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QUALITY IMPROVEMENT METHODOLOGIES FOR CONTINUOUS IMPROVEMENT OF PRODUCTION PROCESSES AND PRODUCT QUALITY AND THEIR EVOLUTION

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Abstract: *In order to be competitive companies try continuously improve their production processes, product quality and increase the level of customer satisfaction by implementing different quality improvement programs, methodologies and approaches. Nowadays there are different worldwide used methodologies like PDAC, 8D, Six Sigma DMAIC, 4Q which enables the companies to select and combine them for continuous improvement. In this paper will be introduced the general idea of using these methodologies, it will be followed by discussion where will be made the comparative analysis that will clarify their advantages and disadvantages and shows in what case the appropriate methodology could be selected.*

Key words: PDCA, 8D, DMAIC, 4Q

1. INTRODUCTION

Today customer satisfaction is the feeling of pleasure that occurs when a company meets a customer's expectations. Gaining high levels of customer satisfaction is very important to a business because satisfied customers are most likely to be loyal and to make repeat orders and to use a wide range of services [1, 2]. A company that succeeds on meeting and exceeding customers' expectations is guaranteed to have great Return On Investment (ROI) [3, 4]. Today the reliable and stable production processes influence on a lot of KPI that are very important for business success. In addition, metrics can provide managers with information about problematic points and show the real status of enterprise at certain time [5]. For instance the more reliable and stable production processes is the less scrap occurs, and less rework is needed, which consumes additional recourses, time and money [6]. Therefore, in order to be competitive and successful on the market place and satisfy customer, companies should continuously improve their production processes and product quality by implementing different quality improvement programs and methodologies [7]. A quality improvement effort will lead to a higher product and service quality that will lead to improved customer satisfaction [8]. In this paper will be reviewed and discussed four different quality and process improvement methodologies which are intended to solve customer complaints and problems in virtual organisation network [9, 10]. Presented findings are intended to be used as information for management decisions about what quality improvement methodology should be selected for continuous improvement in Partner Network enterprises. Figure 1 shows related research papers but in this paper will be presented the third part.

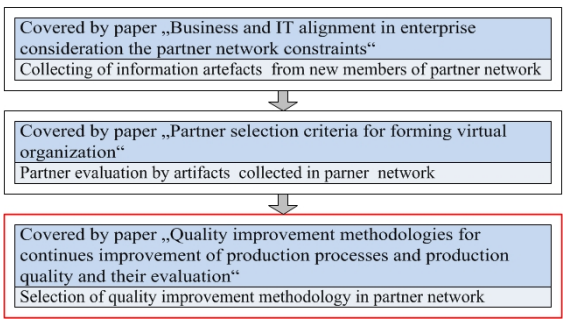

Fig. 1. Related research papers

2. LITERATURE REVIEW

2.1. Plan Do Check Act (PDCA)

In 1939 Walter Shewhart displayed the first version of the scientific method with his cycle "Shewhart Cycle": Specification, Production, Inspection [11]. In 1950, Deming modified the Shewhart cycle at a Japanese Union of Scientists and Engineers (JUSE). His straight line: Design, Produce, Sell was converted to a circle with a forth added step - Redesign through marketing research [12]. In 1950 at JUSE seminar Imai recast the Deming wheel into the Plan, Do, Check, Act (PDCA) cycle and presented the correlation between the Deming wheel and the PDCA cycle shown in Table 1 [13].

Design - Plan	Product design corresponds to the planning phase (definition of a problem and a hypothesis about possible causes and solutions)
Production - Do	Production corresponds to doing-making, or working on the product that was designed (implementing)
Sales - Check	Sales figures confirm whether the customer is satisfied (evaluating the results)
Research - Action	In case of a complaint being filed, it has to be incorporated into the planning phase and action taken for the next round of efforts (back to plan if the results are unsatisfactory)

Table 1. Correlation between the Deming wheel and the Japanese PDCA cycle [13]

PDCA cycle is targeted on the prevention of error repetition by creation standards and the ongoing modification of current standards. Using of the PDCA cycle means continuously improving process/product. It is effective in both doing a job and managing a programme. The PDCA cycle enables two types of corrective action – temporary and permanent. The temporary is aimed at results by practically tackling and fixing the problem. The permanent consists of investigation and eliminating the root causes and thus targets the sustainability of the improved process [14]. In Figure 2 shown the PDCA cycle in detail [15]. In the "*Do*" stage it is possible to involve a *mini-PDCA cycle* until the issues of implementation are resolved [16].

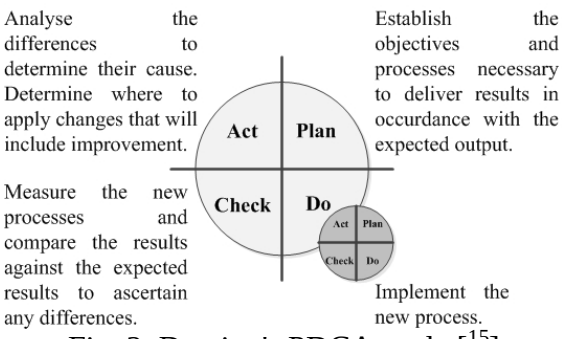

Fig. 2. Deming's PDCA cycle [15]

2.2. 8Disciplines (8D)

The 8D process was standardized during the Second World War by U.S. government, referring to it as Military Standard 1520: "Corrective action and disposition system for nonconforming material". It was later applied by the Ford Motor Company in the 1960's and 1970's. 8D has become a standard in the auto and other industries that require a structured problem solving process, which is used to identify, correct and eliminate problems. The methodology is useful in product and process improvement. It focuses on the origin of the problem by determining root cause. [17]. Further presented the detail description of every step of 8D process.

- **D0:** Planning phase: Plan for solving the problem and determine the prerequisites.
- **D1:** Use a team: Establish a team of people with product/process knowledge.
- **D2:** Define and describe the problem: Specify the problem by identifying in terms who, what, where, when, why, how and how many (5W2H).
- **D3:** Developing interim containment plan: Define and implement containment actions to catch and isolate the problem from any customer.
- **D4:** Determine, identify and verify root causes and escape points: Identify all potential causes that could explain why the problem occurred and why the problem has not been noticed at the time.
- **D5:** Choose and verify Permanent Corrective Actions (PCAs) for root cause:

Confirm that the selected corrective actions will resolve the problem for the customer.

- **D6:** Implement and validate PCAs: Define and implement the best corrective actions. Permanent corrective action.
- **D7:** Prevent recurrence: Modify the management and operation systems, practices and procedures to prevent recurrence of this and similar problems.
- **D8:** Congratulate your team: Recognize the collective efforts of the team and thank them formally.

One of the problems in the implementation of the 8D methodology is using it as a one-page problem-reporting effort. It requires the report to be written within 24 hours, but some steps can take a few hours, while others can take weeks [18].

2.3. Six Sigma DMAIC

Dating back to the mid of 1980s, applications of the Six Sigma methods enabled many organizations to sustain their competitiveness by integrating their knowledge of the process with statistics, engineering and project management [19]. Motorola was the first company who launched a Six Sigma project in the mid-1980s [20]. Initially Six Sigma was applied in manufacturing [21] but today it is accepted in healthcare [22], finance [23] and service [24]. Six Sigma is a project-driven management approach intended to improve products, services and processes by reducing defects [25]. It is a business strategy that focuses on improving customer requirements, business systems, productivity and financial performance. Utilizing analytical tools to measure quality and eliminate variances in processes allows to producing near perfect products and services that will satisfy customers [26]. Below is present Six Sigma's DMAIC description.

- **Define** step is where a problem is identified and quantified in terms of the perceived result. The product and/or process to be improved are identified, resources for the improvement project are put in place and expectations for the improvement project are set.
- **Measure** step enables to understand the present condition of its work process before it attempts to identify where they can be improved. The critical to-quality characteristics are defined and the defects in the process/product developed through graphical analysis. All potential effects on failure modes are identified.
- **Analyse** step adds statistical strength to problem analysis, identifies a problem´s root cause and determines how much of the total variation is.
- **Improve** step aims to develop, select and implement the best solutions with controlled risks. The effect of the solutions that are then measured with the KPI developed during the Measure step.
- **Control** step is intended to design and implement a change based on the results made the Improve step. This step involves monitoring the process to ensure it works according to the implemented changes, capture the estimated improvements and sustain performance [26].

2.4. 4 Quadrants (4Q)

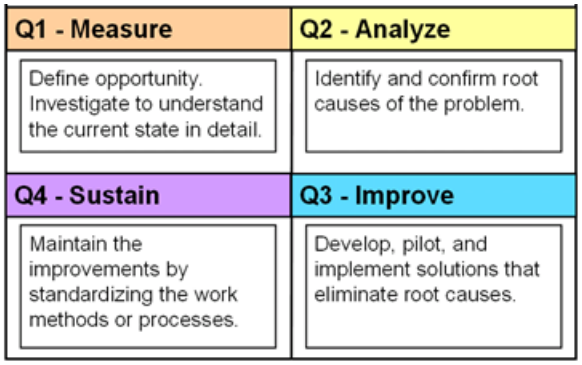

Fig. 3. 4Q process [27]

4Q is data driven problem solving process for continuous improvement also called 4Q improvement methodology that was developed and applied in ABB company in 2009 to stop "religious" fights between Lean, Six Sigma DMAIC, PDCA, 8D and other promoters arguing superiority of one approach against the other. 4Q stands for the 4 quadrants: Measure, Analyse,

Improve and Sustain. The 4Q process is a problem solving method similar to Six Sigma DMAIC. In 4Q the Define step is a part of Q1 Measure and also part of the trigger that starts a 4Q project [27]. Figure 3 shows 4Q process and Table 2 presents the basic description of 4Q steps.

Pre 4Q	Q1 Measure	Q2 Analyse	Q3 Improve	Q4 Sustain
• Develop draft problem statement • Take immediate action • Identify initial project scope • Create business case • Determine objectives • Create project charter • Create and enter project white sheet into SMT • Project sponsor approval to proceed	• Form the project team • SIPOC process map • Capture VOC & translate to CTQ • Stakeholder map • Communication & project plan • Develop 'As-Is' process map • Validate measurement system • Develop data collection plan • Collect data • Calculate baseline process performance • Revisit problem statement • Project sponsor approval to proceed	• Analyse variation • Analyse waste • Team brainstorm to identify root causes • Document root causes on Cause & Effect diagram • Select top 3-5 root causes • Validate selected root causes as actual root causes • Project sponsor approval to proceed	• Team creative brainstorm solutions • Select optimum solutions • Conduct pilot study (or Risk Analysis) • Verify & validate improvements • Develop 'To-Be' process map • Review stakeholder map & common plan • Implementation business case (cost & benefits) & solution plan • Project sponsor, process owner and budget holder approval to proceed • Implement actions on solution plan	• Select control techniques (SPC) • Standardize via documentation • Develop control metrics (KPI's) • Disengage old process • Monitor progress • Validate improvements in process performance • Share lessons learnt (organization memory, newsletters etc) • Thank the team • Celebrate success • Plan future activities • Close project

Table 2. 4Q process basic description [28, 29]

3. DISCUSSION

There are not so many differences between above observed methodologies as they follow a scientific and methodical way to solve the problems. Table 3 shows methodologies evolution (from left to right), correlation and summary.

- PDCA cycle is the classic problem solving approach used in a Lean environment and mostly in automobile industry. It is a fundamental concept of continuous improvement processes embedded in the organization's culture. The most important aspect of PDCA lies in the *"act"* stage after the completion of a project when the cycle starts again for the further improvement. PDCA is used for medium sized problems [14].
- 8D is an effective approach at finding a root cause, developing proper actions to eliminate root causes and implement the corrective actions. The goal of 8D focused on fast reaction to customer complaints. Typically the first three steps should be accomplished and reported to the customer in three days.
- Six Sigma DMAIC is systematic and fact based approach that provides a rigorous framework for project management, also used to create a *"gated process"* for project control. Six Sigma DMAIC is mostly applied to solve big problems where a lot of data available and where statistical tools should be applied. The DMAIC project may last more than three month, it depends on how complex the problem and process to be improved.
- 4Q process is a problem solving method that is similar to the above mentioned methodologies that is intended for continuous improvement of processes. It

was developed by ABB company to help to solve 90% of all issues [30].

Steps	PDCA	8D	Six Sigma DMAIC	4Q
	Plan	D0: Plan	Define	Pre 4Q
		D1: Identify team		
		D2: Define problem		
		D3: Contain symptom	Measure	Measure
		D4: Identify root causes	Analyse	Analyse
	Do	D5: Choose corrective action	Improve	Improve
		D6: Implement corrective action		
	Check	D7: Make change permanent	Control	Sustain
	Act	D8: Recognise the team		
Comparison of methodologies for continues improvement application				
Year	1939	1940´s	1980	2009
Industry	Automobile	Automotive	Manufacturing of all type, healthcare, finance, service	Automotive, electrical,
Project / problem size	Medium sized, till 3 months	Small, some weeks	Big, till 12 months and even more	Small and medium, 1 week till 2 months
Used / Applied	For continuous improvement of small problems	For automotive industry and focused on fast reaction to customer complaints	For large problems where huge amount of data and statistics used	For continuous improvement of various problem (allowed to solve 90% of all issues in ABB company)

Table 3. The evolution, correlation and summary of presented methodologies

4. CONSCLUSION

In this paper were observed different continuous improvement methodologies, their capabilities, similarity and application to different situations. Every company can select and use a proper methodology and even combine some of them in continuous improvement of their processes. It is very important that the right methodology is correctly selected according to the needs and demands of the company and further applied to the appropriate process.

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