

Basic Quality Tools in Continuous Improvement Process

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If organizations wish to achieve continuous quality improvement they need to use appropriate selection of quality tools and techniques. In this paper a review of possibilities of the systematic use of seven basic quality tools (7QC tools) is presented. It is shown that 7QC tools can be used in all process phases, from the beginning of a product development up to management of a production process and delivery. It is further shown how to involve 7QC tools in some phases of continuous improvement process (PDCA-cycle), Six Sigma (DMAIC) and Design for Six Sigma (DMADV) methodologies, and Lean Six Sigma.

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Keywords: DMAIC, improvement processes, quality tools, Six Sigma, PDCA, 7QC tools, DMADV

0 INTRODUCTION

Continuous quality improvement process assumes and requires that a team of experts together with the company leadership actively use quality tools in their improvement activities and decision making process.

Currently there is a significant number of quality assurance and quality management tools available, so the selection of the most appropriate is not always an easy task. Tools are essential ingredients of a process and basic instruments for the success of a quality program. Many companies have used tools without giving sufficient thought to their selection and have then experienced barriers to progress. Quality Tools cannot remedy every quality problem but they certainly are a means for solving problems. Consequently, it needs to be emphasized that while tools can be very effective in the right hands, they can be very dangerous in the wrong hands. It is, therefore, important to know how, when and which tools should be used in problem solving or improvement processes.

Today there are more than a hundred different tools available. Many scientists have tried to define them and differentiate among them on various bases [1]. Tools are generally a means of accomplishing change and in this paper we will focus on the most fundamental quality tools called the seven basic quality tools - 7QC tools. They are easy to learn and handle and are used to analyze solutions to existing problems.

These seven quality tools which are basic for all other tools are:

- Flow chart
- Pareto diagram
- Check sheet
- Control chart
- Histogram
- Scatter plot
- Cause-and-effect diagram.

The seven quality tools were first emphasized by Ishikawa (in the 1960s), who is one of the quality management gurus. His original seven tools include stratification, which some authors later called a flow chart or a run chart. They are also called the seven "basic" or "old" tools. After that other new tools have been developed for various purposes but the basis for every work is related to the 7QC tools [3]. These tools are also fundamental to Kaizen and Juan's approach to quality improvement [2].

1 APPLICATION OF 7QC TOOLS

These simple but effective "tools of improvement" are widely used as "graphical problem-solving methods" and as general management tools in every process between design and delivery. The challenge for the manufacturing and production industry is for: "Everyone to understand and use the improvements tools in their work".

Some of the the seven tools can be used in process identification and/or process analysis.

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One possible approach, proposed by J. G. Pimblott [4] is presented in Fig. 1 where Pareto and Cause and effect diagrams are common and essential in both processes (identification and analysis).

The current approach for using 7QC tools, according to EOQ (European Organisation for Quality) [5], is shown in Fig. 2. The process of data acquisitions includes three tools (Check sheet, Histogram and Control chart), and the process of analysis another four tools (Pareto diagram, Cause and effect diagram, Scatter plot, and Flow chart).

There is a distinction between the two approaches represented in Figs. 1 and 2. The approach in Fig. 1 is much older (1990) and therefore, there are some key distinctions. Some tools which are now used only for analysis were at that time considered as tools for identification or for both processes (identification and analysis). But even then scientists were attempting to find appropriate utilizations of each tool in different processes and methodologies of improvement.

The tools must meet the main purpose or reason for their application. No single tool is more important in isolation, but could be most significant for a specific application [1].

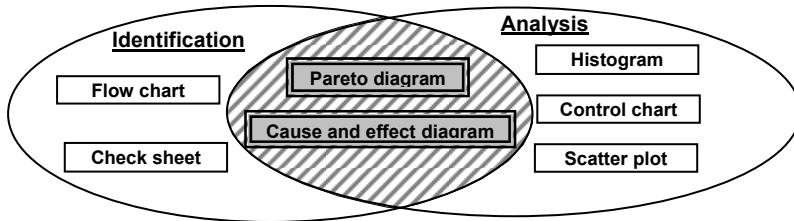


Fig. 1. Use of 7QC tools in process identification and analysis

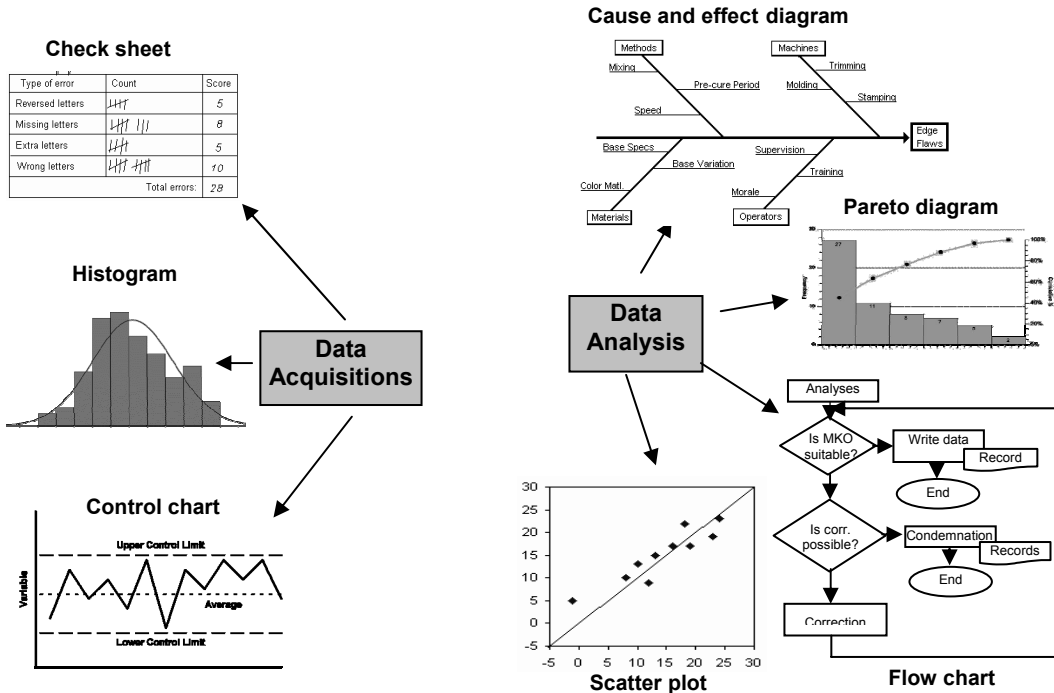


Fig. 2. Current approach for using 7QC tools (according to EOQ)



Fig. 3. Development of quality management concept

2 7QC TOOLS THROUGH PDCA-CYCLE

In successful application of quality tools an implemented quality management system is an advantage. The quality management principles are a starting point for the company's management striving for continuous efficiency improvement over a long period of time and customer satisfaction. A quality management system is based on the integrity of all production and support resources of a certain company. It enables a faultless process flow in meeting related contracts, standards and market quality requirements. Implementation of a quality management system is always a part of a company's development process, Fig. 3 [6].

Having a quality management system in place is a prerequisite for its successful application on a day-to-day basis. The management has to show commitment to development and improvement of a quality management system. Through a quality management system the company's leadership implements their quality policy. Furthermore, a quality management system has to be well documented. When in function, the quality management system provides useful information obtained by different process analyses and audits. If a company's focus is on the customer, the company has to select the most efficient ways of data acquisition and market survey to confirm that the company's products or services meet customer demands and expectations. The gathered information is invaluable in the decision making process based on fact. Data collection and analysis is also significant in defining opportunities for further processes and product quality improvement.

Continuous improvement as a fifth principle of QMS (ISO 9001:2000) could not be realized without quality tools which are presented through four groups of activities of Deming's quality cycle or PDCA-cycle, shown in Fig. 4 [6]. The PDCA-cycle is an integral part of process management and is designed to be used as a

dynamic model because one cycle represents one complete step of improvement.

The PDCA-cycle is used to coordinate continuous improvement efforts. It emphasizes and demonstrates that improvement programs must start with careful planning, must result in effective action, and must move on again to careful planning in a continuous cycle – the Deming's quality cycle is never-ending. It is a strategy used to achieve breakthrough improvements in safety, quality, morale, delivery cost, and other critical business objectives.

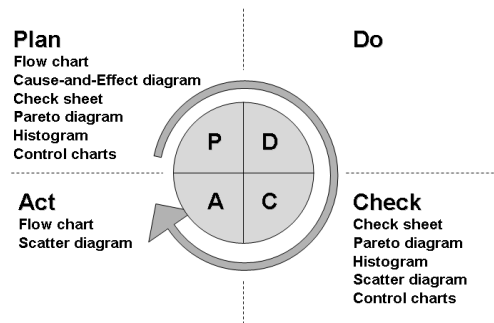


Fig. 4. PDCA-cycle

The completion of one cycle continues with the beginning of the next. A PDCA-cycle consists of four consecutive steps or phases, as follows:

- Plan - analysis of what needs to be improved by taking into consideration areas that hold opportunities for change. Decision on what should be changed.
- Do - implementation of the changes that are decided on in the Plan step.
- Check - Control and measurement of processes and products in accordance to changes made in previous steps and in accordance with policy, goals and requirements on products. Report on results.
- Act - Adoption or reaction to the changes or running the PDCA-cycle through again. Keeping improvement on-going.

Table 1. Seven basic quality tools (7QC tools) in correlation with PDCA-cycle steps

Seven basic quality tools (7QC tools)	Steps of PDCA-cycle				
	Plan	Do	Plan, Check	Plan, Act	Check
	Problem identification	Implement solutions	Process analysis	Solutions development	Result evaluation
Flow chart	✓			✓	
Cause-and-effect diagram	✓		✓		
Check sheet	✓		✓		✓
Pareto diagram	✓		✓		✓
Histogram	✓				✓
Scatter plot			✓	✓	✓
Control charts	✓		✓		✓

The main purpose of PDCA-cycle application lies in process improvement [7]. When process improvement starts with careful planning, it results in corrective and preventive actions supported by appropriate quality assurance tools which lead to true process improvement. The application of the seven basic quality tools in correlation with four steps of PDCA-cycle is shown in Table 1 [8].

As shown in Table 1, most of the 7QC tools can be used for problem identification: Flow chart, Cause-and-Effect diagram, Check sheet, Pareto diagram, Histogram and Control charts. For problem analysis the following tools can be used: Cause-and-Effect diagram, Check sheet, Pareto diagram, Scatter plot and Control charts. When a team is developing a solution for the analyzed problem, Flow chart and Scatter plot can be useful as well. In the phase of achieved results evaluation, most of 7QC tools can also be successfully implemented: Check sheet, Pareto diagram, Histogram, Scatter plot and Control charts.

For effective and successful team work in solving daily quality problems, we propose a simple model for systematic usage of "basic quality tools" for process monitoring, data acquisition and quality improvement, Fig. 5 [6] and [9].

Loop 1 focuses on the analysis of the biggest causes for defects which are found by Pareto diagram, and Loop 2 focuses on continuous process improvement, which is one of the eight QMS principles. The implementation of this principle is a big stride forward which a company can take in order to change their static quality management to a dynamic one.

3 7QC TOOLS IN SIX SIGMA

Six Sigma is an organization-wide approach used to specify exactly how organization managers set up and achieve objectives. It demonstrates how breakthrough improvements tied to significant bottom-line results can be achieved [10].

The Six Sigma methodology goes beyond the improvement process and tools because it requires an intelligent use of data, emphasis of statistical analysis and designed experiments.

Six Sigma prescribes an improvement process known as DMAIC methodology [3]:

- Define - improvement of project goals, goals based on customer needs and wants
- Measure - current process and establish metrics to monitor the path to achievement of goals
- Analyze - current process to understand problems and their causes
- Improve - process by identifying and piloting solutions to problems
- Control - improved process with standardization and ongoing monitoring.

Each of these processes (phases) can be realized with different quality tools and techniques (also 7QC) while some tools can be used in more than one processes (phases). One possible classification (use) of different quality tools and techniques in the Six Sigma methodology, proposed by the authors is presented in Fig. 6 [9].

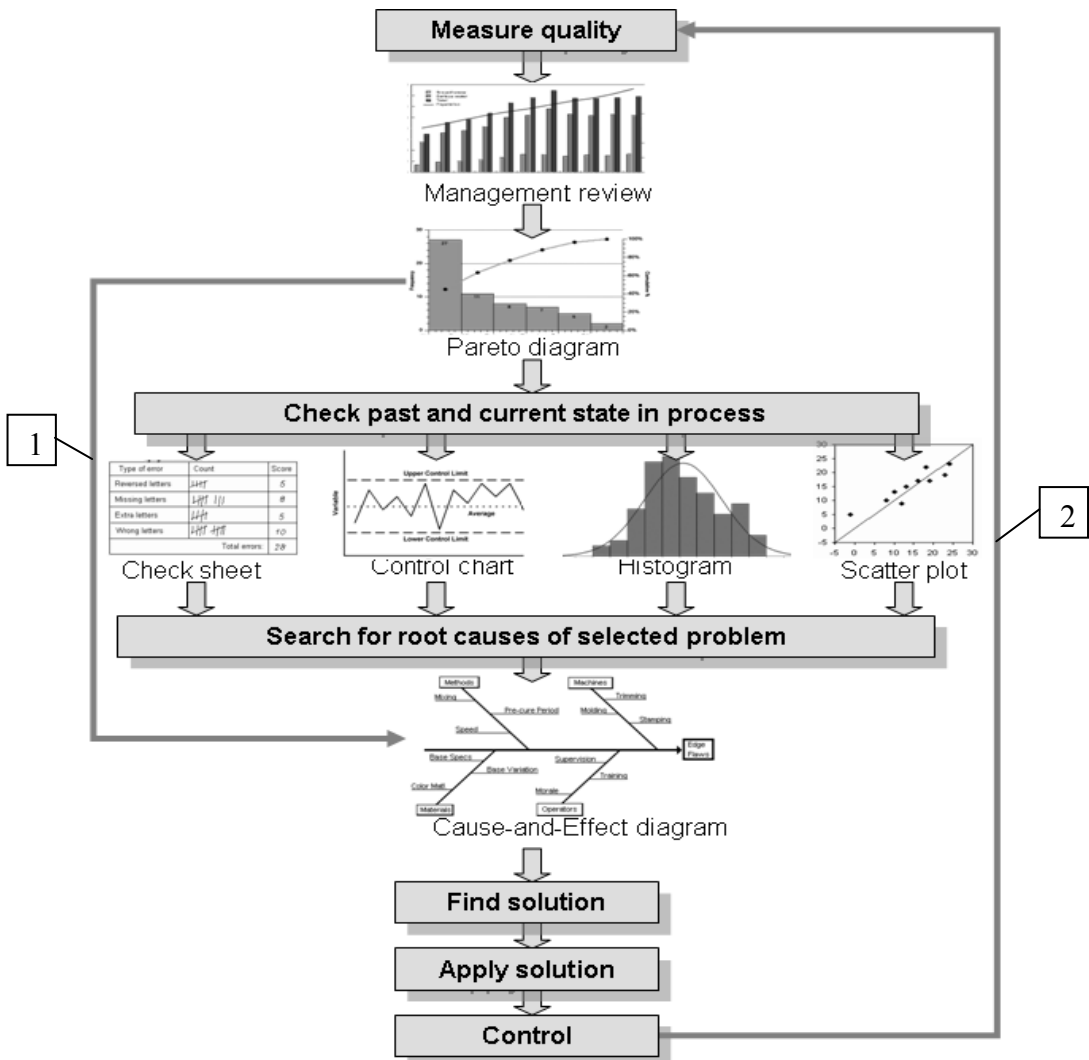


Fig. 5. Seven basic quality tools (7QC tools) for quality improvement

In Fig. 6 the tools which are used in all phases of DMAIC methodology are presented. Below each phase of DMAIC the main tools for each process are presented. Lower still the tools which are not essential for that process but can also be used (Additional tools) are shown. It can be seen that, except the Improve phase, the Analysis and Control phases have one or more QC tools.

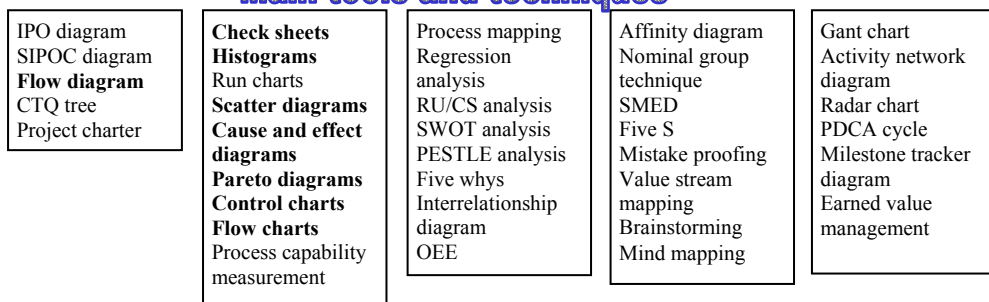
For the development of a new product or a process which focuses on "problem prevention" there is a modified version of Six Sigma called Design for Six Sigma (DFSS). The fundamental characteristic of DFSS is the verification which makes it different from Six Sigma but the

proponents of DFSS are promoting it as a holistic approach of Re-engineering. It is also known as the application of Six Sigma techniques to the development process. DFSS is centred on designing a new product and services while Six Sigma is primary a process improvement methodology. The processes often used in practice in DFSS are called DMADV (define, measure, analyze, design, verify) or IDOV (identify, design, optimise and validate). The first phase in DMAIC and DMADV (or IDOV) is the same (define the goals of the activities) but after that processes go in different ways. If a process exists then you go by the DMAIC way and if not, you follow the DMADV [11].

Six Sigma methodology - DMAIC



Main tools and techniques



Additional tools and techniques for particular phases



Fig. 6. Quality tools and techniques in DMAIC methodology

In Table 2 a possible inclusion of 7QC tools in three methodologies is presented: continuous improvement PDCA-cycle, Six Sigma and Design for Six Sigma [12]. In different phases of the processes various tools can be taken while some phases like (Plan for the future in PDCA-cycle) need some other management, planning or other tools and techniques.

In this approach (Table 2) it is also shown that in the Improve phase of DMAIC two basic quality tools (Control chart and Pareto diagram) could be used while in Fig. 6 this phase does not contain any basic tools. On the other hand, in the Define phase of DMAIC methodology, Fig 6, there is one basic quality tool (Flow diagram) whereas in Table 2 the Define column is empty.

When comparing the inclusion of 7QC tools in PDCA methodology in Tables 1 and 2 it can be seen that the authors in both references [8,12] consider that not a single basic quality tool could be involved in the process which means realization (Do or Implement Solutions).

These approaches are different and definitely need a deeper analysis but it is evident that 7QC tools have a big role in all the key phases of these methodologies.

4 7QC TOOLS IN LEAN SIX SIGMA

Lean Six Sigma are a set of methods that companies can apply to any manufacturing, transactional or service process to reduce waste, eliminate non-value-added actions and cut time. Combining "Lean" with "Six Sigma" can produce a program that brings both short-term results through the power of Lean, and long-term change through the power of Six Sigma. It is for this reason that many companies are turning to a combined Lean and Six Sigma effort.

- Lean means speed and quick action (reducing unneeded waiting time).
- Six Sigma means identifying defects and eliminating them.
- Lean Six Sigma Engineering means best-in-class [13] and [14]. It creates value in the organization to benefit its customers

and saves money without capital investment.

Both, the Lean and the Six Sigma methodologies have proven over the last twenty years that dramatic improvements in cost, quality, and time can be achieved by focusing on process performance. Most practitioners consider these two methods as complementing each other to achieve world class performance (WCP).

Bringing the two concepts together delivers faster results by establishing baseline performance levels and focusing on the use of statistical tools where they will have the most impact. Most companies using both methodologies began by applying basic Lean - manufacturing techniques - the 5Ss, standardized

work and the elimination of waste. Once Lean techniques eliminate much of the noise from a process, Six Sigma offers a sequential problem-solving procedure, the DMAIC cycle, and statistical tools so that potential causes are not overlooked and viable solutions to chronic problems can be discovered [14].

One may obtain Lean Six Sigma training certification by completing the improvement model for Lean Six Sigma Black Belt. This training is available at academic institutions, as well as quality societies or other certified organizations. The preceding steps with quality tools (also 7QC tools) and techniques for Lean Six Sigma Black Belt are shown in Fig. 7 below [13].

Table 2. *Quality Tools and Techniques Selector Chart*

Methodology Tools and techniques	Continuous improvement (PDCA-cycle)						Six Sigma (DMAIC)					Design for Six Sigma (DMADV)					
	Identify opportunity	Analyze the process	Develop solutions	Implement solutions	Evaluate results	Standardize solutions	Plan for the future	Define	Measure	Analyze	Improve	Control	Define	Measure	Analyze	Design	Verify
7 QC tools																	
Cause-and-Effect diagram		x							x					X			
Control chart			x		X			x		x	x					x	x
Check sheet	x												x				
Histogram	x							x					x				
Pareto diagram					X			x		x			x	X			x
Scatter diagram		x			X					x			x	X			
Flowchart																	
• Deployment flowchart	x	x	x			x								x			
• Linear or activity flowchart	x	x	x			x								x			
• Opportunity flowchart		x	x			x								x			

	Objective	Tools and Techniques
Define	Identify Business Drivers Select Customer Critical Processes Define Projects Develop Implementation Plan Lean Concept Process Mapping (Value Added/ Nonvalue Added)	Affinity Diagram/ Interrelation Diagram Quality Function Deployment SIPOC Process Map Project Charter Value Stream Mapping Brainstorming Select Project Team and Goal
Measure	Develop Key Process Measures Collect and Summarize Data Identify the Vital Few That Have the Greatest Impact Estimate Process Capability Measurement Systems Analysis	Data Collection Plan Check/Data Sheet Pareto Chart Gage R&R Histogram Value Analysis Control Charts for Existing Process
Analyze	Understand Cause and Effects Create Multi-vari Analysis Determine Variance Components Assess Correlation	Cause and Effect Diagram Multi-var Charts Scatter Diagram Process Capability Study (Cp, Cpk, Pp, Ppk) Box Plot
Develop	Identify and Prioritize Root Cause Apply DOE (Screen Potential Root Cause) Develop and Evaluate Solutions Implement Variation Reduction Cost Benefit Analysis Standardize Process Assess Risk Factors Kaizen Techniques Cellular Concept Pull System	Benchmarking Design of Experiments Response Surface Methodology Deployment Flowchart Tree Diagram FMEA, RPN, JIT, TPM, 5S Setup reduction
Verify	Implement Process Control Implement Control Charts for Key Variables Mistake-Proof Processes Evaluate Results Lean Metrics	Process Control Plan Control/Precontrol Chart Poka-Yoke Pareto Chart (ongoing) Process Capability Charts (ongoing) Checklist Sheet

Fig. 7. Lean Six Sigma Black Belt improvement model (use of 7QC tools is emphasized)

5 CONCLUSIONS

This paper aimed at defining the role and significance of seven basic quality tools (7QC tools) within a quality management system. The principle of continuous improvement using the seven basic quality tools which guarantee organizations to move from static to dynamic improvement status was presented. As shown, the

7QC tools have an important place in data collecting, analyzing, visualizing and all other phases in PDCA-cycle, DMAIC and DMADV phases, and also in *Lean Six Sigma*. Furthermore, systematic application of 7QC tools will enable a successful quality improvement process.

It is evident that a continuous improvement process cannot be realized without quality tools, techniques and methods. These

tools also help the quality engineer to use accessible data in decision processes. Therefore, it is very important that the passive status (identification needed for tools, techniques and methods) of using these tools, techniques and methods is transformed into proactive status, which is the only way towards further affirmation of a continuous improvement process.

In view of this, it is evident that an even much more synthesized process could be realized and improved using different tools and techniques which have *7QC tools* as their basis.

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