conducted in this area. This thesis therefore concentrates on comparing these methodologies in both a qualitative and quantitative manner.

1.2 Objectives of the Thesis

In this thesis, the history and evolution of CI will be traced, from the earliest CI initiatives to modern CI programs, to hybrid methodologies that have developed in recent years. The modern trends of CI will be studied, and the tools currently used by organizations will be compared and contrasted. The thesis undertakes a comprehensive study of the various CI methodologies that are available on the market, including Lean

Production, Six Sigma, Balanced Scorecard, and Lean Six Sigma, and contrasts and compares each for their strengths, weaknesses, and their applicability to various businesses. A newly emerging CI methodology called Achieving Competitive Excellence (ACE™) will also be introduced and contrasted to the more well-known methodologies listed above. Furthermore, a strategic planning tool has been developed to assess the quantitative and qualitative needs and benefits of implementing each of the above CI methodologies. With various methodologies available to organizations, it is important, when deciding on which one best suit the needs of an organization, to have a clear and accurate view of the resources required and the benefits each offers. This tool will help organizations determine the requirements associated with the implementation of each the various methodologies.

1.3 Research Methodology

The research presented in this thesis was conducted in three parts. First, an extensive literature review was undertaken on CI research and CI methodologies. As part of the review of CI, a case study was conducted at an aerospace company, in which new CI methodology called Achieving Competitive Excellence (ACE™) was studied and compared to existing CI methodologies. Next, a survey was conducted on small, medium and large companies throughout Canada and the United States, in both the manufacturing and service sectors, in order to study CI implementation in practice. Finally the survey was used in guiding the development of a CI implementation model. The model incorporates important factors that can affect the overall outcome of CI implementation, such as the objectives, tools, resources and time. Based on an organization's objectives, the model can provide the user with the tools, resources and time required to achieve them successfully, and furthermore identify the most appropriate CI methodology for the organization.

The thesis is outlined as follows. Discussion on the existing research and the need for research in the field of CI is addressed in the next chapter. Chapter 3 gives a detailed account of the advantages and uses of CI. Chapter 4 focuses on the various CI tools, techniques and systems available to the industry today. In Chapter 5, the evolution of CI is tracked from its beginnings to the current CI methodologies such as Lean, Six Sigma, Balanced Scorecard, Lean Six Sigma and ACE™. Data collected through the questionnaire is analysed in Chapter 6 and Chapter 7 concludes the thesis and provides future avenues of research related to the thesis.

2. LITERATURE REVIEW

2.1 Introduction

The literature shows that there exists no theoretical basis for CI (Savolainen, 1999). CI tends to be used as an umbrella term that has acquired many of its attributes from other quality initiatives such as TQM and Lean Production. While valuable research has been conducted on CI (Bessant et al., 1994; Bessant and Caffyn, 1997), more perspectives are required (Gilmore, 1999).

CI programs were initially developed in organizations with product-focused processes or repetitive processes, i.e., with relatively high standardization of products and processes. Special teams were organized to work on improvement tasks, which were separate from their typical organizational tasks. Berger (1997) suggests that improvement tasks can be integrated into the regular work of individual employees.

Lillrank and Kano (1989) refer to *kaizen*, the Japanese term for CI, as the "principle of improvement"; however, the Japanese Union for Scientists and Engineers (JUSE) literature does not clearly define kaizen, but uses it to define other concepts. While the term *kaizen* is often considered synonymous with CI, Imai (1986) proposes that there exist at least three types of *kaizen*: management-, group-, and individual-oriented *kaizen*. Management oriented Kaizen is considered to be the most important one as it focuses on the company strategy and involves everyone in the company. Group-oriented kaizen is best represented by Quality Circles, which require employees to form a team or a circle with the goal of finding and solving problems faced during their day-to-day work without any interference from the management. Individual-oriented kaizen is derived from the concept of bottom-up design, in which the worker makes a recommendation to the problem faced. This has been very successful in the Japanese industry since it is the worker who is on the shop floor and typically knows the best solution to an existing problem. Certain industries even have incentive programs where, depending on the problem and the solution provided, the worker is rewarded, thus encouraging the workers to concentrate on problem areas and find the best solution.

Lindberg and Berger (1997) have studied the applicability of CI in various types of organizations. The authors found that a number of Swedish organizations with a relatively low degree of standardization of products and processes had successfully integrated CI in work teams. The main thrust of the study was to emphasize the fact that in the traditional Japanese industries, kaizen improvements were being achieved by running the kaizen activities parallel to the regular work of the employees, which was in total contrast to the concept followed by organizations in Sweden, where CI was integrated into the regular work routines. The parallel structure does have some advantage as it leads to interdepartmental collaboration but it also leads to higher administrative costs (Krishnan et. al., 1993).

Berger (1997) suggests that depending on product design and process choice, CI must be adapted to the degree of standardization involved. The implication is that CI programs can be applied to different types of work environments. The authors present a typology of organizational designs for CI based on two dimensions: Basic Task Design (where the two forms of this dimension are individual vs. group tasks) and Improvement Task (parallel vs. integrated). Basic Task Design is reliant on the work process and product standardization: within this dimension, group tasks are more common in places with a low degree of standardization whereas individual tasks are prevalent in places that have high product standardization systems. In a highly standardized production system, the improvement task is the responsibility of an individual who might be a professional from engineering, quality, etc., and is qualified and trained in the improvement activities. In case of production systems with low degree of standardization, there is no resident expert who takes care of improvement but teams consisting of ordinary employees try to carry out improvement activities within their work groups. An Improvement Task deals with the different levels of integration as can be seen in Figure 1, in which improvement activities are separated from ordinary work and they run parallel to each other, also known as Parallel Tasks. An Integrated Task is one in which improvement activities are embedded as part of the everyday activities of the employee.

IMPROVEMENT TASK

		Parallel: **Improvement separated from ordinary tasks**		**Integrated:** **Improvement as one of the ordinary tasks**
BASIC TASK DESIGN	**Group Task**	**QCC**	**Wide-Focus CI**	**Organic CI**
	Individual Task	**Expert task-force CI**		**Individual CI**

Figure 1: A typology for organizational design for CI. (Berger, 1997)

Berger's typology presents five organizational designs based on the two dimensions:

1. Quality Control Circles: a group of people in the staff who meet regularly to discuss problems and issues related to quality so that they may examine them and come up with solutions.
2. Wide-focus CI: a blend of Organic CI and Expert task force CI. It is used for temporary operations and for CI in self-managed work groups by combining continuous improvement process teams (Phillips, 1994).
3. Organic CI: multifunctional work groups are integrated with improvement activities. Organic CI is different from other CI models since the improvement activities are not left to the experts for design and planning and the decision-making is not left to the authorities outside the group.
4. Expert task force CI: this form of CI is based on the reliance on temporary expert task force consisting of professional from quality, engineering and maintenance and therefore the span of improvement tasks requires considerable time and investment.
5. Individual CI: improvements are set off by individuals and generally organized in the form of a suggestion system. Individuals come up with ideas and the implementation of the ideas is left to the specialists.

The CI capability model (Bessant & Caffyn, 1997), developed at CENTRIM at the University of Brighton in the UK, provides a powerful outline and arrangement for evaluating the usefulness of CI implementation. The authors present a framework with suggested routines and behaviours needed to successfully implement CI, and the characteristics needed by companies to develop CI capability. According to Caffyn

(1999), CI capability can be defined as "the ability of an organization to gain strategic advantage by extending involvement in innovation to a significant proportion of its members". It comprises a set of ten generic CI behaviours that are seen as essential fundamentals in organizations of all types and sizes:

1. Employee demonstrates awareness and understanding of the organization's aims and objectives.
2. Individual groups use the organization's strategic goals and objectives to focus and prioritize their improvement activity.
3. The enabling mechanisms (e.g. training, teamwork) used to encourage involvement in CI are monitored and developed.
4. Ongoing assessment ensures that the organization's structure, systems and procedures, and the approach and mechanism used to develop CI, constantly reinforce and support each other.
5. Managers at all levels display active commitment to, and leadership of, CI.
6. Throughout the organization people engage proactively in incremental improvement.
7. There is effective working across internal and external boundaries at all levels.
8. People learn from their own and from other's experience, both positive and negative.
9. The learning of individuals and groups is captured and deployed.
10. People are guided by a shared set of cultural value underpinning CI as they go about their everyday work.

It has been found out through research that some of these behaviours might be difficult to practice because firms might find it difficult to break the traditional mindset and encourage their employees to adapt to these new mindsets. However, in order to sustain such behaviour amongst all employees, this model identifies the requirement for a subject set of CI enablers such as facilitators, recognition systems or company procedures and company policies, which are meant to advance the required CI behaviour, but need to be monitored and developed over a period of time.

Michela et al. (1992) have found that there exists a close link between CI and quality in their survey of the literature. Imai (1987) defines Total Quality Control (TQC) as "organized kaizen activities involving everyone in a company- managers and workers, in a totally integrated effort toward improving performance at every level". The link between CI and quality has been expressed by Berger (1996), who asserts that CI "should rightfully be regarded as a general development perspective, applicable with or without the context of TQM". From the large number of researchers who associate CI with quality, and from the mere implication that CI seeks to improve, it appears that the link between the two is clear, in some form or another.

The Saturn automobile company since its foundation in the 1980's has been following CI and other quality principles such as Just-In-Time (Doyle, 1992) and according to J. D. Powers & Associates, a leading marketing information services firm, Saturn automobile company topped the survey on customer satisfaction[1]. This was due to the fact that all the major functions of the organization, from design, to engineering, to marketing, were responsible for this achievement. The focus on process improvement and quality improvement sought after by Saturn to achieve high levels of performance highlighted the notion that CI and quality are not that different from one another, and that, furthermore, if there was a boundary between the two, it was getting thinner due to

[1] Financial Post Daily, "Saturn wins in customer satisfaction – JD Power & Associates survey"

the increased use of both CI and quality programs by the organizations and the benefits they yield.

Khusrow (2001) proposed a framework comparing seven major performance improvement programs: Total Quality Management, Six Sigma, Reengineering, Quick Response Manufacturing, Agility, Variance Reduction, and Lean Production. He found that Lean Production was the CI program of choice in the industries surveyed. However, his comparison was done specifically for the aerospace industry. If other industries are to be considered, the results would likely vary since the mandates of each organization is typically different.

Toyota, since the 1960's, has pioneered a manufacturing system called the Toyota Production System (TPS), but Womack, Jones and Ross introduced Lean Production as a synonym for TPS to the rest of the world in their 1991 publication "The Machine that Changed the World". Womack and Jones (1991) describe Lean thinking as the "antidote" to *muda*, the Japanese term for waste. Lean Production applied correctly, results in the ability of an organization to learn. Mistakes in the organization are not generally repeated because this in itself is a form of waste that the Lean philosophy seeks to eliminate (Robinson, 1990).

According to the $US5 million study done by Womack and Jones, the Japanese manufacturers were twice as effective as their US and other Western counterparts and they determined that the three principles of Lean Production (Womack et al., 1990; Womack and Jones, 1996) are:

1) improve flow of material and information across business functions;
2) focus on pull by the customer;

3) commitment of organizations to continuous improvement.

Karlsson and Ahlstrom (1996) of the Stockholm School of Economics developed an operationalized model to assess the changes taking place in an organization when going through the process of implementing Lean Production. The model operationalizes the determinants of a Lean Production system; the outline of the model is shown in Figure 2. In order to become Lean, the organization has to make an effort to measure the progress made.

Determinant	**Measurement**	**Lean**
Theoretically derived indicators lying behind the principles of Lean production	Operationalized indicators that have been found to be suitable for use in assessing changes towards Lean production, in an empirical case	Indicate the desired direction of the indicators. If moving in a lean direction: ⇗ Should increase ⇘ Should decrease ⇧ Practice should change in this direction

Figure 2: Outline of the model for assessing changes towards lean production (Karlsson and Ahlstorm, 1996).

According to the study done by Karlsson (1992), Lean Production consists of a number of different functional areas. These functional areas are shown in Figure 3.

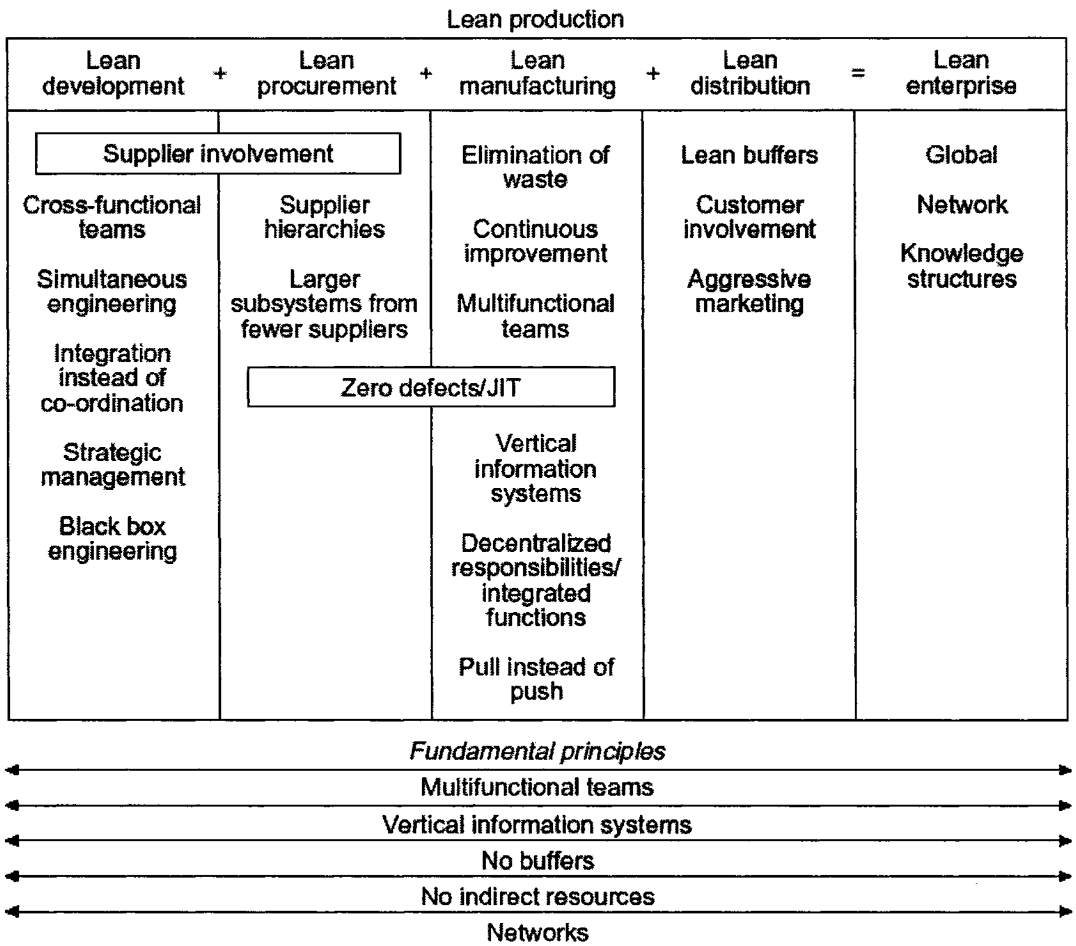

Figure 3: Conceptualization of Lean Production (Karlsson and Ahlstorm, 1996)

In their study, Karlsson and Ahlstorm (1996) focused more on the manufacturing aspect and on the functional area – Lean Manufacturing. The operationalized indicators for Lean Production found to be useful in achieving change are listed below.

- Elimination of Waste – Everything that does not add value to the product (Monden, 1983).
- Continuous Improvement – In the words of Imai (1986), "ongoing improvement involving everyone".

- Multifunctional Teams – A team composed of individuals who are capable of performing a number of different activities effectively.
- Zero Defects – Get the systems error free and stop defects from occurring by discovering errors that could lead to defects (Oakland, 1993).
- JIT – Each process should be provided with the right part, in right quantity and exactly on time (Shingo, 1981).
- Vertical Information System – To provide continuous information to the employees directly in the production flow. (Karlsson and Ahlstorm, 1996). These are very essential for the success of Multifunctional teams.
- Integrated Functions – Various tasks performed previously by different departments are joined, to be performed by the individuals in the Multifunctional Teams, thus increasing the work content of the team and reducing the number of employees in other departments.
- Pull not Push – Provide the product and services only when the customer requires them.

One of them, in the view of Bartezzaghi (1999), is the definition of Lean Production, which is still not very clear. In an effort to address this, Karlsson and Alsthrom (1996) have defined 19 elements as shown in Figure 3 to define Lean Production.

In the 1980's electronics' giant Motorola went about on a mission to improve its services and products considerably in a span of five years, and to achieve its goals, a program called Six Sigma was launched in 1987. Six Sigma was a program that would focus on reducing variation in all the processes of the organization. The name Six Sigma was chosen to represent the statistical name "sigma" which is a measure of the process variation, where Six Sigma signifies the occurrence of defects at the rate of 3.4 defects per million opportunities. Motorola achieved amazing results through the application of Six Sigma, from 1987 to1997, achieving a total savings of $US 14 billion while sales enjoyed a fivefold growth during the same period (Klefsjo et al., 2001). A number of top organizations such as GE, ABB, Honeywell, Sony, Honda, and Ford have followed Motorola's lead and have been using Six Sigma to achieve business excellence.

Many in the field of CI have believed that Six Sigma is not new and has been around for some time. Reed (2000) states that Six Sigma "has been around for many years, just called something else", while Carnell and Lambert (2000) believe that Six Sigma is a tool used to improve the operations within the organization. According to Edgeman (2000), operational excellence is required in order to achieve the overall Business Excellence. Snee (2000) stated, "Six Sigma should be a strategic approach that works across all processes, products, company, functions and industries".

After the apparent benefits of Lean and Six Sigma were brought to the attention of the business world, there were a number of big conglomerates that had implemented both Lean and Six Sigma to attain business excellence. To get a bigger share of the market, they developed a new methodology called Lean Six Sigma, sometimes called Lean Sigma. Since, Lean Six Sigma is a relatively new methodology, and as such, has not been studied in great detail. Some organizations have been using both methodologies parallel to each other for years while some have focused on just Lean Six Sigma as a single methodology for improvement. Michael L. George has been credited with bringing Lean Six Sigma to the attention of the quality professionals and academic circles through his 2002 publication "Lean Six-Sigma Combining Six-Sigma Quality with Lean Speed". Lean Production and Six-Sigma individually cannot achieve the required improvements at the rate at which "Lean Six Sigma", the new hybrid of the two, can, when it comes to customer satisfaction, cost, quality, process speed and invested capital.

In the early 1990's Robert Kaplan and David Norton developed a methodology that translates the objectives of the organizations into measures, goals and initiatives in four different perspectives namely Financial, Customer, Internal Business Process and Learning and Growth. This methodology became to be better known as the Balanced Scorecard. Niven (2002) sees Balanced Scorecard shown in Figure 4 as a combination of three elements; measurement system, strategic management system, and a communication system.

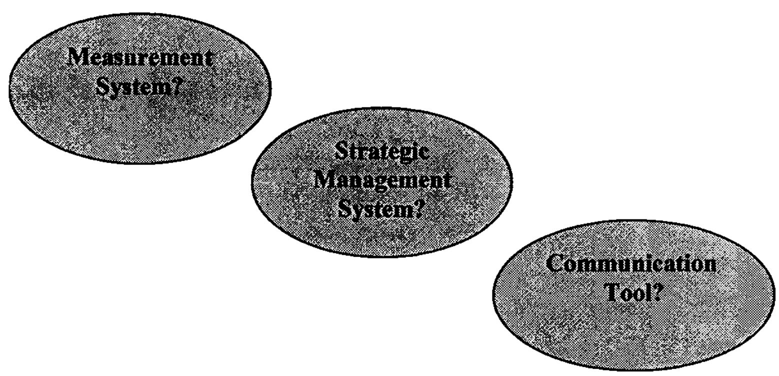

Figure 4: What is a Balanced Scorecard? (Niven, 2002)

Measurement System – Balanced Scorecard helps the organization translate its vision and strategy through the objectives and measures defined rather than stressing on financial measures which provide little guidance. According to Gaplin (1997) "measurable goals and objectives" is one of the most important factors to a successful strategy.

Strategic Management System- Balanced Scorecard helps organizations align short-term actions with their strategy and thus removes barriers towards organizations strategic implementation in the long term.

Communication Tool – Balanced Scorecard describes the organization's strategy clarifies and brings it to the average employee. Employees, once aware of the organization's strategies, can contribute towards the overall goal (Niven, 2002).

2.2 Summary

CI methodologies have evolved from traditional manufacturing-focused systems that concentrate on the production line to reduce waste and improve the product quality, into hybrids that also focus on the organization. It has become clear that without the active involvement of the people, CI in any organization cannot be successful. Large organizations are developing their own CI methodologies to fit their own needs by encompassing the various tools and techniques of individual methodologies. This signals the need for hybrid methodologies. While CI has evolved over the decades, the basic underlying factor driving this change has been the endless pursuit of organizations to improve.

2.3 Need for Research

Although much research has been conducted on the individual CI methodologies and assessment tools have been developed to determine the progress of the CI initiative, to the author's knowledge, little focus has been directed towards developing a framework or model that would enable an organization to identify the CI methodology that best suits its needs. Once an organization has decided to initiate CI, how does it select the most appropriate CI methodology? The organization has to consider a number of deciding factors, which can affect the overall outcome of the CI implementation. These deciding factors can be broadly classified into organizational objectives, tools used, capital, resources and timeline for implementation. Thus, the issue that needs to be addressed is how to determine the appropriate CI methodology for an organization to implement and what are the tools and techniques that need to be deployed to achieve successful implementation. Furthermore, there is also a need for research in the field of the hybrid CI methodologies that have been developed in the recent past and to determine their applicability to various organizations.

3. CONTINUOUS IMPROVEMENT PROGRAMS

3.1 Introduction

Continuous improvement programs are widely implemented in both manufacturing and service organizations. Over the years, these programs have been recognized as contributing greatly to improvements in a firm's products and processes. Firms should view the implementation of CI programs as a dynamic process whereby organizational participants evolve with the environment, and improve in response to it. Often, this ongoing process of improvement is represented by Shewhart's Plan-Do-Check-Act cycle, or by variants of this cycle, as suggested by Caffyn (1999) in Figure 5. Essentially, all cycles or processes begin with an exploration phase, in which a problem area is sought out. Various alternative methods to resolve the problem are identified, of which one is chosen for implementation, the results of the implementation are gauged and reviewed, and then the cycle is repeated for the same and/or other problems.

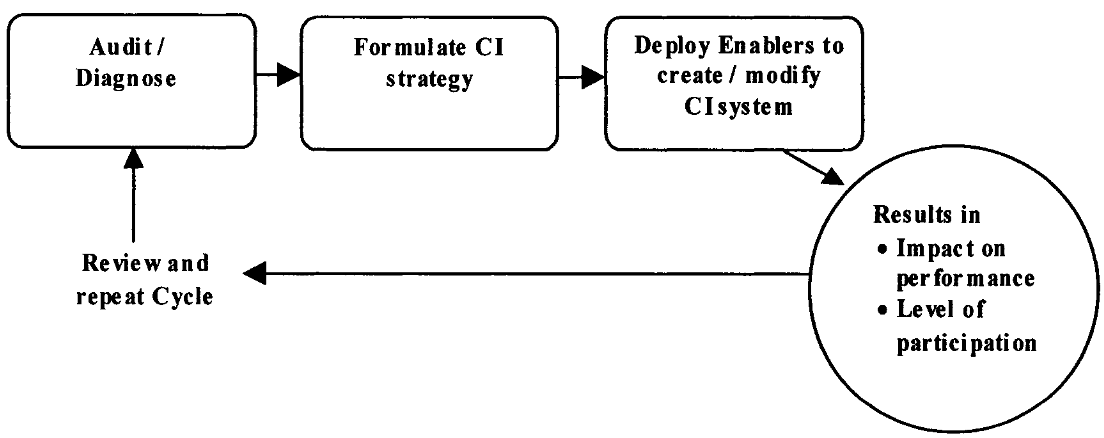

Figure 5: Continuous Improvement cycle (Caffyn, 1997)

Traditionally, CI teams were organized to deal with improvement as a task separate from the regular organizational tasks, and a variety of tools and techniques have been developed to support CI implementation, as for example, Quality Control Circles (QCCs) and employee suggestion systems. Since the employees of an organization are an essential part of any improvement initiative, they serve as critical contributors of CI success, rather than simply as vehicles for using the tools and techniques. In addition to the process, the people, the tools and techniques, organization enablers, as for example, managerial style, commitment, and involvement, available resources, and employee needs, must be also considered in order for CI implementation to work. In other words, an approach that integrates all essential elements in an organization is needed (de Leede and Looise, 1999).

According to Michela et al. (1996), the major elements of modern-day CI programs can be described as follows:

1. Understand and document the process:
   - Identify value-added versus non-value-added activities;
   - Analyze cost, quality, and other relevant measures for equipment, labour, and material inputs.
   - Something about documenting it through charts or tables or in written form etc. should be here
2. Simplify and improve:
   - Reduce, combine or eliminate activities;
   - Improve the performance of equipment, labour, and material inputs with respect to cost, quality and other relevant criteria;

- Implement low grade (incremental) automation;
- Revise business rules as needed.

3. Standardize and integrate:
   - Something about standardizing
   - Reintegrate remaining activities;
   - Stabilize the process at its new level.
4. Monitor performance:
   - Measure and monitor;
   - Set new targets.

These elements closely resemble the improvement processes described earlier, for example, the PDCA cycle. Given these elements, according to Webster (1999), "any approach must be tailored to the particular organization with its own specific history, tradition, values, culture, etc. and particularly to its own mission and place in the marketplace". This list provides the kind of work the employee must do and the kind of skill they may need for CI. The list also indicates the kind of understanding that the employees need in order to participate in a CI initiative.

Berger (1997) summarizes the principles of CI in three parts: process orientation, small step improvement, and people orientation. Table 1 describes them in more detail.

Table 1: *Kaizen* principles, management concepts and practical features (Berger, 1997)

Core principles	Management and improvement steps	Practical outcomes
Process orientation	Process control through process support and evaluation	Training the workforce in simple methods and use existing skills and experience Efforts are emphasized and encouraged while results are rewarded
Small step improvement	Extensive use of standards (Standard Operating Procedures) as the base for improvement Separate the task of improving and the task of maintaining standards	Discipline required to maintain standards Focus on improving own work standards using a common problem-solving format – PDCA Broad participation using permanent or temporary groups for problem solving in parallel structures (QCCs and teams) Individual suggestion systems for training and motivation
People orientation	Active management support and involvement "Mandatory volunteerism", i.e., management policy to join but contributions based on volunteerism	

The process orientation principle states that processes need to be improved before results can be improved, and suggests that organizations must shift from being goal-oriented to process-oriented if any lasting improvements are to be sustained. The small step improvement principle suggests that standards, and adherence to them, are necessary for improvement. Standards provide the benchmark against which improvements can be measured. Finally, the people orientation principle is the well-known principle that people are at the heart of CI programs.

3.2 Advantages and Uses of CI

There is no panacea or "magic bullet" to achieve CI (Webster, 1999). The results of improvement efforts are not always immediate and all encompassing. Although CI can help organizations solve many of their process and quality related problems, it is a process of incremental steps in which micro improvements are achieved, though not always evident, while macro results are more evident over a prolonged period. According to Walden (1993), "Continuous Improvement does not mean only repeated small improvements. Continuous Improvement means repeated improvements of any size". Regardless of the size of the steps and/or improvements, the uses of CI are many and CI has both advantages and disadvantages. In what follows, the advantages and uses of CI are discussed from the point of view of the organization, people, products and processes, and customers.

3.2.1 Organization

Uses: Continuous improvement initiatives are used with the intention of leading to a company-wide focused approach, whereby management looks at a broader picture of maintaining organizational growth, employee empowerment, and environmental, health and safety factors. It is essential that top management supports the whole initiative for CI; the thrust has to come from the top. Once management is involved, the employees will follow. These initiatives, once implemented, have a varying effect on the organization.

Advantages: According to the study by the Federal Office of Regional Development in Québec, CI leads to greater decentralization and improves the ability of management's decision-making by allowing the employees to come up with suggestions and possible solutions to problems. It allows for a smoother work environment as the procedures and methods are standardized which in turn lead to a better quality of life for the worker in the workplace.

Disadvantages: The results of CI in some cases might be slow and due to this, management might decide to abandon the CI initiative thinking it is a waste of time and money. Another important concern is the high investment both in terms of capital, such as restructuring costs, licensing costs, hiring consultants, and resources that might be required if the whole organization pursues CI.

3.2.2 People

Uses: One of the major evolutions that have taken place in CI has been the concentration on a people-centered approach, which suggests that it is necessary that the employees of an organization wholeheartedly follow the CI initiative. People are an integral part of any CI initiative (Jergensen, 2000). It has become clear that without their active involvement, CI in any organization cannot be successful. As Jergensen suggests, "Continuous improvement comes only from people - people learning things they can learn, solving problems they can solve, implementing improvements they can implement".

Advantages: CI leads to a greater interaction between management and the workers since a good CI program requires total employee involvement and their support. It requires that employees be creative and come up with suggestions and new ideas to improve the working condition. Other advantages include continuous staff development as a result of the CI trainings and most importantly a satisfied employee.

Disadvantages: Some of the drawbacks of implementing CI are the extra pressure and work load on the employees. The employees would need to put in extra work hours just to keep up with the CI demands. On the other hand, if implemented properly, CI is expected to make processes more efficient and therefore lead to a reduction in the workforce, as the resources required to do the same job would go down.

3.2.3 Products and Processes

Uses: Products and processes are the main factors for which the CI initiatives are put in place: better product quality and smoother processes are the desired goals in any manufacturing or service company.

Advantages: CI results in an increase in the consistency and enhances the conformity of products and processes. It supports innovation and creativity, as all the employees are encouraged to be creative and try new ideas and the most important of all it reduces the cost of non-conforming and warranty costs items, as high quality is maintained starting from the design stage though to the final sale.

Disadvantages: The capital and resources that are required in improving the process flow from the existing system can be high. For example, companies might need to rearrange the heavy machinery in the shop floor to get the best flow, follow total preventive maintenance, and clean the shop floor to be in accordance with the CI guidelines. All this might require extra labour time and cost as well.

3.2.4 Customers

Uses: CI can be used to achieve higher customer satisfaction. Customer satisfaction is the ultimate goal for any organization. A CI program's goals are to develop defect-free products with shorter lead times, resulting in a customer fit product with on time delivery.

Advantages: Achieving the goals of CI would lead to better relations with the customers. It would lead to a faster response time as the processes are documented and in place. The employees know and are trained to take care of the requirements and what the expectations are. A well-tuned organization with less waste, high quality and smooth process would in turn lead to lower prices, customer satisfaction, and increase in customer base.

Disadvantages: Some weakness of a CI initiative in relation with the people would be the increased expectation of the management from each employee, increase in the workload of the employee by having to maintain CI policies and processes. But overall the benefits of CI outweigh the drawbacks in the long-term.

3.3 Summary

Severe competition has forced organizations to take up the task of improving continuously, often simply to survive on the market. As seen in this section, CI has its advantages and disadvantages, but it can have a positive affect on several aspects of an organization, from the people to the products and processes to the final customer. In order to achieve this, CI programs must be implemented with the correct attitude and procedure.

4. CI TOOLS, TECHNIQUES, AND SYSTEMS

4.1 Introduction

In today's business setting, firms are constantly looking for continuous improvement in the products and services which they offer and the ways in which they produce them. These may come through the rare breakthrough innovation, or through the more typical incremental improvements. Regular change is crucial, not just to remain competitive but often for the survival of business. CI involves gradually building up skills and capabilities within the organization to find and solve problems. There are a number of tools and techniques available to help enable the process of improvement.

CI tools (also known as Continuous Quality Improvement, CQI tools) are those which are primarily used by the change agent or the person responsible in a group of an organization to detect a problem, its source, and to provide a feasible solution for the problem. CI techniques (also known as CQI techniques) are generally used for quality improvement, but they are different from CI tools in that, they do not cater to the quantitative issues, but are more focused on planning and control (Mears, 1995). CI systems (also known as quality systems) are put in place to help the organization deliver the products and services that the customer wants. These systems involve the whole organization and once they are put into place, they are prevalent for a number of years and the whole organization is then structured to run accordingly. They require much commitment and financial backing from management.

4.2 Links of CI and Quality

Quality is a never-ending pursuit for perfection and CI is a never-ending attempt to discover and eliminate the core causes of problems so they are both the same thing? Quality is an important part of the macro view of CI. In order to achieve CI, certain quality improvement tools are available. These are described below.

4.3 CI Tools

There are a number of tools that can be used to detect and solve a problem; it is up to the person in charge of CI in the organization, or the change agent to select the right tool for the study. Some of the tools mentioned below are sometimes also referred to as TQM tools; this is also true since CI can be considered to be a part of TQM. Some of the most commonly used tools in CI are discussed below.

4.3.1 The Seven Quality Improvement Tools

The production environments today require modern quality improvement methods that are a little complicated and require technical understanding, and to compete successfully in today's market, it has become increasingly important to incorporate quality into every management decision. The seven tools, referred to as the Seven Quality Improvement Tools, are aimed to help management achieve precisely this. They are described briefly below.

1. Checksheet - The purpose of a checksheet is to present information in an efficient, graphical format. This may well be accomplished with a straightforward catalogue of items, but the usefulness of the checksheet may be extensively improved by incorporating a representation of the system under study.

2. Flowchart – A flowchart is a graphical representation of a process. An entire procedure can be broken down into individual steps and in doing so each step can be studied in detail.

3. Histogram - A histogram or a bar chart as it is also called, is used to display the distribution and variation for a measure of some sort (Rolstadas, 1995). The graphic representation makes it easier for the user to comprehend the data.

4. Control Chart – The Control Chart is the most basic from of Statistical Process Control (SPC); it indicates the common cause variation or the range of variation that is acceptable for a process. It helps in identifying if the process is under control or not.

5. Pareto Chart – Pareto Charts provide facts which are used in setting priorities. It is used to organize and display information to show the relative importance of various problems or causes of problems. It is a form of a bar chart which puts items in order (highest to lowest) relative to some measurable effect of interest such as cost, time, etc.

6. Cause and Effect Diagram – The cause and effect diagram is one of the most widely used tools in quality management. The main purpose is to identify possible causes for an effect, or a problem (Rolstadas, 1995). This diagram, also called an Ishikawa diagram or fishbone diagram, is used to relate multiple possible causes with a single effect. The diagram starts with the problem and then works backwards to all the possible causes of the problem. The major branches represent the major causes and the minor branches represent the minor causes. These kinds of diagrams are extremely important in analysis since they depict the relationship between cause and effect in an orderly manner.

7. Scatter Diagram – The scatter diagram is another graphical tool that depicts the influence of one variable on another. A scatter diagram is composed of a horizontal axis containing the measured values of one variable and a vertical axis representing the measurements of the other variable. The diagram is used to test the theory that the two variables under question are related.

4.4 CI Techniques

There are a number of CI techniques that are used by the organization to come up with solutions for existing problems and for improving quality. Some of the techniques require the active participation of the management. The major quality improvement techniques are listed below.

4.4.1 Problem-Solving Cycle

The problem-solving cycle is an iterative approach and requires a group of individuals to sit together and brainstorm, analyze, implement, and test until the best solution is reached. The steps are as follows.

Identify - The organization begins by recognizing that there is a problem to be solved. It does not necessarily have to be a problem; it can be an experiment, an attempt to find a new way of doing something.

Define - Finding a problem triggers the next phase, which is to define it more clearly. Once the problem is defined it might be necessary to divide the problem into a number of sub-problems that can be tackled more easily. This process also clarifies who 'owns' the problem and thus who needs to be involved in its solution, if the solution is to sustain for the long-term.

Explore - Once the nature of the problem has been defined and analyzed the next stage is to explore ways of solving it. At this stage, many possibilities are studied through the use of brainstorming or other group tools to generate as many potential solutions as possible.

Select - The next step is the selection of the most promising solutions. The elected alternative is then put into practice and the outcome reviewed. On the basis of this evaluation, the problem may be solved, or it may need another trip around the loop. It often happens that solving one problem brings another problem into focus.

4.4.2 Brainstorming

Brainstorming is the rapid pooling of ideas that a group of people can come up with before any discussion or judgment takes place. Every idea is recorded no matter how irrational. Every individual in the meeting is encouraged to speak up and come up with ideas. The brainstorming process typically should be characterized by the following:

1. The meetings should be informal with a relaxed atmosphere.
2. The team size is very important. Groups of 5 to 7 people work the best.
3. A leader must be chosen. The leader keeps track of what is going on and gives everyone an opportunity to speak.
4. The problem to be discussed should be clearly defined.
5. Everyone should be encouraged to come up with ideas or comments.
6. Criticism should be avoided.
7. Ideas should be recorded for future reference.
8. Ideas should be understood by everyone.

9. Ideas should be allowed to incubate. Brainstorming sessions are a generally a few days apart to allow team members some time to let the ideas run in their mind.

4.4.3 The PDCA Model

One of the most important models for CI used is the PDCA (Plan-Do-Check-Act) model, which encourages proactive discipline. It is different from the problem solving cycle in that the problem solving cycle is reactive in nature, where the best results are sought for a problem which already exists, where as the PDCA model is proactive in approach. The aspect of planning demonstrates it is a proactive discipline because planning precedes any execution.

Plan: This is one of the most important steps in the model. Before jumping into action, the process requires thought. Elements to be addressed here are shown in Table 2:

Table 2 : Elements Involved in the Plan phase

What is the purpose	What is to be accomplished	What are the permitted variations
How shall it be done	Who should do it	Who is responsible, authorized
When shall it be done	What are the actions	How long will it take
What is the sequence	Who are the customers	What are the inputs
What shall be measured	How shall it be measured	What equipment is needed

Do: This is the implementation phase of the model. The plan is tested and tried out to see how it works.

Check: This phase involves finding out what happened during and after implementation. The idea is to determine if the objective was achieved, and if not, how far were the results from the goal, set in the planning phase, and why did it not work.

Act: In this stage it is important to make sure that the improvements made are permanent, i.e. the necessary adjustments are made to assure the improvements remain intact.

4.4.4 Focus Groups

These are groups of people that gather in a structured environment to offer their opinion. These groups brainstorm product or service features within a structured condition. They are useful when there is a need to obtain input either on the design of a new product or service, or a review of an existing product or service. However, they have certain limitations, as it is often difficult to summarize general brainstorming findings into a single, coherent action report (Mears, 1995).

4.4.5 Benchmarking

This is a continuous process of measuring products, services and processes against the strongest competitors or against those renowned as world leaders in their field (Zairi and Leonard, 1994). It is useful when an advance in an approach is needed. Benchmarking can demonstrate that others in a similar business have solved a certain problem well, and in doing so have set standards for others.

4.4.6 Process Ownership

This involves appointing individuals as owners of the individual business process of the enterprise. One person is given the responsibility of the whole process, who then leads and handles the process from the start till the end. This brings in the feeling of ownership of the process and should make the employee more dedicated and accountable for the work he or she does.

4.4.7 Quality Functional Deployment

Quality Functional Deployment (QFD) was developed to represent a customer-oriented approach to product development. It is a method of focusing on customer needs, expectations, and requirements, and translating them into process and product specifications.

4.4.8 Hoshin Planning Technique

The Hoshin Planning Technique involves planning and management to enable the organization to achieve breakthroughs for customers. This technique breaks down the organizational plans into general, intermediate, and detailed steps, which consist of the seven management tools which are described below. The general steps in the planning process consist of two tools; an affinity chart and an interrelationship diagram. An affinity chart is used for grouping similar ideas so that broad issues can be identified; an interrelationship diagram is used to identify the link between cause and effect for the ideas that are generated. The intermediate step in the planning process uses three tools: a tree diagram, a matrix diagram, and matrix data analysis tool. The tree diagram divides the general objectives into clear attainable subtasks; the matrix diagram displays the relationship between various activities; and the matrix data analysis is used to compare the relationships. Finally, the detailed step in the planning process utilizes two tools: a process decision program chart and an arrow diagram. A process decision program chart lists all the possible scenarios and the countermeasures for a new implementation of the plan, and the arrow diagram, also known as program evaluation and review technique (PERT), is a planning and scheduling tool. The Hoshin planning technique is useful when breakthrough thinking is needed in the planning process, but a drawback is that once it is applied, it might result in too many alternatives (Mears, 1995).

4.4.9 Gap Analysis

The gap analysis is a process of identifying the difference between certain approved standards for a product or a process and the real result; in other words, it is the difference between where one should be in terms of standards for a product or a process and where one is in reality. Five major gaps must be assessed, so that the necessary action can be taken to reduce the gap. According to Mears (1995), these gaps are:

<u>Consumer Expectation and Management Perception Gap</u>: This gap is identified by the difference that exists between the real consumer expectation and the management's perception of consumer's exceptions.

<u>Management Perceptions and Service Quality Specifications Gap</u>: This difference arises due to management's perceptions of consumer expectations and the service quality specifications. Management does not always take into consideration all the elements of quality that the customer desires in the service specifications.

<u>Service Quality Specifications and Service Delivery Gap</u>: This is the gap that arises due the difference between service quality specifications and the service that is actually delivered. This might be due to providing incorrect specifications, or mistakes due to high volumes in demand, for example, a customer being served a wrong dinner order in an extremely busy restaurant, where the waiter failed to communicate the customer's order to the cook.

<u>Service Delivery and External Communications Gap</u>: This is the difference between the actual service delivery and what is communicated about the service to the customer.

Expected Service and Perceived Service Gap: This gap is identified by the difference between consumer's expectations of the service and the consumer's perception of the actual service received.

4.4.10 Taguchi Methods

Taguchi methods broaden the quality improvement activity to include product and process design. Taguchi methods are used to apply experimental plans such as studies, surveys, and tests in the most logical and statistical way. It is helpful when the most desirable design for a product is sought or to determine the most appropriate parameters for a process.

4.5 CI Systems

CI systems are created by organizations to satisfy customer needs, requirements and expectations. The CI system consists of the necessary factors that enable the organization to identify, design, develop and support the products and services that the customer needs. They require a significant commitment of organizational resources to be implemented. System implementation requires that certain criteria need to be satisfied, as for example: proper document control, which is a major requirement for ISO certification whereby all the processes must be documented and easily understood by everyone; manufacturing cell repositioning and production flow optimization, where the optimal design for the work area/shop floor is determined to reduce the distance a worker needs to move and the distance the work piece needs to be moved to reduce time; setting up of quality teams, where a problem is studied in all possible angles and the best solution is sought. All this requires considerable person-hours and money and provides long-term quality solutions. As can be seen, a CI system spans several, and often all, organizational borders. Some of the most used CI Systems such as Quality Cost System, Shojinka, Just in Time, Quality Teams, and ISO standards are described below.

4.5.1 Quality Cost Systems

Quality cost systems (QCS) enable the organization to assess the cost of poor quality so that their quality improvement effort can be directed towards it. A QCS, once implemented, highlights the strong and the weak points of the quality program that is currently in place and provides information on how costs can be reduced. A QCS is more like an information system that can be used to identify, measure, and control the quality costs. It has certain shortcomings, however; it is not easy to develop a system that can collect and state all the aspects that are involved in the cost of poor quality.

4.5.2 Shojinka

Shojinka is a Japanese term meaning continuously optimizing the number of workers in a work center to meet the type and volume of demand imposed on the work center. Shojinka requires that the workers must be trained in various disciplines to enable the organization to vary the manufacturing process to fit the requirements. In order to implement Shojinka, three factors are to be followed; a machine layout that is flexible, employees who are cross-trained and CI of operations. The employee must be trained to work at different positions in the production cell to sustain the change in the demand (Mears, 1995).

4.5.3 Just-in-time

Just-in-time (JIT) is a Japanese philosophy that advocates that raw materials and components should be delivered from the vendor or supplier immediately before they are needed in the manufacturing process. According to this philosophy, holding inventory is wrong and costly.

4.5.4 Quality Teams

This involves making a team of employee groups ranging in authority from task teams with virtually no authority. These teams are set up to accomplish a task and then disbanded when the task is complete. They are useful when decisions must be made quickly by a group of employees, without waiting for others' approval. The limitations are that they require well-trained employees and managers who are capable enough to take decisions that might affect the working of the whole organization.

4.5.5 ISO Standardization

ISO standards are a series of standards describing fundamentals for maintaining a quality management system. "Standards are documented agreements containing technical specifications or other precise criteria to be used consistently as rules, guidelines, or definitions of characteristics, to ensure that materials, products, processes and services are fit for their purpose"[2]. An organizations registration for an ISO standard would benefit the company by a reduction in customer complaints, a reduction in operational costs and an increase in the market share. A number of organizations require that their

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[2] International Organization for Standardization (www.iso.ch)

suppliers be registered for the ISO 9000 standard so that, they have the assurance that, what they receive is in conformance to the predefined standards.

4.6 Summary

With the current business environment of uncertainty, change is essential not only to improve in the market but often for survival. In order to be competitive, everyone in the organization must participate in continuous improvement and be familiar with its tools, techniques and the systems to deliver performance improvement in all dimensions of the business.

5. EVOLUTION OF CONTINUOUS IMPROVEMENT

5.1 Introduction

The roots of modern improvement programs can be traced back to initiatives undertaken in several companies in the late 1800's, where management encouraged employee-driven improvements, and incentive programs were set in place to reward employees that brought about positive changes in the organization (Schroeder and Robinson, 1991).

National Cash Register's program started in 1894, in Dayton, Ohio, and was very similar to the programs run by companies today. It consisted of improving the working conditions and providing incentive programs to encourage employees to come up with suggestions.

During the middle of the century, much attention was given to Scientific Management, which involved developing methods to help managers analyze and solve production problems using scientific methods based on tightly controlled time-trials to achieve proper piece rates and labour standards. Much of the inefficiencies of the tasks were reduced through the development of these standards. The basic objective of management according to Frederick Winslow Taylor, the father of scientific management, in his book "The Principles of Scientific Management", was to attain "maximum prosperity". This meant to attain the highest returns for the company and higher wages for the employees and the development of individuals into efficient workers. These principles are similar to the CI thinking, which is concerned with the continuous improvement of both the organization and the employees such that both the organization and the employees are highly efficient and reap the maximum benefits.

During the Second World War, the US government set up the "Training Within Industry" (TWI) service to enhance industrial output. This included Job Method Training, which was a program designed to educate supervisors on the techniques of CI methods and their importance to the organization. This program was later introduced in Japan through training programs by management experts like Deming, Juran, and Gilbreth, and by the US forces present there after the end of WWII (Robinson, 1991). Eventually the Japanese developed their own ideas, and now, quality control, which was used initially in the manufacturing process, has evolved into a much broader term, growing into the management tool for *kaizen*, or an ongoing improvement program involving everyone in the organization (Imai, 1987).

In the 1950's, the Toyota Motor Company first implemented Quality Circles within the production process itself. Quality circles are a group of people in the staff who meet regularly to discuss problems and issues related to quality and come up with solutions. In doing so, quality was inspected at every stage of production rather than checking the completed product for defects. American companies tried to follow the Japanese economic boom by implementing Quality Circles, but failed. This failure was due to the misinterpretation by the American quality practitioners of the nature of the TQM movement evolving in Japan, in which quality circles were just one part of the company wide effort of quality improvement (Lillrank & Kano, 1989; Brennan, 1991).

As the Second World War came to an end, Taiichi Ohno, former Executive Vice President of Toyota, was given the task of developing an efficient production system for the manufacture of automobiles in Japan. Learning a great deal from Henry Ford's assembly lines, and customizing a production process to suit the needs of the Japanese markets, which called for lower volumes of cars, Ohno developed the world renown Toyota Production System (TPS), also known as Lean Production, and now used throughout the world (Womack et al. 1990). The TPS methodology is designed to maintain a continuous flow of products in factories in order to flexibly adjust to the changes in demand. The basis of such a flow is called Just-in-Time (JIT) production, where, through systematic techniques designed to minimize scrap and inventory, and essentially, all forms of waste, quality and productivity are increased, and costs are decreased.

Although CI has found tremendous success in Japan, most of the principles of CI programs were developed in the US. The Japanese, however, were better able to implement and sustain CI programs in their manufacturing firms. Kerrin (1999) suggests that this is due in part to the fact that the Asian firms were more concerned with prospering with the limited resources that was a reality of the country at the time.

The modern-day CI programs, in which the overall organization is involved in change, are more popularly associated with the introduction of the Total Quality Management (TQM) movement, which was also gaining leverage in Japan thanks to Edward Deming. TQM is the development of an organizational culture of achieving customer satisfaction through an integrated system of tools, techniques, and training (Sashkin and Kiser, 1993). Continuous improvement, customer orientation and process orientation have been referred to as the three core fundamental principles of TQM (Hill and Wilkinson, 1995). The real strength of TQM is that CI, and hence people, is the very basis of the concept (Webster, 1999). TQM is not a solution to the problem but an approach to managing effectively an organization, which is built around CI (Kanji and Asher, 1996).

5.2 Modern CI Methodologies

Over the years, a number of CI methodologies have developed. These methodologies are systems that have evolved over time with a basic concept of quality or process improvement or both, in order to reduce waste, simplify the production line and improve quality. They have been developed when and where the need arose and the most well known of them are: Lean Production, Six Sigma, Lean Six Sigma, and the Balanced Scorecard.

A survey was conducted as part of the research study through which data on CI implementation was collected. Results from the survey were used in arriving at certain conclusions in the following section. A questionnaire was used as a tool for data collection for the survey; data from both manufacturing and service sector organizations was collected. A copy of the questionnaire is presented in Appendix I. As a part of the study, data was collected from a number of large, medium and small size organizations, which were using the different CI methodologies. The CI methodologies constituting part of the study were Lean Production, Six Sigma and Lean Six Sigma

In the following sections, each methodology is described, starting with the history of the CI program, the program description describing the fundamentals of each CI program and how it works, the scenarios under which each CI methodology can be implemented, the timeline required to implement each methodology, and the implementation cost for each methodology.

5.3 Lean Production

History: Henry Ford systemized Lean Production during the early 19^{th} century when he developed the concept of mass production in his factories. The term "Lean Manufacturing" was introduced by James Womack in the book "The Machine That Changed the World: The Story of Lean Manufacturing". However, it is the Toyota Motor Company in Japan that is said to have developed the modern Lean thinking, also known as the Toyota Production System, and has been using it since the 1960's.

Program description: Lean Production is a systematic approach to identifying and eliminating waste through CI by following the product at the pull of the customer, in pursuit of perfection. Lean Production consists of a number of practices, such as JIT, cellular manufacturing, and work teams (Shah and Ward, 2002). Eliminating waste is at the heart of Lean Production (Thompson, 1997), and the aim is to eliminate waste in every area of production including customer relations, product design, supplier networks, and factory management. Examples of waste are human effort, inventory, time to develop products, and space. The ultimate goal is to become highly responsive to customer demand while producing top quality products in the most efficient and economical manner possible. The transition to a lean environment does not occur instantly. A CI mentality is necessary to attain a company's goals.

Lean Production results in the ability of an organization to learn. According to the lean philosophy, mistakes are generally not repeated because this is precisely what it seeks to eliminate, waste. Table 3 shows some of the basic components of Lean Production.

Table 3: Basic Components of Lean Production

Elimination of waste	Equipment reliability	Less inventory required throughout the production process, raw material, WIP, and finished goods
Continuous flow	Material flows one part at a time	Error proofing
Defect reduction	Lead time reduction	Takt Time
Stop the Line quality system	Kanban systems	

All of the components of Lean Production follow the same pattern. They are designed to operate with the bare minimum (just enough, just in time).

Implementation scenarios: Lean Production can be applied to organizations that are looking to move away from traditional manufacturing and invest less in stockpiling inventory, reduce labour costs, cross train workers and improve the speed of their processes. It is especially useful for small organizations that cannot afford the high cost of licenses and certifications required by other CI methodologies such as Six Sigma. Lean is also the next logical step if an organization already has a quality management system such as ISO 9000 certification since the basic groundwork for organizations to implement Lean Production would already be taken care of by the ISO norms, and the organization would have people trained in basic quality tools and techniques.

Implementation steps: The basic ideology behind lean thinking is to minimize waste and develop the ability to change. According to Womack and Jones (1996), the principles behind implementing lean thinking consist of the following five important steps:

1. For each product, specify the precise *Value* (where *Value* is defined by the customer and is anything the customer needs, at any time and any place. The whole idea here is to create value for the customer).

2. For each product, identify the *Value Stream* (where *Value Stream* can be defined as the number of progressive steps and processes linked together that allow a product from raw state to finished state and then delivered to the customer).
3. Eliminate or minimize the interruptions in the value *Flow* (where *Flow* is the biggest jump from traditional thinking in which like activities were performed in batches, which led to bottlenecks as the products would wait in queue for the next operation. Lean thinking focuses on a continuous flow of products, where the focus is on the product and process rather than the equipment).
4. Allow the customers to *Pull* value, whenever they want and deliver fast (where *Pull* is a concept that allows the customer to pull the product from the enterprise as and when he/she needs it, rather than pushing the product onto the market even if it is unwanted. In order to accommodate a pull system, the lead time for a product needs to be drastically reduced and this can be done by converting from departments and batches to product teams and flow).
5. Optimize the steps and pursue relentlessly for *Perfection* (where once the continuous flow and pull is achieved, it is time to go through the steps again and again to work towards *Perfection.* Doing so should help people realize that some waste and lead time can still be reduced).

Implementation cost: The implementation cost depends on a number of factors such as the size of the organization, the degree to which the organization wants to adopt the lean methodology, and the resources available. The costs might escalate if a restructuring of the organization is required, such as relaying out the flow line to improve efficiency. According to the survey conducted, the approximate cost for implementing Lean

Production in a medium organization (less than 1000 employees) was in the range of $90,000 – $250,000, and for a large organization (more than 1000 employees), the implementation cost was found to be around $1,000,000.

Typical timeline to implement: The typical timeline to implement Lean Production into an organization from scratch would again depend on the size of the organization and its objectives. It would also depend on the resources, if the internal resources need to be trained or if the services of external consultants are being used. According to the survey, the typical timeline to implement Lean Production in a large manufacturing organization was approximately six months.

Organizational change required: Change is difficult especially if must be brought about in the whole organization. In most cases, change is expensive and can create numerous problems. Some of the major changes associated with implementing Lean production are as follows:

Think lean: The whole mindset of the employees and management needs to change if the initiative is to be successful. They need to ask questions such as "Why are we doing this?" and "How else can this be done to save time, effort and cost?" Once everyone in the organization has embedded this philosophy in his or her daily routine, lean thinking is closer than expected.

Leadership: Strong leadership is required in order for lean implementation to be successful. Leaders who can guide their employees and are open to change would definitely succeed in the process of lean implementation and then in sustaining lean. The management needs to accept the fact that resources and capital are required for a successful implementation and should be ready to allocate them as and when required.

Resources: People responsible for the implementation should have a good understanding of the lean philosophy and have experience with lean tools such as kanban, 5S, poke yoke etc. The organization might train its employees or get the services of an external consultant.

Infrastructure: Infrastructure changes might be required depending on the existing condition of the organization. For example, the shop floor layout might need to be changed to achieve a smooth flow of products; office area may need to be reconfigured to support 5S (Sort, Straighten, Sweep, Standardize, and Sustain), new tools and fixtures to support poke-yoke. Changes may be required in the maintenance procedures to accommodate total productive maintenance schedule, new training facilities for employee training etc.

<u>Major Companies using Lean Production</u>: Some of the top companies using Lean are shown in Table 4.

Table 4: Companies Using Lean

Company	Web Site
Texas Instruments	www.ti.com
The Boeing Company	www.boeing.com
Yamaha Electronics	www.yamaha.com
BASF Group	www.basf.com
Parker Aerospace	www.parker.com
Fujitsu Component	www.fcm.my.fujitsu.com
Bosch Braking Systems	www.bosch.com

<u>List of service providers/consultants:</u> Some of the major consultants offering Lean are shown in Table 5.

Table 5: Consultants offering Lean Production

Company	Web Site
TMB Consulting	www.tbmcg.com
Simpler	www.Simpler.com
Catalyst Connection	www.catalystconnection.org
AEM Consulting	www.aemconsulting.com
Manufacturing Success Consulting	www.manufacturingsuccess.com
Lean Plus	www.leanplus.com
Granite Bay Consulting	www.granite-bay.com

5.4 Six Sigma

History: Six Sigma originated after the evolution of Lean Production, when Motorola developed the Six Sigma program to achieve the goal of a one hundred-fold improvement in quality within five years for the manufacture of their paging devices. It began to gain popularity in the US, when Motorola Inc. introduced it in 1986. Bill Smith, a senior engineer and scientist at Motorola, introduced the concept of Six Sigma to standardize the way defects are counted. Six Sigma started as a means of measuring process quality using statistical process control (SPC). Minimizing defects to the level of accepting close to zero was at the heart of the methodology. Six Sigma has evolved into a much broader terminology which consists of underlying business process model which represents a major opportunity to save cost. The implementation of Six-Sigma provided Motorola with the key to addressing quality concerns throughout the organization, from manufacturing to service and support functions. As a result of the Six-Sigma application within the organization, Motorola won the "Malcolm Baldridge National Quality" award in 1988. Since then, the impact of the Six-Sigma process was so significant that today it is widely used by many leading global organizations. Six-Sigma has made a major impact on the business process improvement front and has encouraged leading global organizations, such as General Electric, Allied Signal, and Citibank, to follow Motorola's trail. This is one of the major reasons that investing in Six-Sigma programs is considered today even among mid-sized and smaller firms a mission-critical best practice. It has the ability to make dramatic, measurable improvements, reducing costs and cycle times while improving product reliability and customer satisfaction, and it provides quality measurement that can be used throughout an organization, not only in manufacturing but also in design, administrative, and service areas.

Program description: Six Sigma has been defined as "an organized and systematic method for strategic process improvement and new product and service development that relies on statistical methods and the scientific method to make dramatic reductions in the customer defined defect rates" (Linderman et al., 2003).

Six-Sigma is based on statistical process control (SPC), which uses quantitative and graphical techniques to reduce the variation of measured attributes and variables from pre-determined limits. A target is set (the mean) for a particular part attribute or variable, along with upper and lower acceptable limits within which the measures can fall (standard deviation), and the process can be controlled using charts. Statistically speaking, the variation about a mean is measured in units called standard deviations or sigma (assuming the distribution in question is normal). The mean plus or minus one sigma will include 68.26 percent of the group measured. The mean plus or minus two sigma will include 95.46 percent of the group measured and the mean plus or minus three sigma will include 99.73 percent of the group. Six Sigma then means accepting no more than 3.4 parts per million defectives (i.e. 99.99966 percent). The number of defects per million opportunities for the different sigma levels is shown in Table 6.

Table 6: Sigma Performance levels

Sigma Level	Defects Per Million Opportunities
1	690,000
2	308,537
3	66,807
4	6,210
5	233
6	3.4

Six Sigma refers to 0.001 parts per million (ppm) on either side of the mean of the normal distribution, which makes the total non-conformance 0.002 ppm. The 3.4 ppm that is commonly discussed in the literature refers to a 1.5 sigma shift in either direction outwards, presumed by Motorola. In reality 6-sigma corresponds to 4.5-sigma. This is an adjustment made by Motorola, to take into consideration the variation that occurs to a process after many cycles of manufacturing.

At one time, designing products for three-sigma variance was acceptable for satisfactory quality. However, as products became more complex and involved a greater number of manufacturing steps, the number of possible defects per unit at the three-sigma quality level multiplied, yielding only a small percentage of defect-free units. The result of achieving a Six Sigma standard is a significantly higher rate of defect-free products.

Implementation scenarios: Implementing the Six Sigma initiative starts off with the objective of change in the way people think and in the way people work. Six-Sigma affects the way business is done. It may not add too much value if there are already tools and processes in place for problem solving and continuous improvement. Pande et al, (2000) have discussed when Six Sigma is right for an organization. Three key questions must be taken into consideration.

1. Does the organization require a critical change?

2. Is there a strong rational thinking in going ahead with Six Sigma for the organization?
3. Are the existing improvement systems strong and capable enough to bring the desired change to make the organization successful and competitive?

Organizations that answer "Yes" to the first two questions and "No" to the third are in a position to further consider the possibility of Six-Sigma implementation.

Implementation steps: Six-Sigma takes a handful of tools and techniques from the TQM pool and trains its own people into highly efficient technical leaders called Black Belts and Master Black Belts. These tools are applied under the DMAIC model, which is a performance improvement framework. DMAIC is an acronym for Define-Measure-Analyze-Improve-Control. Pyzdek (2000), describes DMAIC as follows:

Define: This stage deals with defining the goals of the improvement activity. Organizations' strategic objectives, such as higher return on investment, will be the top-level goals. Increasing the speed of the productions department, for example, might be the goal at the operational level. At the project level the goal might be to reduce the defect level.

Measure: In this phase, the existing system is measured. Metrics are developed to monitor the progress towards the goal which was defined in the Define step. Tools such as control charts can be used for the better interpretation of the data.

Analyze: The system is then analyzed to identify and reduce or close the gap between the actual performance and the goal set in the previous steps. In this phase, answers to critical questions are sought and a practical problem is transformed into a statistical one by using statistical analysis, if it so desired.

Improve: In this step the system is improved. This is the core of the whole methodology. Different ways to do the same work in a more efficient and effective way are sought. It requires one to be creative and to look for alternative ways to get the job done. The use of advanced statistical tools such as DOE and Taguchi methods are used to find a better solution. Once the solution is obtained, project management and other planning tools are used to implement them.

Control: This step deals with controlling the new system, which is standardized across the organization and documented for reference. An ISO 9000 system may be used to verify the documentation.

If the product or process exists in the organization and has been developed before, then DMAIC is used, but if the customer is not satisfied with the product or the process even after DMAIC is used, or if it's a new product or process that needs to be developed, then a different methodology called DMADV is used. DMADV stands for Define, Measure, Analyze, Design and Verify with the Design and Verify being the important steps for a new product or a process.

<u>Implementation cost</u>: The implementation costs of Six Sigma depend on the following major factors:

1. Size of the organization- the number of employees, locations.
2. Existence of current improvement systems in the organization.
3. Internal or external resources to be trained or hired (Neuman and Cavanagh, 2000).

According to the survey, the implementation cost of Six Sigma for an organization with fewer than 1000 employees may range from $500,000 - $2,000,000, while for large organizations with more than 1000 employees, the implementation cost may be anywhere from $2,500,000 and upwards.

Timeline to implement: According to Pande et al (2000), the timeframe to implement Six Sigma is one of the most important factors for an organization. The timeframe again depends on certain factors:

1. Size of the organization - the number of employees, locations.
2. Existence of current improvement systems in the organization. If an existing system is in place the foundation for Six Sigma may be in place as well.
3. Top management commitment – if top management is not totally committed, this may delay the implementation by not releasing the necessary funds and resources.

Based on the survey conducted it was found that Six Sigma was seldom used in small organizations with less than 500 employees. In such organizations Lean Production and Lean Six Sigma were CI methodologies of choice. In a medium sized organization with about 500 to 1000 employees, the timeline for Six Sigma implementation is between 6 months and up to 2 years, and for a large organization with more than 1000 employees, this timeline stretches further to between 6 months to over 2 years.

Organizational change required: The changes required in the organization vary from organization to organization. Changes without which Six Sigma cannot be achieved are:

1. *Resources*- Master Black Belts, Black Belts and Green Belts are required to execute a Six Sigma project. These are the names given to Six Sigma Quality experts that are responsible for the strategic implementations within an organization. The organization may already have the resources and train them or they may hire them for the work.

2. *Creativity*- To be a successful Six Sigma organization, employees must be creative and move away from traditional thinking. Organizations that are successful incorporate those very things traditional management opposes. According to Six Sigma guru, Thomas Pyzdek:

- Redundancy, due to many employees doing the same job, is important, if they have to work on other process improvement and Six Sigma tasks.
- Inefficiency due to people trying experimenting and failing is important too, since this is how people learn. Six Sigma involves people experimenting with different ways to do work.

3. *Management*: Management plays a vital role in the success of Six Sigma. But a major hurdle for management lies in the fact (as discussed in the previous point) that Six Sigma relies on breakthrough thinking which can only be achieved by experimenting and trying new things. The leaders must be aware of when it is time to allocate resources and funds and when its time to pull out.

4. *Infrastructure*: Some of the infrastructure changes required is the integration of Six Sigma with the information system of the organization. In order for the successful implementation of Six Sigma it is desired that the people associated with it be well informed and in touch with the events taking place in the organization. Other types of infrastructure changes that might be required could be necessity of training rooms, materials for training the workers on Six Sigma principles, necessity for software systems for statistical process control etc.

<u>Major Companies using Six Sigma</u>: Some of the top companies using Six Sigma are shown in Table 7.

Table 7: Companies using Six Sigma

Company	Web Site
General Electric Company	www.ge.com
Motorola Inc	www.motorola.com
Bombardier Transportation	www.bombardier.com
The Boeing Company	www.boeing.com
Lockheed Martin Corporation	www.lockheedmartin.com
NASA	www.nasa.gov
CAE	www.cae.com
Honeywell International Inc	www.honeywell.com

List of service providers/consultants: Some of the major consultants offering Lean are shown in Table 8.

Table 8: Consultants offering Six Sigma

Company	Web Site
Mulbury Consulting Limited	www.eurosixsigma.com
The Bourton Group	www.bourton.co.uk
Breakthrough Management Group	www.bmgi.com
Catalyst Consulting Ltd.	www.catalystconsulting.co.uk
The American Supplier Institute	www.amsup.com
The Athon Group	www.athongroup.com
Celerant Institute	www.celerantinstitute.com
Ketch Consulting	www.ketch.ca
Motorola University	www.motorola.com
Pyzdek Consulting, Inc.	www.pyzdek.com

5.5 Balanced Scorecard

History: The Balanced Scorecard was introduced to the world in 1990 and since then, has had a major effect on how organizations conduct business. About 50% of the Fortune 1000 companies have a Balanced Scorecard system in place (Kaplan and Norton, 1996).

Program description: A Balanced Scorecard defines what management means when speaking of "performance". The Balanced Scorecard can be used to translate an organization's mission and vision statements into a broad set of objectives and performance measures that can be quantified and appraised. It then measures whether management is achieving the desired results. It is generally used to:

- Spell out the business strategy.
- Keep everyone informed of the business strategy.
- Relate the intentions of the organization to the annual budget.
- Make room for organizational change.
- Increase the acceptance of the company's vision and mission statements throughout the organization.

Organizations using the Balanced Scorecard are able to realize their goals if Balanced Scorecard is able to transform from a measurement system to a management system. It fills the gap that most organizations have when it comes to getting a feedback about strategy. Implementation of long-term strategy becomes the primary goal and focus of organizations built around the Balanced Scorecard.

According to Kaplan and Norton, (1996) the Balanced Scorecard "retains traditional financial measures", which were helpful for industries of the old since they informed the organizations of the past events. However, organizations of today also need to rely on different criteria such as employees, customers, innovation, technology and suppliers in order to attain their mission and vision. Therefore, companies now are using tools such as Balanced Scorecard, which serves as an integrated management system providing the organization valuable input on achieving its objectives. Niven (2002) refers to the Balanced Scorecard as a combination of a measurement system, a strategic management system, and a communication tool.

According to the Balanced Scorecard, the organization should be viewed from four different perspectives, as shown in Figure 6.

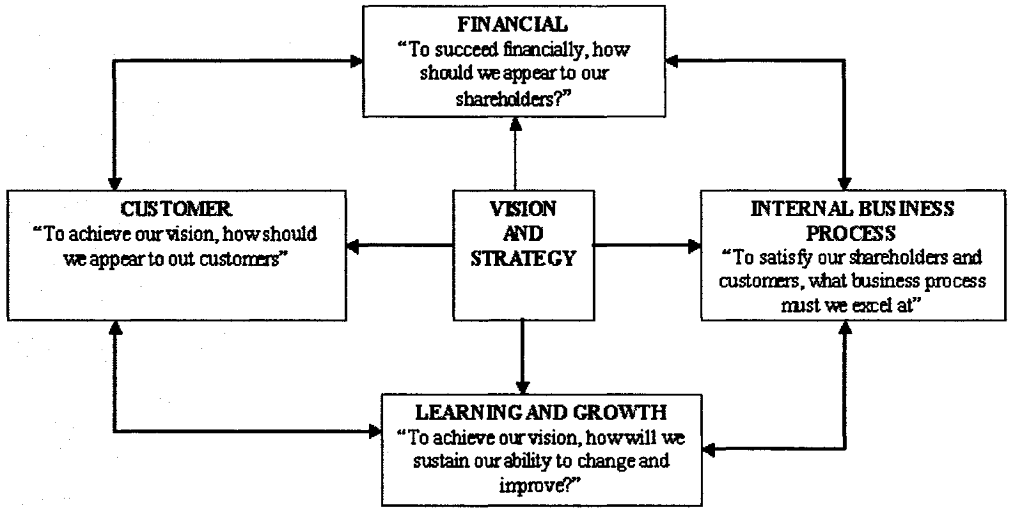


Figure 6: The Balanced Scorecard - Kaplan and Norton (1996)

Customer Perspective: Customer satisfaction lists very high in priority for most organizations. If the customer is not satisfied, they will eventually look for other suppliers. The organization can benefit if they are able to identify measures of the value proposition that could be delivered to the customers in the identified target group.

Internal Process Perspective: This requires that the organization does a check of the process running internally i.e. identify the important process within the organization in which it must do extremely well in order to deliver the value proposition to attract and retain customers and attain good financial returns. This perspective allows the managers to understand how well their business is running and if their products and processes are conforming to the customer's requirements.

Learning and Growth Perspective: This is one of the most important features of Balanced Scorecard and includes employee training directed towards employee selfimprovement. It has become essential that the employees are in a continuous learning mode to keep up with today's technological changes. Once the organization identifies gaps between where it wants to be and where it is (in terms of the employee skills and customer satisfaction), the organization can put in place measures that will help the managers in identifying the training needs.

Financial Perspective: This is another important step in Balanced Scorecard. This perspective informs the organization if their efforts are bringing the improvements that the organizations had initially sought after. Financial perspective relates to profitability, this could be in terms of the operating income, return on investment or growth in sales.

<u>Implementation scenarios</u>: About 90% of the managers surveyed in a study (Balancedscorecard.com partnered with Balanced Scorecard Collaborative, Inc) believe that in order to succeed, a clear, action-oriented understanding of an organization's strategy is required. Less than 60% of the senior managers and less than 10% of the entire organization did not have a clear understanding of the company's strategy. Balanced Scorecard is specifically designed to address the above issues and make the employees of the organization aware of the mission and vision of the organization and "translate strategy into measures that uniquely communicate…vision to the organization" (Kaplan and Norton, 1996). Organizations that are in trouble and are looking to overhaul their operations, or companies looking to launch a new product, would also benefit from such a system.

<u>Implementation steps</u>: Implementing Balanced Scorecard consists of two phases, a planning phase and a development phase.

Before the development of a Balanced Scorecard can begin, the foundation for the project must be laid. The planning phase consists of the following steps:

1. *Objectives for the Balanced Scorecard*: Because many employees in an organization are not aware of the organization's strategy, it is essential that the people associated with the Balanced Scorecard implementation are clear about the objectives, otherwise the effectiveness of the implementation may be limited as the whole work force of the organization may not be working towards the same goals. Some of the reasons that organizations choose the Balanced Scorecard are: new leadership, clarification of current strategy, new organization strategy, and business crisis.

2. *Selecting the Appropriate Organizational Unit*: Once it has been decided that Balanced Scorecard is right for the organization, selection of an appropriate organizational unit for the first Balanced Scorecard is essential in order to ensure its success. Many large organizations believe that starting at the top and developing corporate measures to be the logical choice but smaller organizations do not have the same liberty since their organizational structure is not as rigid. The factors that need to be considered while selecting the appropriate organizational unit are depicted in Figure 7.

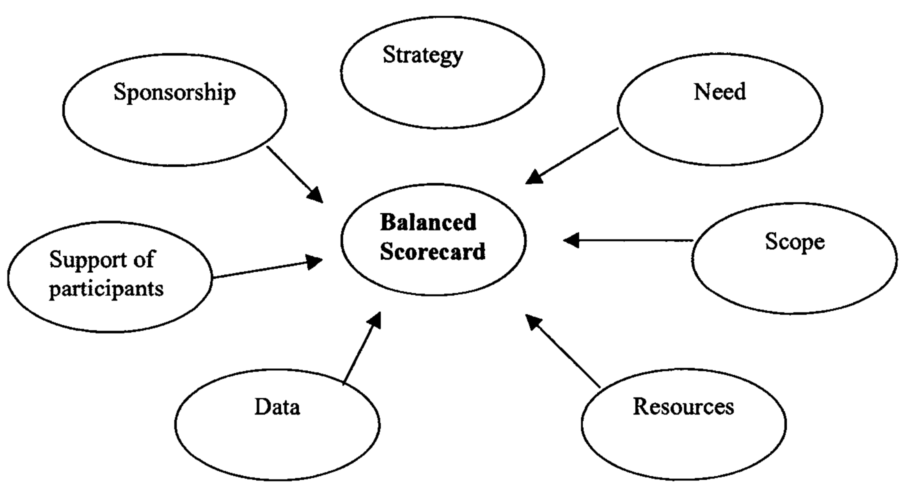


Figure 7: Criteria for choosing where to begin the Balanced Scorecard (Niven, 2002)

- Strategy: One of the major criteria in making this decision is if the unit being considered has a consistent strategy since Balanced Scorecard is all about translating the strategy into objectives that allow the unit to measure the effectiveness in the delivery of the strategy. Without a clear strategy it is possible that that the team implementing Balanced Scorecard ends up with measures that do not link together and are not a part of the organizational strategy and without the link between measures it would be very difficult to understand if improvements in one area of Balanced Scorecard are producing the desired effects on the other key indicators. (Niven, 2002)
- Need: Does the unit under consideration need a new performance measurement system? According to Vitale and Mavrinac in their 1995 article, the following seven signs would help in making this decision.

    1. Performance is acceptable on all dimensions except profits:
    2. Customers don't buy even when prices are competitive
    3. No one notices when performance measurement reports are not produced
    4. Managers spend significant time debating the meaning of the measures
    5. Share price is lethargic despite solid financial performance
    6. You have not changed your measures in a long time
    7. You have recently changed your corporate strategy

- Scope: The unit under consideration should have a set value chain in the organization. It should have a well-defined strategy, customers, specific processes, operations and administration. According to Niven (2002) "Selecting a unit with a narrow, functional focus will produce a Scorecard with narrow, functional focused metrics".

- Resources: In order for the Balanced Scorecard to be a successful management system it is essential that the teams of individuals are committed towards the same goal. It must be ensured that the unit is willing to provide the resources required for a successful implementation.

- Data: There are two elements to this criterion. First, has the unit under consideration ever worked with performance measures; is this the first attempt with the Balanced Scorecard? A unit with some kind of history of relying on performance measures would be a better choice as it will be able to cope with the demands of the implementation process. Secondly, will the unit be able to provide the necessary data for the performance measures. If the unit is having difficulty gathering the data at present, they might have trouble providing the data when the Balanced Scorecard is in place.

Support and Sponsorship of Participants: Similar to the support and leadership of top executives the support of managers and supervisors using the tool in their job is required. Since majority of the initial data collection and analysis work is done by the managers and supervisors, their acceptance and understanding of the Balanced Scorecard can create a cascading effect of driving the scorecard to the all the levels that can lead to breakthroughs in performance.

3. *Balanced Scorecard Team*: In order to have a successful implementation, it is essential to have a solid foundation put in place by a team consisting of a group of individuals who possess the necessary knowledge to make it work. Individuals working together and complementing each other's skills for a common goal forms a good team. It is essential that the roles and responsibilities of each person in the team are clearly defined. The team might need training to attain or enhance their skills.

4. *Project plan*: As is the case for any project to work, it is essential to have a plan in place. Similarly, to implement Balanced Scorecard, it is vital that a project plan is developed.

5. *Communication Plan*: Balanced Scorecard is a change project and any effort leading to a change cannot be successful without a good communication plan. Kotter (1996) in his book has said "Without credible communication, and a lot of it, employees' hearts and minds are never captured". If the organization expects its employees to adapt to Balanced Scorecard it is important that the employees know as much as possible about the new initiative. Niven (2002) in his book states that a good communication plan should include some of the following points:

- Generate awareness about Balanced Scorecard across the organization
- Educate on key concepts of Balanced Scorecard
- Encourage active participation
- Build enthusiasm for Balanced Scorecard.

Once the planning phase has been completed, the development phase begins.

Development Phase: Listed below are some of the steps for the development of a Balanced Scorecard (Niven, 2002).

1. *Make available the information*: The team and everyone in the organization should have access to relevant information such as the organization's mission, vision, and strategy. This information can be distributed to the employees through newsletters, bulletin boards, emails and other sources.

2. *Executive involvement*: As discussed earlier it is important that top management be involved throughout the implementation. It is essential that the team meets and interview the executives to get feedback on the organization's possible measures for the scorecard.

3. *Objectives and measures for the Scorecard*: In this step, the team determines which perspective to focus on, whether it is the customer perspective, the financial perspective etc. Based on each perspective and the organization's strategy, the objectives and the measures for the defined perspective will be developed.

4. *Development of Balanced Scorecard Implementation Plan*: Once all the above steps are followed, the organization would have a Balanced Scorecard measurement tool. Since all the management processes within the organization are linked together as part of Balanced Scorecard, a domino effect will take place that will benefit every department of the organization.

<u>Implementation cost</u>: The cost of implementation would depend on the objectives of the organization, the size and complexity of the organization, and the availability and requirements of resources.

<u>Timeline to implement</u>: The typical timeline for an organization to implement Balanced Scorecard would depend on objectives, size, and resources; however, Niven (2002) suggests that it can take from 4 to 12 months. Figure 8 illustrates a Balanced Scorecard project timeline.

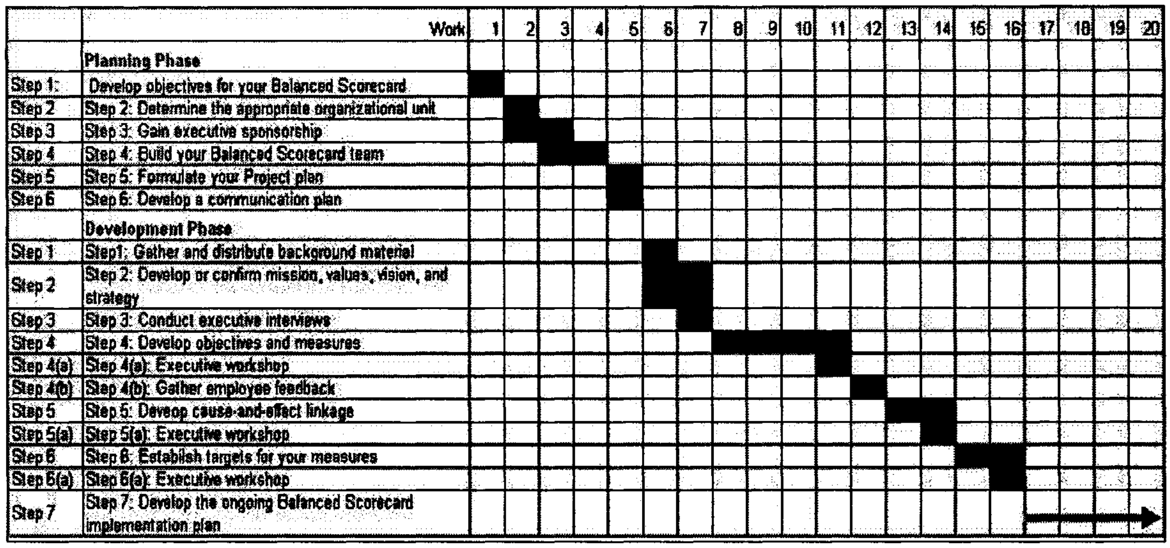


Figure 8: Balanced Scorecard Implementation timeline

Major Companies Using Balanced Scorecard: Some of the major companies using Balanced Scorecard are shown in Table 9.

Table 9: Companies using Balanced Scorecard

Company	Web Site
Amtrak	www.amtrak.com
Cornell University	www.cornell.edu
Sun Life of Canada	www.sunlife.ca
J.C. Penney Life Insurance	www.jcpenney.com
ABB	www.abb.com
Volvo	www.volvo.com
Levi Strauss	www.levi.com

Consultants offering Balanced Scorecard: Some of the major consultancies offering Balanced Scorecard are shown in Table 10.

Table 10: Consultants offering Balanced Scorecard

Company	Web Site
Value Creation Group	www.valuecreationgroup.com
Balanced Scorecard Collaborative, Inc.	www.bscol.com
Balanced Scorecard Institute	www.balancedscorecard.org
Crescent Consulting Inc.	www.crescentconsultinginc.com
Hudson Associates Consulting, Inc.	www.hacinc.com

5.6 Emerging CI Methodologies

A number of new improvement initiatives have generated a lot of interest in the field of continuous improvement. CI Programs such as the revised ISO 9000:2000 and Capability Maturity Model Integrated (CMMI) are the prominent ones. Both of these methodologies have been designed to enable organizations to achieve continuous improvement and since they are relatively new they have not been implemented by a large number of organizations. ISO 9000:2000 is an upgraded version of the ISO 9000:1994 set of standards; organizations looking to register for the new version have to comply with the new regulations that come as a part of the ISO 9000:2000 version. CMMI is also an updated version of the Capability Maturity Model (CMM) which is a model for judging the maturity of the software processes of an organization. CMM is being used exclusively by organizations involved in software development, but the CMMI model can also be used by organizations involved in discipline other than the software community.

5.6.1 ISO 9000:2000

The new ISO 9000:2000 is a standard for business that has superseded the 1994 version. The version 2000 of the ISO standards focuses on the process model with continuous improvement and a customer interface system as the key goals of this quality management system. Using such a model, an existing quality management system can be used as a strategic tool to move towards business excellence by meeting the compliance requirements.

The ISO 9000:2000 is defined by eight quality management principles, the eight principles are[3];

1. Customer Focus – To understand and fulfill customer requirements to sustain and attract new customers.
2. Leadership – To establish clear goals and direction, and work in tandem to achieve them.
3. Involvement of People – To progress and achieve set goals people at all levels must be involved and working together.
4. Process Approach – To manage the activities and the resources as a process so that the desired result is achieved more efficiently.
5. Systems Approach – To achieve effectiveness and efficiency throughout the organization by identifying, understanding and managing interrelated processes as a system.
6. Continual Improvement – To achieve continual improvement throughout the organization, measuring customer satisfaction is not enough; it would need to improve the level of satisfaction. The organization would also have to measure and improve internal processes. Continual or continuous improvement is a crux of the ISO 9000:2000.
7. Factual approach to design making – To analyze, review and challenge the data then base the decision on this data.
8. Mutually beneficial supplier relationships – To create a good and amicable relationship with the supplier to create interdependence between the two.

[3] International Organization for Standardization

The ISO 9000:2000 standards have a number of features similar to Lean, Six Sigma and other CI programs such as the process approach of managing activities, involvement and approval of people at levels and most importantly, the endless pursuit for continual improvement

5.6.2 Capability Maturity Model Integrated (CMMI)

The Capability Maturity Model Integrated (CMMI) is a model that has been developed by Software Engineering Institute (SEI), Carnegie Mellon University, to enable organizations to improve their product and service development, acquisition, and maintenance processes. CMMI is an extension of the Capability Maturity Model for Software (SW-CMM) and enables the CMM concept to be implemented in varying disciplines. CMMI covers system engineering, software engineering, integrated product and process development, and supplier sourcing, process management and project management.

The CMMI has two representations, the Continuous representation and the Staged representation. The Continuous representation uses Capability levels and the Staged representation uses Maturity levels to measure process improvement. The major difference between the capability and maturity levels is the way in which they are applied. Capability levels are applied to a certain focus area of an organization, whereas the Maturity levels apply to the overall organization maturity (Table 11). There are six levels numbered 0 to 5, where each number corresponds to certain specific practices, in a specified focus area within an organization. Capability levels allow the organization to track, evaluate, and demonstrate the progress that is made as part of the improvement in processes associated with a process area. According to the SEI "Using capability levels, generic goals, and generic practices, users are able to improve their processes, as well as demonstrate and evaluate their organization's progress as they improve". The Maturity levels represent the overall development of an organization; there are 5 maturity levels each corresponding to a predefined set of process areas as shown in Table 12. These maturity levels are applicable to the overall organization. Staged and Continuous representations are appraised constantly by CMMI thus enabling organizations using a continuous representation to convert their appraisal ratings into a maturity level.

Table 11: Capability Levels

Capability Level	Continuous Representation Capability Levels
0	Incomplete
1	Performed
2	Managed
3	Defined
4	Quantitatively Managed
5	Optimizing

Table 12: Maturity Levels

Maturity Level	Staged Representation Maturity Levels
1	Initial
2	Managed
3	Defined
4	Quantitatively Managed
5	Optimizing

5.7 The Need for Hybrids

While CI programs help to improve organizational operations in many aspects, they are not necessarily effective at solving all issues. For example, TQM was being used as the primary quality initiative by the manufacturing organizations, but with TQM there was no clear way of prioritizing which quality project should receive the highest quality, and the projects were carried out irrespective of the cost to the corporation. This was one of the reasons for the advent of Six Sigma. Six Sigma is quite explicit about the financial benefits expected from each and every effort. According to Six Sigma initiative each and every Black Belt and Champions are expected to contribute between $250,000 and $100,000 of incremental profit every year (George, 2002). However, Tatham and Mackertich (2003) state that while Six Sigma can be beneficial, it is not appropriate for widespread use.

To overcome the weaknesses of one program or another, a number of companies have merged different CI initiatives together, resulting in a combined CI program that is more far reaching than any are individually. Lean Six-Sigma is the most well-known hybrid methodology, a combination of Six Sigma and Lean Production. This hybrid has evolved since maintaining higher production rates and high quality, or producing less waste, is not enough. The fusion of Lean and Six Sigma was required because Lean cannot bring a process under statistical control and Six Sigma alone cannot dramatically improve process speed or reduce invested capital. So the benefits of both Six Sigma and Lean Manufacturing were combined.

<u>Lean Production</u>: While Lean Production programs help to improve manufacturing operations in many aspects, they are not necessarily effective at preventing unseen quality issues. Lean tools were primarily used in the manufacturing industry and were designed to cater to the manufacturing environment, but due to the enormous success that came with the use of Lean Production, a number of service industries have also followed the philosophy. Lean Production could reduce lead times but did not address the issue of reducing variation, i.e., deviation from optimum parameters.

Once companies had sufficiently reduced their lead times, they reached a point where only further improvements were minimal; organizations looking to improve continuously were focusing on issues which might have been overlooked previously due to constraints such as resources, capital, etc. In their search for continuous improvement, organizations were experimenting with different techniques as Motorola did with the concept of Six Sigma.

Six Sigma: Tatham and Mackertich (2003) state that, while Six-Sigma can be beneficial, it is not appropriate for widespread use. In the past, TQM was being used as the primary quality initiative by manufacturing organizations, but with TQM there was no clear way of prioritizing quality projects, nor could TQM measure progress towards a goal. This was one of the reasons for the advent of Six Sigma. Six-Sigma is very clear about the financial benefits expected from each and every effort. Keeping in accordance with the Six-Sigma initiative, all Black Belt and Champions are expected to contribute between $ 250,000 and $100,000 of profit every year (George, 2002).

In spite of the huge advantages of Six Sigma, it is not perfect; it has certain drawbacks, such as its failure to improve the process speed and the cost of the resources required to carry out the projects. Though Six Sigma can help in fine-tuning the processes, but only once they are in place, it cannot redesign the process nor can it determine which processes are important in the first place. Another disadvantage of Six Sigma is the extended time taken to complete a project and the program creates elite Black Belts who are often cut off from the daily work of the shop floor, since they are busy gathering and analyzing the data (Smith, 2003).

Balanced Scorecard: Balanced Scorecard is an integrated management system used by organizations to translate their vision into attainable objectives. Balanced Scorecard recognizes the interests of shareholders and customers but it does not explicitly integrate the interests of employees, suppliers and the community (Niven, 2002). It only provides insight into what needs to be done to improve, but needs the help of other tools and techniques for execution.

Lean Six-Sigma came into existence because Six-Sigma itself could not improve the process speed. This was possible to achieve, however, using Lean Production, however Lean Production alone could not bring the process under statistical control. So the benefits of both Six-Sigma and Lean Production were combined into a single methodology in the form of Lean Six Sigma.

5.8 Lean Six Sigma

History: Jack Welch, the CEO of General Electric, greatly supported Six Sigma and its benefits, but in its 2000 annual report, GE added another goal, which was to reduce the variation in lead times. Similar to many other companies practicing Six Sigma, GE was also having trouble with its lead times. Six Sigma reduced the variation but not lead times: average lead times were not decreasing according to the December 2000 issue of Industry Week. A number of companies therefore started the concept of Lean Six Sigma, also known as Lean Sigma, in which Lean and Six Sigma methodologies were being used simultaneously. The combination of Lean and Six-Sigma has allowed companies to bring in reduction in manufacturing overhead and quality cost by 20% and inventory by 50% in just two years (George, 2002).

Methodology Description: Lean Six-Sigma is a methodology that enhances shareholder value by improving customer satisfaction, cost, quality, process speed, and invested capital (George, 2002). A blend of Lean and Six-Sigma is desired because a system cannot be brought under statistical control using Lean Production exclusively, and process speed cannot be increased using Six-Sigma alone. Using a combination of lean and Six-Sigma, greater value to the customer can be provided.

Lean Six-Sigma addresses important issues that are overlooked by Six Sigma and Lean Production: the steps in the process that should be first tackled; the order in which they should be applied and to what extent and the ways in which significant improvements can be made in terms of cost, quality and lead times.

Implementation scenarios: Lean Six Sigma would be a favourable methodology to implement if an organization has been following Lean or Six Sigma philosophy. In such a situation the top management knows what to expect as a return and also the resources required for the implementation. Lean Six Sigma would also be looked at by the management for the dual effect of improving the process speed and reducing variation.

Implementation steps: Lean Six Sigma Implementation process involves three major activities:

1. Initiation: The initiation comes from the top. The organizational leaders need set a corporate goal including the people with the necessary skills and experience, and must drive the implementation under their guidance. They must determine the desired outcome, what is the benefit in terms of savings and investments, and prepare for a rollout plan in the first few months. Executive commitment and involvement is absolutely necessary.
2. Project and Resource Selection: This phase deals primarily with the development of an infrastructure which includes: process, organization, key performance indicators, rewards, and tools to implement lean Six Sigma.

a) *Process*: Lean Six Sigma runs on the philosophy that processes run the business and starts at getting the customer requirements and ends at customer satisfaction. Similar to Lean Production each major process is called a value steam. Therefore, there has to be clear understanding of the work in the value stream process and what is required from the earlier steps in order to be done well and what should be delivered to the later steps to meet customer needs.

b) *Organization*: Once the processes are in place the next step is to clearly define the organizational structure. The task is to clearly establish major roles and responsibilities. This involves people working on their traditional roles and people who do specifically Lean Six Sigma work. Black Belts and Master Black belts are people who are highly skilled and work full time on Lean Six Sigma projects and are responsible for developing solutions using Lean Six Sigma tools, but it is the Line managers who are referred to as process owners and are responsible for the implementation for the solutions developed by the Black Belts. In addition to their traditional duties, they work part time on Lean Six Sigma projects.

c) *Key Performance Indicators (KPI)*: KPI's are important to measure the outcome of any initiative. The measure might be in terms of financial gains, lead times, number of defects, or other measures. There should be some quantifiable measure for each initiative.

d) *Recognition*: A lot of money and effort goes in to any sort of implementation and more so if the key resources such as Black belts and Master Black Belts need to be trained. It would not be good for the organization if it could not retain the key resources during or after the implementation. So a recognition and rewards program must be in place. Recognition can come in the form of management involvement and recognizing the good work done, while rewards can come in the form of incentive programs, compensation or bonus programs.

e) *Tools*: They play a major role in any implementation and enhance the efficiency and effectiveness with which projects are carried out. Examples are project identification tools, project management tools, learning and teaching aids, cost tracking systems, etc

3. Sustainability: Once Lean Six Sigma has been implemented, it is necessary to do follow up on activities. It would be of no use if the effectiveness is not maintained. Lean Six Sigma activities need to be imbedded in the daily routine of the employees and made into a way of life.

Implementation cost: The Lean Six Sigma implementation cost should be the same as for Six Sigma initiative since the resource specifications are the same. Lean resources do not require highly specializes training and are available in house in most of the cases and the Black Belts should be able to take care of the lean processes. The cost would depend on the resources, company size, location and other factors also mentioned under Lean and Six Sigma headings. But based on the survey the cost for the implementation of a Lean Six Sigma project for an organization with more than 1000 employees was over $1,500,000.

Implementation Time: In case the company does not have any kind of quality system in place and enough dedicated resources are not available, Lean Six Sigma might take longer than other implementations since the resources would have to carry out Lean and Six Sigma activities together which would take longer than usual. Based on the survey, the implementation time for a small sized organization with less than 100 employees was found to be 1 year and for large organizations with more than 1000 employees the timeline was anywhere between 6 months and in some cases over 2 years. No data on the implementation time was found for medium sized organizations.

Organizational change required: The Organizational change that might occur in a Lean Six Sigma enterprise might be in the internal structure. Since there are highly skilled resources required for the work, such as Black Belts and Master Black Belts it is necessary that the lean organization integrates with the traditional organizational structure. This might include a Business Manager and a Corporate Champion at the top, where the Business Manager looks after the daily traditional activities and the corporate champion heads the Lean Six Sigma activities, they run parallel to each other but with clear lines of communication. In this way both the activities can run smoothly without interfering in each others tasks.

Major Companies Using Lean Six Sigma: Some of the top companies using Lean Six Sigma are shown in Table 13.

Table 13: Companies using Lean Six Sigma

Company	Web Site
Ford Motor Company	www.ford.com
Sears	www.sears.com
Maple Leaf Foods Inc.	www.mapleleafinc.com
Gst Corporation	www.gst-corp.com
Raytheon Company	www.raytheon.com

Consultants offering Lean Six Sigma: Consultants and companies offering Lean Six Sigma consultancy are shown in Table 14.

Table 14: Consultancies offering Lean Six Sigma

Company	Web Site
George Group	www.georgegroup.com
Lean Sigma Technologies	www.leansigmatech.com
Manufacturing Excellence	www.manufacturing-excellence.ie
Colin Barr Associates	www.colinbarr.com

5.9 Achieving Competitive Excellence: The ACE™ Methodology

In recent years, a new CI methodology has been gaining momentum. Achieving Competitive Excellence (ACE™) is a comprehensive methodology that is based on the principle that the customer is number one. Developed over two decades, the methodology combines the benefits of statistical quality control, business and manufacturing process improvement, quality escape identification, root cause determination, and preventive actions to eliminate escapes in the future. Essentially, the ACE™ methodology is a combination of the best of Lean Production, Six Sigma and the balanced scorecard into a progressive implementation plan that results in true culture change in any organization. ACE™ stands on three foundations:

- a philosophy about competitive excellence;
- an operating system (with tools) for controlling and improving the processes and eliminating waste;
- the competence, commitment, and involvement of the entire organization to live the philosophy and to apply the operating system to everything that is done.

ACE™ is a company-wide program that focuses on the drivers of customer and investor value: the processes and people who fuel them. The methodology involves all employees, leaders, and associates alike and it touches all the manufacturing, business and supporting processes that create and deliver customer value. Customer feedback is critical in strengthening the value provided to them and to increase their satisfaction. The ACE™ methodology can be adapted to any industry sector, and to companies of all sizes.

5.9.1 History of ACE™

The ACE™ methodology was developed by United Technologies Corporation and adopted by Pratt & Whitney Canada Corporation (PWC). Based on decades of expertise in CI initiatives, the ACE™ methodology has matured into a sustainable CI program. The roots of ACE™ date to kaizen events held at PWC in the early nineties to reduce manufacturing costs and improve delivery performance. Kaizen events provided each of the UTC divisions with the opportunity to break out of the normal paradigm and look at continuous improvements not as incremental but as requiring radical improvements. Improvements of 3% and 5% were no longer acceptable business goals, and the employees turned their attention to achieving 20%, 30% and 40% improvements.

An initiative began in 1994 to understand and remedy the low effectiveness of engineering productivity, but it disappeared by 1996 because of the daunting size of the task and the inability of each division to link and prioritizes the impact of the proposed metrics on business results.

ACE™ formally began and took its name in 1997 at PWC, at a time when the future of the company looked grim. A quality engineer then assembled a toolbox of methods for improving both quality and delivery. At that time, UTC's Senior Consultant in Quality, the late Mr. Yuzuro Ito, worked with PWC to ensure the effectiveness, simplicity, and ease of use of the ACE™ tools for process improvement, problem solving, and decision-making. Other divisions then began to use ACE™, and Mr. Ito then deployed training for hands–on learning experiences. About a year later, in his honour, UTC established the Ito University to disseminate Mr. Ito's curriculum from the top down. Today, ACE™ is used in companies such as Alcan Primary Metal Products, Bell Helicopter Textron Inc. and Camoplast.

5.9.2 The ACE™ Philosophy

The philosophy of ACE™ is a condensation of Mr. Ito's principle about quality, which had been well tested during his long tenure at the Matsushita Corporation. The key points were outlined as follows:

- Focus on process improvement with equal emphasis on quality and flow: "Right the first time".
- Nurture good hearts, good minds, and total involvement of the organization.
- Use simple, visual approaches to process improvement.
- Treasure problems for their learning potential.

The ACE™ philosophy is also based on the belief that an ideal business, where a business consists of a set of connected processes, uses an operating system to manage these processes. The operating system is a mechanism for controlling and improving processes to achieve desired business goals, starting with customer value and satisfaction.

The ACE™ operating system consists of a set of tools that help an organization identify and solve problems, improve its processes, and make strategic decisions. Through the repeated application of these tools, the organization drives the ACE™ operating system to:

1) close gaps between actual results and business goals;
2) identify, quantify, and eliminate quality deviations;
3) eliminate waste (achieve lean process flow); and
4) create positive change using the power of the individual employee.

Over the years, the benefits of using ACE™ tools at PWC have helped to improve operations by reducing the total equipment downtime and customer escapes from 100% in 1999 to a little over 60% in 2001. Product lead-time has also been reduced from 20-24 months in 1993 to 10-12 months in 1998, and with a target of 3 months in 2003.

The tools supporting the ACE™ operating system are designed to continuously improve processes and eliminate waste, to search for ways to find and solve problems, and to provide a sound basis for making decisions. Table 15 lists the ACE tools which are classified into three categories: Process Improvement and Waste Elimination Tools; Problem Solving Tools; and Decision Making Tools.

Table 15: ACE™ Tools

Process Improvement and Waste Elimination Tools	Problem Solving Tools	Decision Making Tools
5S +1 (Visual Workplace)	Market Feedback Analysis	Passport Process
Process Management and Standard Work	Quality Clinic Process Charts	
Process Certification	Relentless Root Cause Analysis	
Setup Reduction	Mistake Proofing	
Total Productive Maintenance		

Process Improvement and Waste Elimination Tools

- **5S + 1:** The 5S's are the major component of Lean Production. 5S stands for Sort, Straighten, Sweep, Standardize, and Sustain. The '+1' refers to the consideration of Environmental Health and Safety in everything. The 5S is used for organizing and maintaining a workplace.

Sort: This generally starts with taking a tour of the workplace and marking the excess items or items that are out of place. Once the items are identified and reviewed they are put in their respective place or removed if they are not required.

Straighten: The goal of this activity is to establish a place for everything based on usage, and keep everything in its place or to arrange the equipment and products in such a way that it is easy to locate and use them when they are required. This is achieved by labeling and arranging the equipment and products in order to support visual identification.

Sweep: This constitutes cleaning the workspace and equipment. While the workspace and equipment is cleaned, maintenance work can be carried out to prevent any future breakdowns.

Standardize: This calls for maintaining and monitoring the first three S's; integration of Sort, Straighten and Sweep would result in a successful standardization and would lead to an increase in the speed, quality and safety in the work area.

Sustain: All the steps mentioned above would be of no use until they are sustained over a long period of time. The idea is to make 5S+1 a way of life. They need to be performed repeatedly in the same order to reap benefits.

- **Process Management and Standard Work:** A process is a series of activities that takes inputs and produces one or more outputs. It is definable, relatively predictable and repeatable. Process Management is a disciplined approach applying preventive methodologies to improve process performance by increasing effectiveness, efficiency and adaptability. Process Management ensures: that quality products arrive on time, first time and every time; better understanding of the whole process and of the impact of work on customer delight; clarified roles and responsibilities; easier integration of new employees; and reduced frustration. Standard Work is defined as simplified and structured work to ensure consistency and repeatability over time. It is achieved by a disciplined creation of requirements, work methods, tools, process, procedures and work instructions. Standard work ensures that the best practices are imbedded into routine job performance.

- **Process Certification:** Process certification can be defined as the proper use of all the management tools, techniques and initiatives available to assure that the organization has predictable and capable processes which satisfy the organization and its customers' requirements of quality, delivery, and cost. Root Cause Corrective Action Process (RCCA) is at the foundation of process certification. The basic steps for process certification are:

1. Describe and understand the situation
2. Identify required resources to detect the root causes
3. Identify, select and prioritize probable root causes
4. Validate probable root causes
5. Identify, select and prioritize potential solutions
6. Validate potential solutions
7. Implement action plan and monitor effectiveness of solution

8. Standardize similar process

- **Setup Reduction:** A setup is the time elapsed between the last part (after inspection) of the previous batch of products being manufactured and the running of the first part of the following batch. The methodology behind Setup Reduction is to determine the total setup time, find the average setup time, determine the bottleneck equipment and parts with their impact on setups, and identify the starting point of setup data collection on similar parts. Once the above steps are followed and the new setup procedures finalized they are documented to ensure continuity in the application.

- **Total Productive Maintenance (TPM):** TPM is an equipment management strategy designed to achieve maximum equipment efficiency and availability by involving: Operators, Maintenance, Technical Support, and Management. The major TPM objectives are Maximize effectiveness and efficiency (Lead Time), Improve reliability and maintainability (Quality + Lead Time), Optimize cost during life cycle (Cost-effectiveness), Improve employee skills (Operators & Maintenance), Create a proper environment for teamwork.

Problem Solving Tools

- **Market Feedback Analysis (MFA):** MFA is a process used to understand the needs of the customer to improve the quality of the products and services. MFA is used to analyze customer complaints and then work on the problem correction/product improvement. A customer could be internal or external. Data is collected in the form of surveys and Quality Clinic Process Charts (QCPC) forms. The survey results are sent to the change agents. Once the surveys and QCPC forms are available, they are looked up in weekly meetings and problems with the highest priority are identified, proper action plans are developed, and the results obtained are communicated to both internal and external customers.

- **Quality Clinic Process Charts (QCPC):** QCPC is a methodology used to identify problems in a cell though the application of a data collection system. Customers both internal and external fill up a QCPC form if they have any issues that they would like to be resolved. Employees participate in weekly meetings and participate in continuous improvement. The change agents prepare and hold weekly meetings with the supervisors and manage all CI issues during meetings. They participate in CI workshops and clinic activities and provide feedback to the cell employees. The supervisor manages weekly meetings with the change agents and informs employees on the progress of the implementation in the cell via the communication board. The QCPC deals with two types of problems: Official Problems such as quality notifications, rework, repair and Hidden Problems such as health and safety opportunities, delays and tooling/fixture not adequate. The goal of the weekly meetings is to classify the QCPC turnbacks received, prioritize the actions to take, focus on quality and cost reduction, and assign responsibilities.
- **Root Cause Analysis:** This is a method for determining the root cause of a problem, applying the best possible solutions and ensuring that the problem does not recur again by following through and standardizing the solutions. It consists of 8 steps of equal importance; these steps are the same as mentioned in RCCA under Process Certification.
- **Mistake Proofing:** This is a mechanism that prevents defects by eliminating the possibility of error at its source. There are two types of Mistake Proofing; Control and

Warning. Control is achieved by stopping the process before mistakes happen; Warnings are achieved by indicating a situation that requires an intervention during the process.

Decision Making Tool

- **Passport Process:** The Passport™ process is a unique "gated" new product development and design process that allows for a structured review at every step in the development process, from original market potential analysis through final product launch and customer field monitoring. This process is similar to Cooper's Stage-Gate™ process. The Passport™ process incorporates past lessons learned and current technological innovations.

In keeping with the ACE™ philosophy, the ACE™ tools are relatively easy to learn and use and they are accessible to everyone in the organization. In case of a specific process improvement opportunity, the ACE™ tools can be used in conjunction with one another to form a "closed loop" problem solving strategies as seen in Figure 9.

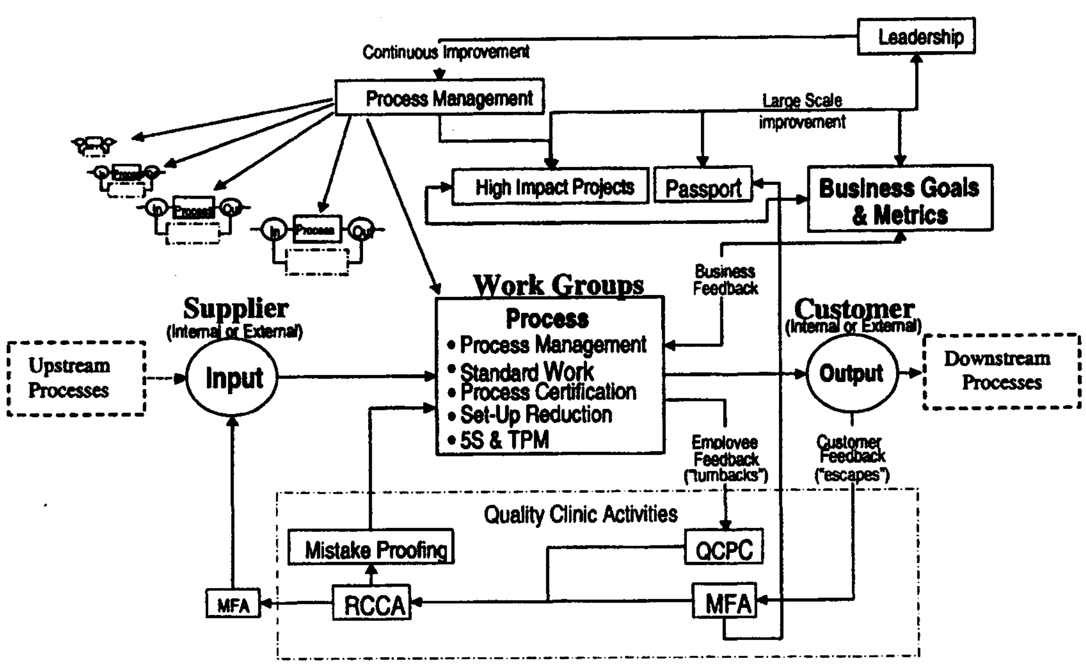


Figure 9: Closed Loop problem solving methodology

It must be noted that not all of the tools described above autonomously drive improvements. It is the associated methodology, specifically the ACE™ Protocol, which will be discussed shortly, which not only describes the desired use of the tools to control business processes but also sets the improvement targets that each cell in the company needs to attain in order to achieve the various ACE™ levels: Qualifying, Bronze, Silver and Gold.

5.9.3 ACE™ Terminology

The ACE™ methodology comes with a terminology that becomes familiar throughout the organization. These terms are described as follows.

ACE™ Central Team – Supervises the implementation of the ACE™ methodology in the entire division. The ACE™ Central team has the mandate of providing training and mentoring in applying the ACE™ Elements, for providing guidance in fulfilling the ACE™ criteria and for ensuring staffing assessments to award certification of ACE™.

ACE™ Elements: The tools of the ACE™ Operating System.

ACE™ Leader: The employee working at the unit level and responsible for facilitating the unit's cell to successfully implement ACE™.

ACE™ Level: Generic term designating one of the four sets of requirements to meet in order to obtain the different ACE™ certifications: Qualification, Bronze, Silver, and Gold.

ACE™ Pilot: The employee working at the cell level and responsible for facilitating a cell to successfully implement ACE™.

5.9.4 Sustaining ACE™

One of the major challenges for any company is how to truly sustain continuous improvement activities. The ACE™ Protocol has been proven to be helpful in the progressive implementation of CI tools throughout PWC.

5.9.4.1 Certification Levels

The basic premise behind the protocol is a system of levels which measure each cell's competency in the ACE™ methodology:

Qualifying: General ACE™ awareness education, local process identification and prioritization, waste elimination and cell organization

Bronze: Advanced ACE™ training; full application of ACE™ tools to a limited number of key processes, 60% cell/workgroup involvement.

Silver: Demonstration of improved customer and business performance, documentation and streamlining of all key processes, defined employee satisfaction target, 80% organizational involvement.

Gold: Best-in-class local customer satisfaction and local business performance, total cell/work group involvement.

Assessments must be scheduled by the ACE™ Leaders and communicated to the ACE™ Central Team of PWC. The purpose of the assessments and reassessments processes is to ensure that the ACE™ criteria continue to be met. These are performed as of the Bronze certification level and between 3 and 6 months after the attainment of the certification level.

It is the ACE™ Protocol that drives the real "continuous" aspect in the use of the ACE™ tools and each cell's movement through the different ACE™ certification levels.

The requirements of the ACE™ levels are more and more demanding as a cell progresses from Qualification through Gold (and beyond). It is only through the use of an external force (the ACE™ Protocol) that the use of the tools can be directed in the right direction in order to achieve the business goals of the company.

5.9.5 Competency in ACE™

Competency in ACE™ resides in empowered employees and in committed and involved leadership. ACE™ competency is built up through many means:

- Awareness education: Awareness-level training relates to the philosophy that all employees need to be involved in CI activities. While there will be CI or Quality experts (ACE™ Pilots), the average employee needs to be at least aware of the various CI tools in use if that employee is to participate in their implementation. The ACE™ Protocol requires that awareness courses (usually one hour in length) on certain tools that will be used by all employees (5S, TPM, QCPC, etc.) be given to 100% of the employees in a cell.
- Supervised action learning engagements (Ito University, ACE™ Pilot training): For more intensive learning experiences, there are more detailed courses which ACE™ Pilots and others attend to ensure that they have the necessary classroom learning and practical application experience to apply specific tools within their own cell. Typically, new ACE Pilot training is a 2-week course.
- Coaching, mentoring and teaching by expert ACE pilots: An important aspect of the ACE methodology is having a local CI expert from within the rank and file of the

department who can best work with his/her peers to implement improvement activities.

- Doing: experience in many different improvement projects: Employees are encouraged to participate not only in CI activities within their own cell but also in activities related to their upstream or downstream value chain. The use of a common language and ACE™ Protocol requirements helps employees in being able to apply what they are doing in their own cell to others.
- Teaching and training others: Not only are ACE™ Pilots tasked with training their peers but average employees are often nominates as team leads and take on leadership roles within the cell. The opportunity to share knowledge, specifically between older, experienced employees and their juniors is an important part of the use of a number of the tools.
- Quality Clinics: These are the primary tool to get together "experts" who have an open exchange on problems and the corrective action needed.

The financial results of applying ACE™ to improve business performance are recorded in the master database Quality Savings Tracking and Reporting Systems (QSTARS). The cumulative financial impact of ACE™ is the ultimate measure of competency. It is important that employees understand and appreciate that the underlying reason for doing CI is to improve the business. By first baselining business results then setting aggressive targets for improvements, employees can clearly see what needs to be done and how the cell's performance is tracking towards the goal. As a corporation, the overall cost of implementing the ACE™ methodology needs to be understood. The ACE™ methodology is an investment in the corporation's future and the QSTARS database tracks all major savings generated at the cell level relating to ACE™ activities in order to make sure the company is realizing a good return for this investment.

5.9.6 Value Chain Overview

At PWC, a value chain (VC) is defined as a series of high-level business processes linked together to produce the goods and services that are provided to the customer. In other words a VC must generate revenue for PWC. There are five VC's in PWC: Power plant, Spare Parts, Overhaul & Repair, Aerospace Components and Fleet Services. The VC model also includes Governing and Support processes.

Each VC will have specific objectives defined. Each high-level process will have pre-defined Key Performance Indicators (KPI's) that will be tracked on an on-going basis to help determine the "health" of each process. A "dashboard" is used to provide visibility over all of these processes' performance. Finally, when the KPI's for a particular process indicate negative trends which could affect the quality, cost or delivery of products/services, the ACE™ Leaders in accordance with the Value Chain Steering Committee will launch a new High Impact ACE™ Team (HIAT) to drive to root cause and incorporate best practices and update Standard Work in the processes. This pro-active approach to problem solving allows ACE™ to correct situations long before they impact customers.

ACE™ as a CI methodology is similar to Lean Production and Six Sigma, but it has many advantages over them. Table 16 lists the similarities and the differences between the three CI methodologies. ACE™ consists of all the tools used by Six Sigma and Lean Production and in addition has a number of other tools such as Quality Function

Deployment (QFD), Market Feedback Analysis (MFA), Root Cause Analysis (RCA), Quality Clinic Process Chart (QCPC), and Passport, which are unique to ACE™ and helps the overall task of identifying defects and bottlenecks to improve continuously. MFA is used to understand the needs of the customer to improve the quality of the products and services; QCPC is used to identify problems in a cell through the application of a data collection system; RCCA is used for determining the root cause of a problem. All of these tools are integrated into the ACE™ methodology, which makes it a complete CI initiative. Having such a CI methodology in place enables an organization achieve something which could not have been attained before through Lean and Six Sigma, namely, reducing variation and improving process speed.

Essentially, what distinguishes the ACE™ methodology from other methodologies is the inherent sustainability of the methodology. The use of the ACE™ Protocol allows different areas of the company to apply proven CI tools in both the evolutionary CI steps as well as in revolutionary Six Sigma-like steps.

Table 16: ACE™ vs. Six Sigma and Lean Production

Major Tool	Six Sigma	Lean Production	ACE™	Description
Cp/Cpk	✓		✓	Process capability assessment
DOE	✓		✓	Design of experiments
SPC	✓		✓	Statistical process control
FMEA	✓		✓	Process/product risk assessment
Regression	✓		✓	Variable effect analysis
Process Mapping	✓	✓	✓	Map of process' detailed activities
5 Whys/2 How's	✓	✓	✓	Root cause identification tools
Pareto	✓	✓	✓	Column chart rank priority
Fishbone	✓	✓	✓	Cause & effect diagram
5S		✓	✓	Waste elimination
Visual Management	✓	✓	✓	Implementation of visual controls
Poka-Yoke		✓	✓	Error proofing techniques
Spaghetti Chart		✓	✓	Material flow or personnel movements
Kanban		✓	✓	Automatic reordering process
TAKT Time		✓	✓	Pace of a process
Standard Work		✓	✓	Time required for activities in process
SMED		✓	✓	Quick machine setup
TPM		✓	✓	Equipment maintenance strategy
Cellular Flow		✓	✓	Production techniques
Passport			✓	Gated review in design process
QFD			✓	Quality function deployment
MFA			✓	Market feedback analysis
QCPC			✓	Quality clinic process chart
RCCA			✓	Root cause corrective action
Benchmark			✓	Internal and external activities

5.10 CI Methodology Comparison

The matrix in Table 17 shows a comparison of all the major CI methodologies. The matrix evaluates the five CI methodologies Lean Production, Six Sigma, Balanced Scorecard, ACE and Lean Six Sigma in terms of its objectives, principles, key performance indicators, speed of returns, the tools used and the infrastructure required for the implementation. Some of the conclusions that can be made by analysing of the matrix are:

1. Lean Production is one of the oldest improvement methodologies and provides high value to the customer by employing best practices such as 5S, mistake proofing, Kanban, etc. Lean Production does not require highly specialized resources and with little training Lean Production principles can be implemented within the organization giving incremental returns.

2. Six Sigma concentrates on improving the business process of the organization by minimizing variation and streamlining processes by utilizing statistical tools such as SPC. Specialized resources with good understanding of statistical tools are required to lead the improvements which are incremental but sometimes can be breakthrough improvements.

3. The Balanced Scorecard provides a means to translate a company's strategy into quantifiable performance measures by looking at different perspectives. The Balanced Scorecard is generally used in conjunction with other CI methodologies and the speed of improvements generally depends on the tools being used.

4. ACE™ is very similar in concept to Lean Production and uses most of its tools in addition to some CI tools exclusive to ACE™ such as Passport and QCPC.

5. Lean Six Sigma is the latest CI methodology and combines the benefits of Lean Production and Six Sigma to provide value to the customer as well as minimize variation by utilizing Lean Production and Six Sigma tools.

Table 17: CI Methodology Comparison

Methodology	Inception	Objective	Principles	KPI's	Tools	Infrastructure	Speed
Lean Production	Early 1900's but modern Lean thinking introduced in early 1960's	To provide high value to the customer	To use the best practices and processes, to improve efficiency, reduce cost and speed up the process	The value provided to the customer	5S, mistake proofing, setup reduction and other TPS tools	Ad – hoc resources can suffice, little formal training, on the job training	Quick initial returns and then incremental.
Six Sigma	1986	Product and process improvement, minimization of variation	To keep the number of defects below 3.4 / per million opportunities	Number of defects, customer satisfaction	DMAIC, DMADV, SPC	Dedicated resources, very specific skills.	Quick initial returns and then incremental.
Balanced Scorecard	1990	To translate company's strategy into performance measures that can be quantified and appraised.	Different perspectives provide a balance between short and long term objectives and between financial and non- financial measures.	Customer retention, new customer base, financial growth.	Brainstorming, Six Sigma Tools, Lean Tools	Dedicated resources, very specific skills.	Depends on the Tools being used
ACE™	1997	To improve customer satisfaction by maintaining high quality and delivery on time.	Use the tools available to reduce waste, improve speed and do the "things right the first time"	Customer satisfaction	Passport process, MFA, RCCA, 5S, mistake proofing etc	Ad – hoc resources can suffice, little formal training, on the job training	Quick initial returns and then incremental
Lean Six Sigma	2000	Reduce variation, speed up production and reduce waste	To use the best practices of Lean Production and Six Sigma, to increase the market share of the organization.	Customer satisfaction, market share	Tools used in Six Sigma and Lean Production	Dedicated resources, very specific skills.	Quick initial returns and then incremental.

As discussed in the chapter, each of the methodologies serves different purposes, and has advantages and disadvantages. However, what further distinguishes the ACE™ methodology from other methodologies is the inherent sustainability of the methodology. The use of the ACE™ Protocol allows different areas of the company to apply proven CI tools in both the evolutionary CI steps as well as in revolutionary Six Sigma- like steps. Some of the important aspects designed into the ACE™ methodology are:

- The gradual application of the ACE™ CI tools allows for slow and fast adopters to learn and begin using the CI tools within their own cells. The ACE™ Qualification level is all about training and communication and not about concrete business results. Even the ACE™ Bronze level is about understanding the cell's performance before demanding improvements. It is only at Silver and Gold that cells are required to perform using the tools to make the improvements necessary.
- ACE™ is very much a bottoms-up approach that uses the average employee to implement positive change. The use of a dedicated ACE™ Pilot taken from within the cell greatly facilitates our ability to motivate employees.
- The ACE™ methodology becomes a single focal point for all CI activities within the company. As focused projects are needed, they simply become extensions of a cell's regular ACE™ activities. PWC has been running High Impact ACE™ Teams (HIAT) for a number of years which amount to Six Sigma projects. The difference is that the same tools and methodologies are used for both these HIAT projects as for a cell's day-to-day activities.

- The ACE™ methodology is flexible and as the company matures in its adoption of CI principles, new, more sophisticated CI. tools can be added to the methodology by simply incorporating them into the ACE™ Protocol.

The question of sustainability is also one great differentiator. An ACE™ cell that achieves any given level does not stop there but rather turns the page in the ACE™ Protocol and looks to the next level's requirements. In this way, PWC has been able to have cells "self-sustain" for as many as six years now without the cell losing focus.

6. DATA ANALYSIS

6.1 Introduction

This chapter presents the results and data analysis from a survey. The first section deals with the analysis of the demographic data and the second section is focused on the impact of the implementation of Lean Production, Six Sigma and Lean Six Sigma on the organizations. This part of the study consisted of conducting a survey to determine the requirements, tools, and performance for CI implementation in organizations. The survey also helped in constructing a tool that would assist organizations in identifying the appropriate CI methodology to meet their objectives. The previous chapters providing descriptions of the various existing methodologies demonstrate the number and variety of tools that are available to organizations. How to choose the most appropriate methodology is not always obvious since there are many factors to consider: which methodology best suits the needs of the company, what are the costs and time required to implement the methodology, what human resources and technology will be required, etc. To address this problem, the survey helped to provide guidance in making decisions related to the above questions. Data from both the manufacturing and service sector was collected, analyzed and incorporated into the tool in order to enable an organization determine the most favourable methodology based on facts from successful CI implementation in other companies.

6.2 Data Collection Instrument

A questionnaire survey was used to collect data from small, medium and large firms using formal CI methodologies, from both the manufacturing and service sectors. A copy of the questionnaire is presented in Appendix I. The questionnaire consists of a total of 24 questions, including multiple-choice questions, open-ended questions, and questions using a five point Likert scale. Questions 1 through 6 in the questionnaire provide information about the respondent company regarding the company sector, number of employees, the CI program being used, and the duration of existence of the CI program. Information on factors affecting the implementation of the CI program are provided through questions 7 through 14, such as questions relating to the time of implementation, cost of implementation (infrastructure cost, cost of resources, training costs and licensing costs), resources required for implementation, and the training required for the employees. Questions 15 through 18 provide details regarding the effectiveness of the CI program implemented by the organization. This section assesses the impact on operations, customers, the market, and the monetary benefits in terms of the annual savings and the return on investment as a result of the CI program in use. Question 19 is designed to report the CI tools that are used by the organizations. Finally, questions 20 through 23 are designed to assess the performance of the CI program at the organization.

Data was gathered using the questionnaire which was electronically mailed out to a total of 250 companies. Of the 250 companies contacted, 27 responded. Because a low response rate was obtained, simple statistical analyses were conducted on the data. Table 18 provides a summary of the respondent companies, which are classified based on the sector, size and the CI program they have used. Table 18 shows that 74% of the respondents were from the manufacturing sector while 26% were from the computer and IT sectors, the consulting sector, and other service sectors combined. This indicates a high penetration of CI methodologies in the manufacturing sector. Certain service sectors, such as computer and software consulting, are also very involved with CI, but the majority of service sector companies which include banks, hospitals, and airline industries, have yet to follow the example set by companies such as Bank One and United Airlines, which, from the survey, have shown tremendous savings and increase in market share as a result of CI implementation. The table also shows that, based on the number of employees in the respondent companies, 67% were from large companies, 11% were from medium size companies and 22% of the respondent companies were from small sized companies. The classification of large, medium and small is based on the number of employees as shown in Table 18.

Table 18: Classification of Respondent Companies

Company Sector	%
Manufacturing	74.10
Service	25.90
Computer & IT	11.00
Consulting Services	7.40
Others	7.50
Company Size (Number of Employees)	**%**
Small (1-500 employees)	22
Medium (500 – 1000 employees)	11
Large (more than 1000 employees)	67
CI Program in use	**%**
Lean Production	44
Six Sigma	41
Lean Six Sigma	15

Table 19 shows the percentage of companies using Lean Production (L), Six Sigma (SS) and Lean Six Sigma (LS) for small, medium and large companies. The most common CI methodology implemented by small size companies is Lean Production. All of the medium sized companies surveyed implemented Six Sigma, while large companies mostly use Lean Production or Six Sigma.

Table 19: Classification of companies by CI methodology

Company Size (No of Employees)	%L	%SS	%LS
Small (1-500 employees)	83.3	0	16.7
Medium (500 – 1000 employees)	0	100	0
Large (more than 1000 employees)	38.90	44.44	16.66

These results suggest that Lean Production is the CI methodology of choice for small sized companies because it is much cheaper to implement than Six Sigma and Lean Six Sigma. Lean Production requires resources that can be trained in a short duration to carry out Lean programs which are ideal for small sized companies. A small percentage of small size companies have incorporated Lean Six Sigma, these companies have achieved the results of reducing lead times, lowering inventory etc, through Lean Production and are working towards reducing the variation in their manufacturing/service process. The number of small sized companies implementing Lean Six Sigma is very small due to the extra capital and resources required to implement and sustain Lean Six Sigma tools. All of the medium size companies surveyed had implemented Six Sigma. This could be due to the lack of resources to implement and sustain both Lean Production and Six Sigma. These companies have invested their resources on Six Sigma to streamline their business process and control variation. From the survey it was also revealed that these companies were also using some of the tools associated with Lean Production such as 5S and kanban but was not implementing the full Lean program. Large companies typically have enough resources to implement any of the three methodologies, and each company selects the methodology based on its objectives. Large organizations had an equal distribution between Lean Production and Six Sigma as seen in Table 19. A small percentage of the large companies implemented Lean Six Sigma. This is probably due to the fact that Lean Six Sigma is a relatively new methodology.

It should be noted all data from small, medium, and large companies, either from the service or manufacturing sector, have been lumped together and analysis was performed on the data as a whole. This was to get a general idea of the resources and tools required for CI, and for resulting performance obtained at a general level. Average scores were therefore useful only. In order to distinguish between companies of different nature, a higher response rate would have been required for meaningful results.

Recall that three perspectives of CI were studied in the survey, i.e., the operational perspective, the customer perspective and the market perspective. These were used to gauge the impact of the CI implementation in the organization. These perspectives consist of factors that determine the impact on the operational performance of the organization, the impact of CI implementation on customers, and the success of implementation on the overall market, respectively. In what follows, the results of the survey for each CI methodology are analysed for each of these three perspectives.

6.3 Impact on Performance – Lean Production

Table 20 represents the mean and standard deviation (SD) of individual factors that have an impact on operations as a result of the implementation of Lean Production. Inventory levels, lead time and rework are the main factors affected by implementing Lean Production. To test the validity of the statement, the t-test is used to measure the difference between the highest mean and the mean of other factors. The p-value is derived from the calculated t-value using a 95% confidence interval. Factors having a higher p-value are significant and are affected by CI implementation.

As seen in Table 20, inventory levels are compared to other operational factors. Lead time and rework has a relatively high p-value, implying that inventory level, lead time and rework are affected significantly by Lean Production implementation. These results are not surprising since the tools and techniques that constitute Lean Production are focused on reducing lead times and inventory levels. Lean Production also provides tools to reduce line rate and setup time, but the data analysis of the survey shows that inventory levels, lead times and rework are the factors that are affected the most by the implementation.

Table 20: The mean and standard deviation of factors in the operational perspective affected by Lean Production

Operational Perspective	Mean	SD	p-value
Lead Time	4.20	0.420	0.2730*
Rework	4.10	0.316	0.0757*
Inventory Levels	4.40	0.516	-
Scrap	3.80	0.440	0.0027
Line Rate	3.20	0.534	0.0001
Setup Time	3.10	0.534	0.0001
Cost of Non-Quality	1.50	1.632	0.0001
Environment Health and Safety	1.10	1.095	0.0001

* significance level of 0.05

The results for the impact of the implementation of Lean Production on the customer perspective are represented by Table 21.

Table 21: The mean and standard deviation of factors in the customer perspective affected by Lean Production

Customer Perspective	Mean	SD	p-value
Customer Satisfaction	4.60	0.516	-
Customer Retention	4.00	0.816	0.0650*
Customer Complaints	4.11	0.333	0.0213
Warranty Claims	2.80	1.095	0.0002

* significance level of 0.05

Customer satisfaction and customer retention are affected the most. This is likely due to the direct effects of Lean Production, which as seen earlier, are reduced lead time, rework and inventory levels, which results in on-time delivery of the product or service at a lower cost, resulting in turn in increased customer satisfaction.

Results for the market perspective are shown in Table 22. Results suggest that both market share and company image are significantly affected by the implementation.

Table 22: The mean and standard deviation of factors in the market perspective affected by Lean Production

Market Perspective	Mean	SD	p-value
Market Share	4.20	0.421	-
Company Image	4.00	0.316	0.2457*

* significance level of 0.05

6.4 Impact on Performance – Six Sigma

The effect of Six Sigma implementation on the organization is discussed in this section. Table 23 displays the mean, standard deviation and p-values of the eight factors constituting the operational perspective, where the p-values of scrap, which has the highest mean, are tested versus other factors using t-test. The results suggest that reduction in scrap; rework, inventory levels, line rate and cost of non quality are affected significantly by Six Sigma implementation. This can be explained by the use of Six Sigma tools and techniques that allow the user to control the variations that arise during a process. The cost of non–quality is another factor that is of importance here whereas under Lean Production implementation it ranked well below other factors. Cost of non quality is the cost that is generated as a result of producing defective material, which includes the labour cost, materials cost and rework cost. It is one of the issues that is addressed before moving ahead with a Six Sigma project and is often used to justify initiating a project. It is also used as a tool for prioritizing the importance of projects in a Six Sigma environment and therefore a reduction in cost of non quality is one of the impacts of Six Sigma implementation.

Table 23: The mean and standard deviation of factors in the operational perspective affected by Six Sigma

Operational Perspective	Mean	SD	p-value
Lead Time	3.36	0.674	0.0210
Rework	4.00	1.322	0.6545*
Inventory Levels	3.88	0.781	0.3590*
Scrap	4.22	0.833	-
Line Rate	3.62	0.517	0.0689*
Setup Time	3.46	0.616	0.0323
Cost of Non-Quality	3.88	0.600	0.3090*
Environment Health and Safety	2.33	1.032	0.0003

* significance level of 0.05

Six Sigma is very customer-oriented and it can be expected that customer satisfaction would be one of the most important factors under the customer perspective. As seen in Table 24 customer satisfaction has the highest mean and is affected significantly by the implementation.

The impact of Six Sigma implementation on market perspective is shown in Table 25. Again, both market share and company image are affected significantly by Six Sigma implementation.

Table 24: The mean and standard deviation of factors in the customer perspective affected by Six Sigma

Customer Perspective	Mean	SD	p-value
Customer Satisfaction	5.00	0.00	-
Customer Retention	4.63	0.504	0.0323
Customer Complaints	4.27	0.467	0.0001
Warranty Claims	3.88	0.718	0.0001

Table 25: The mean and standard deviation of factors in the market perspective affected by Six Sigma

Market Perspective	Mean	SD	p-value
Market Share	4.72	0.476	-
Company Image	4.54	0.522	0.4309*

* significance level of 0.05

6.5 Impact on Performance – Lean Six Sigma

The impact of Lean Six Sigma implementation on operations is shown in Table 26, where inventory level has the highest mean. Inventory levels, lead time, rework and scrap are affected significantly by Lean Six Sigma implementation.

Table 26: The mean and standard deviation of factors in the operational perspective affected by Lean Six Sigma

Operational Perspective	Mean	SD	p-value
Lead Time	4.25	0.957	0.6703*
Rework	4.00	1.154	0.4677*
Inventory Levels	4.50	0.577	-
Scrap	3.75	0.500	0.0971*
Line Rate	3.25	0.500	0.0156
Setup Time	3.00	1.000	0.0396
Cost of Non-Quality	3.00	0.00	0.0017
Environment Health and Safety	2.00	0.00	0.0001

* significance level of 0.05

The impact of Lean Six Sigma implementation on customer perspective is shown in Table 27. Results show that customer satisfaction and a reduction in customer complaints are affected significantly by the implementation.

Table 27: The mean and standard deviation of factors in the customer perspective affected by Lean Six Sigma

Customer Perspective	Mean	SD	p-value
Customer Satisfaction	4.25	0.500	-
Customer Retention	3.75	0.957	0.3902*
Customer Complaints	3.66	1.527	0.4906*
Warranty Claims	2.50	0.707	0.0068

* significance level of 0.05

The impact of Lean Six Sigma implementation on the market perspective is shown in Table 28, and once again, market share and company image are significantly affected by the implementation.

Table 28: The mean and standard deviation of factors in the market perspective affected by Lean Six Sigma

Market Perspective	Mean	SD	p-value
Market Share	4.25	0.957	-
Company Image	4.00	0.816	0.7047*

* significance level of 0.05

6.6 CI Tools Used During Implementation

A number of tools, techniques and systems were used by the respondent companies during implementation. In this section, the tools which were the most effective and were the most commonly used for the implementation of each of the three CI methodologies are presented from the survey results. CI tools, techniques and systems are identified as CI tools in this section for simplicity.

In the case of Lean Production implementation, seven CI tools were identified which were used by at least 50% of the respondents during the implementation, as shown in Table 29. As can be seen, 5S was used the most, followed by JIT and the 5 Why's/2 How's during Lean Production implementation.

Table 29: The most commonly used CI tools in Lean Production implementation

CI Tools	% usage
5S	90
JIT	80
5 Whys/2 How's	80
Kanban	70
Poka-Yoke	60
RCCA	60
Process Mapping	50

The most commonly used CI tools and their usage during Six Sigma implementation is shown in Table 30. Process capability, Statistical Process Control, and FMEA were the CI tools that were employed the most during the implementation

Table 30: The most commonly used CI tools in Six Sigma implementation

CI Tools	% Usage
Cp/Cpk (Process capability assessment)	90.90
Statistical Process Control	90.90
Failure Mode & Effect Analysis	90.90
Design of Experiment	63.63
Quality Function Deployment	63.63
Process Mapping	54.54
Pareto Chart	54.54

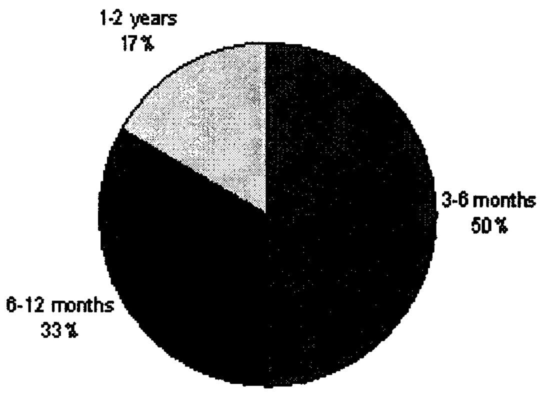
In the case of Lean Six Sigma implementation, Statistical Process Control was used by all of the companies as shown in Table 31. All other CI tools were equally used during Lean Six Sigma implementation.

Table 31: The most commonly used CI tools in Lean Six Sigma implementation

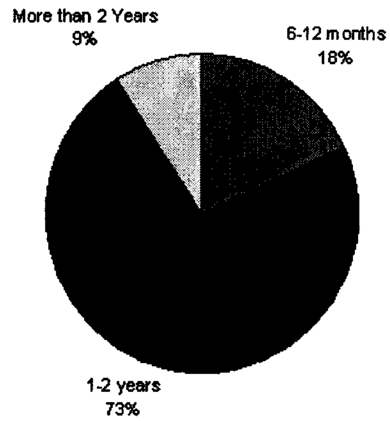
CI Tools	% Usage
Statistical Process Control	100.00
Cp/Cpk (Process capability assessment)	75.50
Failure Mode & Effect Analysis	75.50
Regression Analysis	75.50
Process Mapping	75.50
Pareto Chart	75.50
Quality Function Deployment	75.50
JIT	75.50

6.7 Time Required For CI Methodology Implementation

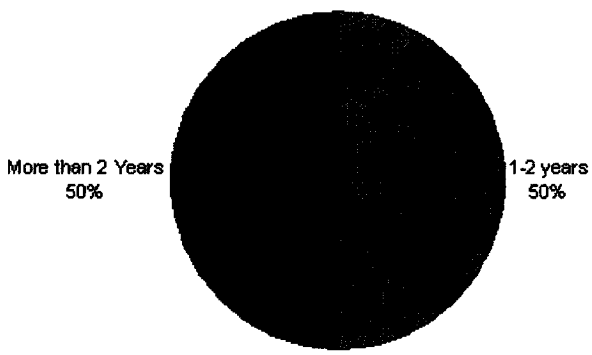
The CI questionnaire asked the respondents to provide information about the time required for CI methodology implementation. Figure 10 shows the distribution of the findings for Lean Production, Six Sigma, and Lean Six Sigma. As seen in Figure 10a, for 50% of the companies, it took between 3 -6 months to implement Lean Production. It took 6-12 months to implement Lean Production for 33% of the responding companies and 1-2 years for 17% of the respondents. According to Figure 10b, 73% of the respondents took between 1-2 years to implement Six Sigma and 18% took 6-12 months, whereas only 9% of the respondent companies took more than 2 years. The time for Lean Six Sigma implementation is the longest as seen from Figure 10c. It is equally divided between 1-2 years and more than 2 years to implement.



10 a : Lean Production



10 b: Six Sigma



10 c: Lean Six Sigma

Figure 10 a, b, and c: Timeline for Lean Production, Six Sigma, and Lean Six Sigma

6.8 Cost of Implementation

One of the major concerns of an organization in selecting a CI methodology is the cost of implementation. The major factors that make up the total cost of implementation are infrastructure cost, cost of resources, licensing cost and training costs. Typically, however, the bulk of the money spent during implementation goes into infrastructure and resource costs. Figure 11, presents the breakdown of infrastructure costs for the three CI methodologies, Lean Production, Six Sigma and Lean Six Sigma.

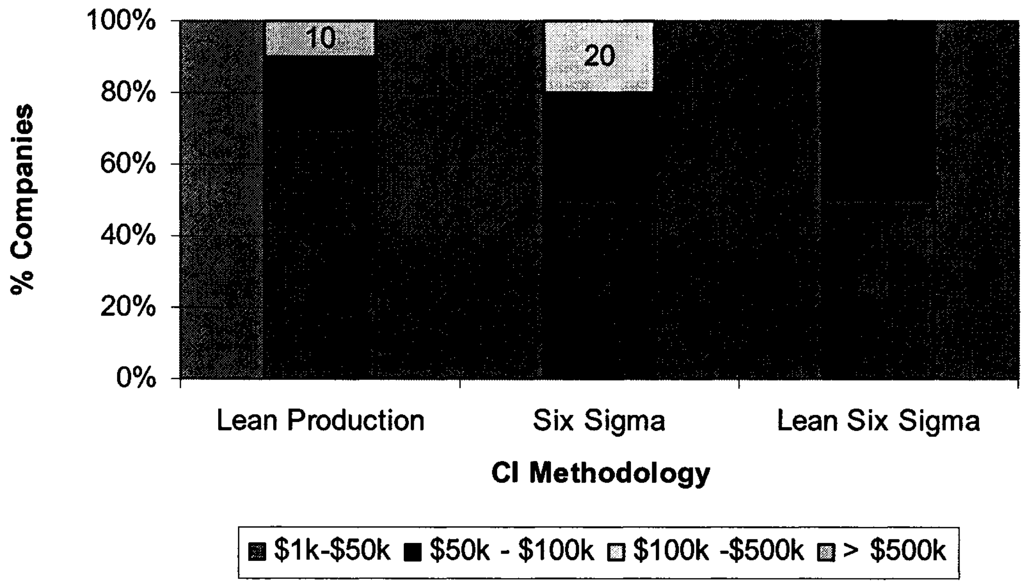


Figure 11: Infrastructure costs for Lean Production, Six Sigma and Lean Six Sigma

As seen in the graph in Figure 11, 70% of the companies implementing Lean Production had spent between $1000 and $50,000 on infrastructure and 20% of the companies had spent between $50,000 and $100,000 while only 10% of the companies spent more than $500,000. 50% of the companies implementing Six Sigma spent between $1000 and $50,000 on infrastructure while 30% and 20% spent between $50,000 - $100,000 and $100,000 and $500,000 respectively. Lean Six Sigma has an equal distribution of 50% between companies who spent \$1000 - \$50,000 and \$50,000 - \$100,000 on infrastructure.

Figure 12, presents the graphical distribution for the cost of resources for Lean Production, Six Sigma and Lean Six Sigma. 70% of the companies implementing Lean Production had spent between \$1000 and \$50,000 on resources, and 20% of the companies had spent between \$50,000 and \$100,000 on resources followed by only 10% of the companies implementing Lean Production had spent in the range of \$100,000 - \$500,000.

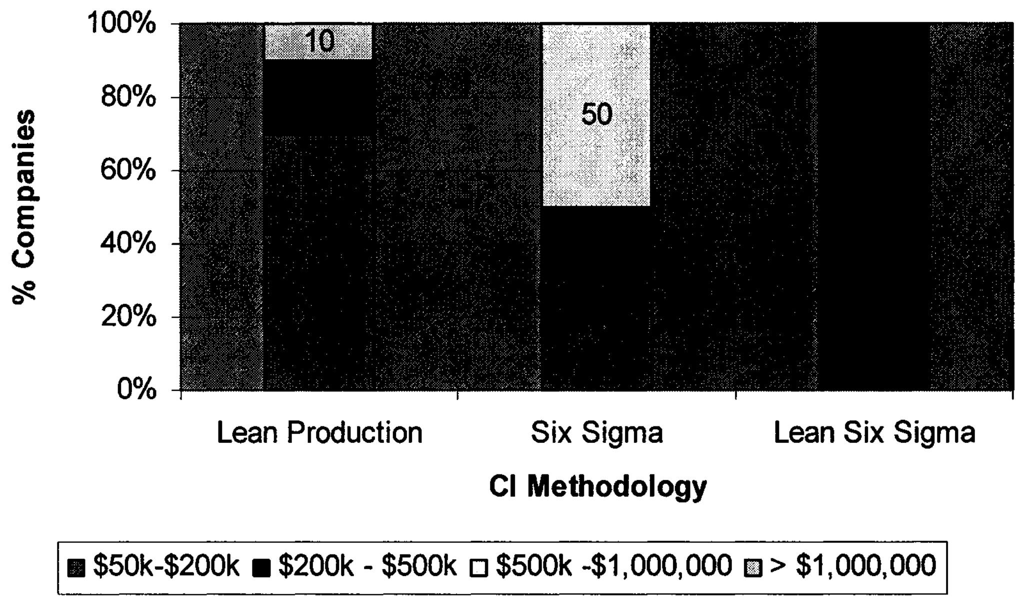


Figure 12: Cost of resources for Lean Production, Six Sigma and Lean Six Sigma

50% of the companies implementing Six Sigma were spending \$100,000 - \$500,000 followed by 30% who were spending around \$1000 - \$50,000 and 20% were paying the resources between \$50,000 and \$100,000. All of the respondents of the questionnaire implementing Lean Six Sigma were spending between \$50,000 and \$100,000 on their resources to maintain and implement Six Sigma.

6.9 Summary

The data analysis provides a good comparison of three popular CI methodologies commonly used in practice. Based on the results and analysis, the following conclusions can be made from the survey:

1. Inventory levels, lead times and rework are affected the most and are reduced by the implementation of Lean Production, while in the case of Six Sigma implementation scrap, rework, inventory levels, line rate and cost of non quality are affected the most. The implementation of Lean Six Sigma in the organization reduces inventory levels, lead time, rework and scrap. An interesting finding here is the effect on inventory levels and rework by the implementation of all the three methodologies.
2. Customer satisfaction was affected significantly by the implementation of all the three methodologies whereas customer retention was affected by Lean Production and Lean Six Sigma while the impact due to Six Sigma implementation was nominal. A reduction in customer complaints was the factor affected only by Lean Six Sigma implementation.
3. Market share and company image were affected positively by the implementation of all CI methodologies, suggesting that the responding companies were able to increase or maintain their market share and improve the company image as a result of CI implementation.
4. The major tools used during Lean Production implementation were 5S, JIT, 5 whys and kanban. Process capability, statistical process control and failure mode and effect analysis were the most commonly used tools during Six Sigma implementation. Companies implementing Lean Six Sigma used statistical process control, process

capability, failure mode and effect analysis, and quality function deployment as the major tools.

5. Lean Production implementation requires the shortest amount of time (3-6 months), as experienced by the majority of companies, while implementing Six Sigma took 1-2 years for the implementation. Companies implementing Lean Six Sigma took the longest, either 1-2 years or more than 2 years.
6. Lean Production requires the least investment, as experienced by most companies. Six Sigma and Lean Six Sigma require a greater investment for implementation. From the data it can be interpreted that Lean Production requires less initial investment on infrastructure and the resources required to maintain the program are not very expensive whereas the initial investment for Six Sigma investment was not much higher than Lean Production but the cost of resources required to sustain the program was the highest. Lean Six Sigma required the same investment on infrastructure as Lean Production and Six Sigma but all of the responding companies spent higher on resources than companies implementing Lean Production, but lower than Six Sigma companies.

Because of the limited response rate, however, these conclusions should not be extended for all organizations. The questionnaire results were therefore useful in guiding the construction of a model to determine the most suitable CI methodology for an organization. Results helped in determining the different objectives and tools associated with each methodology and in creating the data filter and program logic based on which the model proposes the CI methodology that is most appropriate for a given set of objectives.

6.10 CI Implementation Model

6.10.1 Introduction

A CI implementation model has been developed to assist an organization in identifying the most appropriate CI methodology to suit their purposes. Any organization seeking to implement CI can utilize the model to get a better understanding of the requirements to achieve each of its objectives and identify the CI methodology that best corresponds to these objectives. The model can be useful for any organization determined to implement CI but not clear on which methodology matches strongly with their objectives. It has been developed around five major elements that can decide the effectiveness and the overall success of the CI implementation. The model requires inputs on these elements before it can propose a CI methodology. These key elements are:

1. Company Sector
2. Company Size
3. Organizational Objectives
4. Tools required to achieve the objectives
5. Resources requirements
    a) Human Resources
    b) Capital
6. Time for implementation

Once data on all these elements is input by the user, the model provides information on what activities will be needed to achieve the stated objectives, the human resources required, the costs involved, and the time needed for implementation. The model then proposes the most suitable CI methodology based on the inputs provided. The model has been developed using Microsoft Visual Basic.

6.10.2 Overview of the Model

Figure 13 provides an overview of the model. The flowchart describes the model as a seven-step process. The flow of information required is shown; at the end of each step, represented by the boxes, the model computes the data and filters it based on the program logic. The program logic finally decides on which CI methodology to propose. The logic has been programmed after analysing the survey questionnaires, through meetings conducted with CI professionals, and based on the study of existing literature on CI.

As seen in Figure 13, the user would start at the top by selecting the sector in which the organization competes, whether it is a manufacturing or a service sector (step 1), and moves on to selecting size of the organization (step 2). These two inputs should help the model to identify the range and type of tools that are both applicable and appropriate for the organization. The next step involves selecting the objectives of the CI initiative (step 3); the tools required to achieve each of the selected objectives are then generated (step 4). Certain resources are required to implement each tool; these resources are classified into employees required, infrastructure required and the training that is needed for the tool (step 5). Once the resources are determined the time and cost for those resources are calculated based on labour rates that are input into the model by the user (step 6). Finally, the model proposes the most suitable CI methodology based on the filters and the program logic (Step 7).

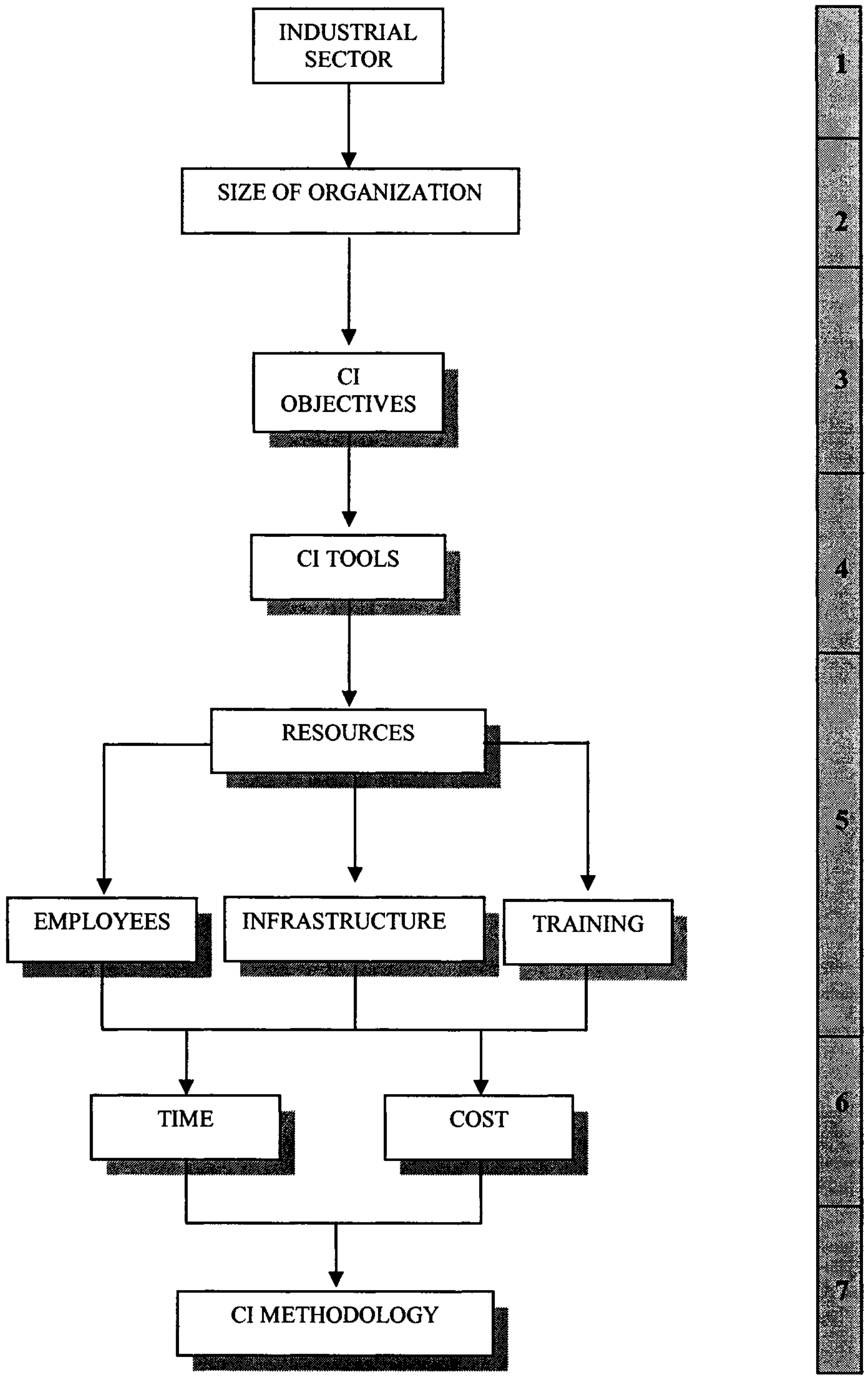


Figure 13: CI Implementation model flowchart

In order to illustrate how the model works and to run the model, data was collected from a large automaker based in the United States. The automaker (left anonymous due to confidentiality) primarily designs and manufactures cars and trucks and has over 325,000 employees globally, with manufacturing operations in 32 countries. Its annual sales are over 7 million cars and trucks which is about 15% of the global vehicle market. The data collected was from one of the manufacturing and assembly plants which has approximately 4,000 employees. The step-by-step functions of the CI implementation model using data from this company are now described.

Step 1: Selecting the Sector

The first step for the user is to identify the sector of the organization, whether it is a manufacturing or a service sector, since the objectives and the CI tools used (explained in steps 3 and 4), will depend on the sector to which the organization belongs. For a manufacturing organization the objectives and the CI tools may be different than an organization in the service sector. As seen in Figure 14, the US automaker is a manufacturing organization and the manufacturing sector has been selected.

Step 2: Identifying the Company Size.

In the next step the total number of employees in the organization is selected. The user can select from Small, Medium and Large, based on the number of employees in the organization, as seen in Figure 14. The number of employees working in the organization can have an overall affect on the implementation of the CI methodology as it affects the employees training required and amount of infrastructure needed, which can increase the total cost and time required for a successful implementation.

Step 3: Identifying the Objectives

The next step in the model is to determine the organizational objectives, what it is that the organization aims to achieve through the CI methodology. The objectives selected by the automaker, as seen in Figure 15, were Lead time reduction, Scrap reduction, Inventory reduction, Setup time reduction and Customer satisfaction. A brief description of the objectives is displayed in the "Description" area. For example, the screenshot in Figure 15 shows that lead time is highlighted and lead time is defined in the "Description" area.

Step 4: Tool Selection

Once the objectives have been selected, the model lists the tools that are required to accomplish the objectives based on the organizations sector. By clicking on each objective, the tools required to meet that objective are listed under the "Tools" category. The user can also select or deselect tools, if, for example they wish to add to the toolbox, or if the company does not have a particular tool that is required. For each objective a certain minimum number of tools which are considered essential must be selected in order to proceed further. Selecting or deselecting the tools can change the final outcome of the model, since each CI methodology has certain tools associated with it. Figure 15 shows the tools selected and implemented by the automaker for Lead Time reduction.

Step 5: Resources Requirements

In the next step, the model provides more information on the resources and the time required to achieve the selected objectives. The resources required are listed under the "Resources" category for each tool. By clicking on the "Employee" button, a new window opens up where more information on each employee, the time required for each employee is displayed, and rate of pay can be entered. As seen in Figure 16 for the US based automaker, the total time required by the resources for implementation was 271,240 man hours where the managers and the engineers were supposed to work on CI activities for an average of 4 hours/day, the supervisors and the workers were supposed to work on CI activities for 2 hours/day and 30 minutes/day respectively for the duration of the implementation (6 months). For example 20 quality engineers working 4 hours/day for 6 months or 120 days gives 480 hours total. The total time spent on training the employees was 33,482 person hours, where the managers and engineers were trained for 3 days (8 hours/day) on the CI methodology and tools, and the supervisor and worker were trained for 15 and 8 hours respectively. A total of 50 person hours were spent on preparing the infrastructure for the implementation. The total time for implementation came to 304,772 person hours. The model computes the total time and presents it in the "Total hrs" textbox.

Step 6: Cost of Implementation

The cost of resources, training, infrastructure, and licensing are calculated in this section. The cost of resources and training is calculated based on the data entered in the previous employee section. Once data for infrastructure and licensing is entered, the textboxes at the bottom represent the total time (in hours) and total cost (in dollars) for the CI implementation, as shown in Figure 17. The total cost for implementation for resources, training, infrastructure and licence for the automaker was US $5,699,800 where the cost for each employee was computed as (number of employees) * (number of hours) * (rate/ hour), as seen in Figure 16.

Step 7: The Proposed CI Methodology

Figure 18 shows the last step where the model proposes a CI methodology. By clicking on the "Proposed CI methodology", the suitable CI methodology based on the data collected from the previous screens is given. In the case of the automaker, the proposed methodology is Lean Production.

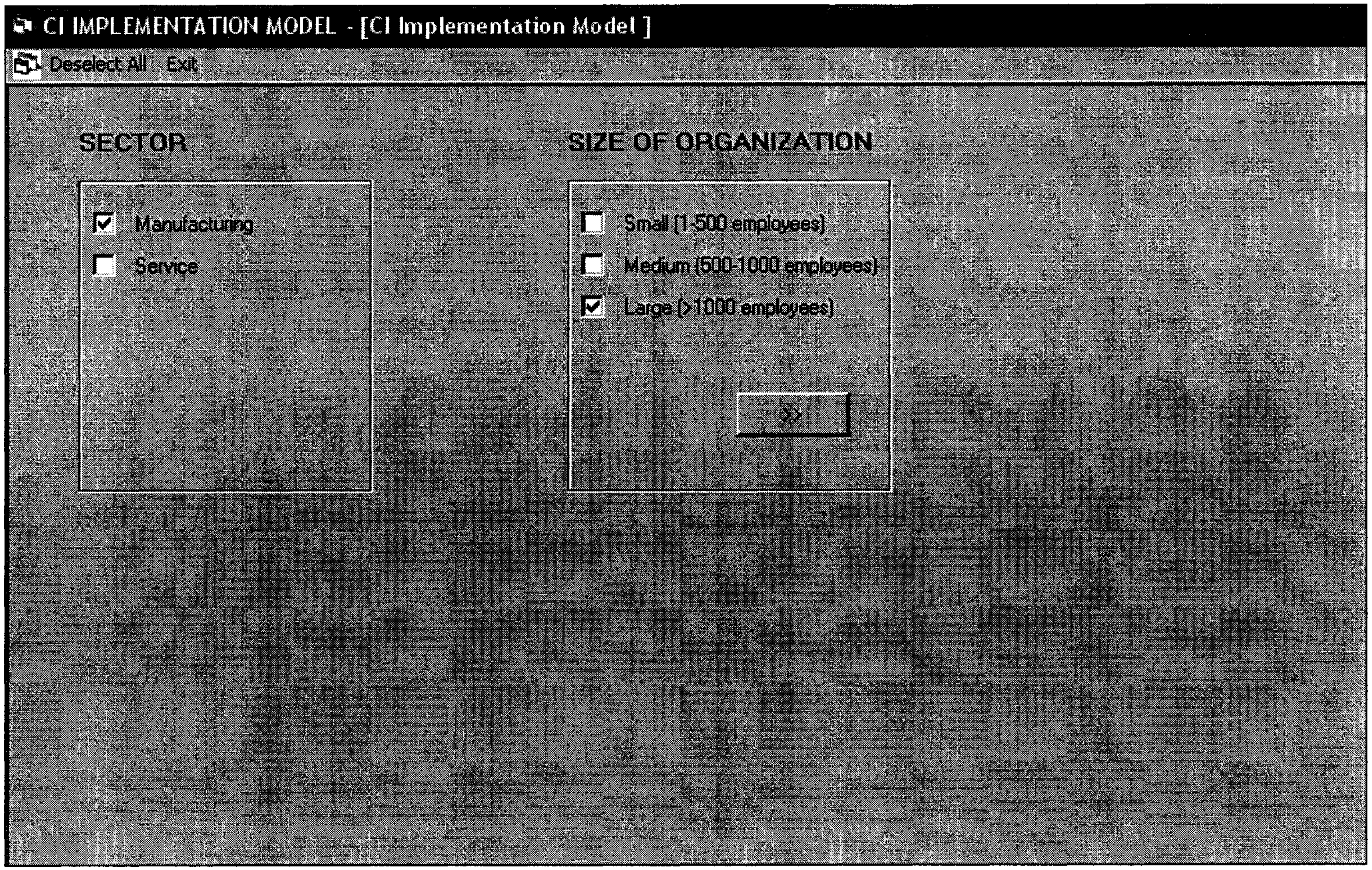


Figure 14: CI Implementation Model – Selecting the Industry sector and Size of the organization

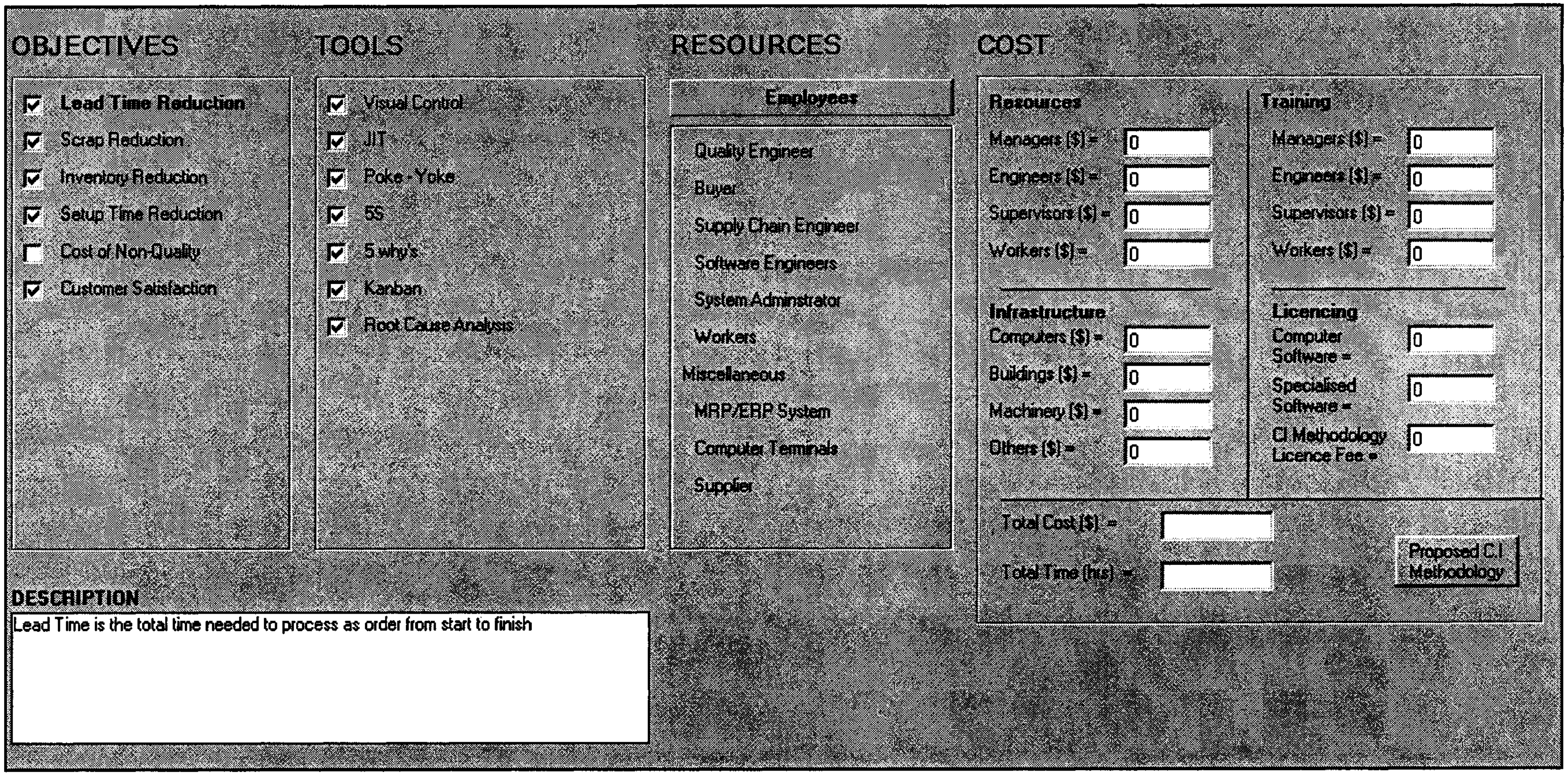


Figure 15: CI Implementation Model - Selecting the objectives and tools

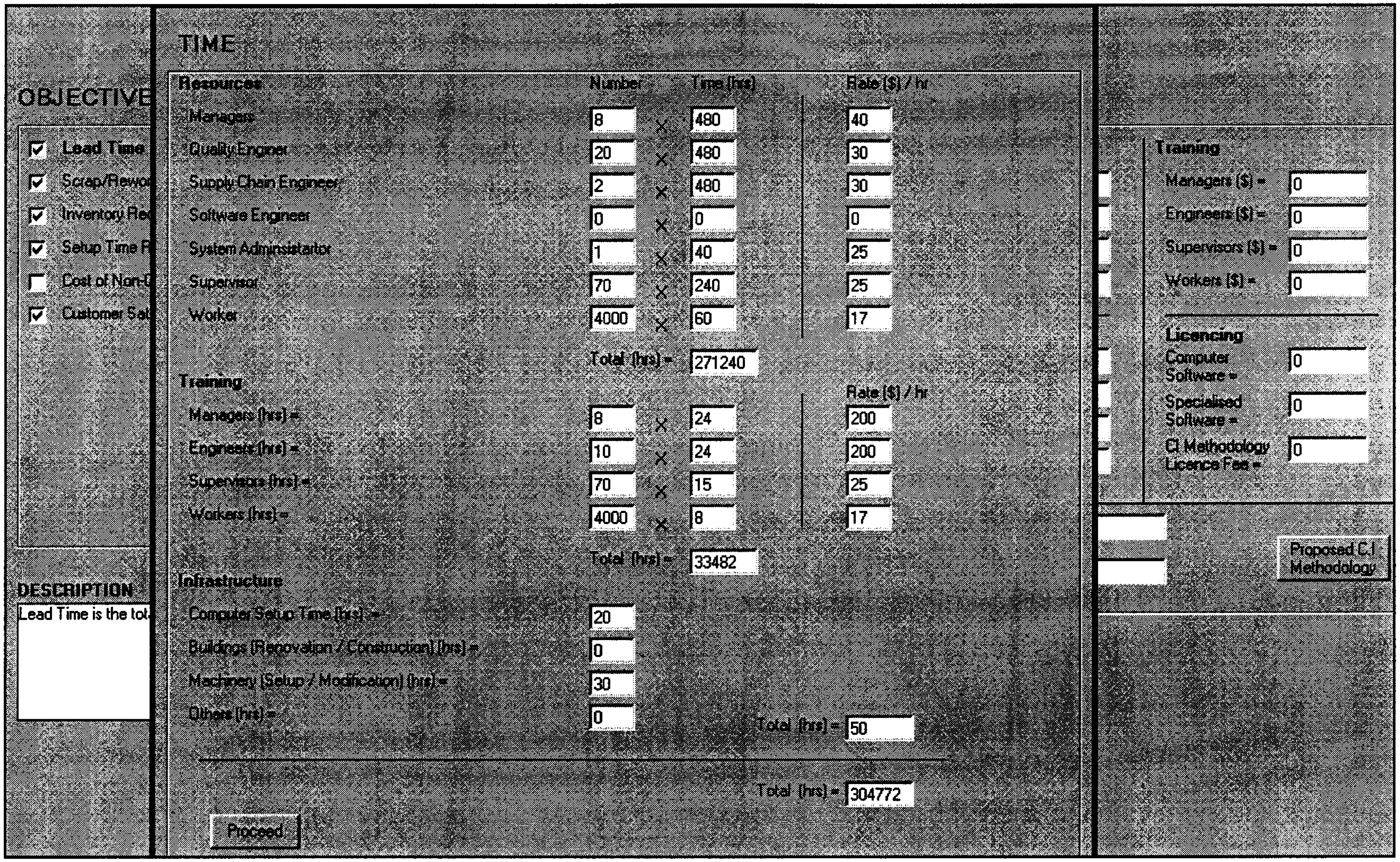


Figure 16: CI Implementation Model - The resources required for the implementation

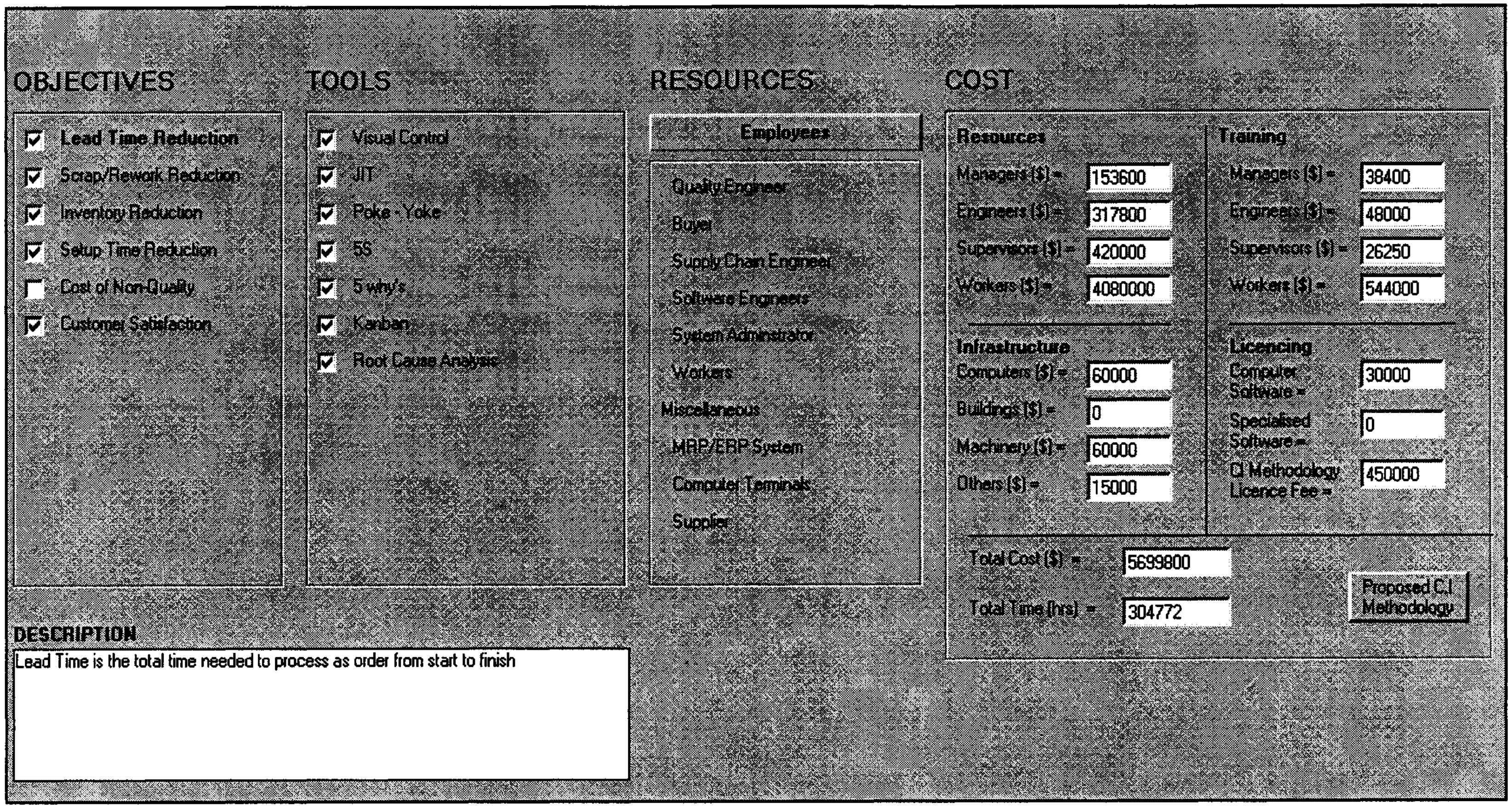


Figure 17: CI Implementation Model - Total cost and time for the implementation

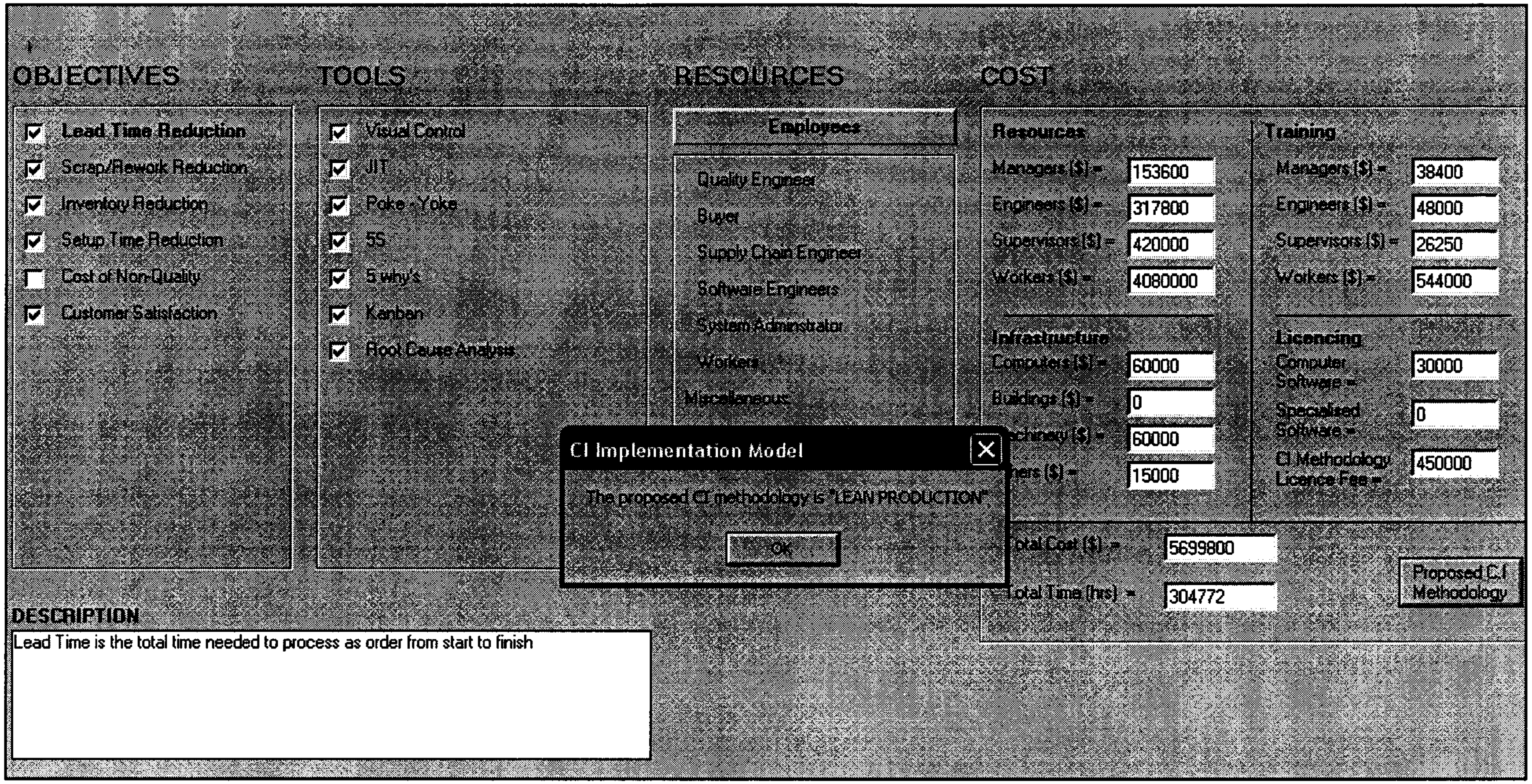


Figure 18: CI Implementation Model - The proposed CI methodology

7. CONCLUSIONS

7.1 Introduction

This chapter presents the conclusions of the study. The study was conducted in three parts which consisted of the literature review and a case study, an industry survey, and finally the development of the CI implementation model. The major findings of the thesis are summarized in the following three sections.

Literature Review and Case Study

A comprehensive literature review has been conducted in which CI has been traced from its origins to its evolution into comprehensive CI methodologies. A comparison between the common CI methodologies such as Lean Production, Six Sigma, Lean Six Sigma and Balanced Scorecard has been presented in terms of its inception, the overall program description, the steps needed to implement each methodology, the time required to implement, the resources required, the cost of implementation and the organizational change required to implement each CI methodology.

A research study was conducted for Pratt & Whitney Canada over a period of 10 months. The objective of the study was to study and compare the CI methodology developed in-house to existing CI methodologies. The study results helped to compare and contrast the various CI programs for their strengths, weaknesses and their applicability to various businesses. The results of this comparison show that ACE™ is a relatively new methodology that uses existing tools, that focuses on improving customer satisfaction by maintaining high quality and delivery on time. This is similar to Lean Production, which strives to provide value to the customer by reducing waste and increasing the speed of production. ACE™ comprises almost all of the Lean Production tools in addition to tools which are specific to ACE™ such as Passport process and Quality Clinic Process Chart. In addition, ACE™ has four certification levels which have been designed to sustain the continuous improvement activities. What distinguishes the ACE™ methodology from others is the inherent sustainability of the methodology. The use of the ACE™ Protocol allows different areas of the company to apply proven CI tools in both the evolutionary CI steps as well as in revolutionary steps.

Survey

A survey was conducted in which data was collected from different organizations which have implemented Lean Production, Six Sigma or Lean Six Sigma. Data was collected using a questionnaire. Since the sample size of the survey was very small, caution should be taken in generalizing the results. The summary of the data collected is as follows:

1. Small sized organizations favoured Lean Production as the CI methodology; whereas medium sized organizations had selected Six Sigma as the CI methodology of choice. Large organizations implemented Lean Production and Six Sigma more than Lean Six Sigma.
2. Lead time, inventory level and rework were the factors that were affected the most as a result of Lean Production implementation and the CI tools most often used during the implementation were 5S, JIT and 5 why's.
3. Scrap, rework, inventory level, line rate and cost of non-quality were the factors that were affected the most by Six Sigma implementation with process capability; FMEA and statistical process control being the most commonly used CI tools during the implementation.

4. Lean Six Sigma had the largest impact on lead time, inventory levels, rework and scrap when implemented by the organization and the most commonly used CI tools were SPC, 5S, kanban, JIT, QFD for Lean Six Sigma.
5. Customer satisfaction was affected the most irrespective of the CI methodology that was implemented.
6. All three CI methodologies had a positive impact on market share and company image.
7. Lean Production took the shortest time for the implementation within the organization, followed by Six Sigma. The time required to implement Lean Six Sigma was the longest.
8. In terms of the overall cost of implementation, Lean Production was the most economical to implement both for infrastructure and resources. Infrastructure costs for Six Sigma and Lean Six Sigma implementation were in the similar range but Six Sigma resources costs are much higher than Lean Six Sigma and Lean Production.

CI Implementation Model

A model has been developed to enable firms to identify the most suitable CI methodology for a given set of objectives. The model takes into account the industry sector, objectives of the organizations, the tools required to implement each of the objectives, the resources required to implement each of the tools, the time required by each resources and the number of employees in the organization. Based on the input data, a CI methodology most suitable for achieving the organization's objectives will be proposed. While the model allows the user to specify the size of the company and the sector it is from, currently, the model will not consider these inputs in proposing the suitable methodology since not enough data has been collected to distinguish among these. The size and sector of the organization can have a profound impact on the CI objectives, CI tools and the overall requirements of resources and cost as the needs of industry sectors and different sized companies are different. Therefore, it is important to be able to collect more data to accommodate these important aspects.

7.2 Limitations of the Research and Need for Further Study

Some of the limitations of the research conducted include:

1. The current CI implementation model does not provide detailed information on the time and the resources required for the implementation while making a decision. It is up to the user to determine this. Although the proposed model takes into consideration the sector, size of the organization, objectives, tools, resources and time but due to lack of detailed data, the current model can only propose the CI methodology based only on sector, objectives and tools selected. By collecting more data from a larger number of companies, the model would be able to provide such information.
2. The response rate for the survey was low; only 27 questionnaires were available for the data analysis. To get a more accurate analysis on the requirements of the CI methodology implementation, a bigger data population is required.
3. The questionnaire survey used to collect data can be more detailed, for example, specific information on cost and time for each of the resources required for the CI implementation would be useful. Also, return on investment is a critical factor in selecting the CI implementation methodology. Future work on the CI implementation

model could use return on investment as a decision criterion for the selection of the CI methodology.

The research conducted in this thesis focused on defining CI from its origins to the development of comprehensive methodologies commonly used in practice today. Data on CI implementation has been collected and analysed from a number of small, medium, and large companies, in both the manufacturing and service sectors, in order to compare the various methodologies for their strengths, weaknesses, and organizational requirements. Finally, a CI implementation model has been developed to help organizations make decisions on which CI methodology best suits their objectives.

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APPENDIX I

The Survey Questionnaire

Company Name: [redacted]

1. **Keep the information source confidential?**

☐ Yes ☐ No

2. **Would you like a copy of the results of the survey?**

☐ Yes
☐ No

3. **Company Sector**

☐ Manufacturing, please specify: [redacted]
☐ Service, please specify: [redacted]

4. **Number of Employees**

☐ 1 - 100
☐ 100 - 500
☐ 500 - 1000
☐ More than 1000

5. **Continuous Improvement Program in use**

☐ Six Sigma
☐ Lean
☐ Lean Six Sigma
☐ Others, please specify: [redacted]

6. **For how long has this program been in existence in your organization?**

[redacted]

7. **Time for implementation**

☐ 3 – 6 months
☐ 6 – 12 months
☐ 1 – 2 years
☐ More than 2 years

8. **Implementation Cost ($US)**

   a) **Infrastructure Cost**

   ☐ $1000 - $50,000
   ☐ $50,000 - $100,000
   ☐ $100,000 – $500,000
   ☐ More than $500,000

b) Cost of Resources
☐ $50,000 - $200,000
☐ $200,000 - $500,000
☐ $500,000 - $1,000,000
☐ More than $1,000,000

c) Licensing Cost (If a license was bought for the CI Program)
☐ $50,000 - $200,000
☐ $200,000 - $500,000
☐ $500,000 - $1,000,000
☐ More than $1,000,000

d) Employee Training (per year)
☐ $1,000 - $50,000
☐ $50,000 - $100,000
☐ $100,000 - $500,000
☐ More than $500,000

e) Miscellaneous Expenses

9. Number of resources required for implementation
☐ 1 - 20
☐ 20 - 50
☐ 50 - 100
☐ More than 100

10. Resources required for implementation?
☐ Internal
☐ External
☐ Both

11. Does the existing CI program require employee training?
☐ Yes
☐ No (please skip, 12 & 13)

12. How long is the training (per person)?
☐ 1- 2 hours
☐ 3 – 6 hours
☐ 8-12 hours
☐ More than 12 hours

13. Who provides the training?
☐ Internal Resources
☐ External Resources (Consultants)
☐ Both

14. How many resources are required to provide the training?

15. Effect of the CI Program on Organizational Performance.

a) Operational Perspective

	No Effect 1	*Minor Effect* 2	*Moderate Effect* 3	*Good Effect* 4	*Strong Effect* 5	*Not Applicable* N/A
Lead Time	☐	☐	☐	☐	☐	☐
Rework	☐	☐	☐	☐	☐	☐
Inventory Levels	☐	☐	☐	☐	☐	☐
Scrap	☐	☐	☐	☐	☐	☐
Line Rate	☐	☐	☐	☐	☐	☐
Setup Time	☐	☐	☐	☐	☐	☐
Cost of Non-Quality	☐	☐	☐	☐	☐	☐
Environment Health and Safety	☐	☐	☐	☐	☐	☐

b) Customer Perspective

	No Effect 1	*Minor Effect* 2	*Moderate Effect* 3	*Good Effect* 4	*Strong Effect* 5	*Not Applicable* N/A
Customer Satisfaction	☐	☐	☐	☐	☐	☐
Customer Retention	☐	☐	☐	☐	☐	☐
Customer Complaints	☐	☐	☐	☐	☐	☐
Warranty Claims	☐	☐	☐	☐	☐	☐

c) Market Perspective

	No Effect 1	*Minor Effect* 2	*Moderate Effect* 3	*Good Effect* 4	*Strong Effect* 5	*Not Applicable* N/A
Market Share	☐	☐	☐	☐	☐	☐
Company Image	☐	☐	☐	☐	☐	☐

16. What is average annual savings from the existing CI program ($US)?

17. Return on investment

☐ Less than Expected
☐ As Expected

☐ More than expected

18. How many improvement projects do you finish annually (Six Sigma, Lean)?

[redacted]

19. From the following list, please select the Tools used by your organization during CI implementation.

Note: If some of the tools used by your organization are not mentioned in the list, please enter them at the end of the list

Cp/Cpk (Process capability assessment)	☐
Design of Experiment	☐
Statistical Process Control	☐
Taguchi Methods	☐
Failure Mode & Effect Analysis	☐
Regression Analysis	☐
Process Mapping	☐
5 Whys/2 How's	☐
Pareto Chart	☐
Fishbone Chart	☐
5S	☐
Visual Management	☐
Poka-Yoke	☐
Spaghetti Chart	☐
Kanban	☐
Single Minute Exchange of Dyes	☐
Quality Function Deployment	☐
RCCA	☐
Benchmark	☐
GAP Analysis	☐
JIT	☐
Other:	☐
[redacted]	☐
[redacted]	☐
[redacted]	☐
[redacted]	☐

20. Overall effect on the organization in terms of work culture

☐ Positive
☐ Negative
☐ No Effect

Please elaborate on your answer:

21. Are you satisfied with the current Continuous Improvement program?

☐ Yes
☐ No
☐ N/A

Please elaborate on your answer:

22. Will you continue with the current Continuous Improvement program?

☐ Yes
☐ No
☐ Undecided

23. Shortcomings of the current Continuous Improvement program

24. Comments

Thank you for your cooperation in this study. Your input is very valuable to us.

APPENDIX II

The Questionnaire Letter

A SURVEY OF CONTINUOUS IMPROVEMENT METHODOLOGIES

This survey has been designed to assist a research study undertaken by the Department of Mechanical & Industrial Engineering at Concordia University, Montreal. The objectives of the study are:

1. To compare and contrast the various CI methodologies/programs in use.
2. To develop a model that will assist organizations, both manufacturing and service based, in selecting the best CI methodology to implement.

Please answer the survey questions and feel free to add your comments at the end of. Once the research is complete, we will be happy to provide you with a copy of the results of the survey. Please be assured that your responses will be handled in strict confidence, if so desired.

In order to increase the accuracy of the result, we need more people to participate in completing the survey. If you know of any practitioners in the field of Quality, please forward the original survey to them.

Please return the completed survey questionnaire by email to:

baghel@me.concordia.ca or **a_baghel78@yahoo.ca**

Or by post to:

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