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IMPROVING THE QUALITY CONTROL PROCESS USING THE PDCA CYCLE

WYKORZYSTANIE CYKLU PDCA W PROCESIE POPRAWY JAKOŚCI WEWNĘTRZNEJ

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Summary: The main purpose of this article is to present the results of research on improving the quality of a finished product by improving the internal control through the use of the PDCA cycle. The research undertaken was carried out by using the case study method supported by the analysis of documentation originating from the surveyed enterprise and the technique of intelligence and observation. Before the study was started, a number of defective finished products was analysed, divided into five main types. Based on the observations made, the disadvantages were assigned to individual work stations and methods of quality improvement were established on each of them. In the next stage the necessary changes were made according to the specifications. The summary of the whole article is a discussion of the results obtained in the field of improving the quality of the finished product in the surveyed enterprise.

Keywords: quality, internal quality, PDCA.

Streszczenie: Głównym celem prezentowanego artykułu jest przedstawienie wyników badań dotyczących poprawy jakości produktu końcowego poprzez poprawę kontroli wewnętrznej dzięki zastosowaniu cyklu PDCA. Podjęte badania zostały przeprowadzone z użyciem metody studium przypadku popartej analizą dokumentacji pochodzącej z badanego przedsiębiorstwa oraz techniką wywiadu i obserwacji. Przed rozpoczęciem badania przeanalizowano szereg wadliwych produktów gotowych, podzielonych na pięć głównych typów. Na podstawie dokonanych obserwacji przypisano wady poszczególnym stanowiskom pracy i ustalono metody poprawy jakości na każdym z nich. W następnym etapie dokonano niezbędnych zmian zgodnie ze specyfikacjami. Podsumowaniem całego artykułu jest omówienie wyników uzyskanych w zakresie poprawy jakości gotowego produktu w badanym przedsiębiorstwie.

Słowa kluczowe: jakość, wewnętrzna kontrola jakości, PDCA.

1. Introduction

One of the conditions determining a company's position in the market, its development and acquiring new customers, is the quality of the products offered by it. It is impossible to achieve lasting success, regardless of the size of the company or the type of services it provides or the products it produces, if the company does not systematically care about the improvement of quality. One of the methods used in attempts to improve quality is the use of the PDCA cycle. The main purpose of this article is to present the results of research on improving the quality of the finished product by improving internal control through using the PDCA cycle.

The increasing efficiency of production plants means that the quality control of manufactured products becomes a serious challenge for enterprises. This applies in particular to consequences related to poor quality, e.g. loss of customers, increased costs of after-sales and warranty service. Therefore it is necessary to improve the quality control processes in such a way that it not only distinguishes good products from the defective ones at the end of the process, but also locates the cause of the irregularities that should be used to improve the process in a given area.

2. The PDCA cycle in quality control

Although the term "quality" is used by both practitioners and academics, there is no generally agreed definition of this concept. Quality is a difficult term to clearly define mainly due to its subjectivity. Problems in defining "quality" arise due to the following reasons [Bugdol 2008, p. 18]:

- a) quality assessment depends, among other things, on experience, knowledge, and product demand;
- b) the concept of quality is changing as a result of the development of humankind and the occurring qualitative changes;
- c) the level of awareness of employees and supervisors as well as the degree of implementation of quality concepts in an enterprise affects the assessment of quality and the practical approach to product quality;
- d) customer requirements determine the level of product quality;
- e) quality is a multidimensional and interdisciplinary concept.

In 1984 D. Garvin [1984] described five basic approaches for quality definition. These approaches were then used in literature as the basis for creating new, refined and expanded definitions. These are: the transcendent approach [Tuchman 1980], the product based approach [Elshaer 2012, p. 5], the manufacturing-based approach, the value-based approach, and the user-based approach [Elshaer 2012, p. 6].

The next step is to define the concept of quality control. The quality control guidelines were prepared by The International Organization for Standardization (ISO) series programme which provides standards for data documentation and audits as part of a quality management system. The ISO standards also defined the concept of quality control as: "a part of quality management focused on fulfilling quality

requirements” [ISO 9000:2015, point 3.3.7]. The ISO standards and guidelines may supplement quality control procedures for inventory development and provide practical guidance for ensuring quality control and a transparent reporting system. The currently functioning ISO standards in this area are:

1. ISO 9004:2018-06: Quality management – Organization quality – Guidelines for achieving lasting success.
2. ISO 10005:2007: Quality management systems – Guidelines on quality plans.
3. ISO 19011:2018-08: Guidelines for auditing management systems.
4. ISO/TR 10013:2001: Guidelines on the documentation of the quality management system.

Achieving the desired quality however, requires its control during the entire process of creating the product. Thanks to the internal quality control, the company can detect any irregularities and defects at the earliest possible production stage. This allows not only to reduce the costs of creating products in the form of salary costs, materials or labour, but also to achieve a higher level of customer satisfaction. Quality control of the product takes place at quality control points. This is a production stage during which the control of parameters and indicators of key importance for a given product is carried out [Lasota 2011]. This control should therefore take place in such places of the production process, so as to be able to detect non-conformities affecting the final product quality as soon as possible. The key indicator of defect monitoring can be a numeric value as the ratio of the number of defects detected to the total number of manufactured units. However, from the point of view of this article, the most important thing is not to identify defective products but rather to improve production processes so that the number of irregularities decreases. One of the methods is the usage of the PDCA cycle, which is shown in Figure 1.

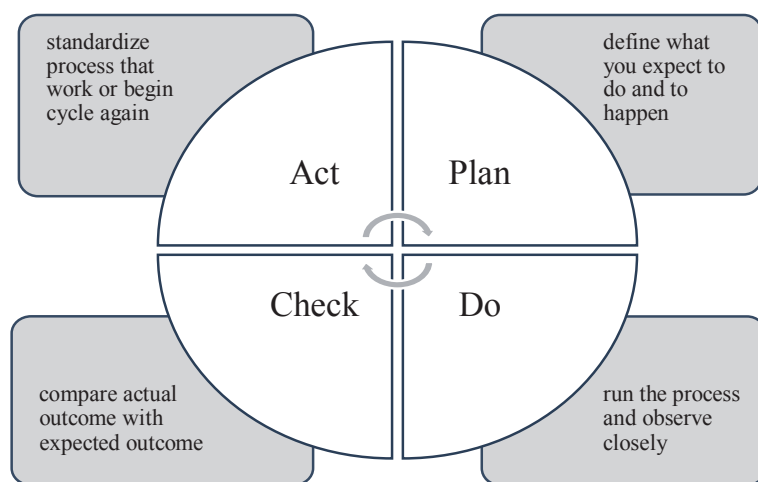


Fig. 1. The Plan-Do-Check-Act (PDCA) cycle

Source: [McKay 2017].

Detailed tasks carried out at individual stages of the PDCA cycle together with the tools are presented in Table 1.

Table 1. Tasks and tools of individual stages of the PDCA cycle

Name of PDCA cycle	Expectation of actions	Tools
PLAN	Identify the problem <ol style="list-style-type: none"> 1. Identify the problem to be examined 2. Formulate a specific problem statement to clearly define the problem 3. Set measurable and attainable goals 4. Identify stakeholders and develop necessary communication channels to communicate and gain approval Analyse the problem <ol style="list-style-type: none"> 1. Divide the overall system into individual processes - map the process 2. Brainstorm potential causes for the problem 3. Collect and analyse data to validate the root cause 4. Formulate a hypothesis 5. Verify or revise the original problem statement 	<ol style="list-style-type: none"> 1. Direct observation of process 2. Process mapping 3. Flowcharting 4. Cause and Effect diagrams 5. Pareto analysis
DO	Develop solutions <ol style="list-style-type: none"> 1. Establish experimental success criteria 2. Design experiment to test hypothesis 3. Gain stakeholder approval and support for the chosen solution Implement a solution <ol style="list-style-type: none"> 1. Implement the experiment/solution on a trial or pilot basis 	<ol style="list-style-type: none"> 1. Design of Experiment (DOE) 2. On-the-job training 3. Stakeholder management and communication
CHECK	Evaluate the results: <ol style="list-style-type: none"> 1. Gather/analyse data on the solution 2. Validate hypothesis Achieve the desired goal: <ol style="list-style-type: none"> 1. If YES go to act 2. Or else go to plan, revise hypothesis/problem statement 	<ol style="list-style-type: none"> 1. Direct observation of process 2. Graphical analysis 3. Control charts 4. Key performance indicators
ACT	<ol style="list-style-type: none"> 1. Identify systemic changes and training needs for full implementation 2. Plan ongoing monitoring of the solution 3. Continuous improvement 4. Look for other improvement opportunities 	<ol style="list-style-type: none"> 1. Process mapping (new process) 2. Standardization of work and process 3. Visual management 4. Error proofing 5. Formal training

Source: [Weinstein, Vasovski 2004].

It is possible to use the PDCA cycle to improve the quality control system in an enterprise. In this case, the individual PDCA cycle steps may proceed as follows [Ying 2010]. The first step, “plan”, allows for the analysis of quality problems, especially in enterprises where there are difficulties associated with complex techniques, strict quality requirements or the use of new techniques, new technologies, new structure and new materials. This step is the basis for analysing problems that appear in quality management and for identifying the main factors affecting quality. The second step, “do”, allows to organize the implementation of the quality control system. The next step, “check”, is used to verify the effects of action taken. This step is very important in checking whether the operation is taken according to the requirements of the plan, and in identifying which requirement is effective and which one is not. The main goals of the last stage, “act”, is to sum up the experience and achievements. In this step, it is most important to prepare relevant documents, regulations, standards and rules of quality management, to strengthen the accomplishment.

M. Sokovic, D. Pavetic, K. Kern Pipan [2010, pp. 477-478] claim that the PDCA cycle is more than just a tool. The PDCA cycle is a concept of continuous improvement processes that operate in the company and are associated with organizational culture. The most important point in the operation of the whole cycle is the moment when it starts from the beginning and causes further improvement of the process. The idea of the PDCA cycle is presented in Figure 2.

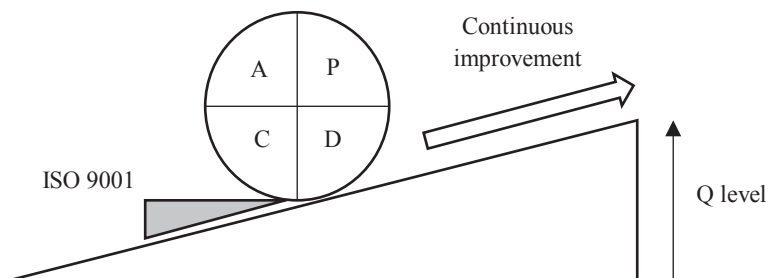


Fig. 2. PDCA cycle in continuous improvement process

Source: [Sokovic, Pavetic, Pipan, Kern 2010, p. 478].

The PDCA cycle is extensively used in the development and deployment of quality policies in enterprises [Sokovic, Pavetic 2007]. In the next part of the article, the PDCA cycle is presented in business practice.

3. Own research methodology

One example of a system approach to solving internal quality problems, among others, is through the use of PDCA. This was implemented as part of a consulting

project in an automotive industry production company. The company manufactures 26 electric two-wheeled vehicles per day on two assembly lines and employs ca. 30 members of staff divided into six work stations performing tasks in a single production shift (eight hours). The main investigation problem resulted from the management board's expectation that the company must significantly improve the quality of its production process. Prior to the commencement of work the qualitative results of the production process were measured within the so-called First Yield Pass (FYP). The indicator measures the number of vehicles leaving the line which – after verification by quality control – do not have any quality errors. The 'significance' of the error does not matter because each error has the same weight and should not occur at all. A higher value of the indicator is desirable and informs of a larger number of vehicles without defects.

The company launched the quality improvement project based on data from the first half of the year, the monthly results of which are presented in Figure 3.

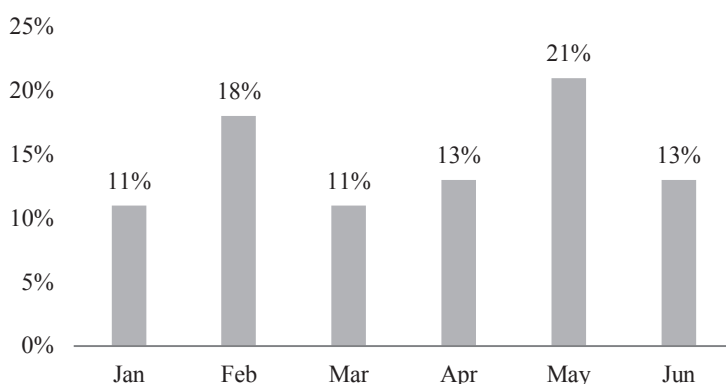


Fig. 3. The poor level of “good quality” measured by FYP

Source: own work.

As part of the preparation prior to the ‘kick-off’, a few important questions were formulated with the expected answers to be obtained as part of a structured PDCA approach:

1. What are the reasons for poor quality in the production process?
2. Are there any causes among those identified whose elimination would result in a significant improvement in quality?
3. Is there a Pareto relationship, where 20% of shares affect 80% of the FYP indicator?
4. What action should be taken to eliminate the causes of poor quality and to improve the final product quality?

The investigation procedure was elaborated on the basis of R.K.Yin's recommendation [Yin 1984, p. 11] which consists of 4 steps:

1. Designing the study.
2. Data collection.
3. Analysis of data.
4. Forming conclusions.

Further to the planning of the investigation, the following elements were indicated:

1. Selection of test object – as the assembly line consists of six work stations for step-by-step assembly of the final product and there was a concomitant lack of standardised knowledge regarding possible error sites, the entire assembly line (i.e. all the six work stations) was taken as the test object.

2. Determining investigation period – sales department orders which formed the basis for the preparation and the realisation of a production plan were stable. The activities of all the six work stations were repeatable and the operations carried out led to the transfer of intermediary products to the next stage and ultimately to the storage area where the finished product was subjected to a final quality inspection. With this in mind, the planned investigation period was 24 working days, four full days (each of 7.5 hours) being spent on each position so as to facilitate the maximum possible observation of employees.

In reference to the method of data collection, it should be noted that the consultant conducted full-shift observations of the selected employee's work at his/her assembly site with a view to understanding the work performed and whether employees apply the functioning operating standards and, most importantly through the prism of improving quality: which work station is responsible for the individual components of the two-wheeler selected for qualitative assessment at the end of the process.

A day of full-shift observations was standardised and began with an explanation from the operator of what his/her day's work would entail. It was then observed how he/she used and referred to work station instructions and what problems occurred while carrying out the duties. The results of the observation were recorded in the activities space on the analysis sheets. Additionally, as part of the work it was planned to analyse the types of errors identified and attributed to the work station using a tool called The Problem Analysis Sheet. This tool is used to analyse the problem by 5xWhy¹ and to propose the removal of repeated risk of error. The AAP meeting formed an introduction to the work aimed at eliminating quality errors during the following stage of the project.

The aim of the data analysis stage is to assign the quality errors identified at the end of the process to individual work stations, which in turn are used as the basis for preparing a systemised summary of the obtained data. The next step is to propose remedial action.

¹ 5 × Why is one of the methods to define the source of problems. Asking a few questions "Why?" allow to come to the source of defects, thoroughly investigate their cause and focus on their effective eliminating. The method was described by Ohno Taiichi: "Toyota production system: beyond large-scale production" Portland: Productivity Press, 1988.

4. The course of process in the investigated company

In the period from August 1 to September 4 the consultant performed 24 full-shift observations of all the six work stations. The total work observation time was 180 hours excluding breakfast breaks. The quality errors identified at the end of the process were grouped into five categories: aesthetics, functionality, completeness, system, assembly.

The errors were collected and compiled based on the knowledge of the consultant and then assigned to the appropriate category. Their combination is presented in Figure 4.

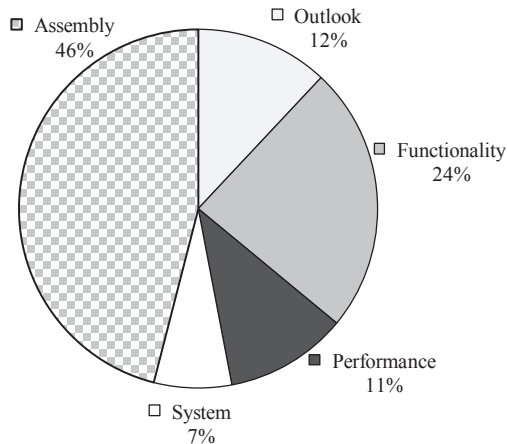


Fig. 4. Types of quality defects during the observations

Source: own work based on FYP.

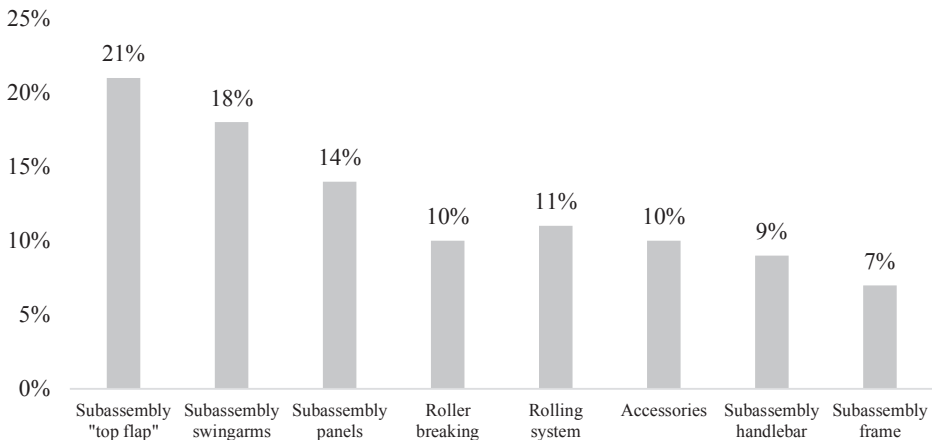


Fig. 5. Errors assigned to the points of origin

Source: own work.

Based on the knowledge of all activities and assembly elements it was also possible to assign the errors to their points of origin. The results in this area are presented in Figure 5.

The collected data analysis was started in detail through the implementation of a tool designed for the analysis of quality problems and errors occurring on the production line. Pertinent to this, an analytical tool called the Problem Analysis Sheet (AAP) was introduced. Each problem analysis sheet was saved on the database which allowed us to gather information.

5. Analyses of the data collected

Both the observations and AAP summaries showed that most errors belonged to the “incorrect subassembly” category and the potential causes of errors (indicated during interviews with employees and their supervisors) resulted from the lack of repeatability and standardisation of activities, combined with inefficient methods of retraining and employee induction, in particular:

1. The employees are not working according to instruction – all the observed employees assembled items contrary to the existing instruction.
2. The critical points for quality assurance are not respected: employees do not use the ‘inter-stand checklist’.
3. No repeatability – employees perform the operation ‘each in his own way’ (quote from one of the operators).
4. Mistakes caused by differing interpretations of the instructions – the instructions consist of a large number of photographs, imprecise descriptions of activities, containing many generalisations e.g. ‘mount correctly’ ‘put properly’ etc.
5. Operators do not want to use the instructions – the instructions consist of several or a dozen pages, making them less functional.
6. The final control identified defects that should be noticed at the work stations during operation – the training method is based on “trial and fail/error” – not all errors can be identified in time.
7. Focusing on quantity not quality – at the expense of quality – employees know that they must produce a specified number of scooters regardless of the instructions.
8. Ineffective training – job training at the stand is carried out by an inexperienced Process Engineer.
9. Inexperienced operators allowed to work without sufficient training – during observation, new employees were allowed to work without job training and detailed work instructions.

Summing up the actions addressed to internal quality, it can be concluded that the following were implemented as part of the analytical work to define the causes of the errors:

1. The system of collecting data on internal inconsistencies was adjusted. In particular: the descriptions of the defects have been clarified and introduced to quality reports, including defining points where the defects occur and the way of conducting an internal control with the final control has been standardised.

2. The analysis process and resolution of qualitative problems were developed by the implementation of an appropriate problem analysis tool (AAP) and the training of production staff to use problem-solving tools and techniques such as: 5xWhy, 5W2H, the Ishikawa diagram. Simultaneously a detailed database and task lists resulting from the AAP was established.

6. Summary of project results

In summary it can be observed that as part of the implementation activities, many actions were taken to eliminate or reduce the inefficiencies and risks identified in the first part of the project. In particular:

- a) the reduction of the amount of final inspections in favour of quality control during assembly,
- b) the transfer of control from the final inspection directly to the production line. Set points as part of the assembly together with an increase of the scope of control (introduction of additional checks on assembly line: before breaking, after accessories, final inspection),
- c) the implementation of regular quality meetings at all management levels,
- d) increasing involvement by changing the organisational culture in relation to the quality. The meetings are attended by production leaders, process engineers and quality engineers with R&D specialists,
- e) tracing the course of defects for each AAP,
- f) conducting regular meetings on problem solving through systematic accounting for the realised AAP and the implementation status of remedial measures,
- g) implementation of visual management tools: One Point Lesson for internal training of production staff,
- h) developing or updating job cards and job instructions for operators together with training on how to induct new employees,
- i) the introduction of inter-workstation control cards,
- j) the preparation of information boards for the visualisation of quality indicators for recording current quality problems.

The effect of the work was a significant improvement in the FYP index is illustrated in Figure 6.

The data from the graph confirm the success of the project. The average quality results in the months following the end of the project (December - February) are nearly three times higher than in Q3m, i.e. immediately prior to the start of implementation activities. It should not be forgotten, however, that achieving such a significant improvement was a process that took several months and which involved virtually every operator. One helpful factor was that the production process is relatively simple with activities which can be standardised along with staff who are relatively young and open to change. The PDCA-based approach has made it

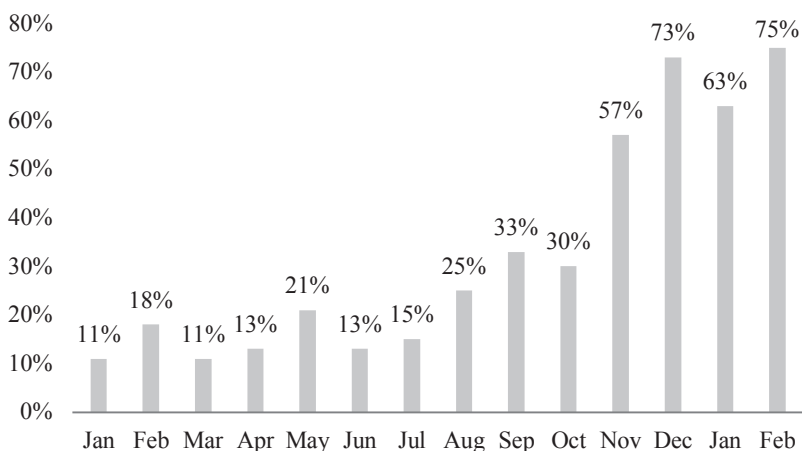


Fig. 6. Quality increase due to project activities

Source: own work.

possible to achieve fast positive results and is a good starting point not only for maintaining but also for continuous quality improvement.

7. Conclusion

The significant improvement in quality that was achieved from December resulted from a systematic approach to the problem based on PDCA. The method used is an effective instrument to manage the quality improvement process, but even more importantly, the results can be improved based on PDCA again and again. Improvement should be a continuous process and not be limited to one activity or a single cycle. The purpose is to improve the work system and achievable results, which in turn lead to the overall improvement of the whole organisation. Additionally, PDCA may be applied broadly by employees, and need not be restricted to issues regarding quality. It is worth emphasizing that effective implementations based on PDCA also affect the increase in the maturity of the organisational culture throughout an enterprise. Virtually every issue – not only those of production and business – may benefit from Deming's cycles as management systemisation, regardless of the type of process on which it is based, will always in the longer-term be more effective than activities based upon mere chance and error.

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