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Process improvement methodology selection in manufacturing: A literature review perspective

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ABSTRACT

Problems in manufacturing have always been a hurdle for leadership, engineers, and professionals. They can lead to low productivity, poor quality, high costs, and ultimately loss of customers. Problems should be prevented by fair means and following well-established methodologies of continuous process improvement. The present paper addresses this topic, which in both academic and professional literature has been discussed from one single angle–that is, how to use a specific methodology in a certain situation. From that perspective, researchers from academia and consultancy promote the use of a particular method. One of the greatest challenges to researchers and practitioners in manufacturing is to select the right methodology for problem-solving and process improvement. The present paper attempts to address this issue from a literature review perspective. The approach followed is based on the fact that understanding the attributes of process improvement methodologies reported in the open literature and their linkages to the main phases of the continuous improvement process will provide insights on how the selection of the methodologies can be carried out in real manufacturing situations.

1. Introduction

Over the last two decades, global competition has increased as a result of the rapid and profound changes in all aspects of modern life, such as technology, consumer behavior, regulations, and standards. The rapid technological development driven by the Fourth Industrial Revolution (Industry 4.0) led to the expansion of the products offered, particularly in terms of variety and customization options. In this business context, in order to ensure profitability, companies should constantly follow best practices that help them to enhance their processes, products, and services and to achieve efficient and scalable customer services at competitive costs. The reliability of processes, products, and services is an important factor in the business strategy and has, therefore, evolved in line with the competitive reality that companies face. Organizations must then continue to improve their processes through the adoption of advanced technologies in manufacturing processes associated with appropriate process management methodologies. World-class manufacturing companies are implementing lean operations principles, process improvement methodologies, and problem-solving techniques and tools to keep their competitive advantage and continuously deliver high-quality products at the lowest production costs (Zairi, 2017).

The present paper addresses the challenging topic of continuous process improvement, which in both academic and professional literature has been discussed from one single angle–that is, how to use a specific methodology to resolve specific problems. From that point of view, researchers in academia and consultancy promote the use of particular methods. One of the greatest challenges to researchers in manufacturing is to select the right process improvement methodology. The present paper attempts to address this important issue from a literature review perspective. The research approach followed is based on the fact that understanding the attributes of process improvement methodologies reported in the open literature and their linkages to the core phases of the continuous improvement process will provide useful insights on how the selection of the methodologies can be carried out in real industrial situations. The present paper seeks to make a literature review on process improvement

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methodologies in manufacturing processes, with the aim is to identify the most widely used methodologies. This will help organizations to make the proper selection of the adequate methodology for their improvement projects.

2. Literature review on process improvement in manufacturing

Process improvement (PI) is a widely practiced methodology in manufacturing and service industries around the world to improve products or services quality, reduce lead times, optimize costs, and improve delivery reliability. In manufacturing, PI is one of the core strategies adopted by firms to achieve performance excellence and customer satisfaction (Radej et al., 2017; Aichouni et al., 2017). The literature concerning the implementation of process improvement methodologies and tools in manufacturing is abundant, and research is still going on.

2.1. General review on process improvement methodologies

According to DTI (2020), it is very important to study and understand manufacturing processes in order to improve them through a systematic approach; this requires knowledge and a certain expertise in a number of process improvement techniques and methodologies. The effective use of these tools and techniques requires their application by people who are operating these processes, in addition to the commitment of leadership and management towards quality improvement. Management must show its commitment by providing the training and support required for proper implementation. The tools and techniques most commonly used in manufacturing and services in process improvement are (a) Problem-solving methodologies such as PDCA, DMAIC, and DRIVE, (b) quality improvement tools such as process mapping, flowcharts, force field analysis, Root Causes Analysis, Brainstorming, the 20/80 Pareto analysis, Statistical process control (SPC), Control charts, Check sheets, Scatter diagrams, and Histograms.

Based on an extensive review made by Sahno and Shevtshenko (2014) on process improvement methodologies and their application in manufacturing processes, four main continuous improvement methodologies were identified as the most widely used in manufacturing. These are the PDCA, Ford 8D Model, the Six Sigma DMAIC approach, and the four Quadrants (4Q) ABB methodology (ABB, 2020). A comparison between these methodologies was performed based on their similarities, capabilities, and implementation in different industrial settings. The paper concluded that every industrial company could make a proper selection and use of a methodology or a combination of some of them in its continuous improvement projects based on its needs and characteristics.

Sokovic et al. (2010) reviewed the process improvement methodologies, which include the PDCA, Six Sigma DMAIC, DFSS, and the EFQM and their application for continuous quality improvement of products and services. It was concluded that depending on the purpose, organizations should have their proper way to select the right combination of methodologies for their process improvement projects (Sokovic et al., 2010).

Through the analysis of the literature, it was noticed that with the advent of digital technologies, manufacturing processes are increasingly dependent on technology and automation. They are still in need of continuous improvement. The process of continuous improvement, first pioneered in manufacturing companies in Japan, primarily in response to the introduction of the JIT and lean production systems, facilitates a constant reduction in waste and continuously reduces process variability. It was stressed on actively encouraging employees to participate in the continuing incremental improvement of products and processes. The review concludes that for successful implementation of continuous process improvement, manufacturing organizations should equip their workforce with important skills such as critical and innovative thinking, team building, and effective leadership. Manufacturing companies should have access to knowledge and expertise in lean techniques and tools such as 5S, SPC, FMEA, and SMED to attain long-term market leadership and competitive advantage (Singh and Singh, 2015).

2.2. The PDCA methodology

The concept of PDCA (Plan-Do-Check-Act) was first developed by Shewhart (1939), at Bell Laboratories, in the US, then introduced in Japan by Dr. Edwards Deming early 1950s. Toyota was among the first manufacturing companies to adopt the concept for process improvement. The main focus of the approach is on preventive problem solving to reduce variation in all parts and to build all products and systems right from the first time based on planning (Liker and Franz, 2011).

Several studies have documented the use of the PDCA cycle in process improvement in manufacturing and services. The use of the PDCA methodology associated with quality tools for achieving a cleaner production environment was investigated (Silva et al., 2017). The study showed that it is possible to gain integration between two different systems (quality system and sustainability system), using the PDCA and Cleaner Production concepts. The approach is capable of improving the company's performance from its economic and environmental perspectives through process improvement and reduction of waste. Silva et al.`s (2017) study suggested that the use of quality tools and techniques is essential to determine the root causes of problems and to identify the corrective actions to be taken to eliminate them from the manufacturing process and to improve it. This is mainly focused on process analysis and making proposals for improvement plans. In this study, a number of quality tools were used in support of the Deming PDCA cycle, which includes brainstorming, and Ishikawa Diagram, the identification and prioritization of the causes of the problem; and 5W2H in the action plan design. According to this study, PDCA is considered much more than a simple tool. But it is a continuous improvement philosophy introduced into the organization's culture. The practical steps to implement the PDCA shown in Fig. 1 can be understood as follows:

- Plan Phase: In this phase, the focus is on how to identify and prioritize improvement opportunities; the current situation of the process is studied through the analysis of data gathered from the process; the causes of the problem are identified, and possible actions to eliminate the issues are proposed.
- Do Phase: The main purpose here is to implement the action plan, form an implementation team, and assign responsibilities for select implementation in the process, and schedule progress meetings to assess implementation. Notes should be taken on unexpected events, lessons learned, and knowledge gained during this phase.
- Check: At this point, the results of the action plans are studied and analyzed through a comparison between the new situation and the previous one.
- Action Phase: At this stage, the improvement team involved develops methods that will standardize the improvement (if goals have been reached); or make another run to the cycle beginning from stage 1 (if the actions are taken did not generate effective improvements and the objectives were not met).

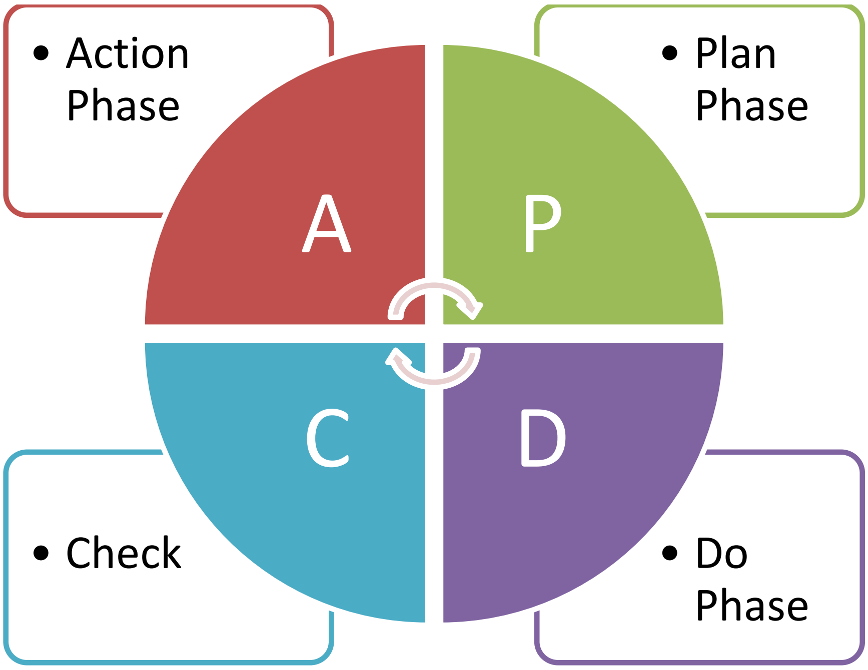

Fig. 1: PDCA cycle steps (Silva et al., 2017)

In the 1980s, Toyota developed the A3-Report method, based on the 8-step PDCA that should fit on an A3 sheet of paper. This method is a collaborative and visual tool where charts should be included. Mainly, the A3 method can be used for solving medium-sized problems, which can be solved in a week or less. The A3-Reports are a common practice in manufacturing organizations that adopted Lean concepts (Liker and Franz, 2011).

The study presented by Radej et al. (2017) made a review of quality improvement methods and tools from the manufacturing and supply-chain perspectives. The research showed clearly the effectiveness of qualitative methods such as PDCA, SPC, and QFD and quality tools such as the seven basic quality tools on manufacturing process quality and costs. A generic model for process improvement in manufacturing was proposed. Using this improvement model, one company can combine different quality methods and quality tools, as shown in Table 1. Every company can adopt this model for quality improvement, especially in situations where:

- Unacceptable low level of the first-pass yield within the manufacturing process.
- Higher scrap in the product.
- High level of customer complaints due to poor product quality.

Statistical Process Control methods, coupled with the PDCA, have been reported in the Bosnian military industry to improve the performance of production operations (Hrvacic, 2018). The study focused on the use of control charts to assess and maintain the stability of the production process and the consistency in manufacturing operations. The study reached the following conclusions: (a) The optimal use of control charts helps to maintain a high quality of the product quality. In addition, it allows quick and visual alarm in case of the occurrence of defects or errors in the product; (b) The method used allowed to notice situations where the manufacturing process is unstable due to some causes related to the manufacturing process, including the method of changing the cutting tool in the CNC production machine. Rezaee et al. (2018) pointed out the importance of process improvement in the automotive industry from a manufacturing, sales, and services point of view. In a similar study. Abtew et al. (2018) presented a methodology based on the implementation of statistical process control (SPC) in the sewing section of the clothing industry in India for quality improvement. The seven basic quality tools were shown to be very effective in reducing manufacturing errors and defects and improving product quality. Successful implementation of SPC control charts for monitoring characteristics of high-quality products in manufacturing processes reported (Moghaddam et al., 2014; Bashiri et al., 2013).

Table 1: Summary of methods and tools used in manufacturing (Radej et al., 2017)

Quality Methods and Tools			Manufacturing Departments		
			Research and Development	Production	Customer Support and Service
Quality Department	Quality Methods	Quality Function Deployment	Yes	No	No
		Statistical Process Control	No	Yes	Yes
		Failure Mode and Effect Analysis	Yes	Yes	Yes
		PDCA	No	Yes	Yes
		Poka-Yoke	No	Yes	No
		5 S	No	Yes	No
	Quality Tools	Ishikawa Diagram	No	Yes	Yes
		Flow chart	Yes	Yes	Yes
		Control table (Check sheet)	Yes	Yes	Yes
		Control Chart	No	Yes	Yes
		Histogram	No	Yes	Yes
		Pareto Analysis (20/80)	Yes	Yes	Yes
		Scatter Diagram	yes	Yes	Yes

2.3. The DMAIC methodology

One of the most widely used improvement methodologies is the six sigma DMAIC approach. This methodology was first developed and implemented by Motorola in the 1980s in the US. Since then, it becomes very popular in the west (Attiaa et al., 2019). The six sigma DMAIC methodology refers to a data-driven life-cycle approach to Six Sigma projects for process improvement. The simplified definitions of each phase of the DMAIC are:

- Define by identifying, prioritizing, and selecting the right problem,
- Measure key process characteristics, and quantify the problem,
- Analyze by identifying key causes of the problem, and make a proposal for solutions,
- Improve by implementing the potential solutions and verifying the results,
- Control by maintaining the solution and sustaining the gains.

The last four decades have seen a growing trend towards the use of the DMAIC Six Sigma methodology as a strategy for process improvement in manufacturing and services. An improvement model based on the DMAIC Six Sigma methodology associated with the seven basic quality tools was used to improve production yields and product quality in manufacturing (Black, 2015). The improvement model was applied to a US hardwood flooring company. The combination of the DMAIC approach and the basic quality tools permitted to reduce the defect rate in the production processes and improve the quality of the products.

Attiaa et al. (2019) successfully implemented the Six Sigma methodology for the reduction of defects in the clothing industry and to achieve substantial improvement in process performance. Li et al. (2019) presented a modified, enhanced version of the DMAIC approach for continuous quality improvement in multi-stages machining processes. The approach associated with quality tools was found to be efficient in reducing manufacturing costs and improve product quality, hence improve the overall industrial manufacturing process performance. The research showed that the process capability method could be used as a statistical measure of process capability to meet customer requirements and design specifications in the continuous process improvement efforts. That is its ability to produce and to generate output within specifications limits hence contributing to customer satisfaction (Li et al., 2019).

Berardinelli (2012) reviewed the strategies for successful implementation of the DMAIC in manufacturing. Two approaches were identified. A first strategy is a team-based approach in which individuals who have expertise in tools and methods, such as quality or process improvement experts, lead an improvement team. Team members work part-time on the project while taking care of their day-to-day responsibilities. Several projects may be assigned to a quality or process improvement expert. These are long-term projects that take months to complete. The second strategy involves the kaizen method, an intense progression through the six sigma DMAIC process, usually done in about a week.

Preparation work is completed by quality or process improvement experts and focuses on the phases of definition and measurement (Berardinelli, 2012).

Lean manufacturing concepts for waste reduction in processes have been combined together with the DMAIC methodology for variability reduction to form the Lean Six Sigma methodology, which is widely used in a world-class company for breakthrough performance improvement (Rashid and Ahmad, 2013). Substantial research work has been devoted to the LSS approach in recent years. Muganyi et al. (2019) showed that Lean Six Sigma DMAIC methodology is effective to attain strategic survival in the marketplace for a chemical manufacturing organization. The study showed that the LSS principles were effectively used for the assessment of the eight wastes of the manufacturing process and to improve the product quality and ultimately attaining substantial financial gains for the organization. The analysis of the results of LSS implementation by the company has shown that, when applied correctly, LSS is effective in attaining enhanced business performance, resulting in substantial financial and quality gains, which are ultimately translated into a strategic business tool. The research concluded that the goal of the LSS DMAIC approach is an excellent approach for manufacturing in waste reduction, cycle times, process variability, and enhancement of quality of product or service. DMAIC methodology of LSS is a key tool to reduce costs and save money for the organization and render competitive advantage and strategic survival in the marketplace. Such gains can be achieved by any manufacturing organization when the DMAIC LSS approach is properly implemented in processes using commonly used quality tools such as those depicted in Fig. 2 (Muganyi et al., 2019).

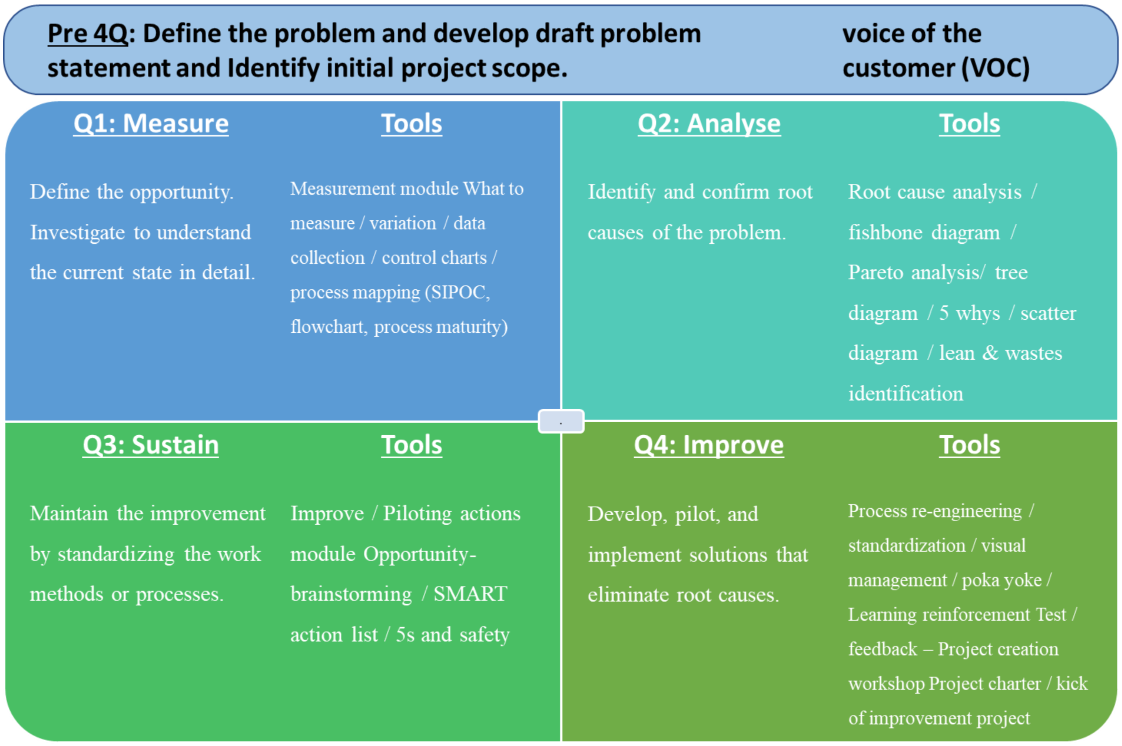

Fig. 2: DMAIC methodology phases (Adapted from Muganyi et al. (2019))

2.4. The 8 disciplines methodology

The 8D method was first used by the U.S. government during the Second World War, as Military Standard 1520 (Barsalou, 2016). Later, the method was adopted by Ford Motor Company in the 1960s. The methodology, which was approved as a standard in the automotive and other industries, requires a structured problem-solving process, which is used to identify, correct, and eliminate problems.

The eight disciplines (8D) model for problem-solving and process improvement is an approach typically employed by quality professionals in the automotive industry and other manufacturing in the US. It has also been successfully implemented in services such as healthcare, finances, banking, and government services. The main objective of the methodology is to identify, correct, and eliminate recurring problems, making it useful in product and process improvement (Rambaud, 2006).

The 8D problem-solving model establishes a permanent corrective action based on a statistical analysis of the problem and focuses on the origin of the problem by determining its root causes. Although it originally comprised eight stages, or disciplines, the eight disciplines system was later augmented by an initial planning stage. A brief description can be illustrated in Table 2.

The 8D methodology is useful in product and process improvement in any type of manufacturing since it focuses on the origin of the problem through proper planning and by determining root causes to address potential solutions. Among the drawbacks of implementing the 8D methodology is its use as a one-page problem-reporting effort, and it requires the report to be produced within 24 hours, but some steps can take a few hours, while others can take weeks (Rambaud, 2006). Banica and Belu (2019) presented the 8D method as a methodology of the Quick Response Quality Control (QRQC) tool. It is one of the most widely used problem-solving tools related to nonconformity reoccurrence prevention in the manufacturing process, commonly used for complaints management in the automotive industry. This is a quick and comprehensive problem-solving process for manufacturing and service organizations that guarantees problems do not reoccur; at the same time, it establishes dynamics of continuous improvement and changes management culture. Banica and Belu (2019) reported the results of a case study on implementing the 8D methodology for the improvement of the painting process in the body of cars in the Romanian automotive industry (Banica and Belu, 2019). Zarghami and Benbow (2017) argued that the 8D problem-solving method is a scientific, systematic approach which present similarities to the DMAIC method. Mainly, the approach is driven by the customer since it is used to resolve specific customer complaints. They showed that the successful implementation of the 8D methodology requires an investment of time, resources, and buy-in from both management and the process improvement team (Zarghami and Benbow, 2017).

Table 2: Illustration of the eight disciplines methodology (ASQ, 2020)

D0: Plan	Plan for solving the problem and determine the prerequisites.
D1: Use a team	Select and establish a team with product/process knowledge.
D2: Define and describe the problem	Specify the problem by identifying in quantifiable terms the who, what, where, when, why, how, and how many (5W2H) for the problem.
D3: Contain the Problem	Develop interim containment plan; implement and verify interim actions - Define and implement containment actions to isolate the problem from any customer.
D4: Determine, identify, and verify root causes	Identify all applicable causes that could explain why the problem occurred. Also, identify why the problem was not noticed at the time it occurred. All causes shall be verified or proved, not determined by fuzzy brainstorming. One can use 5 Whys and cause and effect diagrams to map causes against the effect or problem identified.
D5: Choose and verify corrective actions	Choose and verify permanent corrections (PCs) for problem/nonconformity through preproduction programs, quantitatively confirm that the selected correction will resolve the problem for the customer.
D6: Implement and validate corrective actions	Define and implement the best corrective actions (CA).
D7: Take preventive measures	Modify the management systems, operation systems, practices, and procedures to prevent the recurrence of this and all similar problems.
D8: Congratulate your team	Recognize the collective efforts of the team. The team needs to be formally thanked by the organization.

Based on the literature, it can be argued that the major benefit of the 8D methodology is that it uses a multi-step approach to identify the problems, find and implement solutions, and remain focused on ensuring that the problem does not recur in the future again. When implemented by manufacturing many times, this will help to reduce problems dramatically in the workplace, which will help to improve the overall bottom-line performance of the manufacturing system. Relatively few disadvantages can be registered on using the 8D methodology. The most significant one is that it requires the team to have some training on the 8D process and some common quality tools such as to cause and effect analysis, process flow charts, Pareto analysis, histograms, and some other tools.

2.5. The 4Q methodology

The 4 Quadrants (4Q) is a data-driven problem solving and continuous improvement methodology developed and applied in ABB Company in 2009 (ABB, 2020). Fig. 3 shows the fundamental structure of the methodology. Mainly the 4Q quadrants are: Measure, Analyze, Improve, and Sustain. The 4Q process is thought of as a problem-solving method similar to Six Sigma DMAIC. ABB considers the 4Q methodology as a management system for process improvement and performance excellence, specific to the company. The company trains its employees and get them certified as trainers, coaches, and technical specialists from within ABB (ABB, 2020). Fig. 3 summarizes the main steps of the 4Q methodology with the associated quality tools that can be adopted by the improvement project team (Jahan, 2012).

Jahan (2012) reviewed the quality improvement methodologies, mainly the PDCA, DMAIC, FADE, and the 4Q, for the purpose of selecting an approach for the improvement of the waste management system in ABB Corporate Research Centre (ABB, 2020). Based on his comparison, the DMAIC methodology associated with the seven basic quality tools were used for quality improvement of waste management in the research center (Jahan, 2012). Practical recommendations were proposed to improve the research Centre's existing waste handling system.

2.6. Other process improvement methodologies

Other improvement methodologies have been described in the literature and include the DRIVE and FADE models. The DRIVE is another approach to the PDCA and DMAIC methodologies, except it is not a cycle of a flowchart with an end. DRIVE can be formatted as a separate activity to consider during process improvement, which can help to analyze a problem using various techniques and tools. The DRIVE approach is composed of five phases. The Define phase is devoted to determining the scope of the problem and how success can be measured. Then a review of the current situation is made to understand the background and collect information and data. In the Identify phase is improvements or solutions to the problem are identified, and required changes to the process are proposed to enable and sustain the improvements in the manufacturing process. A Verify phase is used to check the proposed improvements to see if they bring about the expected results for the process. Then in the Execute phase, the implementation plan of the solutions is executed, and a review is run to gather feedback and measure the impact of the solution on the process.

Fig. 3: The 4Q improvement methodology and quality tools used (Jahan, 2012)

The FADE Improvement model is one of the models used to improve quality. It stands for (Focus, Analyze, Develop, and Execute). In the Focus step, it is important to define and verify the process and consequently identify the area that needs to be improved. In the Analyze step, the problem is defined based on prioritization, then to collect data as well as required information to establish a baseline through analysis. Then the root causes of the problem are analyzed, and possible solutions are proposed. The Develop phase is devoted to proposing an action plan or solution for improving the process and solving the problem. During the Execute step, the action plan is implemented on a pilot basis and used to monitor and record the effects on the problem. Only very limited research has been reported in the open literature on these two improvement methodologies (Sahno and Shevtshenko, 2014).

2.7. Process improvement approaches and tools in the era of industry 4.0

Industry 4.0 refers to the fourth industrial revolution. This new wave of global technology is changing manufacturing industries and production processes. Technologies like Artificial Intelligence, Big Data Analytics, additive manufacturing (3D printing), and robotics are among the major components of Industry 4.0. A new concept of Quality 4.0 emerges. The question that can emerge, what is the effect of these changes on traditional quality and process improvement methods? The effect of Big Data Analytics on traditional problem solving and process improvement approaches has been discussed in recent years and analyzed with the objective to make alignment between urgent needs of companies and new technological developments dictated by Industry 4.0 (Zairi, 2017). The discussions presented in these studies indicated clearly that well established traditional process improvement methodologies such as PDCA and DMAIC and quality tools are still needed by the quality professional to improve the production process in manufacturing (Tamás and Illés, 2016). The use of sophisticated and open-source software solutions such as R can be adequate to run improvement projects in manufacturing and services while dealing with a huge amount of process data (Ghernaout et al., 2018; Cano et al., 2012).

3. Synthesis and discussion

The previous sections were devoted to present and discuss the various types of process improvement methodologies, with a particular focus on their application in manufacturing. The methodologies covered include the PDCA, DMAIC, 8

Disciplines, ABB Q4, the DRIVE, and the FADE models (ABB, 2020). All the methodologies follow a common logic, identify the problem in the process, finding the root cause of the problem, and recommending improvements to be implemented in the process to improve quality and reduce waste and costs.

The PDCA cycle is considered as the classic problem-solving approach used in a Lean environment and mostly in the 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 further improvement. PDCA is very suitable for medium-sized problems in organizations (Sokovic et al., 2010). Table 3 summarizes this comparison between the four improvement methodologies. The most universally used methodologies are the PDCA and the DMAIC in manufacturing and services.

The Six Sigma DMAIC methodology is a more systematic and factual-based approach that provides a rigorous framework for an improvement project at a larger scale. Six Sigma DMAIC is mostly applied to solve big problems where a large amount of data can be collected from the process. The methodology is heavily based on statistical tools and methods, which requires trained and skillful members of the improvement team. The DMAIC project may last more than three months. It depends on how complex the problem and process to be improved. This requires some investments in terms of time and spending.

Table 3: Summary of process improvement methodologies

	PDCA	DMAIC	8D	4Q
Scope	For continuous improvement and problem solving of small to medium size problems.	For continuous improvement and problem solving when dealing with big problems.	For the automotive industry, It focuses on quick reaction to customer complaints.	For continuous improvement of processes.
Focus On	Improve process and develop people	Reducing variation improving process capability	Customer complaints in the automotive industry	Problem-solving
Project/problem size	Medium-sized, up to 3 months	Big, till 12 months and even more	Small, with a duration of some weeks	Small and medium, from one week to 2 months
Complexity	Low complexity	High	Medium	Medium
People Involvement	Wide employee involvement	Top management and experts	Intermediate Management	Specialists and experts
Cost	Low Cost	High Cost	Moderate Cost	Moderate Cost

The other methodologies (8D, Q4, DRIVE, and FADE) are effective approaches at finding root causes for problems, developing proper actions to eliminate root causes, and implement corrective actions. Thought these methodologies had been used by world-class organizations, the literature remains still scares and limited. All these methodologies lack the universality characteristic and require some investments in the training of the improvement teams. Table 3 can be used as a guide to select the methodology to be adopted by manufacturing companies in specific industrial settings. Although differences of opinion still exist between experts, there appears to be a good agreement that PDCA and DMAIC are the most appropriate improvement methodologies for manufacturing companies, especially when dealing with medium and big problems. What can identify the problem is its impact on customer satisfaction and overall business performance.

4. Conclusion

The main goal of the current study was to make a review of the process improvement methodologies, discuss their capabilities in improving manufacturing processes. From the reviewed literature, it can be concluded that organizations can achieve significant improvements in their manufacturing processes, which enhance customer satisfaction and reduce waste and costs, through the implementation of process improvement practices. The PDCA, DMAIC, 8D, Q4, and other methodologies have been presented and discussed in the paper. The right selection of the methodology should be based on the needs of the organizations, the resources available for improvement projects, and even the culture of the organization. Experience showed that these methodologies should be enhanced by the use of appropriate quality tools such as the basic quality tools and the new tools for management and planning, to achieve attended results in continuous improvement, waste reduction in the process, and customer satisfaction, as required by international quality management systems (ISO, 2000).

Compliance with ethical standards

Conflict of interest

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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