DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

A STUDY ON SIX SIGMA APPLICATIONS FOR DEVELOPING PROCESS PERFORMANCE

by
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İZMİR

A STUDY ON SIX SIGMA APPLICATIONS FOR DEVELOPING PROCESS PERFORMANCE

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by

Senem VAHAPLAR

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Ph.D. THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"A STUDY ON SIX SIGMA APPLICATIONS FOR DEVELOPING PROCESS PERFORMANCE"** completed by **SENEM VAHAPLAR** under supervision of **PROF. DR. ALİ ŞEN** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Doctor of Philosophy.

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A STUDY ON SIX SIGMA APPLICATIONS
FOR DEVELOPING PROCESS PERFORMANCE

ABSTRACT

The importance of the performance of business processes for the success of organisations is undeniable. For surviving and being able to compete, organisations have to improve themselves by improving their business processes. This explains why process performance improvement is very popular and beneficial today. Therefore, it is used widely in organisations nowadays. There are many studies realised and published on this subject and many new studies are being performed.

This thesis aims to integrate the techniques such as process qualification, fifth discipline, sustainability and six sigma, which are used in different points throughout process performance management, to examine the relationships between them and to investigate the possible contributions they may have on each other. In this manner, these techniques and methodologies will become more powerful by being used together and this will provide a more efficient performance management.

The thesis shows the cause and effect relationship between process qualification and process performance. How an improvement obtained in process qualification causes an improvement in process performance is demonstrated by an application in an organisation working in automotive sector. Also, the model proposed for ensuring sustainability of realised improvements is given.

Keywords: Process performance, Performance improvement, Six sigma, IDEF0, Process qualification, Harrington qualification criteria, Sustainability, Fifth discipline

SÜREÇ PERFORMANSININ İYİLEŞTİRİLMESİ İÇİN ALTI SİGMA UYGULAMALARI ÜZERİNE BİR ÇALIŞMA

ÖZ

İş süreçlerinin performansının kuruluşların başarısı için önemi inkar edilemez. Yaşamlarını sürdürebilmek ve rekabet edebilmek için kuruluşlar iş süreçlerini iyileştirerek kendilerini geliştirmelidirler. Bu da, süreç performansının iyileştirilmesinin günümüzde neden çok popüler ve faydalı olduğunu ve kuruluşlarda neden sıkça uygulandığını açıklamaktadır. Bu konuda yapılmış ve hala yapılmakta olan pek çok çalışma bulunmaktadır.

Bu tezin hazırlanması ile amaçlanan; süreç performansının yönetimi alanında farklı noktalarda kullanılan süreç nitelendirilmesi, beşinci disiplin, sürdürülebilirlik, altı sigma gibi yöntemleri bir araya getirerek aralarındaki ilişkileri ve birbirlerine sağlayabilecekleri katkıları incelemektir. Böylelikle, bu yöntemler birlikte kullanılarak daha güçlü hale getirilecek, bu da daha etkin bir performans yönetimi sağlayacaktır.

Tezde süreç niteliği ile süreç performansı arasındaki sebep-sonuç ilişkisi gösterilmektedir. Süreç niteliğinde sağlanan bir iyileşmenin süreç performansında nasıl iyileşme sağladığı otomotiv sektöründe çalışan bir kuruluşta yapılan uygulama ile gösterilmiştir. Ayrıca, gerçekleştirilen iyileştirmelerin kalıcılığını sağlamak için önerilen model verilmiştir.

Anahtar sözcükler: Süreç performansı, Performans iyileştirme, Altı sigma, IDEF0, Süreç nitelendirilmesi, Harrington nitelendirme kriterleri, Sürdürülebilirlik, Beşinci disiplin

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CHAPTER ONE
INTRODUCTION

Business processes are very important for the economic survival of the organisations. Consequently, if organisations want to survive and compete with their competitors, they have to improve themselves by improving their business processes. For improving business processes, process performance criteria should be measured, analysed, monitored and evaluated. Also, the variability in the processes has to be reduced. So, for examining the variability in processes, process data should be analysed with statistical techniques, which means that data analysis and statistical thinking is a must in business process improvement.

The main point of this thesis is improving performance of business processes. It is aimed to examine the relationships between the tools and techniques used in process performance improvement. So these relations will be used for increasing the efficiency and strength of these techniques.

The purpose of this thesis is to show the relationship between causes; process qualification levels, and effects; process performance results, to determine how to improve process performance with statistical data analysis and to give some propositions on how to provide sustainability of obtained improvements. Statistical tools and techniques are very useful for improving quality and process performance. Not only the advanced tools but also the basic and elementary tools may be helpful. Also, process walkthrough, process performance, data analysis, process qualification and cause and effect analysis are the parts of improvement process.

This thesis consists of 8 chapters. Chapter 2 gives general information on six sigma and its DMAIC methodology. Chapter 3 describes the fundamentals of business process improvement. Chapter 4 explains process qualification and highlights the details of Harrington qualification criteria. Chapter 5 investigates learning organisations and their five core disciplines including systems thinking as the fifth discipline. Chapter 6 is about ensuring the sustainability of realised

improvements in processes. Chapter 7 represents the application of the thesis. This application consists of two parts; an application of process improvement through process qualification and a six sigma project for ensuring sustainability of realised improvements. Finally, Chapter 8 includes the conclusions of the thesis.

CHAPTER TWO
SIX SIGMA

2.1 Scope and Purposes

Six sigma has been defined in many ways in the literature such as a high performance data driven approach for analysing the root causes of business problems and solving them (Blakeslee, 1999), as a business process that allows companies to drastically improve their bottom line by designing and monitoring everyday business activities in ways that minimise waste and resources while increasing customer satisfaction (Harry & Schroeder, 2000), as a disciplined and statistically based approach for improving product and process quality (Hahn, Doğanaksoy & Hoerl, 2000), or as a management strategy that requires a cultural change in the organisation (Sanders & Hild, 2000 and Schroeder, Linderman, Liedtke & Choo, 2007). Integrating all these definitions, it helps the organisations manufacture near-perfect products or services (General Electric Company [GE], 2007).

This chapter has the purpose of giving general information on six sigma and its DMAIC methodology. For this purpose, the history of six sigma methodology is given briefly. Then, the differences between six sigma and total quality management are examined. Finally, DMAIC methodology is described.

2.2 Six Sigma Philosophy

Six sigma philosophy was developed by Motorola company in 1987 for reducing manufacturing defects (Kumar, Nowicki, Ramirez-Marquez & Verma, 2007). In 1990, Motorola came together with IBM, Texas Instruments and Xerox and created the concept of black belts who would be experts in applying statistical methods (Barney, 2002). Then, AlliedSignal introduced six sigma as a business programme to produce high level results, improve business processes, expand the skills of employees and change the culture (American Society for Quality [ASQ], 2002; Schroeder, Linderman, Liedtke & Choo, 2007). Also, General Electric began to apply six sigma methodology in 1995 (Slater, 1999; Schroeder, Linderman, Liedtke & Choo, 2007).

Six sigma was created as a continuous quality improvement technique, but today it is significantly different from total quality management (TQM) approach of the 1980s. The key differences between six sigma and TQM are listed on Table 2.1 (Barney, 2002).

Table 2.1 Differences between six sigma and total quality management (Barney, 2002)

Six Sigma	**Total Quality Management**
Executive ownership	Self-directed work teams
Business strategy implementation system	Quality programme
Truly cross functional	Largely within a single function
Focused training with verifiable return on investment	No mass training in statistics and quality
Business results oriented	Quality oriented

So, six sigma can be defined as a process improvement methodology that aims to increase business performance through a solid and accurate business focus (Savolainen & Haikonen, 2007). Also, Pyzdek defines six sigma as the application of the scientific method to the design and operation of management systems and business processes, while enabling employees to deliver the greatest value to the customers (Pyzdek, 2003). So it can be specified as a systematic approach for accomplishing continuous process improvement.

Table 2.2 shows the relation between sigma levels and DPMO values. It is clear that DPMO and sigma levels are indirectly proportional. Sigma levels increase as DPMO values decrease. The lower the DPMO value, the higher the sigma level and this shows an absolute improvement in the processes. This improvement can be monitored with the success rate column in Table 2.2. As DPMO value decrease and therefore sigma level increase, the success of the process increases.

Table 2.2 DPMO values, sigma levels and the corresponding success rates

DPMO	Success rate	Sigma level
841,000	16.00000 %	0.5
691,000	31.00000 %	1.0
500,000	50.00000 %	1.5
309,000	69.10000 %	2.0
159,000	84.10000 %	2.5
66,800	93.32000 %	3.0
22,800	97.72000 %	3.5
6,210	99.37900 %	4.0
1,350	99.86500 %	4.5
233	99.97670 %	5.0
32	99.99680 %	5.5
3.4	99.99966 %	6.0

2.3 DMAIC Methodology

The tools used in six sigma projects are often applied within a simple performance improvement model known as DMAIC methodology; consisting of define, measure, analyse, improve and control phases (Pyzdek, 2003).

On the define phase; the goals of the improvement activity are defined. The most important goals are obtained from the customers. On the measure phase; the existing system is measured. Valid and reliable metrics to help monitor progress towards the goal are established. On the analyse phase; the system is analysed for identifying ways to eliminate the gap between the current process performance and the desired goal. Exploratory and descriptive data analysis techniques are used in this step for understanding the data. It is clear that statistical tools guide the analysis. On the improve phase; the system or the process is improved. New ways are found for doing things better, cheaper and faster. Project management and other planning and management tools are used in this step. Also, the improvement is validated with statistical methods. Finally on the control phase; the new system or the new process is controlled. Statistical tools are used for monitoring the stability or sustainability of the new system or process. Figure 2.1 clearly shows the use of DMAIC methodology on a six sigma project (Pyzdek, 2003).

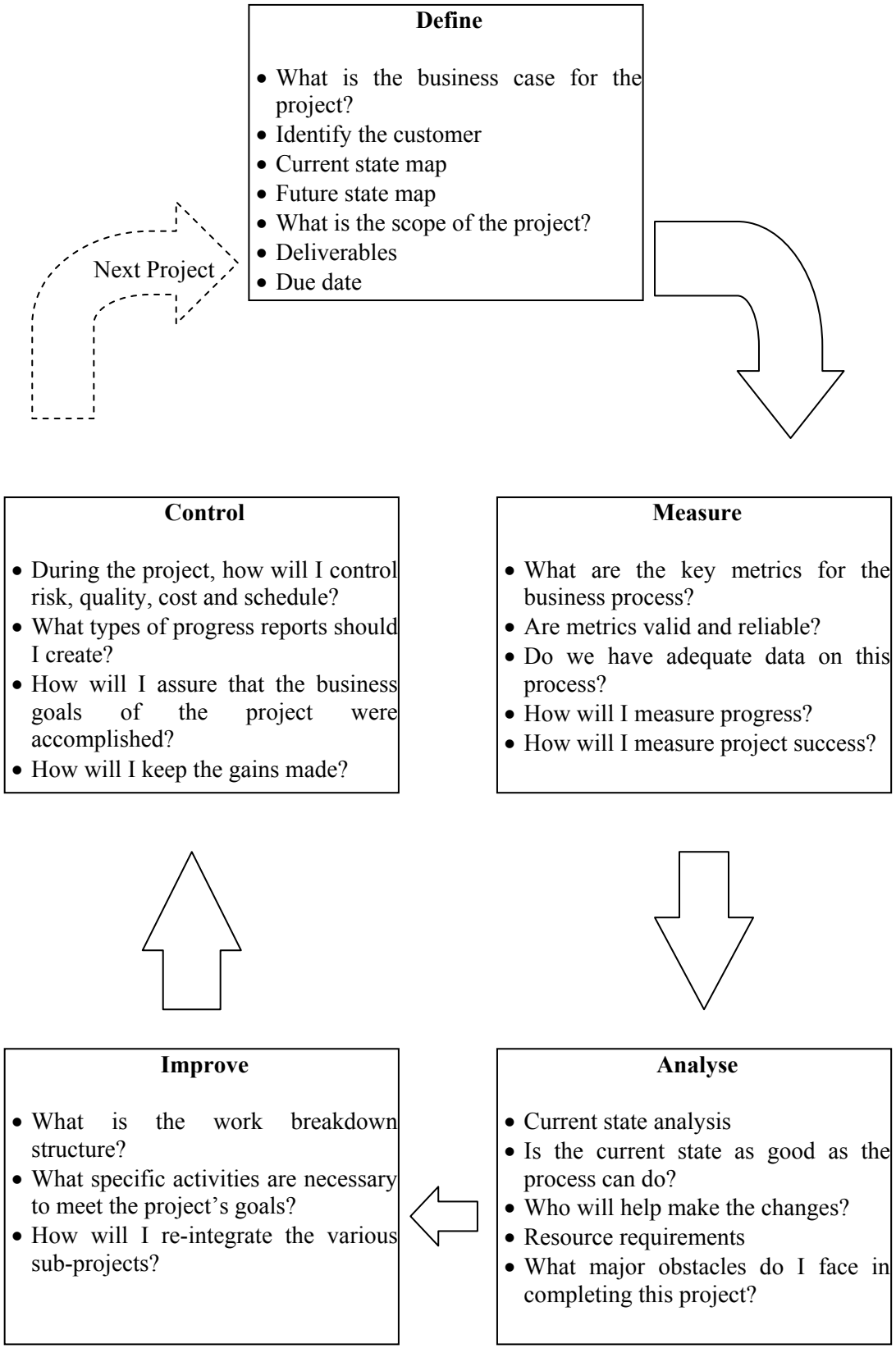


Figure 2.1 The use of DMAIC methodology on a six sigma project (Pyzdek, 2003, p. 239).

There are many tools and techniques used in each phase of DMAIC methodology of six sigma for data analysis. These tools and techniques are listed on Table 2.3. It should be noted that there exist a connection between statistical tools and process improvement. By using suitable statistical tools, processes can be improved in an easier and more efficient way. As an example, a process containing many defects may be improved with simple and elementary tools instead of advanced statistical tools. The choice of suitable tools depends on the characteristics and structure of the process.

Table 2.3 Tools and techniques used in DMAIC methodology (Pyzdek, 2003)

DMAIC Phase	**The Tools Used in the Corresponding DMAIC Phase**	

Define	Problem solving tools	• Process mapping
		• Check sheets
		• Pareto analysis
		• Cause and effect diagram
		• 7M tools
		  o Affinity diagrams
		  o Tree diagrams
		  o Process decision program charts
		  o Matrix diagrams
		  o Interrelationship digraphs
		  o Prioritisation matrices
		  o Activity network diagram

Measure	Measurement systems analysis	• Repeatability & Reproducibility (R&R) studies for continuous data o Gage R&R
Analyse	Knowledge discovery	• Run charts • Descriptive statistics • Histograms • Exploratory data analysis • SIPOC (Suppliers, Inputs, Process, Outputs, Customers)
	Statistical process control techniques	• Control charts
	Process capability analysis	• Process capability indices • Estimating process yield

	Statistical analysis of cause and effect	• Regression analysis
		  o Scatter plots
		  o Correlation
		  o Logistic regression
		• Analysis of categorical data
		• Nonparametric methods

Improve	Managing six sigma projects	• Feedback loops • Gantt charts • CPM • PERT
	Risk assessment	• Reliability analysis • FMEA • Statistical tolerancing
	Design of experiments	• ANOVA
	Other techniques	• Data mining • Artificial neural networks
Control	Maintaining control after the project	• Business process control planning o Project planning o Brainstorming o Process decision program chart o FMEA • SPC for ongoing control • Process audits

CHAPTER THREE
BUSINESS PROCESS IMPROVEMENT

3.1 Scope and Purposes

At the present time, business process improvement is a crucial and indispensable concept for being competitive in the market. In order to realise business process improvement, which is a difficult and time consuming process, the performance of business processes should accurately be measured, analysed, monitored, evaluated and improved.

This chapter has the purpose of giving information on business process improvement basics. So it composes of explanations on process approach, business processes and their performance, performance measurement and improvement and finally process performance criteria.

3.2 Process Approach

Most commonly used definition of a process is an integrated collection of activities that converts inputs into outputs. Process approach, which is a management strategy, can be defined as managing processes by examining the relations between processes and inputs and outputs of processes that link them to each other (Praxiom Research Group Limited [PRG], 2007).

3.2.1 Benefits of Process Approach

The most important advantage of process approach is that it aids the organisations to comprehend what actually is happening in the organisation, and discover the bottlenecks, inefficiencies and problems that could be hidden. Process management also helps the organisations to reduce lead times, decrease costs, improve efficiency, improve quality and increase customer and employee satisfaction. “Modelling and

analysing the business processes enables the organisations to develop and improve its effectiveness and quality of work" (QPR Software Plc [QPR], 2006). Besides, process approach has an enabling effect on quality management system principles. It also helps the organisations to distinguish between value added and not value added processes and discriminate waste.

Moreover, process mapping part of process approach has some advantages compared to other flow charts. Process mapping ensures to see all the linkages present in the processes and therefore to see how a change in one part will affect the other.

3.2.2 Process Mapping

Process mapping can be defined as identifying, documenting, analysing and developing an improved process. A process map is a visual aid for picturing business processes which shows how inputs, outputs and tasks are linked to each other. It is used to understand an organisation's business and improve the performance of the processes. A process map encourages new thoughts about how work is done. It shows major steps taken to produce an output, who performs the steps and where the important problems consistently occur. Process mapping also makes the organisations notice the areas in which a change in processes will have the greatest impact on improving quality (Anjard, 1998).

3.2.2.1 Integrated Definition Language 0 for Function Modelling (IDEF0)

Process maps are used to represent processes in such a way that it is easy to read and understand them (Peppard & Rowland, 1995). There are many techniques developed for mapping processes. Among these, Integrated Definition Language 0 (IDEF0) is selected for being used in the thesis owing to its advantages given in this section.

IDEF0 is a method designed to model the decisions, actions and activities of an organisation or a system. The graphical tools used in IDEF0 method are very simple; boxes and arrows. Boxes represent actions and arrows represent interfaces between these actions (Feldmann, 1998). The general form of an IDEF0 model is shown in Figure 3.1.

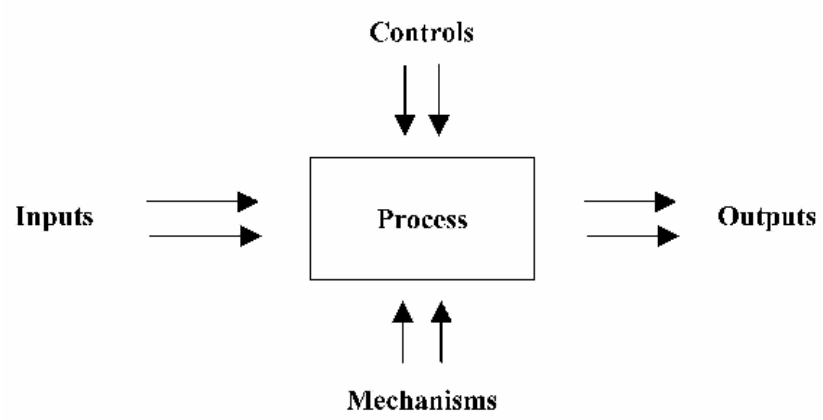


Figure 3.1 IDEF0 model general form.

"IDEF0 describes a business process as a series of linked activities, each with inputs and outputs. External or internal factors control each activity, and each activity requires one or more mechanisms or resources. Inputs are data or objects that are consumed or transformed by an activity. Outputs are data or objects that are the direct results of an activity. Controls are data or objects that specify conditions which must exist for an activity to produce correct outputs. Finally, mechanisms or resources support the successful completion of an activity but are not changed in any way by it" (Fülscher & Powell, 1999, p. 212).

As an example to IDEF0 maps, Fülscher & Powell drew the map of general insurance activity in their workshop study as shown in Figure 3.2. As it is seen from the figure, a very complicated process such as an insurance process can be mapped with sufficient detail, ensuring it being easily understood by readers.

Finally, the strength of IDEF0 mapping is that; it starts with the simplest possible description of the process and refines it in an ordered series of steps to a level of detail that meets the organisation's needs (Fülscher & Powell, 1999).

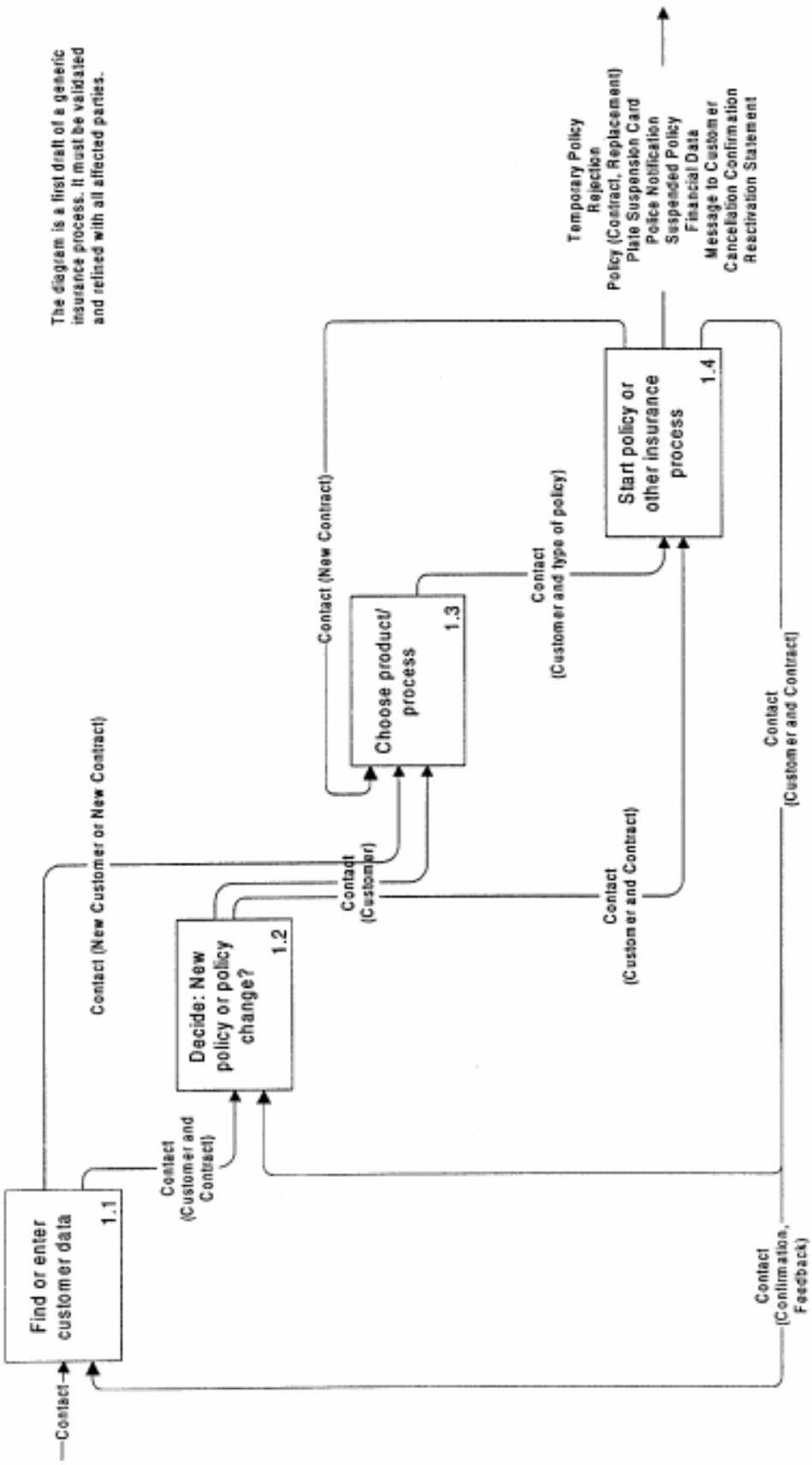


Figure 3.2 IDEF0 map of general insurance activity (Fülscher & Powell, 1999, p. 226).

3.3 Business Processes

As it can be clearly seen, business process term consists of both business and process. Therefore, it is something different from a normal process. In order to separate a company's processes from other forms of processes, the word business has been added to form the term business process. Ericsson Quality Institute has defined business process as a chain of logical connected, repetitive activities that utilizes the enterprise's resources to refine an object for the purpose of achieving specified and measurable results or products for internal or external customers (Ericsson Quality Institute [EQI], 1993). So it is clear that business processes play an important role in the economic survival of the organisations (Harrington, 1991).

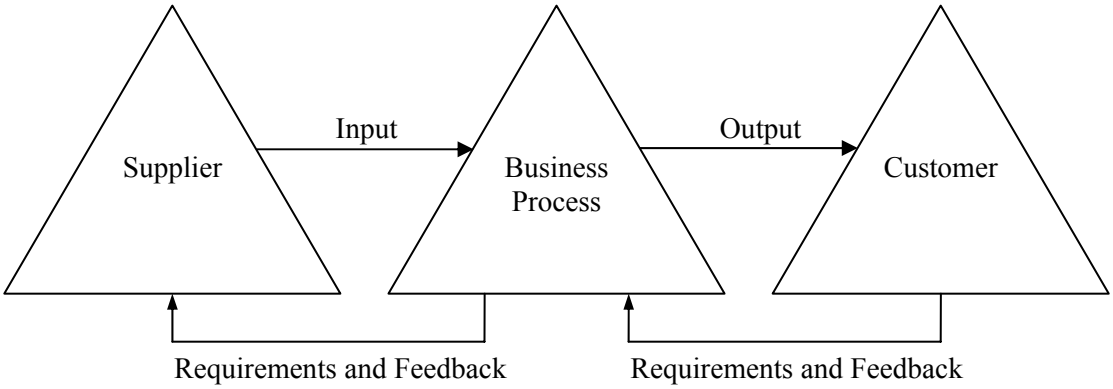


Figure 3.3 Business process with supplier and customer.

It is also shown graphically in Figure 3.3 that, every business process has a customer. This customer may be internal or external. Therefore, as almost all activities in a company has a customer, these activities can be seen as business processes or parts of business processes.

3.4 Process Performance

3.4.1 Importance of Process Performance

Business processes and their performance are certainly extremely important for the success and continuance of organisations. Especially in the recent years, this

importance has been discovered and studies on this subject have started. Before organisations changed their way of thinking on importance of business processes, they had some wrong thoughts such as;

- Ineffective business processes do not cost much money to the organisation,
- There is not much to be gained by improving business processes,
- It is not possible to control business processes,
- Business processes do not have much importance compared to production processes (Harrington, 1991).

John R. Opel, who was the chairman of the board of directors for IBM, stated that; *"We need a business process that is worthy of respect and is respected. This means a process that can handle today's values and complexities accurately and efficiently – one that is positioned for the future and, therefore, can move ahead with the business, not struggle along behind as it has been doing"* (Harrington, 1991, p. 18).

Also seen from this statement, if an organisation wants to take place in today's marketplace, it has to measure, analyse, monitor and evaluate the performance of its business processes carefully.

3.5 Performance Improvement

The success of an organisation depends on how well its business processes are. If the organisation decides to improve itself, it has to improve its business processes. For making the improvement, sources of variability should carefully be analysed and variability should be decreased, and this cannot be thought separately of statistical thinking (Şahan Vahaplar & Şen, 2006).

Business process improvement;

- enables the organisation to focus on the customer,
- allows the organisation to predict and control change,
- improves organisation's ability to compete by improving the use of available resources,
- helps the organisation to manage its interrelationships,
- provides a systematic view of organisation's activities,
- keeps the focus on the process,
- helps the organisation understand how the inputs become outputs,
- prevents errors from occurring,
- provides a view of how errors occur and a method for correcting them,
- develops a complete measurement system for the business areas,
- provides an understanding of how good the organisation can be and defines how to get it there,
- provides a method to prepare the organisation to meet its future challenges (Harrington, 1991).

3.5.1 Reasons for Improving Process Performance

Andersen listed the reasons for the necessity of process performance improvement, as given below.

- Performance levels of processes mostly show a tendency to decrease over time unless forces are exerted to maintain it.
- An organisation may not improve, but its competitors will. So, if an organisation wants to at least keep its market share, it has to improve its business processes.
- "Today's customers are becoming more and more demanding. Supply and the quality of the supply are ever increasing, which in turn cause the expectations to rise dramatically." It may not always be possible to exceed expectations but if the organisation does not want to lose its customers, it at least has to meet the expectations (Andersen, 1999).

3.6 Performance Measurement

It is not possible to manage something that can not be measured. For improving a business process, it has to be measured first. Measuring the business processes' performance level is important. Performance measurement provides much useful information about how well a process is being conducted and how good its results are. By measuring the processes, organisations can;

- understand what is occurring in the organisation,
- evaluate the need for change,
- identify processes or areas that need to be improved,
- get an idea of the development over time,
- compare its performance level against other organisations,
- determine whether started or finished improvement projects have produced or will produce good results,
- determine how effectively its resources are used,
- determine which improvement tools should be used (Andersen, 1999 and Harrington, 1991).

3.7 Process Performance Criteria

For evaluating performance levels of business processes, many performance criteria have been developed. ENAPS criteria, Harrington criteria, Malcolm-Baldrige criteria, EFQM criteria are among these. All of these criteria are used for measuring business processes' performance levels and qualifying them.

Process performance criteria are classified in three categories;

- Efficiency Criteria
- Effectiveness Criteria
- Adaptability Criteria

Efficiency criteria are used to determine if the outputs are free of problems. Effectiveness criteria are used to determine whether resources are used optimally. It can also be defined as obtaining the maximum output from specified input or obtaining specified output with minimum input. Finally, adaptability criteria are used to determine how fast the process can give response to the changes in outputs.

CHAPTER FOUR
PROCESS QUALIFICATION

4.1 Scope and Purposes

Harrington defines process qualification as milestones and recognition points for process improvement teams. The companies all have the same target; to have the best business processes. It is difficult to reach this target and it will take a long time. So, the companies need some milestones during this process to show that they are making progress, their processes are being improved. This is process qualification and it involves evaluating a complete process to determine whether it can perform at the appropriate level or not (Harrington, 1991).

There exist a cause and effect relationship between process qualification and process performance. Qualification is the cause and performance is the effect. Therefore, evaluations and audits that will be made on process qualification will give more effective results than the audits that will be made on process performance. Also, quality management system principles will be more permanent. In this manner, by making improvements in the qualification of the process, improvement on process performance will be ensured. This is proved in the application chapter of the thesis.

The cause and effect relationship between process performance and process qualification is shown in Figure 4.1 (Şahan Vahaplar & Şen, 2006).

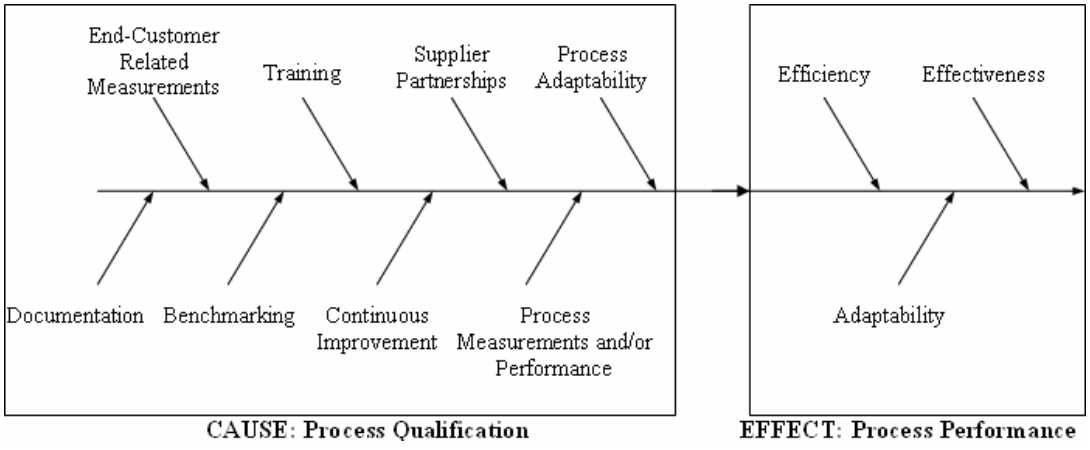


Figure 4.1 Cause and effect relationship between process qualification and process performance.

Therefore the aim of this chapter is to examine Harrington qualification criteria in details and investigate the relations between Harrington criteria and quality management system principles.

4.2 Harrington Qualification Criteria

H.J. Harrington developed some business process performance measures. According to these measures, business processes are qualified in one of six levels. These levels are shown in Table 4.1.

Table 4.1 Qualification levels of Harrington criteria (Harrington, 1991, p. 206)

Level	Status	Description
6	Unknown	Process status has not been determined.
5	Understood	Process design is understood and operates according to prescribed documentation.
4	Effective	Process is systematically measured, streamlining has started, and end-customer expectations are met.
3	Efficient	Process is streamlined and is more efficient.
2	Error-free	Process is highly effective (error-free) and efficient. Rarely there is a problem in the process. Schedules are always met and stress levels are low.
1	World class	Process is world class (the process is one of the 10 best processes of its kind in the world) and continues to improve. These processes are often benchmark target processes for other organisations.

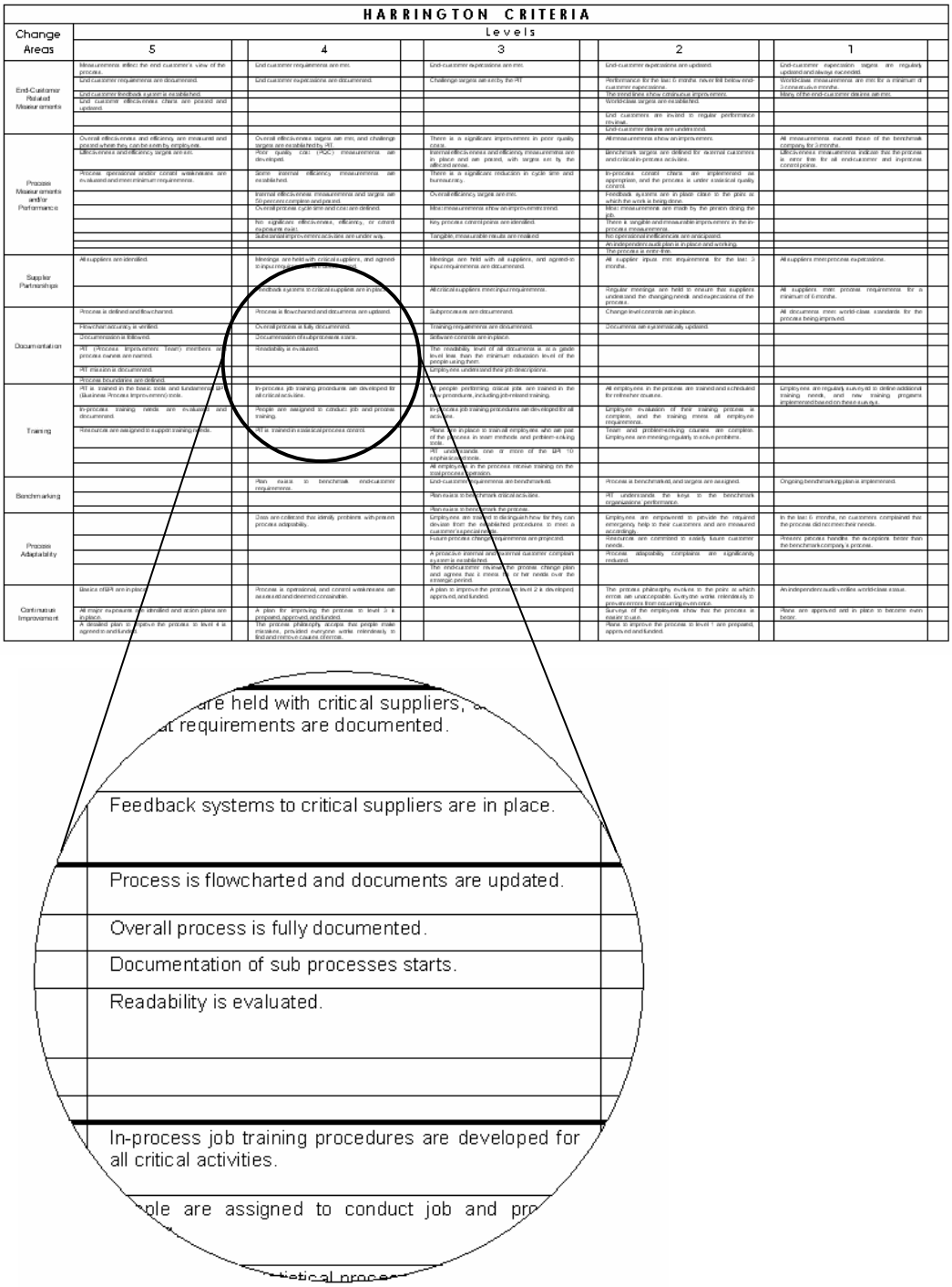
For determining the performance levels and process status of business processes, there are eight change areas that should be examined in this criteria set. These areas are listed below.

- End-customer related measurements
- Process measurements and/or performance
- Supplier partnerships
- Documentation
- Training
- Benchmarking
- Process adaptability
- Continuous improvement

Change areas determine the requirements to move from one qualification level to another. The requirements in all change areas of each process status are defined by Harrington. It should be noted that, all business processes are considered to be at level six until any business process improvement methodology has been applied. Processes move from qualification level six to qualification level one. “To be qualified at any level, all the criteria in each of the eight major change areas must be met or exceeded” (Harrington, 1991).

4.2.1 Requirements to be Qualified in Each Level

The requirements to be qualified in each qualification level are tabulated as shown in Figure 4.2. Following this figure, the requirements for level five are listed. The requirements for other levels are given in Appendix A.



HARRINGTON CRITERIA

Change Areas	Levels 5	4	3	2	1
End-Customer Related Measurements	Measurements reflect the end customer's view of the process.	End customer requirements are met.	End-customer expectations are met.	End-customer expectations are updated.	End-customer expectation targets are regularly updated and always exceeded.
	End customer requirements are documented.	End customer expectations are documented.	Challenge targets are set by the PIT	Performance for the last 6 months never fell below end-customer expectations.	World-class measurements are met for a minimum of 3 consecutive months.
	End customer feedback system is established.			The trend lines show continuous improvement.	Many of the end-customer desires are met.
	End customer effectiveness charts are placed and updated.			World-class targets are established.	
				End customers are invited to regular performance reviews.	
				End-customer desires are understood.	
Process Measurements and/or Performance	Overall effectiveness and efficiency are measured and posted where they can be seen by employees.	Overall effectiveness targets are met, and challenge targets are established by PIT.	There is a significant improvement in poor quality areas.	All measurements show an improvement.	All measurements exceed those of the benchmark company for 3 months.
	Effectiveness and efficiency targets are set.	Prior quality cost (PQC) measurements are developed.	Internal effectiveness and efficiency measurements are in place and are posted, with targets set by the affected areas.	Benchmark targets are defined for external customers and critical in-process activities.	Effectiveness measurements indicate that the process is error free for all end-customer and in-process commitments.
	Process operational and/or control weaknesses are evaluated and meet minimum requirements.	Some internal efficiency measurements are established.	There is a significant reduction in cycle time and bureaucracy.	In-process control charts are implemented as appropriate, and the process is under statistical quality control.	
		Internal effectiveness measurements and targets are 50 percent complete and posted.	Overall efficiency targets are met.	Feedback systems are in place close to the point at which the work is being done.	
		Overall process cycle time and cost are defined.	Most measurements show an improvement trend.	Most measurements are meet by the persons doing the job.	
		No significant effectiveness, efficiency, or control deficiencies exist.	Key process control points are identified.	There is tangible and measurable improvement in the in-process measurements.	
		Substantial improvement activities are under way.	Tangible, measurable results are realized.	No operational inefficiencies are recognized.	
				An independent audit plan is in place and working.	
				The process is error-free.	
Supplier Partnerships	All suppliers are identified.	Meetings are held with critical suppliers, and agreed-to input requirements are documented.	Meetings are held with all suppliers, and agreed-to input requirements are documented.	All supplier inputs met requirements for the last 3 months.	All suppliers meet process expectations.
		Feedback systems to critical suppliers are in place.	All critical suppliers meet input requirements.	Regular meetings are held to ensure that suppliers understand the changing needs and expectations of the process.	All suppliers meet process requirements for a minimum of 6 months.
Documentation	Process is defined and flowcharted.	Process is flowcharted and documents are updated.	Subprocesses are documented.	Change-level controls are in place.	All documents meet world-class standards for the process being improved.
	How/their accuracy is verified.	Overall process is fully documented.	Training requirements are documented.	Documents are systematically updated.	
	Documentation is followed.	Documentation of subprocesses starts.	Software controls are in place.		
	PIT (Process Improvement Team) members and process owners are named.	Readability is evaluated.	The readability level of all documents is at a grade level less than the minimum education level of the people using them.		
	PIT mission is documented.		Employees understand their job descriptions.		
	Process boundaries are defined.				
Training	PIT is trained in the basic tools and fundamentals of Business Process Improvement tools.	In-process job training procedures are developed for all critical activities.	All people performing critical jobs are trained in the new procedures, including job-related training.	All employees in the process are trained and scheduled for refresher courses.	Employees are regularly surveyed to define additional training needs, and new training programs implemented based on these surveys.
	In-process training needs are evaluated and documented.	People are assigned to conduct job and process training.	In-process job training procedures are developed for all activities.	Employee evaluation of their training process is complete, and the training meets all employee requirements.	
	Resources are assigned to support training needs.	PIT is trained in statistical process control.	Plans are in place to train all employees who are part of the process in team methods and problem-solving skills.	Team and problem-solving courses are complete. Employees are meeting regularly to solve problems.	
			PIT understands one or more of the BPI "10 emphasis" methods.		
			All employees in the process receive training on the total process orientation.		
Benchmarking		Plan exists to benchmark end-customer requirements.	End-customer requirements are benchmarked.	Process is benchmarked, and targets are assigned.	Ongoing benchmarking plan is implemented.
			Plan exists to benchmark critical activities.	PIT understands the keys to the benchmark organizations' performance.	
			Plan exists to benchmark the process.		
Process Adaptability		Data are collected that identify problems with present process adaptability.	Employees are trained to distinguish how far they can deviate from the established procedures to meet a customer's special needs.	Employees are empowered to provide the required emergency help to their customers and are measured accordingly.	In the last 6 months, no customers complained that the process did not meet their needs.
			Future process changes/requirements are projected.	Resources are committed to satisfy future customer needs.	Process personnel handle the exceptions better than the benchmark company's process.
			A proactive internal and external customer complaint system is established.	Process adaptability complaints are significantly reduced.	
			The end-customer reviews the process change plan and agrees that it meets his or her needs over the strategic period.		
Continuous Improvement	Basics of BPI are in place.	Process is operational, and control weaknesses are assessed and deemed conservable.	A plan to improve the process to level 2 is developed, approved, and funded.	The process philosophy evolves to the point at which errors are unacceptable. Every employee relentlessly to prevent errors from occurring even once.	An independent audit verifies world-class status.
	All major exposures are identified and action plans are in place.	A plan for improving the process to level 3 is prepared, approved, and funded.		Surveys of the employees show that the process is easier to use.	Plans are approved and in place to become even better.
	A detailed plan to improve the process to level 4 is agreed to and funded.	The process philosophy accepts that people make mistakes, provided everyone works relentlessly to find and remove causes of errors.		Plans to improve the process to level 4 are prepared, approved and funded.	

Figure 4.2 Requirements of Harrington qualification criteria (Şahan Vahaplar & Şen, 2006, p. 243).

4.2.1.1 Requirements to be Qualified in Level 5

Requirements for end-customer related measures are listed below.

- Measurements reflect the end customer's view of the process.
- End customer requirements are documented.
- End customer feedback system is established.
- End customer effectiveness charts are posted and updated.

Requirements for process measurements and/or performance are listed below.

- Overall effectiveness and efficiency are measured and posted where they can be seen by employees.
- Effectiveness and efficiency targets are set.
- Process operational and/or control weaknesses are evaluated and meet minimum requirements.

Requirement for supplier partnerships is listed below.

- All suppliers are identified.

Requirements for documentation are listed below.

- Process is defined and flowcharted.
- Flowchart accuracy is verified.
- Documentation is followed.
- Process improvement team members and process owners are named.
- Process improvement team mission is documented.
- Process boundaries are defined.

Requirements for training are listed below.

- Process improvement team is trained in the basic tools and fundamental business process improvement tools.
- In-process training needs are evaluated and documented.
- Resources are assigned to support training needs.

Benchmarking and process adaptability are not required for level 5.

Requirements for continuous improvement are listed below.

- Basics of business process improvement are in place.
- All major exposures are identified and action plans are in place.
- A detailed plan to improve the process to level 4 is agreed to and funded (Harrington, 1991, pp.208-209).

4.2.2 Qualification Level Change

When business process improvement champion receives a request for changing qualification level of a process, he or she meets with the process owner to review the process data to verify that they are complete. Process improvement team has to submit a report for this meeting including;

- Process backup data (process name, process improvement team mission, process improvement team members, process scope)
- Status of all measurements
- Process flowchart
- Documented current status compared to the requirements to change to the next level
- Improvements made since the latest level change
- Problems solved
- Problems unsolved
- Plan to improve the process to the next qualification level

During this meeting, process improvement team compares the current process with the requirements of the desired qualification level. If the review committee approves that all requirements are met, then the committee issues a formal qualification letter stating that the process has evolved to the appropriate level (Harrington, 1991).

As an improvement is achieved in the qualification level of a process, efficiency, effectives and adaptability of the process also improve. This can be seen on Table 4.2. On the table, ⦿ shows strong relation, ○ shows intermediate relation and △ shows weak relation.

Table 4.2 Relations between process performance criteria types and change areas of Harrington criteria

	Efficiency	Effectiveness	Adaptability
End-customer related measurements	⦿	△	○
Process measurements and/or performance	⦿	⦿	⦿
Supplier partnerships	⦿	△	○
Documentation	⦿	-	-
Training	○	⦿	○
Benchmarking	○	⦿	⦿
Process adaptability	○	-	⦿
Continuous improvement	⦿	⦿	⦿

Although Table 4.2 summarises the relations very clearly, a few comments may be stated. End-customer related measurements and supplier partnerships are efficiency criteria and they have weak relation with effectiveness and medium relationship with adaptability. Process measurements and/or performance have strong relationship with all three criteria. Documentation is an efficiency criteria and it is not related to the other criteria. Training is an effectiveness criteria and it has medium relationship with efficiency and adaptability. Benchmarking is an effectiveness and adaptability criteria and it has medium relationship with efficiency.

Process adaptability is an adaptability criteria and it has medium relationship with efficiency. Finally, continuous improvement has strong relationship with all three criteria.

4.2.3 Rewarding Process

If process improvement team ensures the process to be qualified at a higher level, it is suggested to reward the team. The nature of the reward may change according to the level. The higher the level achieved, the bigger the reward should be. As an example, when the team upgrades process' qualification level from five to four, they may be rewarded with a lunch and small gifts. Or, when the team upgrades process' qualification level from two to one, then the members may be rewarded with a holiday or cash awards (Harrington, 1991).

4.3 The Relations Between Harrington Qualification Criteria and Quality Management System Principles

Process qualification reflects to process performance. Besides, eight quality management system principles, listed below, also reflect to process performance. So it is meaningful to draw such a relationship diagram as shown in Figure 4.3 (Şahan Vahaplar & Şen, 2006).

- Customer focus
- Leadership
- Involvement of people
- Process approach
- System approach to management
- Continuous improvement
- Factual approach to decision making
- Supplier relationships

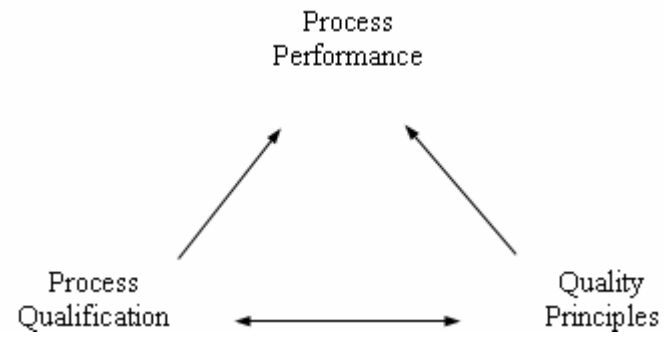


Figure 4.3 The relationships between process performance, process qualification and quality principles (Şahan Vahaplar & Şen, 2006, p. 245).

Also, the relations between Harrington criteria and quality management system principles are examined, and the results are shown in Table 4.3. In the table, ⊙ shows strong relation, ○ shows intermediate relation and △ shows weak relation. The empty cells mean that there is no relation.

Table 4.3 Relations between Harrington criteria and quality management system principles (Şahan Vahaplar & Şen, 2006, p. 245)

		Quality Management System Principles							
		Customer Focus	Leadership	Involvement of People	Process Approach	System Approach to Management	Continuous Improvement	Factual Approach to Decision Making	Supplier Relationships
Change Areas in Harrington Criteria	End-customer related measurements	⊙	△	-	-	-	⊙	-	⊙
	Process measurements and/or performance	-	△	⊙	⊙	△	⊙	-	⊙
	Supplier partnerships	-	-	-	-	-	⊙	⊙	⊙
	Documentation	-	-	○	⊙	⊙	⊙	⊙	⊙
	Training	○	⊙	⊙	○	⊙	⊙	○	-
	Benchmarking	-	-	-	-	△	⊙	○	⊙
	Process adaptability	⊙	○	○	○	-	⊙	⊙	-
	Continuous improvement	⊙	○	○	⊙	⊙	⊙	⊙	⊙

CHAPTER FIVE
SYSTEMS THINKING: THE FIFTH DISCIPLINE

5.1 Scope and Purposes

The fifth discipline is developed by Peter Senge with the aim of establishing learning organisations. In learning organisations, people continually expand their capacity to create the results they truly desire, new and expansive patterns of thinking are raised, collective ambition is set free and people continually learn how to learn together. According to Senge, the most important point differing learning organisations from traditional authoritative controlling organisations is that they master five basic disciplines. Therefore these five disciplines are described as the means of building learning organisations. These disciplines are systems thinking, personal mastery, mental models, shared vision and team learning. Among these, systems thinking is the fifth discipline since it makes the results of the other disciplines work together (Senge, 1990).

With the aim of interpreting Harrington criteria in terms of laws of fifth discipline, this chapter investigates the relationships between Harrington criteria, which are developed for evaluating performance levels of business processes, and the fifth discipline. For this purpose, the relations between change areas of Harrington criteria and laws of the fifth discipline, their effects and contributions en each other are investigated and interpreted (Şahan Vahaplar & Şen, 2008).

5.2 Core Disciplines for Establishing Learning Organisations

5.2.1 Personal Mastery

The capacity and desire of an organisation for learning is limited with the capacities of the people working for that organisation. Individual learning does not assure organisational learning, but without it, organisational learning can not occur (Senge, 1990; Senge et al., 1994). Therefore, personal mastery can be described as

the discipline of continually describing and deepening personal vision, focusing energies, developing patience and seeing reality objectively (Senge, 1990).

5.2.2 Mental Models

Senge defines the mental models as deeply ingrained assumptions, generalisations, or even pictures or images which affect the way we understand the world and how we take action. When we meet someone, the first thing we do is to place that person into one of the mental models in our mind. But, there is a continuous change in the market and business environment. Therefore it is not true to insist on our mental models. Adapting to changing business environment is based on organisational learning process in which company management can change their mental models.

> "*The discipline of working with mental models starts with turning the mirror inward; learning to unearth our internal pictures of the world, to bring them to the surface and hold them rigorously to scrutiny. It also includes the ability to carry on learningful conversations that balance inquiry and advocacy, where people expose their own thinking effectively and make that thinking open to the influence of others"* (Senge, 1990).

5.2.3 Shared Vision

Building shared vision can be defined as everybody in the organisation espousing the same idea for the strategic targets of the organisation and striving for reaching these targets. In such a situation, everybody in the organisation will work for the vision they personally believe, not for the one they are told to. The important thing here is a discipline that will convert individual visions into shared visions. The practice of shared vision involves the skills of finding shared pictures of the future that encourage real commitment and enrolment rather than obedience (Senge, 1990).

5.2.4 Team Learning

Except from team members learning separately, there is a concept of learning as a team. Team learning is important because fundamental learning unit in modern organisations is teams instead of individuals. So, team learning discipline can be defined as the ability of a group of people to suspend their assumptions and freely think together, which means going beyond personal defensiveness and presenting ideas openly (Senge, 1990).

5.2.5 *Systems Thinking*

Senge defines systems thinking as a conceptual framework, a body of knowledge and tools to make the full patterns clearer, and to help people see how to change them effectively. It is the ability and practice of consistently examining the whole system, rather than just trying to fix the isolated problems (Senge, 1990).

Developing all five disciplines together has vital importance. But this is very difficult as it is more difficult to integrate new tools rather than applying them separately. For this reason, systems thinking is the fifth discipline. It is the discipline that integrates all five disciplines, combining them into a coherent body of theory and practice (Senge, 1990).

5.3 The Loops of Systems Thinking

Systems thinking not only investigates the events but also searches patterns of behaviour and seeks essential interrelationships that cause the events. According to systems thinking, system behaviour is the result of the effects of reinforcing and balancing loops. Therefore, instead of linear relationships, systems thinking studies the relationships with loops.

Reinforcing loops are used when small changes cause big changes. In a reinforcing loop, an increase in a system component creates an increase in another component. Figure 5.1 gives an example to reinforcing loops. According to the figure, as sales increase, income of the organisation also increases. Then, the increase in the income causes the resources to increase and this increases the sales.

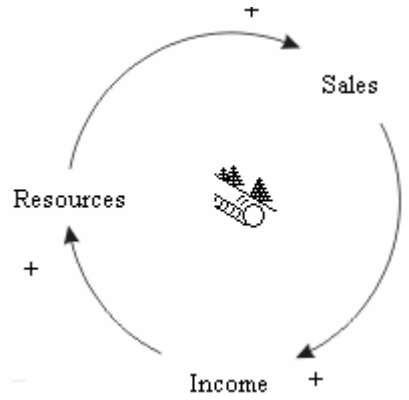


Figure 5.1 An example of a reinforcing loop.

Different from a reinforcing loop, an increase in a system component cause a decrease in another component in a balancing loop. Balancing loops create resistance and this will limit the growth in the future. But, they are the mechanisms that fix problems, maintain stability and accomplish equilibrium. Figure 5.2 gives an example to balancing loops. According to the figure, customer satisfaction increases the demand and the increase in demand cause a decrease in the quality. Then, as quality increases, customer satisfaction also increases.

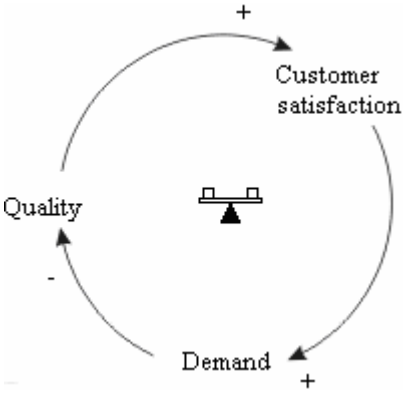


Figure 5.2 An example of a balancing loop.

Sometimes, the action to perform may take some time. This is called delay and it is shown with two parallel lines. Delays can influence the systems greatly, because they emphasize the impact of other forces. Figure 5.3 shows an example to the loops with delays.

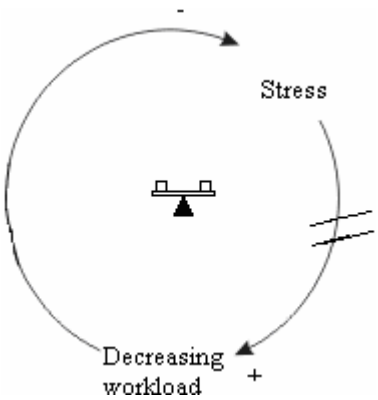


Figure 5.3 An example to delay in loops.

5.4 The Laws of the Fifth Discipline

Mings developed the chart in Table 5.1 as a reference tool to ensure decisions and strategies to have the best possibility of success, for applying the laws of the fifth discipline and the insights of Peter Senge. This chart clearly explains each law.

The first column of Table 5.1 presents the laws. On the second column, key comments by Peter Senge on each law are given. On the third column, Mings's comments on the potential implications of the laws and Senge's comments for problem solving and strategy implementation are presented. And finally column four represents the key questions developed by Mings to ask whenever one is involved with the resolution of a problem or the design of a new strategy (Mings, n.d.; Senge, 1990).

Table 5.1 Reference chart for applying the laws of the fifth discipline (Mings, n.d.)

The Laws of the Fifth Discipline	**Notes from Senge on the Laws of the Fifth Discipline**	**Implications for Seeking Solutions in the Organisations**	**Critical Questions to Ask When Looking at a Problem or Proposed Solution**
Today's problems come from yesterday's solutions	Solutions that merely shift problems from one part of a system to another often go undetected because those who solved the first problem are different from those who inherit the new problem.	The problems or challenges facing a program, discipline or the entire organisation may have roots in strategies implemented over five years ago.	Does the proposed problem have any relationships with a past strategy or fix?
The harder you push, the harder the system pushes back	Systems thinking has a name for this phenomenon: Compensative feedback	The implementation timetable and the type of interventions may be much more aggressive in actual life than they are in the planning stages.	In practical resource terms, how aggressive is the intervention? Does the proposed intervention leave all parties at least as well as they were before the intervention? Do all parties understand the benefits of the intervention?
Behavior grows better before it grows worst	In complex human systems there are always many ways to make things look better in the short run. The key word is; eventually.	Traditional measuring tools or sign posts can often lead one to believe things are getting better as a result of an implemented strategy or solution. However, the tools may not capture the essential information to accurately predict the future behavior of the system.	What tools are in place to measure the performance of the system in focus? Do all parties in the system have access to the data generated from the tools? Do the tools help predict the systems performance and potential areas of compensative feedback?

The cure can be worse than the disease	Sometimes the easy or familiar solution is not only ineffective, but it can also be addictive and dangerous. In the long run, most insidious consequence of applying non-systemic solutions is increased need for more and more solutions.	Solutions to existing problems can become just another problem if the original problem is not defined. A problem stated as a solution often leads to the generation of additional problems which then overshadow the original problem.	Does a clear statement of the problem exist? Does the problem statement contain a solution? If so, can the problem be restated to ensure it is a problem statement?
The easy way out usually leads back in	Pushing harder and harder on familiar solutions, while fundamental problems persist or worsen, is a reliable indicator of non-systemic thinking.	Corrective action strategies often deal with the problem which is presented to the group. However, the problem may be a system of a more systemic issue. It's important to seek out the root of the problem from a systemic point of view before trying to eliminate problems.	Is the problem being presented part of a larger system? If the problem is eliminated, what else could happen? As management, are we contributing to the problem?
Faster is slower	Virtually all natural systems have inherently optimal rates of growth. The optimal rate is far less than the fastest possible growth. When growth becomes excessive the system itself will seek to compensate by slowing down.	Every organisation (system) has its own speed for getting things done. The question is to determine how to quantify that speed so everyone knows what it really looks like.	Do we have tools to explain the real rate of change or growth in the organisation? What tools are used to celebrate significant change in the organisation? What is too fast in our organisation?

Cause and effect are not closely related in time and space	There is a fundamental mismatch between the nature of reality in complex systems and our predominant ways of thinking about that reality. The first step in correcting that mismatch is to let the notion that "cause and effect are close in time and space" go of.	In planning and problem solving, a standard assumption is; "If we do this, then we will get that". Systems thinking indicates; "if we do this, we may get a whole bunch of that's".	What do we want to accomplish as a program or service? What are the implications of what we want to accomplish? Can our system support and meet the challenge with engaging resources to offset the compensative feedback?
Small changes can produce big results, but the areas of highest leverage are often the least obvious	System thinking shows that small, well focused actions can sometimes produce significant enduring improvements, if they are in the right place. Systems thinkers refer to this principle as leverage.	Finding the right combination of key points in the organisation (system) to make meaningful organisational change for long term viability is a challenge.	What tools do we use to determine the key leverage points in our organisation? What are the key business decisions facing our organisation? Do the key business decisions facing our organisation have relationships to the key leverage points of our organisation? What are the long term consequences of not addressing the key business decisions for our organisation?
You can have your cake and eat it too, but not at once	Many apparent dilemmas are by-products of static thinking. They are rigid because we think what is possible at a fixed point in time.	Business decisions and solutions should be undertaken in the context of the system. To be able to see the whole picture, it may help to eliminate the need to make HARD choices.	What is the problem under focus or discussion? Is the problem a symptom of a bigger issue?

Dividing an elephant in half does not produce two small elephants	Living systems have integrity. Their characters depend on the whole. The same is true for organisations. The most challenging managerial issues require seeing the whole system that generates the issues.	Subdivision of a problem into component parts often creates more problems than its worth.	What are the boundaries of the system under study? Does the system have a name? Does the system have an owner?
There is no blame	Systems thinking shows us that there is no outside; that you and the cause of your problem are part of a single system. The cure lies in your relationships with your "enemy".	Often, system owners try to solve system problems without full information or full participation. System solutions require system participants.	If a conflict exists, is it personal or is it the result of a systemic problem? Does the resolution of the systemic problem involve all of the system participants? What are the consequences of excluding people from the conversation?

5.5 The Relationships Between Harrington Criteria and Laws of the Fifth Discipline

For examining the relationships, each change area is analysed separately. The requirements necessary for each change area are listed and each requirement is questioned for each law whether they have a relation or not. Then, the number of requirements that have relation with each law are determined, and their percentages are calculated. These percentages form the relationship scores as shown in Table 5.2. Besides, the files prepared for each change area can be seen on Figure 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, 5.10 and 5.11 respectively. Also, from the scores determined as shown in Table 5.2, the relationship matrix shown in Table 5.3 is formed. While forming this matrix, the scores between 1 and 33 are accepted to be showing weak relationship with the symbol △, the scores between 34 and 66 are accepted to be showing medium relationship with the symbol ○, and the scores between 67 and 100 are accepted to be showing strong relationship with the symbol ⊙ (Şahan Vahaplar & Şen, 2008).

Table 5.2 Relationship scores between change areas of Harrington criteria and laws of the fifth discipline (Şahan Vahaplar & Şen, 2008, pp. 257-258)

		Change Areas in Harrington Criteria							
		End-customer related measurements	Process measurements and/or performance	Supplier partnerships	Documentation	Training	Benchmarking	Process adaptability	Continuous improvement
Laws of the Fifth Discipline	Today's problems come from yesterday's solutions	77	86	56	33	73	29	80	75
	The harder you push, the harder the system pushes back	12	64	56	22	80	86	60	83
	Behaviour grows better before it grows worst	47	68	56	17	40	14	70	100
	The cure can be worse than the disease	41	71	11	6	87	14	60	92
	The easy way out usually leads back in	41	61	56	11	100	14	60	75
	Faster is slower	47	64	78	67	87	86	40	92
	Cause and effect are not closely related in time and space	59	57	78	28	73	71	80	83
	Small changes can produce big results, but the areas of highest leverage are often the least obvious	65	61	89	6	93	14	60	83
	You can have your cake and eat it too, but not at once	29	86	78	33	80	71	80	92
	Dividing an elephant in half does not produce two small elephants	53	86	78	17	80	14	70	92
	There is no blame	35	93	67	0	20	86	60	100

End-Customer Related Measurements	Laws										
Requirements	1	2	3	4	5	6	7	8	9	10	11
Measurements reflect the end customer's view of the process.	-	-	+	-	-	+	-	+	-	-	-
End customer requirements are documented.	+	-	-	-	-	-	-	-	-	-	-
End customer feedback system is established.	+	+	-	-	-	-	-	-	-	-	-
End customer effectiveness charts are posted and updated.	-	-	+	-	-	-	-	-	-	-	-
End customer requirements are met.	+	-	-	-	+	+	+	+	-	+	-
End customer expectations are documented.	+	-	-	-	-	-	-	-	-	-	-
End-customer expectations are met.	+	-	-	-	+	+	+	+	-	+	-
Challenge targets are set by the PIT.	+	-	+	+	-	-	+	+	-	+	+
End-customer expectations are updated.	+	-	-	-	-	-	-	-	-	-	-
Performance for the last 6 months never fell below end-customer expectations.	+	-	+	+	+	+	+	+	+	+	+
The trend lines show continuous improvement.	+	-	+	+	+	+	+	+	+	+	+
World-class targets are established.	-	-	-	+	-	-	+	+	+	+	+
End customers are invited to regular performance reviews.	-	+	+	-	-	-	-	-	-	-	-
End-customer desires are understood.	+	-	-	-	-	-	+	+	-	-	-
End-customer expectation targets are regularly updated and always exceeded.	+	-	+	+	+	+	+	+	+	+	+
World-class measurements are met for a minimum of 3 consecutive months.	+	-	+	+	+	+	+	+	+	+	+
Many of the end-customer desires are met.	+	-	-	+	+	+	+	+	-	+	-
Number of (+) :	13	2	8	7	7	8	10	11	5	9	6
Percentage of (+) :	0,7647	0,1176	0,4706	0,4118	0,4118	0,4706	0,5882	0,6471	0,2941	0,5294	0,3529
Score (over 100) :	77	12	47	41	41	47	59	65	29	53	35

Figure 5.4 Relationship score calculation for end-customer related measurements (Şahan Vahaplar & Şen, 2008, p .258).

Process Measurements and/or Performance Requirements	Laws										
	1	2	3	4	5	6	7	8	9	10	11
Overall effectiveness and efficiency are measured and posted where they can be seen by employees	-	-	-	-	-	-	-	-	-	-	-
Effectiveness and efficiency targets are set.	+	+	+	+	-	-	+	-	+	+	-
Process operational and/or control weaknesses are evaluated and meet minimum requirements.	+	+	+	+	+	+	+	+	+	+	+
Overall effectiveness targets are met, and challenge targets are established by PIT.	+	+	+	+	+	+	+	+	+	+	+
Poor quality cost (PQC) measurements are developed.	+	-	-	-	-	+	-	-	+	+	+
Some internal efficiency measurements are established.	+	-	-	+	-	+	-	-	+	+	+
Internal effectiveness measurements and targets are 50 percent complete and posted.	+	-	+	+	+	+	+	+	+	+	+
Overall process cycle time and cost are defined.	+	-	-	-	-	-	-	-	+	+	+
No significant effectiveness, efficiency, or control exposures exist.	+	+	+	+	+	+	-	+	+	+	+
Substantial improvement activities are under way.	+	+	+	+	+	+	+	+	+	+	+
There is a significant improvement in poor quality costs.	+	+	+	+	+	+	+	+	+	+	+
Internal effectiveness and efficiency measurements are in place and are posted, with targets set by the affected areas	+	+	+	+	+	+	+	+	+	+	+
There is a significant reduction in cycle time and bureaucracy.	+	+	+	+	+	+	-	+	+	+	+
Overall efficiency targets are met.	+	+	+	+	+	+	+	+	+	+	+
Most measurements show an improvement trend.	+	+	+	+	+	+	+	+	+	+	+
Key process control points are identified.	+	-	-	-	-	-	-	-	+	+	+
Tangible, measurable results are realised	+	-	-	-	-	-	-	-	+	+	+
All measurements show an improvement.	+	+	+	+	+	+	+	+	+	+	+
Benchmark targets are defined for external customers and critical in-process activities.	+	+	+	+	-	-	+	+	+	+	+
In-process control charts are implemented as appropriate, and the process is under statistical quality control	+	+	+	+	+	-	+	+	+	+	+
Feedback systems are in place close to the point at which the work is being done.	-	-	-	-	-	-	-	-	-	-	+
Most measurements are made by the person doing the job.	-	-	-	-	-	-	-	-	-	-	+
There is tangible and measurable improvement in the in-process measurements.	+	+	+	+	+	+	+	+	+	+	+
No operational inefficiencies are anticipated.	+	+	+	+	+	+	-	-	+	+	+
An independent audit plan is in place and working.	-	-	-	-	-	-	-	-	-	-	+
The process is error-free.	+	+	+	+	+	+	+	+	+	+	+
All measurements exceed those of the benchmark company for 3 months.	+	+	+	+	+	+	+	+	+	+	+
Effectiveness measurements indicate that the process is error free for all end-customer and in-process control points	+	+	+	+	+	+	+	+	+	+	+
Number of (+) :	24	18	19	20	17	18	16	17	24	24	26
Percentage of (+) :	0,8571	0,6429	0,6786	0,7143	0,6071	0,6429	0,5714	0,6071	0,8571	0,8571	0,9286
Score (over 100) :	86	64	68	71	61	64	57	61	86	86	93

Figure 5.5 Relationship score calculation for process measurements and/or performance (Şahan Vahaplar & Şen, 2008, p. 259).

Supplier Partnerships	Laws										
Requirements	1	2	3	4	5	6	7	8	9	10	11
All suppliers are identified.	-	-	-	-	-	-	-	-	-	-	-
Meetings are held with critical suppliers, and agreed-to input requirements are documented.	-	-	-	-	-	+	+	+	+	+	-
Feedback systems to critical suppliers are in place.	-	-	-	-	-	-	-	+	-	-	+
Meetings are held with all suppliers, and agreed-to input requirements are documented.	-	-	-	-	-	+	+	+	+	+	-
All critical suppliers meet input requirements.	+	+	+	-	+	+	+	+	+	+	+
All supplier inputs met requirements for the last 3 months.	+	+	+	-	+	+	+	+	+	+	+
Regular meetings are held to ensure that suppliers understand the changing needs and expectations of the process.	+	+	+	+	+	+	+	+	+	+	+
All suppliers meet process expectations.	+	+	+	-	+	+	+	+	+	+	+
All suppliers meet process requirements for a minimum of 6 months.	+	+	+	-	+	+	+	+	+	+	+
Number of (+) :	5	5	5	1	5	7	7	8	7	7	6
Percentage of (+) :	0,5556	0,5556	0,5556	0,1111	0,5556	0,7778	0,7778	0,8889	0,7778	0,7778	0,6667
Score (over 100) :	56	56	56	11	56	78	78	89	78	78	67

Figure 5.6 Relationship score calculation for supplier partnerships (Şahan Vahaplar & Şen, 2008, p. 259).

Documentation Requirements	Laws 1	2	3	4	5	6	7	8	9	10	11
Process is defined and flowcharted.	-	-	-	-	-	+	+	-	-	-	-
Flowchart accuracy is verified.	-	-	-	-	-	-	-	-	-	-	-
Documentation is followed.	-	-	-	-	-	-	-	-	-	-	-
PIT (Process Improvement Team) members and process owners are named.	-	-	-	-	-	-	-	-	+	-	-
PIT mission is documented.	-	-	-	-	-	-	+	-	+	-	-
Process boundaries are defined.	-	-	-	-	-	+	-	-	+	-	-
Process is flowcharted and documents are updated.	-	-	-	-	-	+	+	-	+	-	-
Overall process is fully documented.	-	-	-	-	-	+	-	-	-	+	-
Documentation of subprocesses starts.	-	-	-	-	-	+	-	-	-	-	-
Readability is evaluated.	+	-	-	-	-	-	-	-	-	-	-
Subprocesses are documented.	-	-	-	-	-	+	-	-	-	-	-
Training requirements are documented.	+	+	-	-	-	+	-	-	-	-	-
Software controls are in place.	+	+	+	-	-	+	-	-	-	-	-
The readability level of all documents is at a grade level less than the minimum education level of the people using them.	+	-	-	-	+	-	-	-	-	-	-
Employees understand their job descriptions.	-	-	-	-	-	+	+	-	+	+	-
Change level controls are in place.	+	+	+	-	-	+	-	-	-	-	-
Documents are systematically updated.	-	-	-	-	-	+	-	-	-	-	-
All documents meet world-class standards for the process being improved.	+	+	+	+	+	+	+	+	+	+	-
Number of (+) :	6	4	3	1	2	12	5	1	6	3	0
Percentage of (+) :	0,3333	0,2222	0,1667	0,0556	0,1111	0,6667	0,2778	0,0556	0,3333	0,1667	0,0000
Score (over 100) :	33	22	17	6	11	67	28	6	33	17	0

Figure 5.7 Relationship score calculation for documentation (Şahan Vahaplar & Şen, 2008, p. 260).

Training Requirements	Laws 1	2	3	4	5	6	7	8	9	10	11
PIT is trained in the basic tools and fundamental BPI tools.	-	-	-	+	+	+	-	+	-	-	-
In-process training needs are evaluated and documented.	+	+	+	+	+	+	+	+	+	+	-
Resources are assigned to support training needs.	+	+	-	+	+	-	+	+	+	+	-
In-process job training procedures are developed for all critical activities.	+	+	-	-	+	+	+	+	+	+	-
People are assigned to conduct job and process training.	-	+	-	-	+	-	-	-	+	+	-
PIT is trained in statistical process control.	-	-	-	+	+	+	-	+	-	-	-
All people performing critical jobs are trained in the new procedures, including job related training.	-	+	-	+	+	+	+	+	+	+	-
In-process job training procedures are developed for all activities.	+	+	-	+	+	+	+	+	+	+	-
Plans are in place to train all employees who are part of the process in team methods and problem-solving tools.	+	+	-	+	+	+	+	+	+	+	-
PIT understands one or more of the BPI 10 sophisticated tools.	+	-	-	+	+	+	-	+	-	-	-
All employees in the process receive training on the total process operation.	+	+	+	+	+	+	+	+	+	+	-
All employees in the process are trained and scheduled for refresher courses.	+	+	+	+	+	+	+	+	+	+	-
Employee evaluation of their training process is complete, and the training meets all employee requirements.	+	+	+	+	+	+	+	+	+	+	+
Team and problem-solving courses are complete. Employees are meeting regularly to solve problems.	+	+	+	+	+	+	+	+	+	+	+
Employees are regularly surveyed to define additional training needs, and new training programs implemented based on these surveys.	+	+	+	+	+	+	+	+	+	+	+
Number of (+) :	11	12	6	13	15	13	11	14	12	12	3
Percentage of (+) :	0,7333	0,8000	0,4000	0,8667	1,0000	0,8667	0,7333	0,9333	0,8000	0,8000	0,2000
Score (over 100) :	73	80	40	87	100	87	73	93	80	80	20

Figure 5.8 Relationship score calculation for training (Şahan Vahaplar & Şen, 2008, p. 260).

Benchmarking	Laws										
Requirements	1	2	3	4	5	6	7	8	9	10	11
Plan exists to benchmark end-customer requirements.	-	+	-	-	-	+	+	-	+	-	+
End-customer requirements are benchmarked.	-	+	-	-	-	+	-	-	-	-	+
Plan exists to benchmark critical activities.	-	+	-	-	-	+	+	-	+	-	+
Plan exists to benchmark the process.	-	+	-	-	-	+	+	-	+	-	+
Process is benchmarked, and targets are assigned.	+	+	+	+	+	+	+	+	+	+	+
PIT understands the keys to the benchmark organisations' performance.	+	-	-	-	-	-	-	-	-	-	+
Ongoing benchmarking plan is implemented.	-	+	-	-	-	+	+	-	+	-	-
Number of (+) :	2	6	1	1	1	6	5	1	5	1	6
Percentage of (+) :	0,2857	0,8571	0,1429	0,1429	0,1429	0,8571	0,7143	0,1429	0,7143	0,1429	0,8571
Score (over 100) :	29	86	14	14	14	86	71	14	71	14	86

Figure 5.9 Relationship score calculation for benchmarking (Şahan Vahaplar & Şen, 2008, p. 261).

Process Adaptability	Laws										
Requirements	1	2	3	4	5	6	7	8	9	10	11
Data are collected that identify problems with present process adaptability.	+	+	+	+	+	+	+	+	+	+	+
Employees are trained to distinguish how far they can deviate from the established procedures to meet a customer's special needs.	+	-	+	+	+	-	+	+	+	+	+
Future process change requirements are projected.	+	+	+	+	-	-	+	+	+	+	+
A proactive internal and external customer complaint system is established.	-	+	-	-	-	-	-	-	-	-	-
The end-customer reviews the process change plan and agrees that it meets his or her needs over the strategic period.	+	+	-	-	+	-	+	-	+	-	-
Employees are empowered to provide the required emergency help to their customers and are measured accordingly.	+	-	-	-	-	-	-	-	-	-	-
Resources are committed to satisfy future customer needs.	+	+	+	+	+	+	+	+	+	+	+
Process adaptability complaints are significantly reduced.	+	+	+	+	+	+	+	+	+	+	+
In the last 6 months, no customers complained that the process did not meet their needs.	+	-	+	+	+	+	+	+	+	+	+
Present process handles the exceptions better than the benchmark company's process	-	-	+	-	-	-	+	-	+	+	-
Number of (+) :	8	6	7	6	6	4	8	6	8	7	6
Percentage of (+) :	0,8000	0,6000	0,7000	0,6000	0,6000	0,4000	0,8000	0,6000	0,8000	0,7000	0,6000
Score (over 100) :	80	60	70	60	60	40	80	60	80	70	60

Figure 5.10 Relationship score calculation for process adaptability (Şahan Vahaplar & Şen, 2008, p. 261).

Continuous Improvement Requirements	Laws 1	2	3	4	5	6	7	8	9	10	11
Basics of BPI are in place.	-	+	+	-	-	+	-	-	-	-	-
All major exposures are identified and action plans are in place.	+	+	+	+	+	+	+	+	+	+	+
A detailed plan to improve the process to level 4 is agreed to and funded.	+	+	+	+	+	+	+	+	+	+	+
Process is operational, and control weaknesses are assessed and deemed containable.	+	+	+	+	+	+	+	+	+	+	+
A plan for improving the process to level 3 is prepared, approved, and funded.	+	+	+	+	+	+	+	+	+	+	+
The process philosophy accepts that people make mistakes, provided everyone works relentlessly to find and remove causes of errors.	+	+	+	+	+	+	+	+	+	+	+
A plan to improve the process to level 2 is developed, approved, and funded.	+	+	+	+	+	+	+	+	+	+	+
The process philosophy evolves to the point at which errors are unacceptable. Everyone works relentlessly to prevent errors from occurring even once.	+	+	+	+	+	+	+	+	+	+	+
Surveys of the employees show that the process is easier to use.	-	-	+	+	-	+	+	+	+	+	+
Plans to improve the process to level 1 are prepared, approved and funded.	+	+	+	+	+	+	+	+	+	+	+
An independent audit verifies world-class status.	-	-	+	+	-	-	-	-	+	+	+
Plans are approved and in place to become even better.	+	+	+	+	+	+	+	+	+	+	+
Number of (+) :	9	10	12	11	9	11	10	10	11	11	12
Percentage of (+) :	0,7500	0,8333	1,0000	0,9167	0,7500	0,9167	0,8333	0,8333	0,9167	0,9167	1,0000
Score (over 100) :	75	83	100	92	75	92	83	83	92	92	100

Figure 5.11 Relationship score calculation for continuous improvement (Şahan Vahaplar & Şen, 2008, p. 261).

Table 5.3 Relations between change areas of Harrington criteria and laws of the fifth discipline (Şahan Vahaplar & Şen, 2008, p. 262)

		Change Areas in Harrington Criteria							
		End-customer related measurements	Process measurements and/or performance	Supplier partnerships	Documentation	Training	Benchmarking	Process adaptability	Continuous improvement
Laws of the Fifth Discipline	Today's problems come from yesterday's solutions	◉	◉	○	△	◉	△	◉	◉
	The harder you push, the harder the system pushes back	△	○	○	△	◉	◉	○	◉
	Behaviour grows better before it grows worst	○	◉	○	△	○	△	◉	◉
	The cure can be worse than the disease	○	◉	△	△	◉	△	○	◉
	The easy way out usually leads back in	○	○	○	△	◉	△	○	◉
	Faster is slower	○	○	◉	◉	◉	◉	○	◉
	Cause and effect are not closely related in time and space	○	○	◉	△	◉	◉	◉	◉
	Small changes can produce big results, but the areas of highest leverage are often the least obvious	○	○	◉	△	◉	△	○	◉
	You can have your cake and eat it too, but not at once	△	◉	◉	△	◉	◉	◉	◉
	Dividing an elephant in half does not produce two small elephants	○	◉	◉	△	◉	△	◉	◉
	There is no blame	○	◉	○	-	△	◉	○	◉

Examining the scores in Table 5.2, there are three 100 scores showing perfect relationship between training and “the easy way out usually leads back in”, between continuous improvement and “behaviour grows better before it grows worst”, and between continuous improvement and “there is no blame”. Also, there is one cell with a zero score which means that there is no relation between documentation and “there is no blame”.

Table 5.2 shows that all laws of the fifth discipline are highly related to continuous improvement. Therefore, by applying these laws, the organizations will provide continuous improvement more easily. Besides, training has strong relationship with most of the laws. This shows the importance of training once more. So, by applying the laws, the impact of training will be increased. Also, process measurements and/or performance have strong relationship with most of the laws. Finally, the laws do not have much effect on documentation and benchmarking.

Examining from the point of view of the laws, “faster is slower” supports almost all change areas. This is natural because this law is valid for most change areas. Another law supporting almost all change areas is “you can have your cake and eat it too, but not at once”. “Cause and effect are not closely related in time and space” is another law supporting most of the change areas. “Today’s problems come from yesterday’s solutions” and “dividing an elephant in half does not produce two small elephants” also support most of the change areas. The least related law to the change areas is found to be “the easy way out usually leads back in” (Şahan Vahaplar & Şen, 2008).

CHAPTER SIX
SUSTAINABILITY

6.1 Scope and Purposes

One of the best definitions of sustainability is given by The Jamaica Sustainable Development Network Ltd., as a characteristic of a process that can be maintained indefinitely. As clearly understood from this definition, sustainability is briefly making realised improvements last long. So it is obvious that this is a hard job, even it is as difficult as realising the improvements (Jamaica Sustainable Development Network [JSDN], 2007).

The purpose of this chapter is to investigate present sustainability studies and integrate them into DMAIC methodology. Literature review on sustainability shows that there are some methodologies developed for providing sustainability such as 5S philosophy, 5C philosophy and DMAIC methodology of six sigma. Besides, there are some studies in which frameworks or models are developed for ensuring sustainability. One of these studies is realised by Bateman, in which the authors have researched the factors that enable and inhibit sustainability (Bateman & David, 2002).

Following these, the model developed for ensuring sustainability is given and the steps of the model are described. Finally, the suggestions for a more sustainable DMAIC methodology are given.

6.2 Methodologies Developed for Ensuring or Including Sustainability Aspects

6.2.1 5S Philosophy

5S is a set of techniques that organise the workplace and remove waste from the work environment. Abbreviated from the Japanese words seiri, seiton, seison,

seiketsu and shitsuke, 5S are translated into English as sort, set in order, shine, standardise and sustain.

Sort can be stated as clearing the work area. Work areas should only have the items necessary to perform the work. All the other things should be cleared from the area.

Set in order means organising the work place so that all items can easily be reached. Everything should have a place and everything should be in its place.

The term shine is used for cleanliness and the appearance of the work place. The area should be both clean and clear.

Standardise means that; everyone in the work area should do everything in the same way.

Finally, the last S for sustain is defined as ingraining the five S's into organisation culture. 5S needs a culture change. Therefore, everyone in the organisation should accept that change.

Using 5S techniques in the organisation would help the company to reduce the hidden waste, improve quality, reduce lead times, save costs, increase sales and profit, increase employee and customer satisfaction. In other words, by the help of 5S, productivity will be increased, product quality will be improved, manufacturing costs will be reduced, on-time delivery will be ensured and finally, safe working environment will be provided. It is clear that, the last two S's, standardise and sustain, are related to sustainability.

6.2.2 5C Philosophy

5C can be mentioned as the English equivalent of 5S. 5C consists of clear out, clean and check, configure, conformity and custom and practice (O'hEocha, 2000).

Just like 5S, 5C philosophy is used for creating and maintaining an organised, clean and high performance workplace (Institute for Innovation and Improvement [NHS], 2006).

Clear out is used for the same purposes with sort, which means removing all unused materials from the work place. Clean and check is the equivalent of set in order, which is used for arranging items in such a way that they will be easy to reach. Configure, which is shine in 5S, is simply neatness. Conformity has the same aim with standardise. Finally, custom and practice means sustain and ongoing improvement, which is directly related to sustainability.

On Table 6.1, 5S and 5C philosophies are summarised briefly.

Table 6.1 5S and 5C philosophies

5S	5C	Explanations
Sort	Clear out	Clearing the work area from unused materials
Set in order	Clean and check	Organising the work place so that all items can be easily reached
Shine	Configure	Cleanliness and appearance of the work place
Standardise	Conformity	Everyone in the work area should do everything in the same way
Sustain	Custom and practise	Ongoing improvement

6.2.3 Six Sigma DMAIC Methodology

General Electric defines six sigma as a highly disciplined process that helps focusing on developing and delivering near-perfect products and services. Sigma is the statistical term that measures how far a given process deviates from perfection. The central idea behind six sigma is that if one can measure how many defects are present in a process, then he can systematically figure out how to eliminate them and get as close to zero defects as possible. To achieve six sigma quality, a process must produce no more than 3.4 defects per million opportunities. An opportunity is

defined as a chance for nonconformance or not meeting the required specifications (General Electric Company [GE], 2007).

DMAIC, which is the acronym for the phases define, measure, analyse, improve and control, is a methodology used for continuous improvement. It is a process which eliminates unproductive steps, focuses on new measurements, and applies technology for improvement (GE, 2007).

For obtaining the best possible results, each step in the cyclical DMAIC process should be performed. In the define phase, the customers, project boundaries and the process to be improved are defined and the process to be improved is mapped. In the measure phase, data collection plan is developed and data is collected. In the analyse phase, collected data and process map are analysed to determine root causes of defects, gaps between current performance and target performance are determined and sources of variation are identified. In improve phase, target process is improved, solutions are created using technology and implementation plan is developed. Finally in the control phase, realised improvements are controlled to keep the process on the new course, so that the process will be prevented from returning back to its old state (iSix Sigma LLC [iSS], 2007). Therefore control phase of DMAIC methodology is closely related to sustainability.

6.2.4 Other Methodologies Developed for Sustainability

Bateman & David developed a model for ensuring the sustainability of process improvement programmes. The model is part of a research project investigating enablers and inhibitors of process improvement projects. The aim of their model is to determine the level of sustainability that process improvement programmes can reach. The model consists of two parts; cell level and factory level. There are five improvement classes at cell level, which can be seen on Table 6.2. By looking at this table, sustainability levels of realised improvements can be determined (Bateman & David, 2002).

Table 6.2 Summary of sustainability classes (Bateman & David, 2002, p. 521)

Classification	Improvement in workshop?	Maintain new procedure?	Close out technical issues?	Continuous Improvement?
Class 'A'	✓	✓	✓	✓
Class 'B'	✓	✓	✓	×
Class 'C'	✓	✓	×	×
Class 'D'	✓	×	✓	×
Class 'E'	✓	×	×	×

Bateman & Rich investigated the enablers and inhibitors of sustainability and determined the factors that enable or inhibit the sustainability of improvement or performance. As a result, they determined the important enablers and inhibitors as seen in Figure 6.1 and Figure 6.2, respectively (Bateman & Rich, 2003).

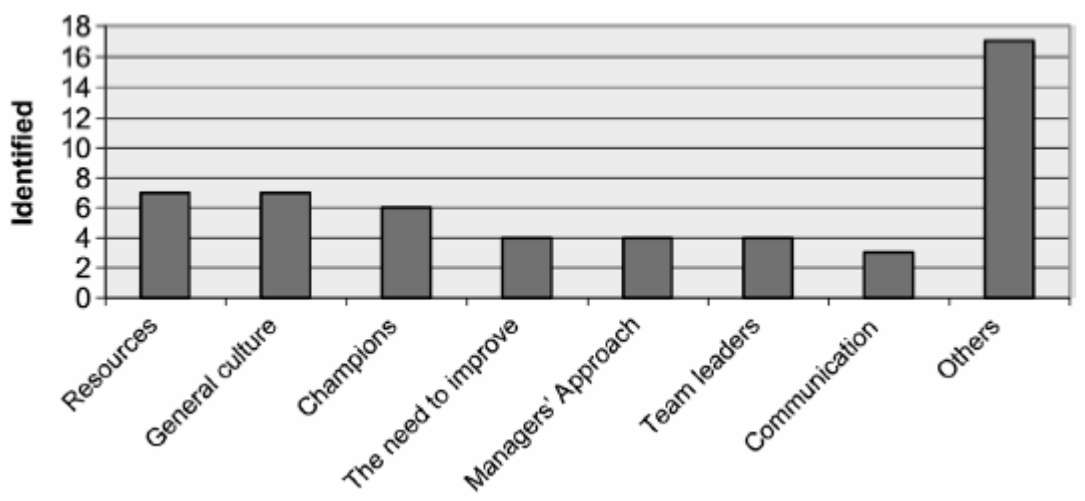


Figure 6.1 Enablers for sustainability of process improvement programmes (Bateman & Rich, 2003, p. 194).

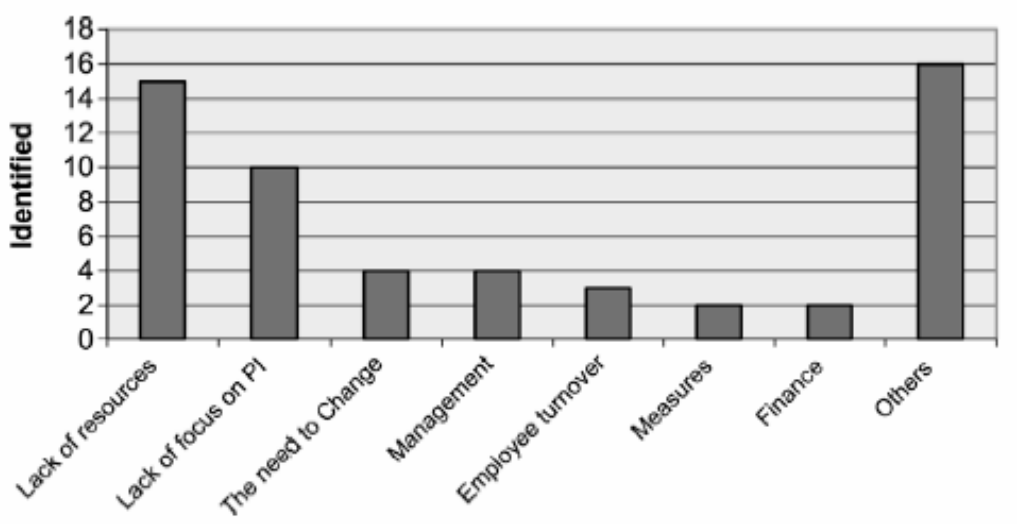


Figure 6.2 Inhibitors for sustainability of process improvement programmes (Bateman & Rich, 2003, p. 192).

Bateman identified ten enablers for sustaining process improvement activities in 2005. For this, 40 activities were analysed and the significant enablers from the more successful activities were identified. As a result, five enablers that fully realise process improvement activity were found. These significant enablers can be seen on Figure 6.4 (Bateman, 2005).

Enablers	Level
Time should be dedicated to 5C (or 5S) activities on a frequent (e.g. daily) basis	Factory
QCD type measures should be used to monitor the shop floor	Cell
Problems should be communicated properly from the shop floor	Cell
Managers should stay focussed on process improvement activities	Cell
Operators should have a high level of decision-making	Cell

Figure 6.3 Significant enablers for sustaining process improvement programmes (Bateman, 2005, p. 268).

Dale, Boaden, Wilcox & McQuarter examined the pitfalls of development of total quality management. They determined these pitfalls as inadequate leadership, fear and resistance to change, lack of quality management and problem solving skills, failure to complete projects, break up of improvement teams, lack of resources devoted to quality improvement and inadequate information and its analysis. According to the authors, these pitfalls impact negatively on the sustainability of total quality management (Dale, Boaden, Wilcox & McQuarter, 1997).

6.3 Proposed Model for Ensuring Sustainability

Integrating all these methodologies and investigations, a framework for ensuring sustainability is developed. The model composes of five steps in a loop as shown in Figure 6.4. Also in Table 6.3, how the loop in Figure 6.4 will supplement into each phase of DMAIC methodology is interpreted. ⊙ shows strong relationship, ○ shows medium relationship and △ shows weak relationship in the table.

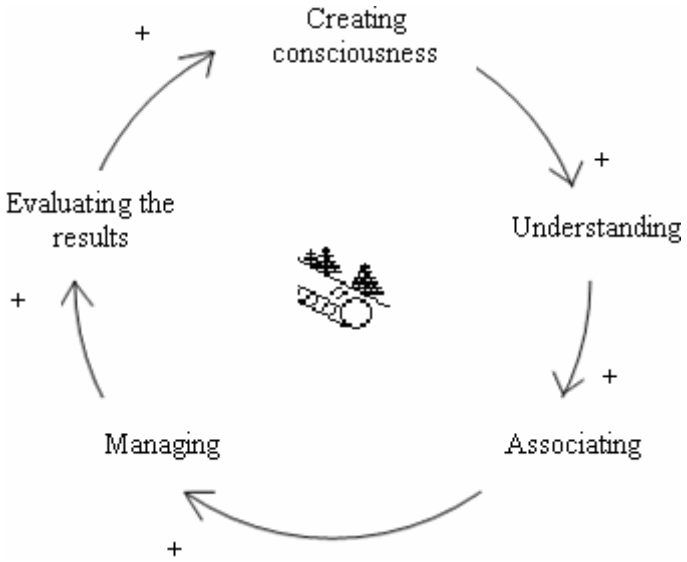


Figure 6.4 The loop existing in the sustainability model (Vahaplar & Şen, 2007, p. 846).

Table 6.3 The relationships between proposed model and phases of DMAIC methodology (Vahaplar & Şen, 2007, p. 846)

	Define (D)	Measure (M)	Analyse (A)	Improve (I)	Control (C)
Creating consciousness	⊙	-	-	-	⊙
Understanding	-	⊙	⊙	⊙	○
Associating	-	△	⊙	○	⊙
Managing	-	-	△	○	⊙
Evaluating the results	-	-	-	-	⊙

6.3.1 Creating Consciousness

Define and control phases are the most important phases for creating consciousness for sustainability. By clearly defining process boundaries in the define phase and by understanding the importance of sustaining realised improvements in the control phase, sustainability concept is comprehended and necessary consciousness is created. General culture and managers' approach, which are defined as enablers by Bateman, are important factors at this point.

6.3.2 Understanding

Analyse, improve and control are the phases of DMAIC methodology where importance and necessity of sustainability are best understood. In the analyse phase, as process data are analysed, present situation of the process is clearly understood. In the improve phase, how difficult it is to improve a process is seen and this shows the importance of sustainability.

6.3.3 Associating

In analyse, improve and control phases of DMAIC methodology, it is very important to correctly establish the relationships. During the improvement process, it is commonly encountered that improvement of a variable may cause deterioration in another variable. For this reason, it is important to correctly analyse the relationships for sustainability.

6.3.4 Managing

The improvements in the processes and sustainability of them are managed in the control phase. In this way, return of the process to its initial state is prevented and sustainability is ensured.

6.3.5 Evaluating the results

Just like in the managing step, the results are evaluated in the control phase of DMAIC methodology. Correctly evaluating the results of improvement process both helps to ensure sustainability and gives information on new improvement needs.

6.4 Suggestions for a More Sustainable DMAIC Methodology

As we have stated earlier, we have the purpose of giving some suggestions for making DMAIC methodology become more capable for sustainable improvements.

Considering enablers and inhibitors Bateman has defined, it is clear that 5C or 5S philosophies would be very helpful and facilitative for sustainability. Therefore if the organisations give more importance to 5S or 5C during their six sigma projects, it will be easier for them to make their improvements be sustainable. Another important point is that, the problem should be carefully detected. If an area that does not need to be improved is selected, sustaining that improvement will not be so meaningful. This will cause the organisation to lose money, time and effort. So, the process should be analysed in a detailed way to state the problem correctly.

It is so clear that resources and managers' focus are very important for improvement, six sigma and sustainability studies. None of these can be realised without enough resources or the support of management.

Finally, the operators play an important role in these studies. Mostly, they are the ones that meet the problems and have to find urgent solutions. So, they have important roles for sustainability studies. They have to have a high level of decision making. It would be very well for the organisations to train their operators on the subject of decision making.

CHAPTER SEVEN
APPLICATION

7.1 Scope and Purposes

The purpose of this chapter is to support the propositions and relations given in the previous chapters.

The application consists of two main parts. The first part has the purpose of applying Harrington qualification criteria and demonstrating the relationship between process qualification and process performance. For this purpose, a process improvement team is formed in a company working in automotive sector and this team realised a process improvement project. The second part aims to ensure sustainability of realised improvements in the process by using DMAIC methodology. For this purpose, the same process improvement team realised a six sigma project.

7.2 General Information on the Company

As stated, the application is realised in an organisation working in automotive sector, producing axles for car manufacturers. The name of the company is kept secret as the authorised personnel of the company requested so. For this reason, the company will be called as company hereafter.

The company manufactures commercial vehicle axles and axle components including fabricated axle housings and tag axles. Many global commercial vehicle producers use the company's products on their vehicles.

The company functions in two plants both located in İzmir. Among the things they produce, axle components, axle housings, trailer axle beams, front axle beams, stearing knuckles, front axle linkage components and suspension components can be listed.

7.3 General Information on Business Process Improvement Process at the Company

The goal of the company is to become the most preferable business partner for their customers by exceeding their expectations through supplying them the best quality products, understanding their requirements and having good relationship with them. Therefore product design and improvement capabilities and studies support the company's competitive structure.

The company gives great importance to six sigma and process management. They have realised many six sigma projects and there are also many projects on which they are working. Through these projects, the company gained many financial and non-financial benefits.

7.4 Process Qualification Throughout the Improvement Process

For determining qualification level of the company, first of all, process improvement team was formed. This team consisted of 5 members; Senem Şahan Vahaplar, Ali Şen and three employees of the company. Among these three employees, member one was responsible for planning and organisation, member two was responsible for process flows, documentation and capability studies and member three was responsible for process flows, measurements and monitoring the production.

As a first task, process improvement team drew the map of the production process using IDEF0 with the aim of examining the process in detail and seeing the flow of the process clearly. The map can be seen on Figure 7.3. Drawing the process map took a long time as this is a complicated task. For drawing this map, in addition to process improvement team, many people from all departments worked together.

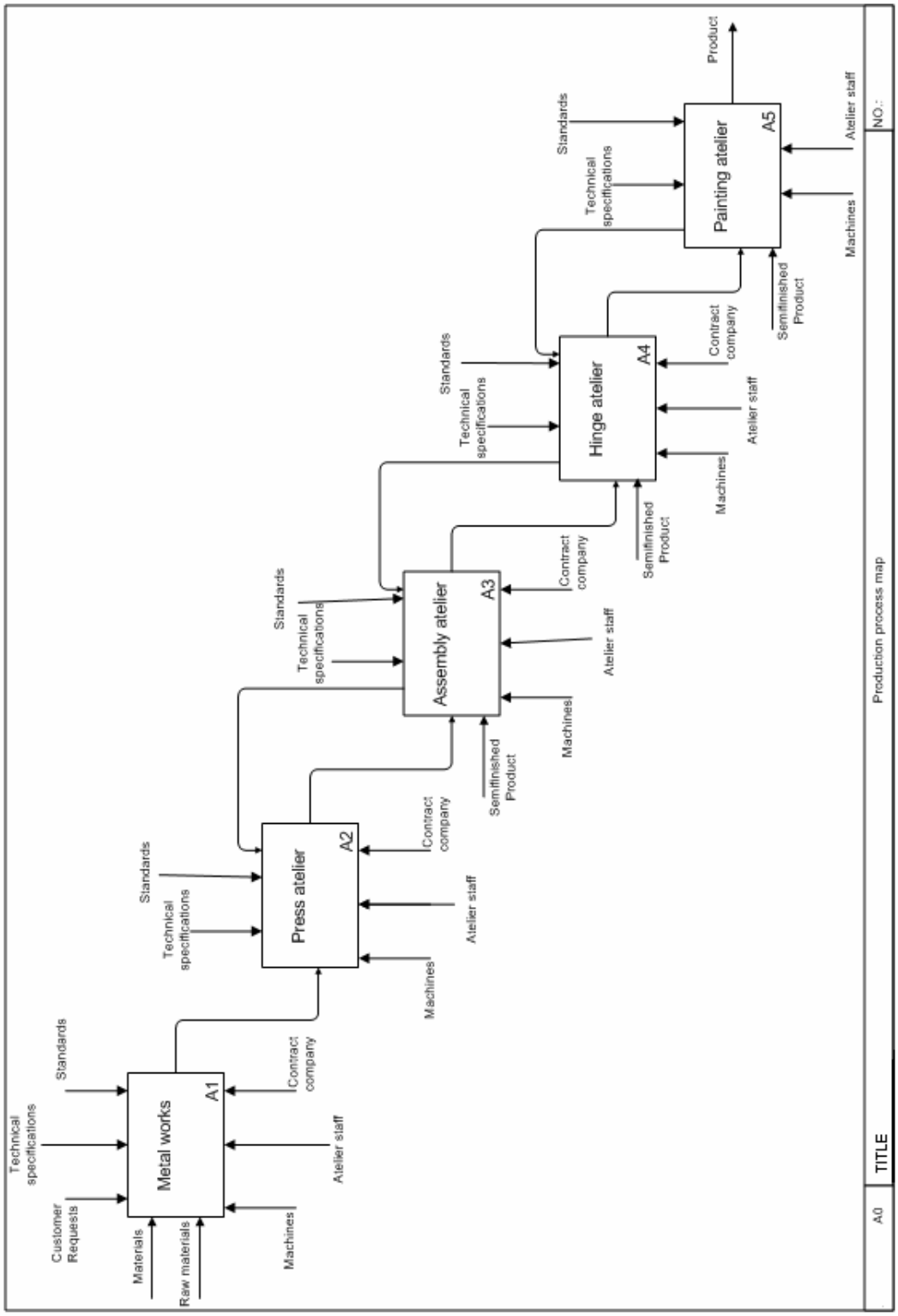


Figure 7.3 IDEF0 map of the production process of the company.

For the team to evaluate the qualification level of a process, all members have to master process qualification, its basics and details. So, the team members were trained on the subject of process qualification and Harrington qualification criteria.

This training included six qualification levels, their details and differences, eight change areas and the requirements for all change areas in all levels.

Following this training, after ensuring all team members have sufficient knowledge on process qualification, the team realised the first evaluation with Harrington criteria before any improvement studies were done. As stated earlier, unless any business process improvement methodologies are applied, all processes are considered to be at level 6. So, the team accepted the production process to be at level 6 and started to evaluate the process with the audit checklist for level 5. The results of this evaluation are shown in Table 7.1. In the table, F means that requirement is finished, realised. P means that requirement is in progress, is being worked on but not finished yet. The empty cells mean that requirements are not met yet and there are no studies on it.

As it is seen from Table 7.1, the process can not meet the requirements for level 5 yet. So, the process is still qualified at level 6.

One of the improvement targets for this process determined by the organisation is to increase initial approval efficiency by decreasing measurement times. Initial approval efficiency is a critical indicator in production process as every item that will be used in production has to be confirmed in initial approval. So, the team started improvement studies on initial approval efficiency.

Initial approval efficiency is measured with some measures such as waiting time for initial approval, process waiting time and measurement time. Between January 2005 and December 2005, measurement times are recorded. The team analysed this data with a four panel chart as shown in Figure 7.4. Four panel chart is a technique consisting of four parts. In the first part, the data take place. In the second part, a cause and effect diagram takes place. In the third part, suggestions for improving the process take place. And finally in the fourth part, the improvement trend is shown with a histogram or a similar graphical tool. Figure 7.4 shows that measurement times have decreased and initial approval efficiency is being improved.

Table 7.1 Audit checklist for level 5: At the beginning of improvement studies

Change Areas	Requirements	State	Necessary Actions for Conformity
End-Customer Related Measurements	Measurements reflect the end customer's view of the process.	**P**	End customers' views about the process should be obtained.
	End customer requirements are documented.		
	End customer feedback system is established.		
	End customer effectiveness charts are posted and updated.		
Process Measurements and/or Performance	Overall effectiveness and efficiency are measured and posted where they can be seen by employees.		
	Effectiveness and efficiency targets are set.		
	Process operational and/or control weaknesses are evaluated and meet minimum requirements.		
Supplier Partnerships	All suppliers are identified.		
Documentation	Process is defined and flowcharted.		
	Flowchart accuracy is verified.		
	Documentation is followed.		
	PIT (Process Improvement Team) members and process owners are named.		
	PIT mission is documented.		
	Process boundaries are defined.		
Training	PIT is trained in the basic tools and fundamental BPI (Business Process Improvement) tools.		
	In-process training needs are evaluated and documented.		
	Resources are assigned to support training needs.		
Benchmarking			
Process Adaptability			
Continuous Improvement	Basics of BPI are in place.		
	All major exposures are identified and action plans are in place.		
	A detailed plan to improve the process to level 4 is agreed to and funded.		

During the improvement studies, the second evaluation with Harrington criteria was realised. The results are shown in Table 7.2. From the table, it is seen that the process can still not meet the requirements for level 5, so it is still qualified at level 6.

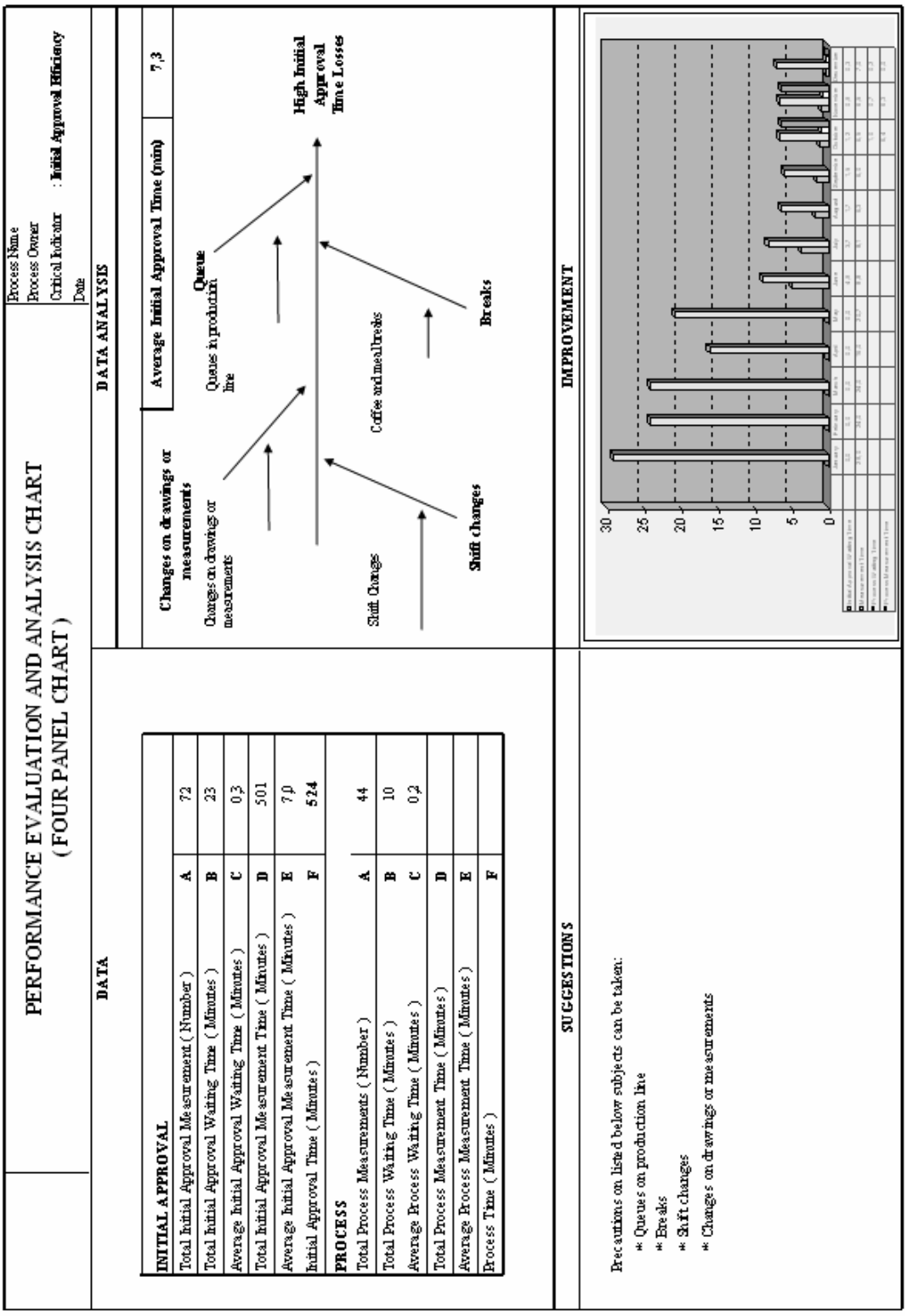


Figure 7.4 Four panel chart showing performance evaluation of the production process.

The final evaluation realised at the end of improvement studies show that the process can now be qualified at level 5 as it meets all the necessary requirements. Related audit checklist can be seen on Table 7.3.

Table 7.2 Audit checklist for level 5: During improvement studies

Change Areas	Requirements	State	Necessary Actions for Conformity
End-Customer Related Measurements	Measurements reflect the end customer's view of the process.	**F**	
	End customer requirements are documented.	**F**	
	End customer feedback system is established.	**F**	
	End customer effectiveness charts are posted and updated.	**P**	
Process Measurements and/or Performance	Overall effectiveness and efficiency are measured and posted where they can be seen by employees.		
	Effectiveness and efficiency targets are set.	**F**	
	Process operational and/or control weaknesses are evaluated and meet minimum requirements.	**P**	
Supplier Partnerships	All suppliers are identified.	**F**	
Documentation	Process is defined and flowcharted.	**F**	
	Flowchart accuracy is verified.	**F**	
	Documentation is followed.	**F**	
	PIT (Process Improvement Team) members and process owners are named.	**F**	
	PIT mission is documented.	**P**	
	Process boundaries are defined.	**F**	
Training	PIT is trained in the basic tools and fundamental BPI (Business Process Improvement) tools.	**F**	
	In-process training needs are evaluated and documented.	**P**	In process training needs should be determined carefully.
	Resources are assigned to support training needs.		
Benchmarking			
Process Adaptability			
Continuous Improvement	Basics of BPI are in place.	**F**	
	All major exposures are identified and action plans are in place.	**P**	
	A detailed plan to improve the process to level 4 is agreed to and funded.		

Table 7.3 Audit checklist for level 5: At the end of improvement studies

Change Areas	Requirements	State	Necessary Actions for Conformity
End-Customer Related Measurements	Measurements reflect the end customer's view of the process.	**F**	
	End customer requirements are documented.	**F**	
	End customer feedback system is established.	**F**	
	End customer effectiveness charts are posted and updated.	**F**	
Process Measurements and/or Performance	Overall effectiveness and efficiency are measured and posted where they can be seen by employees.	**F**	
	Effectiveness and efficiency targets are set.	**F**	
	Process operational and/or control weaknesses are evaluated and meet minimum requirements.	**F**	
Supplier Partnerships	All suppliers are identified.	**F**	
Documentation	Process is defined and flowcharted.	**F**	
	Flowchart accuracy is verified.	**F**	
	Documentation is followed.	**F**	
	PIT (Process Improvement Team) members and process owners are named.	**F**	
	PIT mission is documented.	**F**	
	Process boundaries are defined.	**F**	
Training	PIT is trained in the basic tools and fundamental BPI (Business Process Improvement) tools.	**F**	
	In-process training needs are evaluated and documented.	**F**	
	Resources are assigned to support training needs.	**F**	
Benchmarking			
Process Adaptability			
Continuous Improvement	Basics of BPI are in place.	**F**	
	All major exposures are identified and action plans are in place.	**F**	
	A detailed plan to improve the process to level 4 is agreed to and funded.	**F**	

Finally, examining the performance metrics; determined as initial approval waiting time, measurement time, process waiting time and process measurement time, the histogram in Figure 7.4 shows the improvement in all metrics clearly. In Table 7.4, values that the metrics took during improvement process can be seen.

Therefore, the use of Harrington qualification criteria ensured an improvement in process performance which is one of the main points in our thesis.

Table 7.4 Values of performance metrics during improvement process in minutes

	Initial Approval Waiting Time	Measurement Time	Process Waiting Time	Process Measurement Time
January		29.0		
February		24.0		
March		24.0		
April		16.0		
May		20.7		
June	4.9	8.8		
July	3.7	8.1		
August	1.7	6.3		
September	1.5	6.0		
October	1.2	6.5	1.0	6.4
November	0.9	6.5	0.7	6.3
December	0.3	7.0	0.2	0.0

7.5 A Six Sigma Project for Ensuring Sustainability of Realised Improvements

Following the process improvement application through process qualification, the same process improvement team realised a six sigma project with the aim of ensuring sustainability of realised improvements through DMAIC methodology. Throughout this six sigma project, the team had the purpose of making improvements in the production process by decreasing defects and increasing productivity and capability of Mandelli workbenches. This project is chosen for application because the company wants to be permanent supplier of the car manufacturer he sells axes, to become faultless in the products he supply and to increase its quality performance. Also, by increasing the efficiency of the workbenches, rework or rejection costs will

decrease which will cause the company to increase its competitiveness and so customer satisfaction will increase.

As stated, DMAIC methodology is used in this project and the implementation of this methodology is described step by step.

7.5.1 Define Phase

In the define phase of DMAIC methodology, customer, expectations of customer and boundaries of the process are defined and process is mapped.

The customer is defined as a big car manufacturer whose name is kept secret by the company. The expectation of the manufacturer from the company is to receive axles that have no defects. Also, the process map was drawn before by the team as shown in Figure 7.3. Furthermore, the aim of the project is defined as decreasing stopping times in Mandelli workbenches and thus increasing their productivity and capability.

7.5.2 Measure Phase

In the measure phase, necessary data is collected from many sources to determine the types of defects. For this, the team members talked to the workers of this process asking them everything related to the activities they are responsible for. They also examined the reports about customer complaints in the year 2006. Mostly received complaints are determined as late delivery times, welding defects, painting defects, assembly defects and processing defects. Also, the team examined the stopping times in the workbenches due to four different reasons. Stopping times can be seen on Figure 7.5.

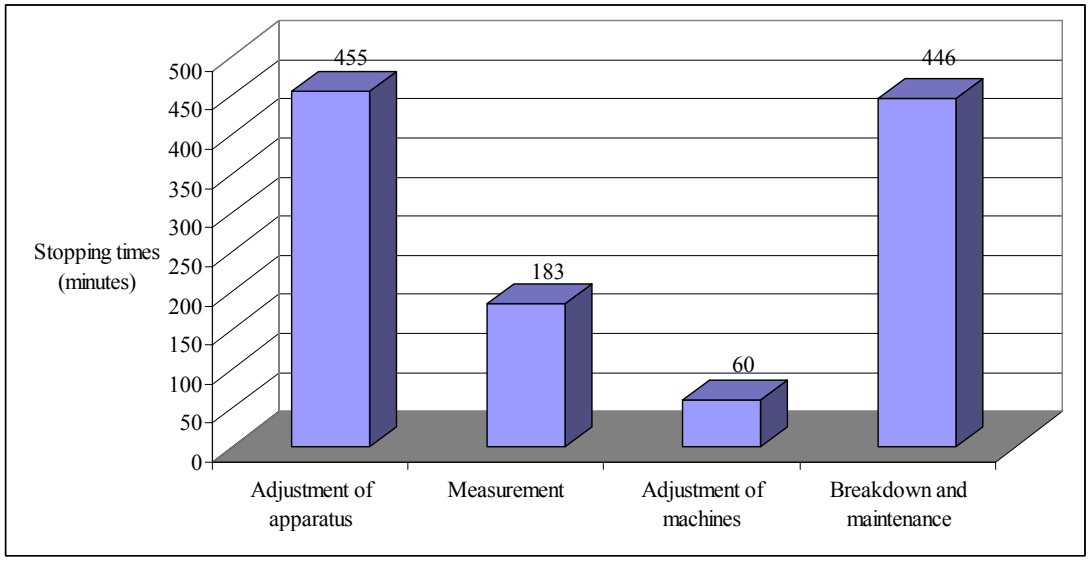


Figure 7.5 Monthly average stopping times of Mandelli workbenches.

7.5.3 Analyse Phase

In this phase, collected data is analysed and opportunities to improve are identified. Process improvement team came together for meetings systematically, and in these meetings, they analysed the data they have and evaluated their present situation. One of the analyses they realised is failure mode and effects analysis (FMEA). FMEA is a method that investigates potential failures in products or processes. The team analysed the manufacturing process with FMEA. Examining risk priority number (RPN) values, some actions to improve are determined. The action that has priority according to RPN values is determined as brake flange turning. By the way, RPN is a measure used for prioritising items that require additional quality planning or action. It identifies the greatest areas of concern. RPN consists of severity rating, occurrence rating and detection rating for a potential failure mode (Hammett, n.d.).

The team also used many statistical tools for searching areas to improve such as gage repeatability and reproducibility analysis, variables control chart analysis, cause and effect diagram and Pareto analysis. The cause and effect diagram can be seen on Figure 7.6.

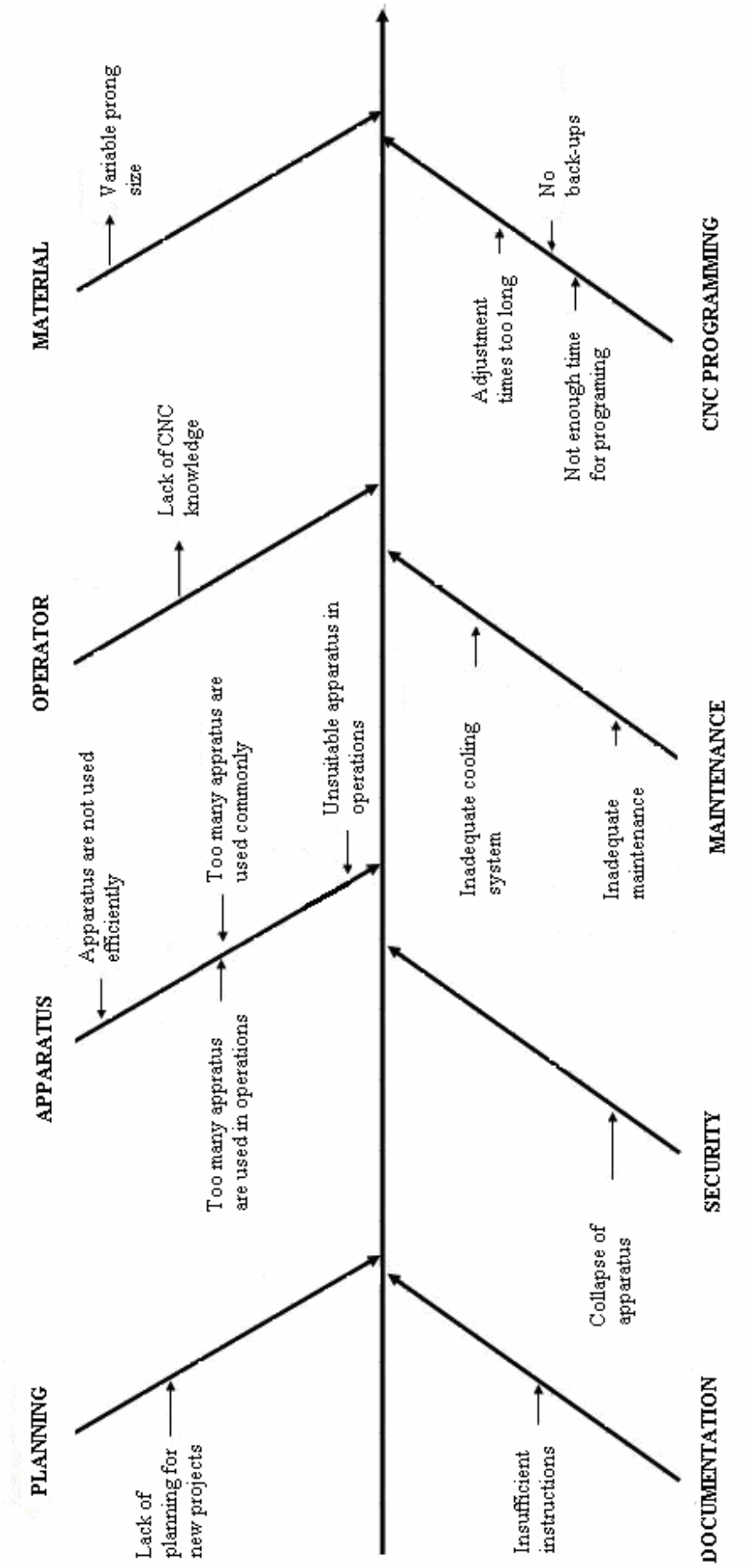


Figure 7.6 Cause and effect diagram used for searching areas to improve.

7.5.4 Improve Phase

In the improve phase of DMAIC methodology, determined improvement actions are performed. For this phase, process improvement team performed improvement actions on brake flange turning and some other actions whose RPN values were also high, such as swaging, friction welding, centerless grinding, carrier mounting face and bore machining and brake bush assembly. The team also worked for decreasing stopping times in Mandelli workbenches. After recommended actions were taken, these actions were improved.

During this six sigma project the team made three calculations for determining the sigma level. The chart showing these values can be seen on Figure 7.7. Also, DPMO values recorded during this project can be seen on Figure 7.8. Defects per million opportunities (DPMO) is the observed average number of defects per unit. As it can be seen from Figure 7.7 and 7.8, the process is improving because DPMO values have decreased and sigma level has increased.

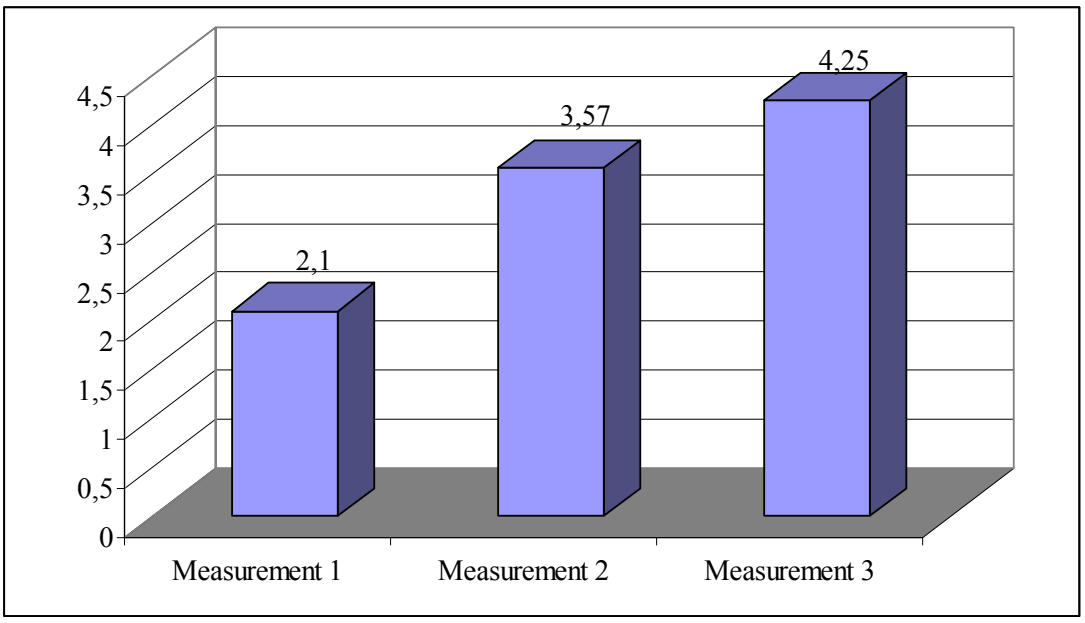


Figure 7.7 Sigma levels measured during the project.

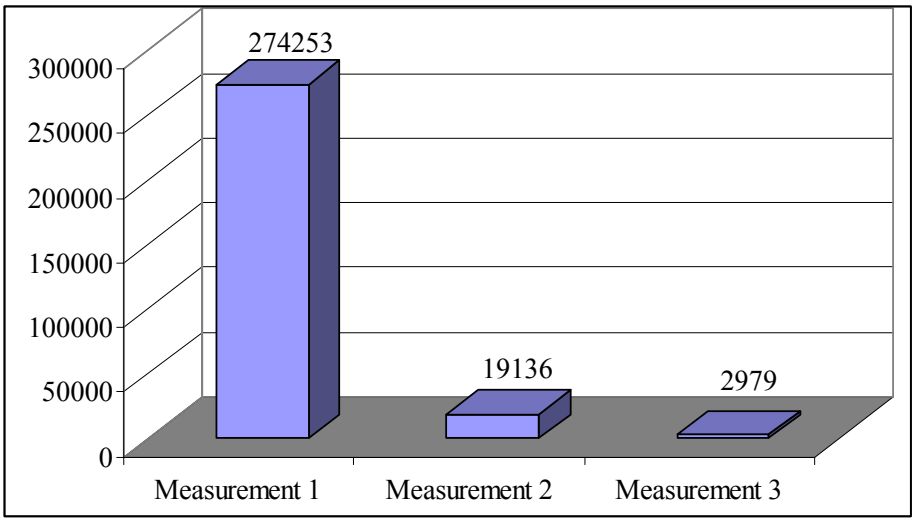


Figure 7.8 DPMO values recorded during the project.

The team realised process capability analysis for increasing the capability of workbenches. On Figure 7.9 the results of process capability analysis before improvement actions can be seen. On Figure 7.10, the results of process capability analysis after improvement actions can be seen. The improvement is clear according to C_P indices. Before improvement actions, the process was not capable as its C_P value of 0.715 was smaller than 1. After improvement actions, C_P value became 1.504 which means that the process became capable. Thus the process has improved.

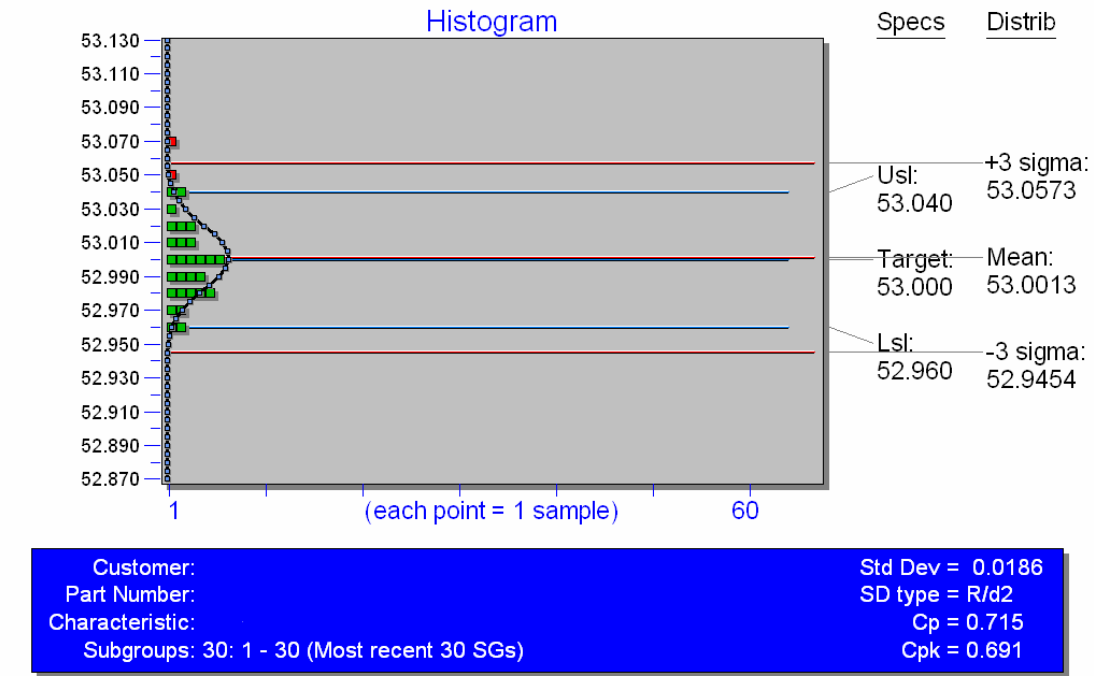


Figure 7.9 Results of process capability analysis before improvement actions.

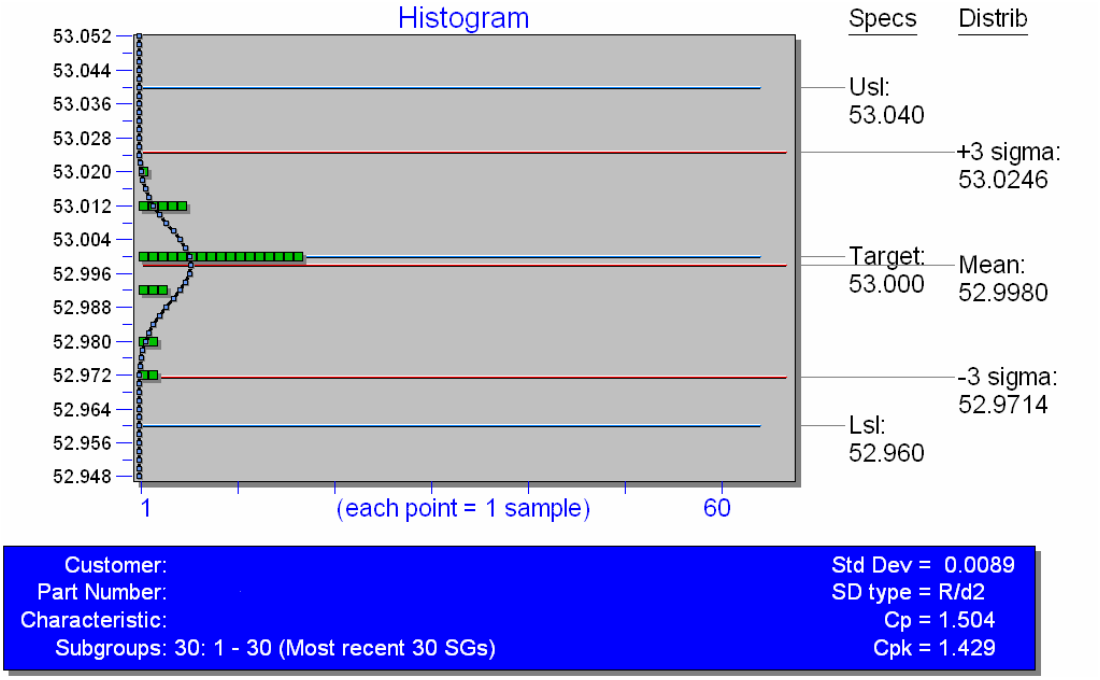


Figure 7.10 Results of process capability analysis after improvement actions.

Finally, Figure 7.11 shows the values of stopping times after improvement actions. The improvement in stopping times is very clear when compared to Figure 7.5.

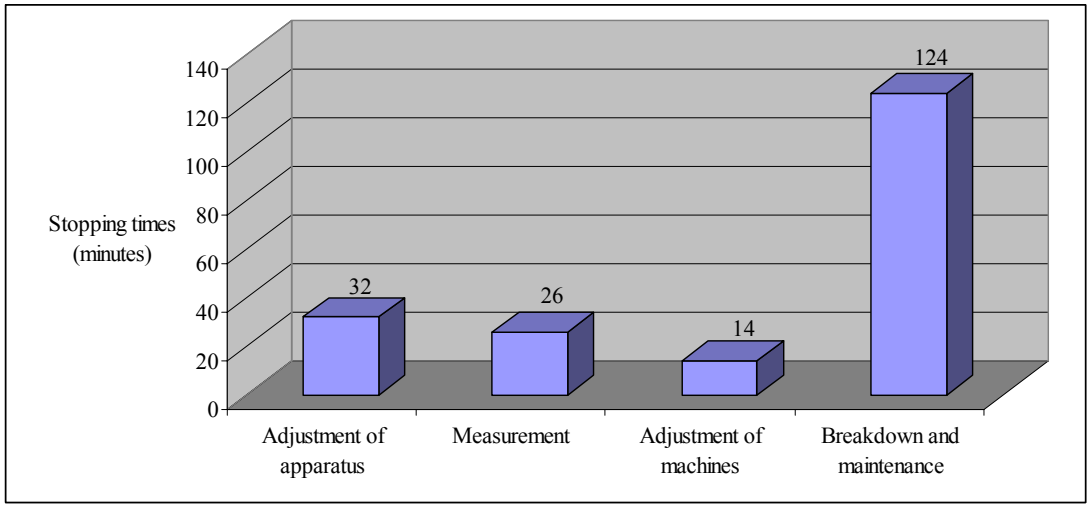


Figure 7.11 Monthly average stopping times of Mandelli workbenches after improvement actions.

7.5.5 Control Phase

Control phase of DMAIC methodology is the one which is most related to sustainability. It is the phase where realised improvements are examined and ensured to be sustainable. Process improvement team realised an improvement in the manufacturing process by increasing sigma level to 4.25 and decreasing DPMO value to 2979. As important as making such an improvement, the team also realised studies and organised meetings for ensuring sustainability of this improvement. They come together once a month to examine the present state of the process. If a decrease in sigma level is examined, they investigate the reasons and take precautions.

7.6 Findings and Results of the Application

The first part of the application about process qualification shows the application of Harrington qualification criteria in business process performance improvement. As it is stated, process qualification is important as it shows that the process is making progress. By improving the production process, its qualification level upgraded from level 6 to level 5.

The main purpose of this application was to improve the process by using the cause and effect relationship between process qualification and process performance. By making audits on process qualification, process performance and quality management system principles are improved. All performance metrics show the improvement in the process clearly.

As a result of upgrading qualification level of the process, and as a result of audits realised in the organisation, quality management system principles are also developed. The organisation became more customer focused as it is also a change area in Harrington criteria. Also, process approach improved because process approach is one of the basics of Harrington criteria. The company started to realise continuous improvement. Supplier partnerships became more important for the

organisation. And finally, factual approach to decision making improved in the company.

On the second part of the application, a six sigma project is realised with the aim of ensuring sustainability in that project. The team used DMAIC methodology in this project and the phases are described in detail. As a result, the team made an improvement in the production process by increasing its sigma level from 2.10 to 4.25 and by decreasing DPMO values from 274253 to 2979. Following this improvement, the team decided to meet once a month to examine the process and take precautions if necessary. As a result of this six sigma project, the company gained an amount of 107,000$ approximately.

CHAPTER EIGHT
CONCLUSIONS

It is stated and proved in the thesis that there is a cause and effect relationship between process qualification and process performance, where qualification is the cause and performance is the effect. Hence, evaluations and audits made on process qualification give more effective results than the audits made on process performance. In this manner, by making improvements in the qualification of the process, improvement on process performance is ensured. All performance metrics showed the improvement in the process performance clearly.

As it is specified, the improvement in process performance is ensured with an improvement in process qualification. Process qualification is important as it shows that the process is making progress. By improving the production process of an organisation working in automotive sector, its qualification level is upgraded from level 6 to level 5.

As a result of upgrading qualification level of the production process and as a result of audits realised in the organisation, quality management system principles are also developed. The organisation became more customer focused as it is also a change area in Harrington criteria. Also, process approach improved because process approach is one of the basics of Harrington criteria. The company started to realise continuous improvement. Supplier partnerships became more important for the organisation. And finally, factual approach to decision making improved in the company.

Besides, Harrington qualification criteria are interpreted in terms of the laws of the fifth discipline. The relationships between eight change areas of Harrington criteria and eleven laws of the fifth discipline, their effects and contributions en each other are investigated and interpreted. According to the results obtained, all laws of the fifth discipline are highly related to continuous improvement change area of Harrington criteria. Process measurements and/or performance have strong

relationship with the laws. Examining from the point of view of the laws, it is clear that “faster is slower” supports almost all change areas. The least related law to the change areas is found to be “the easy way out usually leads back in”.

Finally, the importance of sustainability of process improvement is emphasized. Present sustainability studies are investigated and integrated into DMAIC methodology for making it become more capable for sustainable improvements.

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APPENDICES

APPENDIX A. Requirements for Harrington qualification criteria (Harrington, 1991, pp.209-214)

1 Requirements to be Qualified in Level 4

A process, for being qualified at level 4, must meet all the requirements for qualification level 5 and the following requirements.

Requirements for end-customer related measures are listed below.

- End customer requirements are met.
- End customer expectations are documented.

Requirements for process measurements and/or performance are listed below.

- Overall effectiveness targets are met, and challenge targets are established by process improvement team.
- Poor quality cost (PQC) measurements are developed.
- Some internal efficiency measurements are established.
- Internal effectiveness measurements and targets are 50 percent complete and posted.

Requirements for supplier partnerships are listed below.

- Overall process cycle time and cost are defined.
- No significant effectiveness, efficiency or control exposures exist.
- Substantial improvement activities are under way.

Requirements for documentation are listed below.

- Process is flowcharted and documents are updated.
- Overall process is fully documented.
- Documentation of sub-processes starts.
- Readability is evaluated.

Requirements for training are listed below.

- In-process job training procedures are developed for all critical activities.
- People are assigned to conduct job and process training.
- Process improvement team is trained in statistical process control.

Requirement for benchmarking is listed below.

- Plan exists to benchmark end-customer requirements.

Requirement for process adaptability is listed below.

- Data are collected that identify problems with present process adaptability.

Requirements for continuous improvement are listed below.

- Process is operational, and control weaknesses are assessed and deemed containable.
- A plan for improving the process to level 3 is prepared, approved and funded.
- The process philosophy accepts that people make mistakes, provided everyone works relentlessly to find and remove causes of errors.

2 Requirements to be Qualified in Level 3

A process, for being qualified at level 3, must meet all the requirements for qualification level 5 and 4, and the following requirements.

Requirements for end-customer related measures are listed below.

- End-customer expectations are met.
- Challenge targets are set by the process improvement team.

Requirements for process measurements and/or performance are listed below.

- There is a significant improvement in poor quality costs.
- Internal effectiveness and efficiency measurements are in place and are posted, with targets set by the affected areas.
- There is a significant reduction in cycle time and bureaucracy.
- Overall efficiency targets are met.
- Most measurements show an improvement trend.
- Key process control points are identified.
- Tangible, measurable results are realised.

Requirements for supplier partnerships are listed below.

- Meetings are held with all suppliers, and agreed-to input requirements are documented.
- All critical suppliers meet input requirements.

Requirements for documentation are listed below.

- Sub-processes are documented.
- Training requirements are documented.
- Software controls are in place.

- The readability level of all documents is at a grade level less than the minimum education level of the people using them.
- Employees understand their job descriptions.

Requirements for training are listed below.

- All people performing critical jobs are trained in the new procedures, including job-related training.
- In-process job training procedures are developed for all activities.
- Plans are in place to train all employees who are part of the process in team methods and problem solving tools.
- Process improvement team understands one or more of the business process improvement 10 sophisticated tools.
- All employees in the process receive training on the total process operation.

Requirements for benchmarking are listed below.

- End-customer requirements are benchmarked.
- Plan exists to benchmark critical activities.
- Plan exists to benchmark the process.

Requirements for process adaptability are listed below.

- Employees are trained to distinguish how far they can deviate from the established procedures to meet a customer's special needs.
- Future process change requirements are projected.
- A proactive internal and external customer complaint system is established.
- The end-customer reviews the process change plan and agrees that it meets his or her needs over the strategic period.

Requirement for continuous improvement is listed below.

- A plan to improve the process to level 2 is developed, approved and funded.

3 Requirements to be Qualified in Level 2

A process, for being qualified at level 2, must meet all the requirements for qualification level 5, 4 and 3, and the following requirements.

Requirements for end-customer related measures are listed below.

- End-customer expectations are updated.
- Performance for the last 6 months never fell below end-customer expectations.
- The trend lines show continuous improvement.
- World-class targets are established.
- End-customers are invited to regular performance reviews.
- End-customer desires are understood.

Requirements for process measurements and/or performance are listed below.

- All measurements show an improvement.
- Benchmark targets are defined for external customers and critical in-process activities.
- In-process control charts are implemented as appropriate, and the process is under statistical quality control.
- Feedback systems are in place close to the point at which the work is being done.
- Most measurements are made by the person doing the job.
- There is tangible and measurable improvement in the in-process measurements.
- No operational inefficiencies are anticipated.
- An independent audit plan is in place and working.
- The process is error-free.

Requirements for supplier partnerships are listed below.

- All supplier inputs met requirements for the last 3 months.
- Regular meetings are held to ensure that suppliers understand the changing needs and expectations of the process.

Requirements for documentation are listed below.

- Change level controls are in place.
- Documents are systematically updated.

Requirements for training are listed below.

- All employees in the process are trained and scheduled for refresher courses.
- Employee evaluation of their training process is complete, and the training meets all employee requirements.
- Team and problem solving courses are complete. Employees are meeting regularly to solve problems.

Requirements for benchmarking are listed below.

- Process is benchmarked and targets are assigned.
- Process improvement team understands the keys to the benchmark organisations' performance.

Requirements for process adaptability are listed below.

- Employees are empowered to provide the required emergency help to their customers and are measured accordingly.
- Resources are committed to satisfy future customer needs.
- Process adaptability complaints are significantly reduced.

Requirements for continuous improvement are listed below.

- The process philosophy evolves to the point at which errors are unacceptable. Everyone works relentlessly to prevent errors from occurring even once.
- Surveys of the employees show that the process is easier to use.
- Plans to improve the process to level 1 are prepared, approved and funded.

4 Requirements to be Qualified in Level 1

A process, for being qualified at level 1, must meet all the requirements for qualification level 5, 4, 3 and 2, and the following requirements.

Requirements for end-customer related measures are listed below.

- End-customer expectation targets are regularly updated and always exceeded.
- World-class measurements are met for a minimum of 3 consecutive months.
- Many of the end-customer desires are met.

Requirements for process measurements and/or performance are listed below.

- All measurements exceed those of the benchmark company for 3 months.
- Effectiveness measurements indicate that the process is error free for all end-customer and in-process control points.

Requirements for supplier partnerships are listed below.

- All suppliers meet process expectations.
- All suppliers meet process requirements for a minimum of 6 months.

Requirement for documentation is listed below.

- All documents meet world-class standards for the process being improved.

Requirement for training is listed below.

- Employees are regularly surveyed to define additional training needs and new training programs implemented based on these surveys.

Requirement for benchmarking is listed below.

- Ongoing benchmarking plan is implemented.

Requirements for process adaptability are listed below.

- In the last 6 months, no customers complained that the process did not meet their needs.
- Present process handles the exceptions better than the benchmark company's process.

Requirements for continuous improvement are listed below.

- An independent audit verifies world-class status.
- Plans are approved and in place to become even better.