

Quality Improvement Methodologies – PDCA Cycle, RADAR Matrix, DMAIC and DFSS

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ABSTRACT

Purpose: of this paper is to introduce the reader to the characteristics of PDCA tool and Six Sigma (DMAIC, DFSS) techniques and EFQM Excellence Model (RADAR matrix), which are possible to use for the continuous quality improvement of products, processes and services in organizations.

Design/methodology/approach: We compared the main characteristics of the presented methodologies aiming to show the main prerequisites, differences, strengths and limits in their application.

Findings: Depending on the purpose every organization will have to find a proper way and a combination of methodologies in its implementation process. The PDCA cycle is a well known fundamental concept of continuous-improvement processes, RADAR matrix provides a structured approach assessing the organizational performance, DMAIC is a systematic, and fact based approach providing framework of results-oriented project management, DFSS is a systematic approach to new products or processes design focusing on prevent activities.

Research limitations/implications: This paper provides general information and observations on four presented methodologies. Further research could be done towards more detailed study of characteristics and positive effects of these methodologies.

Practical implications: The paper presents condensed presentation of main characteristics, strengths and limitations of presented methodologies. Our findings could be used as solid information for management decisions about the introduction of various quality programmes.

Originality/value: We compared four methodologies and showed their main characteristics and differences. We showed that some methodologies are more simple and therefore easily to understand and introduce (e.g. PDCA cycle). On the contrary Six Sigma and EFQM Excellence model are more complex and demanding methodologies and therefore need more time and resources for their proper implementation.

Keywords: Quality continuous improvement; PDCA Cycle; EFQM Excellence Model; RADAR Matrix; Six Sigma

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1. Introduction

Different organizations use different methodologies, approaches and tools for implementing a quality management and programmes for continuous quality improvement. The programme is likely to have a different name or label, such as TQM (Total Quality Management), Six Sigma, BPR (Business Process Re-engineering), Operational Excellence or Business Excellence. Regardless of the methodology, approach, tool or the name of the continuous improvement programmes, each organization will certainly need to use a proper selection and combination of different approaches, tools and techniques in its implementation process. Most of these tools, approaches and techniques are used worldwide and simple to understand and can be used by a large number of people of the company, *e.g.* PDCA cycle or Deming's circle. However, some techniques in this area are more complex and demanding, *e.g.* Six Sigma, Lean Sigma, Design for Six Sigma or EFQM excellence model. Specialists for specific problem-solving applications and implementation use these advanced techniques and methodologies. It is very important that tools, approaches and techniques should be selected for the

appropriate team and applied correctly to the appropriate process. The successful implementation of approaches, tools and techniques depends on their understanding, knowledge and proper application in organizational processes.

2. The PDCA cycle

2.1. Definition

In a central process, the actual results of an action are compared with a target or a set point. The difference between the two is then mentioned and corrective measures are adopted if the disparity becomes large. The repeated and continuous nature of continuous improvement follows this usual definition of control and is represented by the PDCA (Plan-Do-Check-Act) cycle [1].

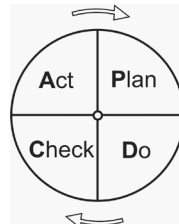
This is also referred to as the Deming circle, named after W. E. Deming. Another variation of PDCA is PDSA (Plan, Do, Study, Act) [2].

Act

- Managing Nonconformity
- Improvement
- ISO 9001 Certification
- Cultural and Organizational Aspects
- Total Quality Management
- Environmental Management Systems
- Management System Integration

Plan

- The Quality Concept and Objectives
- Statutory Considerations
- Product Liability and Product Safety
- Training for Quality
- The Control of Design



Check

- An Introduction to Statistics
- Control Charts
- Inspection
- Functional Testing
- Inspection and Measurement Equipment
- Metrology
- Quality Audits and Reviews
- Quality- and Safety-related Cost
- Benchmarking

Do

- Procurement
- Just-in-Time Supplies
- Process Capability
- Product Reliability
- Materials Handling
- Servicing
- Service Quality
- Documentations and Records
- Controlling Changes
- Standards, Standardization, Conformity and
- Compatibility

Fig. 1. PDCA cycle

2.2. Application

The application of the PDCA cycle has been found more effective than adopting “the right first time” approach. Using of the PDCA cycle means continuously looking for better methods of improvement. The PDCA cycle 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 action* is aimed at results by practically tackling and fixing the problem. The *permanent corrective action*, on the other hand, consists of investigation and eliminating the root causes and thus targets the sustainability of the improved process.

The aspects of the PDCA cycle were applied to internal quality-assurance procedures:

- What are we trying to accomplish?
- How will we know that a change is an improvement?
- What changes can we make to improve?

Figure 1 shows the PDCA cycle in detail [3,4]. In the *Do* stage or implementation stage it is possible to involve a *mini-PDCA cycle* (Fig. 2) until the issues of implementation are resolved [5].

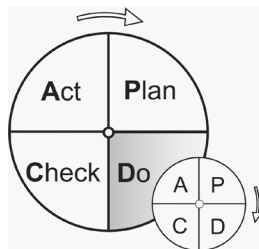


Fig. 2. Advanced PDCA cycle [5]

The PDCA cycle is more than just a tool; it is a concept of continuous improvement processes (Fig. 3) 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.

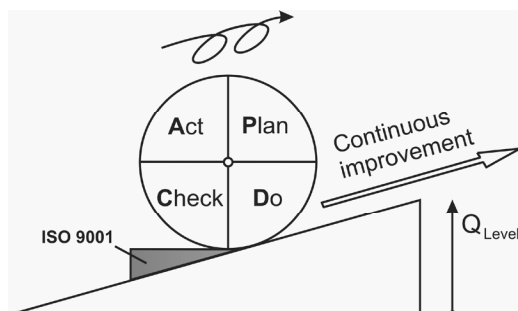


Fig. 3. PDCA cycle in continuous improvement process

The PDCA cycle is also possible to use within the Kaizen concept, Figure 4. In this case we are talking about the SDCA - PDCA cycle [6].

While Deming's PDCA cycle has been extensively used in the development and deployment of quality policies, DMAIC (Six Sigma) and DMADV (DFSS) have added the rigour of project life-cycle (PLC) to the implementation and close-out of Six Sigma projects, RADAR (EFQM Excellence model) has been used for assessment of organizational performance. Figure 5 shows the relationship between PDCA cycle, DMAIC, DMADV, and typical project-life cycle and RADAR matrix [1,2].

3. Conclusions

3.1. Definition

EFQM Excellence Model is a non-prescriptive framework that recognizes that sustained excellence can be achieved by using different approaches [7-9]. Excellence Model is based on the idea that customer satisfaction, employee and positive impact on society together contribute to excellent business results [10]. Organizations through the cyclical process of self-assessment obtain a powerful tool to further enhance of continuous learning, improvement and innovative thinking. Philosophy of Excellence model is that the organization achieves exceptional key results of performance with integration of employees and process improvement [11]. EFQM Excellence Model in its 15 years of existence proved its credibility in relation to the purposes for which it was founded: to recognize excellence (this is the highest organizational level of quality). In general the model effects like “standard” for identification of organizational quality and enables comparisons between different organizations [12]. The EFQM Excellence Model is a practical, non-prescriptive framework that enables organisations to:

- Assess where they are on the path to excellence; helping them to understand their key strengths and potential gaps in relation to their stated vision and mission.
- Provide a common vocabulary and way of thinking about the organisation that facilitates the effective communication of ideas, both within and outside the organisation.
- Integrate existing and planned initiatives, removing duplication and identifying gaps.
- Provide a basic structure for the organisation's management system [9].

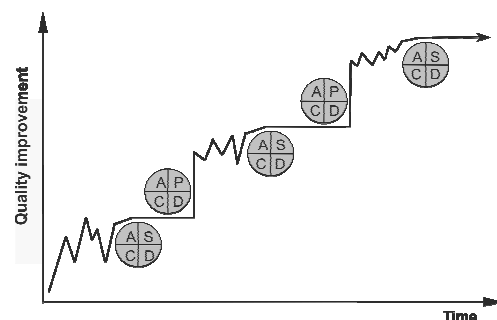


Fig. 4. SDCA – PDCA cycles for quality improvement in the Kaizen concept

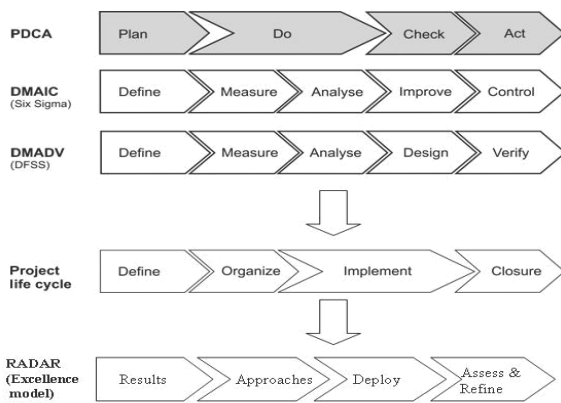


Fig. 5. The PDCA cycle vs. DMAIC (Six Sigma), DMADV (DFSS), the Project-Life Cycle (PLC) and RADAR (Excellence model)

3.2. Application

The EFQM Excellence Model belongs to the integral management tools where all important organisational areas can be analysed against its targets (results) and resources (enablers). Model provides a cause-and-effect link between the approaches used by the organisation to reach the set goals, and the actual results achieved. The model makes it possible to establish a rounded system for measuring progress in the performance of all key areas of activity of the organisation using the RADAR matrix methodology (0 to 1000 points) [13].

EFQM excellence model [9] (Fig. 6) consists of nine criteria, five of them are enablers (Leadership, Strategy, People, Partnerships & Resources and Processes, Products & Services) and four of them are results (Results criteria; Customer Results, People Results, Society Results and Key Results). The left side of the Model, "Enablers", and the right side, "Results", directly follow each other and are in direct cause-effect relationship, and together they make a whole. The Results reflect successfully implemented approaches at the "Enablers" side. Learning, creativity and innovation are the driving forces of development in an organization. Within this framework the RADAR matrix lying at the heart of the model should be considered [9].

However essential part in using model can be found in internal self-assessment of organization. Experiences of different organizations show that self-assessment effects positively on team work, organizational culture, dialogue and communication. The regular self-assessments systematically encourage the organizations and its people to on-going learning, continuous improvement and innovation. As a summary of the application of the EFQM excellence we can conclude that model is a long-term, strategic tool where all organizational aspects and areas can be monitored, assessed and improved. Therefore it cannot be used as a tool for day-to-day business, since its positive effects can be seen in long term. Due of its complexity it should be introduced properly with strong support and commitment of top-management and appropriate training of the people included.

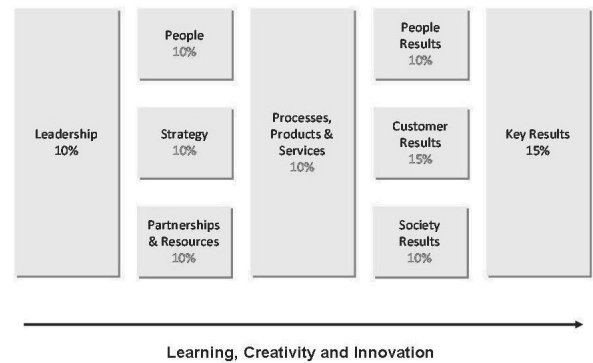


Fig. 6. EFQM Excellence model (version 2010)

4. RADAR Matrix

4.1. Definition

RADAR (Results, Approach, Deploy, Assess and Refine) provides a structured approach to question the performance of an organisation; it is an essential part of a company's programme using EFQM excellence model. RADAR is an acronym for five interconnected phases: results, approach, deploy, assess and refine. The simplified definitions of each phase are [9]:

- Determine the *Results* it is aiming to achieve as part of its strategy.
- Plan and develop an integrated set of sound *Approaches* to deliver the required results both now and in the future.
- *Deploy* the approaches in a systematic way to ensure implementation.
- *Assess and Refine* the deployed approaches based on monitoring and analysis of the results achieved and ongoing learning activities.

RADAR matrix support all nine criteria of EFQM excellence model with enabler matrix which is used to support the analysis of the approaches within the five enabler criteria and the results matrix which is used to support the analysis of the results within the four results criteria.

4.2. Application

The tool of RADAR Matrix is used for assessment of organizational performance and applied within the EFQM excellence model. As such, it is an integral part of the excellence model methodology. RADAR provides a structured approach to question the performance of an organisation.

The RADAR logic provides a structured approach to question the performance of an organisation using EFQM excellence model. It also supports the scoring mechanism behind the European Excellence Award and other recognition or assessment schemes and can help to lead change and manage improvement projects in an organisation. Today more than 26 national and excellence awards are established in countries of European Union.

With the support of RADAR logic it is possible to make a robust assessment of the degree of excellence of any organisation [9]. The criteria for a particular phase of RADAR are defined and organization (or its part) is reviewed through all four phases to assess organizational performance in a systematic way, Figure 7 [9,14].

We can find synergy of the RADAR matrix with the Deming cycle. Every approach, which is being introduced into an organisation, can be checked against the PDCA cycle, as follows:

1. In the Plan phase – check that the approaches used are sound, focused on the all stakeholders the needs and integrated with other appropriate approaches.
2. In the Do phase – check that the approaches are implemented systematically in all relevant areas throughout the organisation to the full extent. Check that the appropriate tools exist to measure the effectiveness and the planned benefits of the implemented approaches.
3. In the Check and Act phases – check that the efficiency of the approaches and their deployment are regularly measured; that there are enough learning activities; that benchmarking is performed, e.g. in sector / best in class. Check that the improvement of approaches is based on learning activity and performance measurements [15].

As a summary of the application of the RADAR matrix methodology, if you *cannot measure your process, you cannot define its level of performance and you cannot improve it*. That means if you cannot establish the systematic integrated

monitoring system on your approaches you are not able to utilize RADAR in your organization. Therefore, appropriate systematic monitoring and assessing system is the basis for implementation of continuous improvements in the organization.

5. DMAIC

5.1. Definition

DMAIC (Define, Measure, Analyse, Improve, and Control) refers to a data-driven life-cycle approach to Six Sigma projects for improving process; it is an essential part of a company's Six Sigma programme. DMAIC is an acronym for five interconnected phases: define measure, analyse, improve and control. The simplified definitions of each phase (Fig. 8) are [1]:

- *Define* by identifying, prioritizing and selecting the right project,
- *Measure* key process characteristic, the scope of parameters and their performances,
- *Analyse* by identifying key causes and process determinants,
- *Improve* by changing the process and optimizing performance,
- *Control* by sustaining the gain.

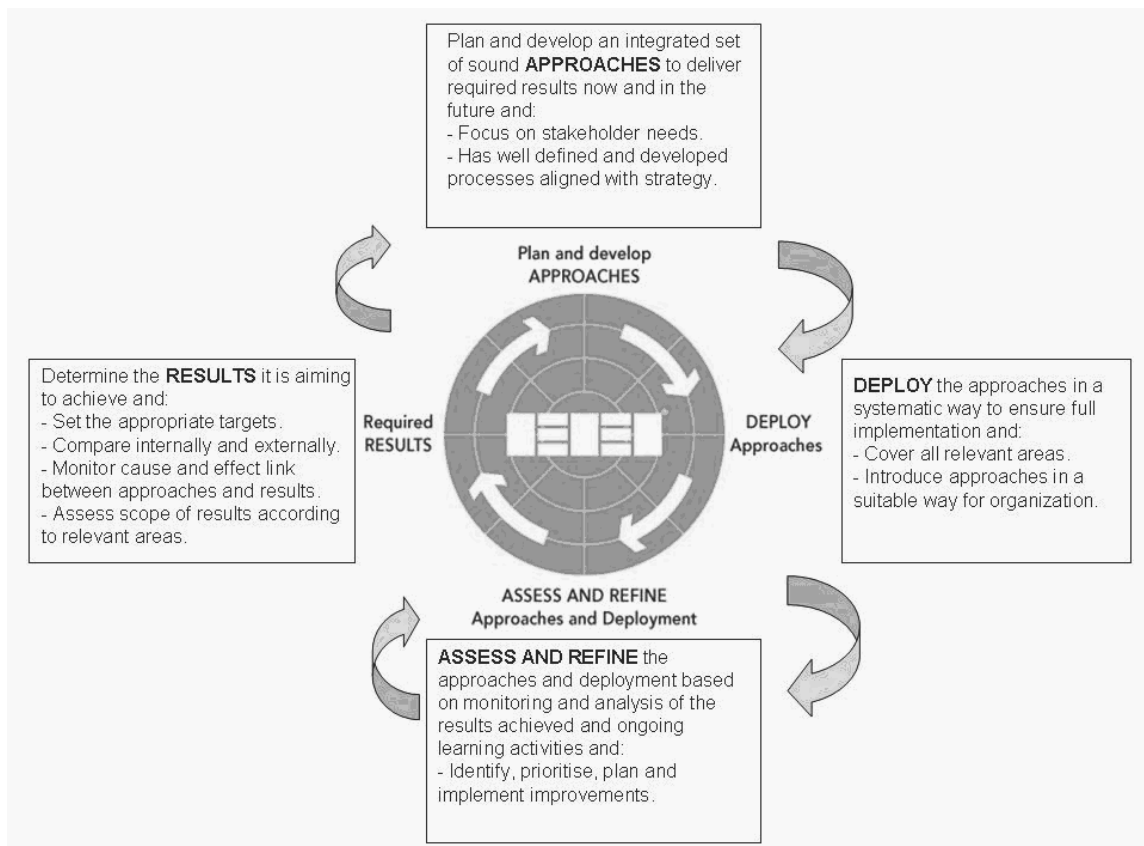


Fig. 7. The RADAR matrix cycle as a methodology of EFQM Excellence model

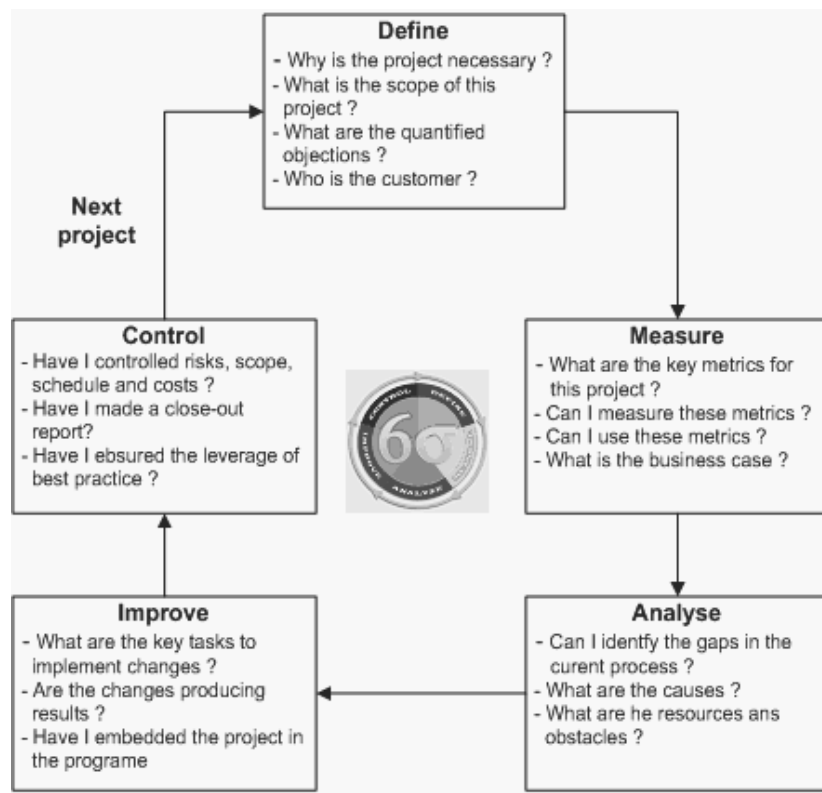


Fig. 8. The DMAIC cycle as a methodology of Six Sigma

5.2. Application

The tools of Six Sigma and operational excellence are most often applied within the framework of DMAIC. As such, DMAIC is an integral part of a Six Sigma initiative.

DMAIC also used to create a “*gated process*” for project control. The criteria for a particular phase are defined and the project is reviewed, and if the criteria are met then the next phase starts (Fig. 8) according to [1,16].

As a summary of the application of the DMAIC technique, if you *cannot define* your process you *cannot measure* it. That means if you cannot express the data you are not able to utilize DMAIC in your development actions. Therefore, you cannot improve and sustain the quality [17, 18].

DMAIC is an integral part of Six Sigma. It is systematic and fact based and provides a rigorous framework of results-oriented project management. The methodology may appear to be linear and explicitly defined, but it should be noted that the best results from DMAIC are achieved when the process is flexible, thus eliminating unproductive steps. An iterative approach may be necessary as well, especially when the team members are new to the tools and techniques.

6. DFSS

6.1. Definition

DFSS (Design for Six Sigma) is a systematic and structured approach to new products or processes design that focuses on “*problem prevention*”. This is done with the aim of meeting or exceeding all the needs of the customer and the *CTQ (critical to quality)* output requirements when the product is first released. The major objective of DFSS is to “*design things right the first time*”.

System consists from the set of tools, needs-gathering, engineering and statistical methods to be used during the product’s development. DFSS requires the rigorous use of tools and best practices to fulfil customer requirements and brings financial benefits by satisfying customer requirements [19].

One fundamental characteristic of DFSS is the verification, which differentiates it from Six Sigma. The proponents of DFSS are promoting it as a *holistic approach* of re-engineering rather than a technique to complement Six Sigma.

6.2. Application

The primary application of DFSS as a technique is in the design and development stage of a product, process or service. Designing new products or processes using DFSS approach does *not replace* current engineering methods, nor does it relieve an organization of the need to pursue excellence in engineering and product development. It adds another dimension to product development. It helps in the process on inventing, developing, optimizing and transferring new technology into product design program. It also enables sub-sequent conceptual development, design, optimization and verification of new products prior to launch into their respective market [20, 21]. DFSS methodology delivers qualitative and quantitative results by managing critical parameters against the clear set of product requirements based on *Voice of customer (VOC)*.

Design for Six Sigma fits within the context of the key business process, namely the product development process; encompasses many tools and best practices that can be selectively deployed during the phases of a product development process. Specifically, DFSS integrates three major tactical elements to help attain the ubiquitous business goals of low cost, high quality and rapid cycle-time from product development [19].

- A clear and flexible product development process.
- A balanced portfolio of development and design tools and best practices.
- Disciplined use of project management methods.

DFSS avoids counting failures and places the engineering team's focus on measuring real functions. The resulting fundamental model can be exercised, analyzed and verified

statistically through Monte Carlo simulations and the sequential design of experiment (DoE).

Defects and time-to-failure are not the main metrics of DFSS. DFSS uses continuous variables that are leading indicators of impending defects and failures to measure and optimize critical functional responses against assignable causes of variation in the production, delivery and use environment. We need to prevent the problems – not wait until they occur and then react to them. The reason to using DFSS is ultimately financial. It generates shareholders value based on delivering customer value in the marketplace. DFSS helps fulfil *voice of the business* by fulfilling *voice of the customer*.

Most frequently reported methodologies for putting DFSS into practice are **DMADV** (**Define, Measure, Analyze, Design and Verify**) and **IDOV** (**Identify, Design, Optimise and Validate**). DMADV is often described as the next stage of DMAIC (Six Sigma) and thus may lead to a generic approach [1]. In order to emphasize the distinctive characteristic of DFSS we have adapted IDOV to show the basic steps of the process, Figure 9 [2].

The proponents of DFSS believe that within the new few years, as experience grows, DFSS will be used in design houses with the same familiarity as ISO standards (ISO 9001, ISO 14001, ISO/TS 16949, and ISO OHSAS 18001).

DFSS is a longer-term, resource-hungry process and it is expensive. Therefore, it should be deployed with care and on just a few vital projects, and specifically targeted towards the development of new products. Do not start a DFSS project without the customer, sales involvement, top-management commitment and a team, preferably one with Six Sigma training. DFSS is a powerful technique and its power should not be abused.

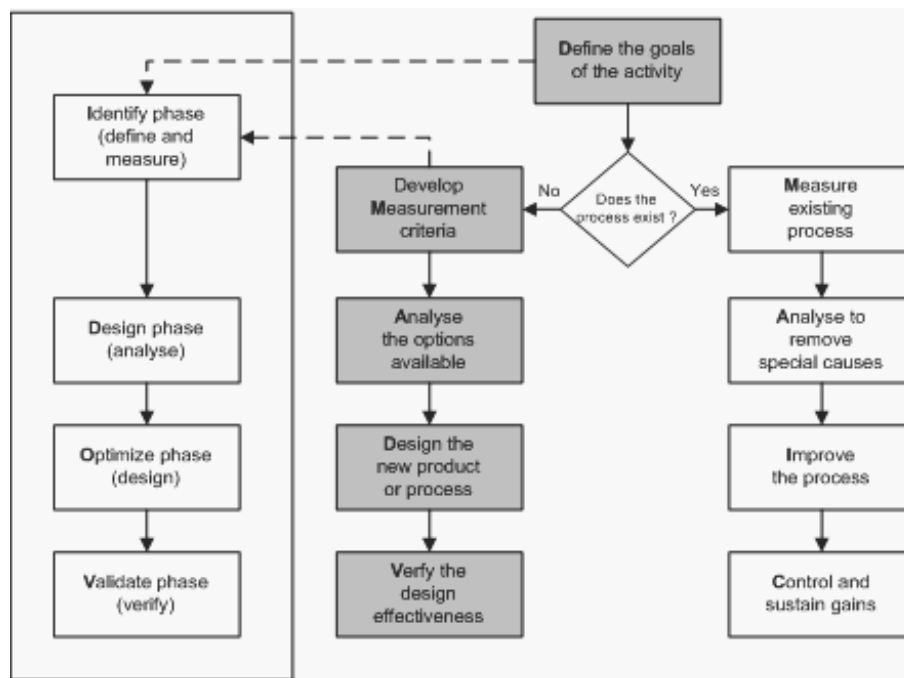


Fig. 9. The relationship between DMADV (DFSS) and classical DMAIC (Six Sigma) - a new approach IDOV also is added [2]

7. Conclusions

The methodology of implementing continuous quality improvement can be varied in different organization. Regardless of the methodology of the continuous-improvement programmes, every organization needs to use a proper combination and selection of quality tools, methodologies and techniques in their implementation process. It is very important that the tools, methodologies and techniques are properly selected according to the need and demands of the team and further applied correctly to the appropriate process and approach in organization.

The PDCA cycle (Deming's circle) is more than just a quality tool. The PDCA cycle is a fundamental concept of continuous-improvement processes embedded in the organization's culture. It is simple to understand and should be used by a large number of people in the company (also through-out standard ISO 9001:2008). 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.

The methodology DMAIC (an integral part of Six Sigma) is systematic and fact based and provides a rigorous framework of results-oriented project management. It should be noted that the best results from DMAIC are achieved when the process is flexible, thus eliminating unproductive steps. An iterative approach may be necessary as well, especially when the team members are new to the tools and techniques.

DFSS methodology is a systematic and disciplined approach to product or process design including all organization functions from the early beginning, with the objective to *design things right from the first time*. Voice of the customer (VOC), to gather customer requirements, and Quality Function Deployment (QFD) are tools to identify customer requirements, translate them into product's technical design requirements and prioritize them according to weighted importance to meet customer basic requirements. The methodology RADAR (an integral part of EFQM Excellence model) is strategic, systematic, fact-based framework which provides tool for evaluation of organizational results, approaches, deployment, assessment and review.

Do not start a DFSS project or self-assessment project using excellence model and RADAR without the customer, sales involvement, top-management commitment and a team, preferably one with adequate training. Both DFSS and RADAR are complex, powerful techniques and their power should not be abused, and do not forget: both tools a longer-term and resource-demanding processes and should be deployed with care and implemented by appropriate planning, training, and monitored by project management.

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