

# On the Use of Quality Tools: A Case Study

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**Abstract**— Organizations need to improve their processes to continually achieve customer satisfaction and, to do that in an effective and efficient way, should use quality tools. The main objective of this research project is to improve the level of quality through the use of quality tools in a company in the installation phase. The PDCA cycle is applied as a methodology to trigger the use of quality tools in problems solving. It is also intended to verify the effectiveness of the PDCA cycle as a methodology for quality tools implementation. A case study was performed starting with the diagnosis of the quality management function, identifying the most critical processes. Subsequently, an analysis of the historical data of the company was made to detect problems and prioritize actions. After, the intervention focused on solving a specific process problem following the PDCA cycle and using quality tools in all its steps. The presented methodology can help companies to increase the use of quality tools which, according to recent study, continues to have little use. All tools have proved to be useful and effective. The application of the Taguchi method to determine the optimum combination of factors of a station (together with other improvement actions) caused a 50% decrease of the most critical defective component and an overall reduction of 29% in the level of nonconformities in the preparation section.

**Index Terms**—Quality Management, Quality Tools, Process Improvement

## I. INTRODUCTION

QUALITY management can be used as a competitive advantage for an organization. According to ISO 9001:2008, organizations should ensure that customer requirements are determined, to ensure their satisfaction [1]. Thus, organizations need to improve their processes and for that use a set of practices, which include various techniques and tools, including most importantly quality tools.

Ishikawa [2] discusses the importance of implementing quality tools, stating that 95% of quality problems can be solved by simple tools such as the basic quality tools. The importance of quality tools is recognized by [3] by stating that many businesses do not succeed in implementing Total Quality Management (TQM), since they do not apply appropriate methods of quality management, especially quality tools. According to [4], quality tools can be used at

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all stages of the product development and production, with the goal of cost reduction and customer satisfaction.

However, it is recommended first to diagnose the different processes to identify those most in need of improvement. This will provide managers with the justification for the selection of one particular process for improvement over others. Once the process has been selected, a definition of the problem must be made and the right tools must be chosen to make the resolution more effective and efficient.

Lopes, et al. [5] present a study on the use of quality tools and improvement methodologies in Portuguese firms. The main findings of this study revealed that Portuguese companies recognize the value and impact of quality tools, but their use falls short of this recognition. Companies with a low degree of maturity in quality processes use few tools and when they reach a higher level of maturity its use increases [3]. Similarly, the use also increases with firm size.

The main objective of this research project is to use quality tools to improve the level of quality management in an industry in the installation phase. First a diagnostic of quality management functions is made to identify priority areas for quality improvement, later quality tools are used to carry out effective actions to improve quality. The PDCA cycle is also used as an effective support for continuous improvement.

Thus, this research aims to be a practical contribution in the implementation of quality tools and uses case study as research method. This method allows a detailed observation of a context [6], whose main limitation is the reduced possibility of making generalizations from the study, however, allows responding to the "how" and "why" of a particular issue and offers the researcher the possibility to focus on a specific case and identify the various interactive processes underway [7].

To achieve the established research goal the methodology presented in Figure 1 will be applied.



Fig. 1. Implementation methodology of quality tools.

This methodology consists of three steps, wherein the first stage (Assessment of quality management processes) there is an evaluation of the company's quality management processes to diagnose possible problems and limitations in these processes leading to the identification of improvement

opportunities. The second step (General quality data analysis) aims to analyze the historical records of occurrence of nonconformities in the entire production process in order to prioritize actions to resolve the problems. The third step consists of the application PDCA cycle (to solve a specific problem that was considered a priority in the previous step). At all stages, where appropriate, quality tools will be applied to increase the effectiveness and efficiency of actions.

## II. COMPANY BACKGROUND

The production unit under study, located in northern Portugal, is dedicated to the production of leather components for leather goods and is being installed. This company, during installation, plans to recruit, train and integrate the human resources needed for growth over three years, until stabilization. Since its beginning and throughout the study, the company had an average monthly enrollment of twelve direct workers (currently has about one hundred workers), intending to continue this pace until the end of the installation phase.

The production system is organized into three functional sections: *cutting* (raw material (leather) is cut giving rise to various components); *preparation* (components undergo various operations, including, uniformity and reduction of leather thickness, pressing, bonding, molding and painting); and *assembly* (components are assembled to form the end product, through sewing operations).

The main system inputs are leather and textiles and the main outputs are four families of products, each with an average of around ten product references. There is, typically, an introduction of a new product family quarterly.

## III. ASSESSMENT OF QUALITY MANAGEMENT PROCESSES

The quality function of the company under study is part of the sub-department of Quality and involves a person who leads this area, although the Logistics Department has some tasks related to this management, particularly as regards the relationship with suppliers and customers. The company has no certification on quality management, and there is no formal quality management system.

At the beginning of this study, the sub-department of Quality had been created for about 3 months and had procedures and processes relating to quality management with a low degree of maturity and robustness. This finding emerged from a review of the processes of quality planning, control and improvement, practiced in this company. The evaluation was conducted by reference to the processes and sub-processes defined by [8], for the evaluation of the quality function, which are shown in Table I.

Upon completion of the evaluation of processes and sub-processes of quality planning, control and improvement, the following was established:

- There are some procedures of quality planning, however they are not documented.
- Regarding quality control, it was verified that sampling or 100% inspections are performed in different stages of the production process.
- It was also found that no actions were undertaken to avoid quality problems in manufacturing.

• Concerning quality improvement, there was no established methodology and the use of tools and techniques was expressionless.

• In general, the application of quality tools was nearly inexistent in the studied processes, with the exception of the use of record and check sheets that are used regularly.

• The fact that there is a record of historical data shows the company's concern in measuring the process, which provides an opportunity to use tools to assist decision making.

TABLE I  
PROCESSES AND SUB-PROCESSES FOR QUALITY MANAGEMENT

Quality Function	Process
A. Quality Planning	A.1. Suppliers qualification
	A.2. Definition and communication of the raw materials/components or subcontracted services requirements to the supplier
	A.3. Definition of the specifications/acceptance criteria and critical features of the product
	A.4. Customer requirements survey and product features validation to meet customer requirements
	A.5. Survey and verification of the compliance with the statutory and regulatory requirements applicable to the product
	A.6. Preliminary studies on the processes capability (products) or skill (services) and operating conditions
	A.7. Ensure that who is involved in the processes have the necessary capabilities and knowledge to the products realization
	A.8. Identification of potential problems (that may arise in the product realization) and solutions
B. Quality Control	B.1. Planning of inspection and testing in the production
	B.2. Inspection and testing of raw materials/components and control of subcontracted services
	B.3. Calibration /verification of measurement, inspection and testing equipments (MITES)
	B.4. Identification and treatment of nonconforming product
	B.5. Corrective actions to sporadic problems
	B.6. Verification of the process capability
C. Quality Improvement	C.1. Identification of improvement opportunities
	C.2. Priorities definition
	C.3. Analysis of opportunities for improvement
	C.4. Definition and planning of improvement actions
	C.5. Verification/ monitoring of the effectiveness of improvement actions

Taking into account the conducted evaluation, it was concluded that the most important problem the company is facing is related to the production process. Due to the low maturity of the production process, there is the need to strengthen the control of manufacturing processes and to focus also on quality improvement.

Concerning quality improvement processes, it was found that improvement opportunities were not identified, that priorities are not defined, nor are implemented improvement actions and verified their effectiveness. In this sense, the need arose to implement quality tools in order to support decision-making with the aim of continuous improvement of processes performance and customer satisfaction.

## IV. GENERAL QUALITY DATA ANALYSIS

To detect improvement opportunities in the production process, the first step was to analyze historical data about nonconformities in all production section. The analysis was performed taking into account the records made in the past three months. Until then, no statistical analysis had been made to the collected data that were only recorded on check sheets.

Therefore, the undertaken analysis aims to understand

what are the most common problems and in which sections they were located to provide a support for defining appropriate actions.

To accomplish this objective, two histograms were built considering: the percentage of defective components in the preparation section by day (see Figure 2) and the percentage of defective components in the assembly section by day. The histograms show the variation over time of the percentage of nonconforming components. None of the histograms show a trend or nor fit a known distribution. This tool showed that the percentage of nonconforming components in the preparation section is higher than the percentage of nonconforming component in the assembly section for almost considered days.

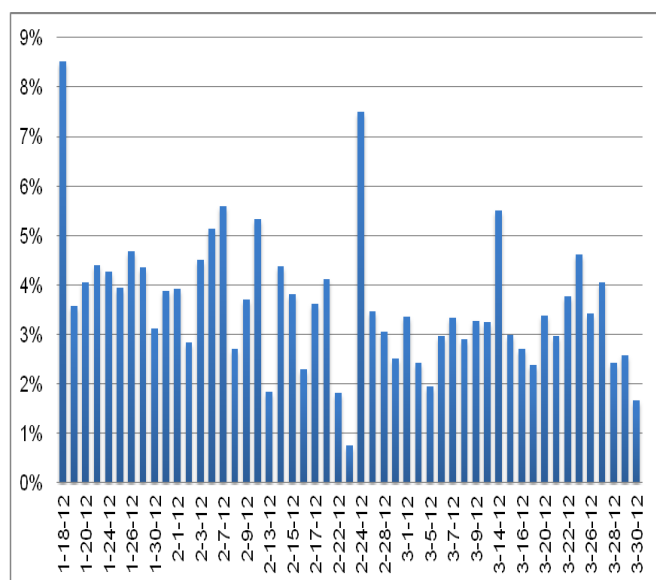


Fig. 2. Histogram of nonconforming components in preparation.

The average number of nonconforming components in the preparation section is 3.5%. Similarly, the average number of nonconforming components in the assembly section was 2.1% of defective components, which denotes that the number of detected nonconformities is significantly higher in the preparation section.

Taking this into account, another histogram was elaborated to understand the influence of the preparation section in the next section of the productive process, the assembly section. This new histogram represents the percentage of nonconforming components detected in the assembly that are originated in preparation. The average percentage of nonconformities from preparation section detected in assembly was of 20% of the total number of detected nonconformities and on some days the percentage reached 50%.

After the preparation section was identified as the most problematic, the next step was to understand what component contributes more for the total percentage of nonconforming components originated by this section. Therefore, another histogram was elaborated, showing the distribution of nonconformities among the different components produced by the company in the last three months. From this histogram, the component designated by FL was identified as the one that has the biggest impact in

the total percentage with a percentage of 9.6 %.

Although the preparation section was identified as the hardest, no one knew the origins of the problems and their size. Thus, a Pareto chart was elaborated classifying nonconforming components by its origin. It was found that three of twelve origins contributed significantly to the total percentage of nonconformities. The IG station (Equalization), along with the folding station (VC), downstream the IG station, and the raw material (MP) represented about 70% of nonconformities of this section.

The station IG represented 20.7% of the total nonconforming components registered in preparation section. Thus, taking into consideration that this is the first station of this section's production process and that other operations depend on the compliance of this station, the IG station was considered a priority once it has a high opportunity for improvement.

Following the above findings, it was considered necessary to verify if the production of nonconforming components of the more problematic section - Preparation - was under control, or if there were assignable causes influencing the process. For this, an *attribute control chart* was designed (illustrating the variation of the percentage of nonconforming components of this section) and it was concluded that the process was not under control, since some points were outside the control limits, most of them above the Upper Control Limit, indicating the presence of assignable causes and, therefore, the necessity to develop actions to eliminate these causes.

In summary, the quality tools applied in this step allowed to conclude the following:

- The preparation section was the most troublesome;
- Many of the assembly section problems stemmed from the preparation section;
- The FL component was the most troublesome;
- The priority station in the implementation of improvement initiatives is the IG station;
- There were assignable causes in the IG station and it is therefore necessary to take actions to stabilize this process.

## V. PDCA CYCLE

### A. Plan

In this stage a detailed characterization of the problem under study was performed and goals were set. The likely causes of the problem were analyzed and an action plan was established to eliminate or reduce such causes.

The problem identified is located (in the first operation after cutting the raw material) in the station *IG*, the first operation the preparation section, and was related to the nonconforming components originated in this operation (thinning of the leather) that were detected in process and which led to several complaints from customers. However, from the various components that are handled in this station, the FL component, identified in the previous step as the component with the highest percentage of nonconforming, will be subject of detailed analysis. The most common defects of the FL component are:

- Component is destroyed during operation;

- The thickness of the component is outside the specification limits of  $0.40 \pm 0.05$  mm;
- The thickness varies along the component, being outside of the tolerances.

So, it was concluded that the problem to be studied, following the methodology PDCA was: FL component production with a thickness outside the specification limits and / or non-uniform, originated from the *station X*.

The goal established by the Production Director, was to reduce by about 10% the number of nonconforming components of the *preparation* section.

The identification of this problem as an improvement opportunity arose with the analysis of existing data concerning this station. A survey of the historical occurrences of this problem was performed (data previously recorded but not yet analyzed) and stakeholders were questioned (team leaders, responsible for Quality) concerning the occurrence of this problem.

According to the available data, the objectives were to analyze the daily evolution of the problem and to find out if there were differences in its occurrence on different shifts. A histogram stratified by work shift (A and B) and day (throughout the month of March) was built. It was found that there is no significant difference between the two shifts regarding the registration of nonconforming components.

To gather more evidence on the problem, the implementation of a record sheet was proposed. After this implementation it would be possible to know in an efficient way which components detected in *preparation* are nonconforming products and which ones had been caused by *station IG*.

After the implementation of this record sheet, it became necessary to analyze if the process of station X was under statistical control. Thus, a control chart for attributes was constructed, calculating the average fraction of defective units and the respective control limits. By analyzing the chart, it was found that the process was not controlled (the production of nonconforming components was not controlled), as featured points outside the limits (mainly

above the upper limit of control), indicating the presence of assignable causes in the process.

Aiming to analyze the unknown assignable causes a multidisciplinary working group was defined, consisting of the coordinator of the Quality sub-department, the responsible for maintenance, the Head of Production and IG station operators. Brainstorming sessions were performed in regular meetings to identify the possible causes of the problem. Following this process a cause-effect diagram was built to expose in a visually and intuitive manner the main root causes of the problem (Figure 3).

The main causes pointed were, in general, related to the experimental procedure, control methods, measurement method, parameterization of the machine, devices, equipment, among others.

An R&R study was performed to analyze the capability of the measurement system, i.e. the assessment of the precision of the measurement system. The repeatability study consists of the ability of the measuring instrument to repeatedly provide the same results and the reproducibility is the ability of the measuring system repeatedly providing the same results when one factor changes (in this case it was done with different operators).

For this, 30 samples representative of the product range were separated and measured twice by two operators. One operator measured in an identified position of the component and later, without knowing that it was the same component, repeated the measurement, with the same measuring instrument (repeatability). The other operator carried out the same procedure to allow the estimation of reproducibility. Ultimately, it was found that the capability of the measuring process was not acceptable since the precision to tolerance Ratio was much greater than 10%. However, the value of the estimated standard deviation for repeatability ( $\sigma_r$ ) is almost three times greater than the estimated standard deviation of reproducibility ( $\sigma_R$ ), thus the main source of variation that affects system precision comes from the measurement instrument. A reduction in the amount of  $\sigma_R$ , which could be achieved with the workers' training, in this case, would have little influence on the results.

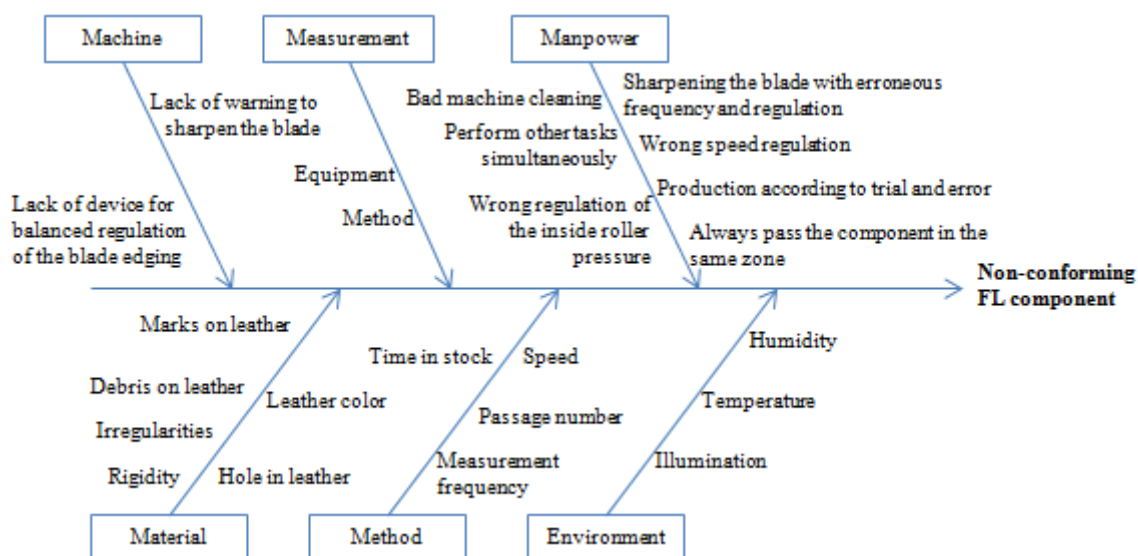


Fig. 3. Cause-effect diagram of nonconforming FL components.

Given that one of the causes cited was related to incorrect machine parameterization (of station IG), the goal was to define the optimal parameters for FL component. For this, a design of experiments was performed, following the Taguchi method, to minimize process variability. The need to define standard (and optimal) parameters for the equalization machine emerged after it was found that most of the parameters were selected without any defined criteria and were constantly modified during production in a trial and error approach. This logic occurred when the characteristics of the raw material ranged stiffness, or even when changing product, although the specifications are the same.

To implement the Taguchi method, after describing the problem, a series of steps for setting the optimum combination of parameters for this problem was followed:

1. Setting the response characteristic
2. Identification of factors (control and noise)
3. Choose factor levels
4. Selection of orthogonal matrix
5. Performing the experiment
6. Interpretation of results
7. Confirmation Test

After executing these steps, it became possible to define optimal combinations of parameters for each type of stiffness of leather that would minimize variations in the FL component. The method allowed 89% reduction in the number of tests realized, when compared to test all combinations.

Following the identification of the problem, the analysis of the possible causes and the size of the problem, a plan of action was elaborated, (mainly corrective actions), taking into account the causes identified in the previous subsection. The action plan was built using the quality tool 5W1H which allowed defining the actions to perform, the responsible for each action and when it would be performed. From the twelve planned actions, some of the most relevant are: the implementation of the optimum combination of parameters for the equalization machine, the replacement of the measuring instrument in FL station, changes of operation modes and control, and placement of mistake-proofing devices in the machine.

#### *B. Do*

After formulating the action plan it was necessary to implement it, by acting on the processes.

The parameters of the equalization station were changed according to the factor levels identified by the Taguchi method. These levels depend on the stiffness level of leather (high, medium or low).

Given the problem of non-uniform wear of the machine roll due to the passage of the component always on the same roll location, a mistake proofing device was developed (*Poka-Yoke*) to force operators to use the entire roll width to introduce the component.

Since one of the main critical points of the machine was the procedure of sharpening the blade, it was defined a new one to reduce variability.

Given that the status display of the blade was used to verify the need for tuning, it has developed a mechanism to

manage visual proof of error to handle different scenarios viewing.

The decision to buy a new measurement equipment to support the work at station IG was decided but the equipment did not arrive until the end of this study.

#### *C. Check*

After the Plan and Do steps, the Check step was carried out to evaluate the effectiveness of the actions taken according to the Action Plan. To verify the effectiveness of the actions, the data before and after the plan implementation was compared.

An attribute control chart of the percentage of defective components in the *station IG*, was built to verify if, with the performed corrective actions, the process was under control. Therefore, a new attribute control chart was built and past data from March to April was compared to new data from June to July. With this comparison, it was possible to verify the following:

- The process is now under statistical control (previously it was out of control);
- The average production of nonconforming components decreased from about 0.40% to 0.20%.

From this analysis, it was possible to presume that the actions taken resulted in improvements in the process and that during this period, although short, the process remained under control.

One of the goals of the company was that the percentage of nonconforming components of each section did not exceed 2%. In the initial analysis performed to the percentage of nonconforming components in the preparation section (period until March), it had been found that the average percentage of nonconforming components was 3.5%. This percentage was calculated again based on data from June and July and allow concluding that the percentage of nonconforming components in the preparation area has decreased significantly to 2.5% (a reduction of 29%), however the percentage limit is still exceeded.

#### *D. Act*

The last step of the PDCA cycle is based on the standardization of the actions in which effectiveness was observed in the Check step.

The actions referred in the Do step were standardized to maintain its results over time. Training was also provided to operators, mainly to explain the motives that supported the changes and to share best practices.

A work instruction was built to clarify the set up of the equalization machine based on the leather stiffness.

The *Poka-Yoke* resulted in a visual instruction placed on the machine.

At the quality management level, the referred tools were standardized as a mean to control and improve quality.

In the present step, some tasks were also identified to be undertaken in the future.

- Preventive Maintenance: the development and implementation of record sheets of breakdowns allowed starting to create a record of failures which will be useful in the future to predict failures and to

define appropriate preventive maintenance actions for the equalization machine;

- Device for the detection of the end of the blade: it was not implemented due to circumstantial impairments, but it was considered necessary for the future and will, therefore, be included in the next improvement project;
- Variation in raw material: is one of the most critical factors and it is presumed to have great influence in the process variability. Once the raw material is of animal origin, the characteristics of the raw material, such as the stiffness, elasticity and humidity, could vary within the same batch. However, these characteristics are not measured. The acquisition of stiffness and humidity meters was suggested in order to identify a cause and effect relationship between the operation performance and the raw material. In the future, a screening checkpoint on raw material reception should also be implemented to reduce the variability earlier in the process. The performed data analysis showed that nonconformities from external sources (raw material) were of great number.

New PDCA cycles will be performed in the future to continuously improve the analyzed processes.

## VI. RESULTS AND DISCUSSION

Quality tools and methods were applied at various stages of this work, either in the general quality data analysis or in each step of the PDCA cycle for the reduction of nonconforming components in the IG station. Table II summarizes the application of quality tools throughout the study.

TABLE II  
APPLIED QUALITY TOOLS

Tools		Quality data analysis	P	D	C	A
Basic	Control Chart	√	√		√	√
	Pareto diagram		√		√	
	Cause & Effect diagram		√			
	Record sheet		√		√	√
	Histogram	√	√			
Others	Brainstorming		√			
	5W1H		√			
	Design of experiments		√			
	Visual Management			√		√
	Poka Yoke			√		
	R&R study		√			

As shown by Table II, a great number of tools were required in the Plan phase in order to analyze the problem, define solutions and prepare an action plan. In this phase, other tools were necessary in addition to the basic quality tools. The use of Taguchi method was considered to have an important role in the reduction of nonconformities.

## VII. CONCLUSIONS

This case study started with a diagnostic of the quality management function of the company involved in the study. This diagnostic allowed identifying a priority area to increase its quality level. It was concluded that the most

important problem the company is facing is related to the production process which must be improved to reduce the high number of nonconforming component.

The main objective of this research project (to use quality tools to improve the level of quality management in an industry in the installation phase) was achieved. Despite the introduction of new products and the hiring of new collaborators, the use of quality tools provided a reduction of 29% in the number of nonconformities in the most problematic section (preparation). Additionally, the process associated with the most problematic component (FL) was put under statistical control and the average number of nonconformities reduced 50%.

This research shows in a practical application why and how quality tools are used framed on the PDCA cycle as an effective support for continuous improvement.

The main limitation is research context and the lack of replication; however it supports literature on the low level of use of quality tools in companies [5], [9]. Finally, the methodology presented in detail can contribute for companies to start using quality tools efficiently.

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