International Journal for Quality Research 19(2) 571-584
ISSN 1800-6450

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REDUCING NON-CONFORMITIES UNDER THE TQM PARADIGM: A CASE STUDY

Article info:
Received 15.10.2024.
Accepted 14.04.2025.

DOI – 10.24874/IJQR19.02-15

Abstract: *This article describes an empirical case study of a company that manufactures and designs tableware and accessories made of fine stoneware providing a rich description of a real context of application of TQM principles. The increasing number of non-confirming pieces was leading to the loss of resources and missed opportunity costs. The PDCA cycle was adopted as the predominant mechanism for continuous improvement in the TQM paradigm. The improvement actions implemented helped the factory reach the lowest rework percentage in the last 5 years, with an estimated increase in sales of around 200 thousand euros. The study contributes to strengthen the literature on TQM, and it can be a useful guide on how to use this approach to reduce defects, whether using the same or other strategies in each phase of the PDCA cycle.*

Keywords: *total quality management, PDCA cycle, defects reduction, continuous improvement, product quality*

1. Introduction

In the current competitive environment, customers are more aware of product quality (Shafiq et al., 2019). Whether in manufacturing or service companies, costs arising from poor quality can range from 5% to 30% of their gross revenue (Gunasekaran et al. 2019). Therefore, quality improvement initiatives, such as Total Quality Management (TQM) and Lean Manufacturing, must be part of companies' daily lives, aiming to avoid these costs and contributing to gain competitive advantage in terms of quality, productivity, customer satisfaction and profitability (Wiyatno et al., 2024; Shafiq et al., 2019).

TQM is a management philosophy that has proven to have a positive impact on several dimensions of company performance. According to Kumar et al. (2009), it contributes to improving employee participation and morale, the quality of products and services, improving processes and productivity, as well as reducing errors, defects and customer complaints, and increasing profitability. Continuous improvement and learning is one of the principles of TQM that is shared by different quality models. It refers to the continuous search for ways to improve operations, identifying good practices and instilling a sense of ownership of the process in employees (Moccia, 2016).

The ceramics industry is a very competitive sector, with many national and global players. However, there are other factors that can affect its profitability such as labor shortages and costs. This makes it essential for companies operating in this sector to minimize any waste that may exist, such as non-conforming pieces, overproduction,

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inventory or waiting time (Ulewicz et al., 2021). As far as we know, there are no studies reporting the application of TQM principles in this sector.

This article describes an empirical case study of a company that manufactures and designs tableware and accessories made of fine stoneware, aiming to contribute to the strengthen the literature on TQM. The TQM principles were applied to reduce the number of non-conforming pieces that required rework in one of its factories, leading to the loss of resources and missed opportunity costs. The PDCA (Plan-Do-Check-Act) cycle was adopted to support the empirical work, as it has become the predominant mechanism for continuous improvement in the TQM paradigm (Chountalas & Lagodimos, 2019). Each PDCA phase is described, including the investigation of root cases of defects, and the identification and implementation of solutions to reduce them. This study can be a useful guide on how to use this approach to reduce defects, applicable to different industrial sectors, whether using the same or other strategies in each phase of the PDCA cycle.

The paper is organized as follows. The next section provides the theoretical background which supports the description and analysis of the case study. Then, the methodology adopted is presented, followed by the contextualization and description of the case study. Finally, a concluding section is offered, in which some contributions are highlighted, and managerial implications are drawn.

2. Background

Quality control has a long tradition in industry. Quality inspection and process control have helped companies to reduce errors and produce efficiently and effectively. However, the increasing complexity of products and processes has required a broader approach to achieving better product quality as a result of well-designed and controlled processes (Chen et al., 2022).

TQM is a management philosophy that aims to enable organizations to provide high quality products and services to their customers (Chountalas & Lagodimos, 2019). Initially, it was considered by academics and practitioners as an approach used only to improve product quality, whereas it is currently used for the continuous improvement of all processes within an organization (Shafiq et al., 2019). Changes to improve processes are usually frequent and small scale. Traditional TQM principles such as process quality and management by facts play an important role in guiding TQM implementation (Moccia 2016). The availability of objective data is extremely important to support appropriate decision-making to improve processes, especially in cases of defects in manufacturing processes (Baird et al., 2011). Nevertheless, TQM has demonstrated its ability to be adaptable to changes in customer value and the external environment (Chen et al., 2022). In addition to continuous improvement and learning, Moccia (2016) identified customer orientation, leadership commitment, social responsibility, and cooperation and partnership development (internal and external) as the principles most associated with TQM.

Quality management tools and techniques can support its implementation and the promotion of best practices (Chen et al., 2022). For instance, the use of the seven quality control tools and the seven management tools is frequently mentioned in the TQM literature (Andersson et al., 2006). However, Nasim (2018) also refers the existence of soft elements in TQM related to people factors such as involvement, commitment, teamwork and empowerment, emphasizing their role in complementing the implementation of hard elements (i.e., tools and techniques). The adoption of different tools and techniques can support efforts to make the process more rigorous.

A literature review conducted by Sreedharan et al. (2018) on the critical success factors of various continuous improvement approaches point out the commitment of top management, training and education, communication, customer focus, organizational culture, employee involvement, teamwork and supplier focus as the main critical success factors in TQM. Haffar et al. (2019) stress the importance of individuals and micro level processes that take place during TQM implementation.

TQM has proven to be a critical determinant of success for both manufacturing and service companies. Its principles and concepts are being applied in many companies operating in different sectors, which invest resources in the adoption and implementation of TQM to increase their competitive advantage (Nasim, 2018).

3. Methodology

This study describes in detail the process used in an improvement exercise, offering a rich description of a real context of application of TQM principles. The reported case study followed the PDCA methodology, as it is considered the predominant mechanism for continuous improvement in the TQM paradigm. Proposed by Deming, it is a continuous cycle composed of four successive stages: planning for change (Plan), executing the plan (Do), evaluating the results (Check) and standardizing the new and improved process (Act) (Chountalas & Lagodimos, 2019). Several tools can be used to support the operationalization of each phase, some of them very simple and straightforward, others more complex. Their selection should depend on the maturity of the company's quality management and the complexity of the problem to be addressed (Silva et al., 2013).

The study was carried out in one of the factories of a company that manufactures and designs tableware and accessories made of fine stoneware. The company has four manufacturing units and two logistics centers with around a thousand employees, and it is located in Portugal. The factory under study aimed to reduce the increasing number of non-conforming pieces that required rework.

In a first instance (Plan phase), the problem was characterized with the identification of the most recurrent defects and their respective root causes. Priorities were established and an action plan was developed, proposing solutions for each problem. Then, in the Do phase, improvement actions were implemented. In the Check phase, the impact of the improvement actions implemented was monitored and reported. Different performance indicators were defined and used to measure the impact of each improvement action, in addition to monitoring the number of non-conforming parts, which was the main indicator defined for the study. Finally, actions were taken to continually improve the process (Act phase).

4. Case study

4.1. Contextualization of the problem

The factory under study aimed to reduce the number of non-conforming pieces that required rework. In 2021, there was a clear increasing trend in the percentage of rework, mainly due to the lack of workers to carry out inspections at different stages of the process (Figure 1). From January to November, around one million and sixty thousand pieces needed to be touched up.

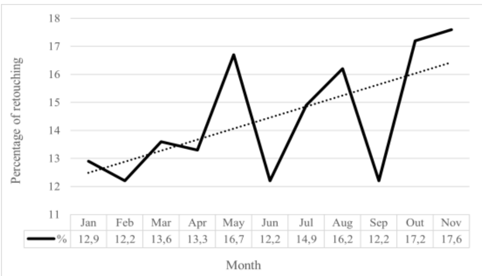

Figure 1. Percentage of rework in 2021
(Source: elaborated by the authors)

Pieces that leave the kiln with defects acceptable for rework go through a retouching process and then return to the kiln. An additional cost of 0.157 euros per unit was estimated for each touch-up piece, when compared to a conforming piece. Considering the number of pieces retouched, this represented an additional cost of around 167 thousand euros for the factory in the first eleven months of 2021. In addition to this cost, there is also an opportunity cost related to refinishing, since, by placing these pieces in the kiln, there is less available space for new pieces, as the kiln is the bottleneck resource in the factory. Therefore, reducing the number of non-conforming pieces would lead to financial savings and an increase in the number of pieces produced.

4.2. Plan

After identifying the problem to be addressed and quantifying its impact, it was important to better characterize it. Therefore, the most recurrent defects and their respective root causes were identified. Priorities were then established, and an action plan was developed with solutions for each problem.

To ensure that pieces with defects are not delivered to the customer, there is a selection workstation after the firing process. Workers classify the pieces according to the type of defects identified. If the defect can be corrected, the pieces are sent for refinishing. Defects that are admissible for retouching are stipulated by the Quality Department. In the selection process, when employees forward parts for touch-up, they need to identify the main defects detected in the system.

The three main defects recorded are pores (54.5%), dirt (13.7%), and chipped glaze (13%). Although pores represent more than half of the registered defects, they arise from the composition of the glaze, which is independent of internal factors. The company is working with suppliers to find a new glaze composition that can reduce pores. Furthermore, pores are impossible to detect before firing. Therefore, efforts to reduce the number of pieces subject to refinishing were focused on the other two types of defects.

In order to identify the causes that originate the two previously mentioned defects, an Ishikawa Diagram was created for each of them (Figure 2 and Figure 3). After a joint analysis with several stakeholders, it was possible to determine that some of the causes that had the greatest impact on the chipped glaze were the poor organization of the park where pieces await the firing process, which led to excessive movement of cars, and the incorrect handling of pieces by the workers. The lack of quality control did not allow for the timely detection of these defects before the firing process. In relation to dirt, the causes that most influenced the defect were dirty kiln cars and loading kiln cars in the wrong order. The lack of quality control also played an important role in the occurrence of this defect.

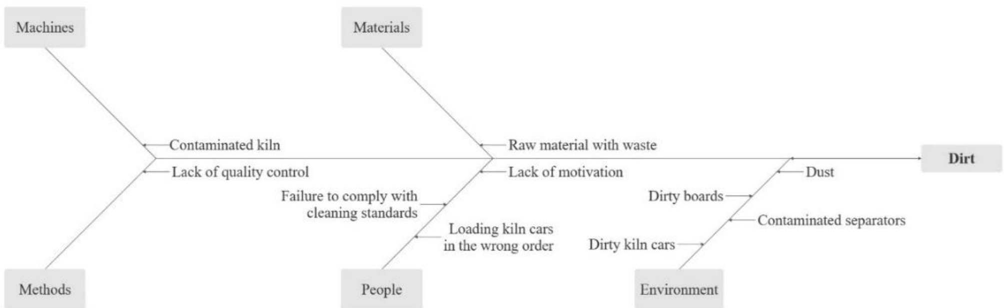

Figure 2. Ishikawa diagram for “dirt” defect (Source: elaborated by the authors)

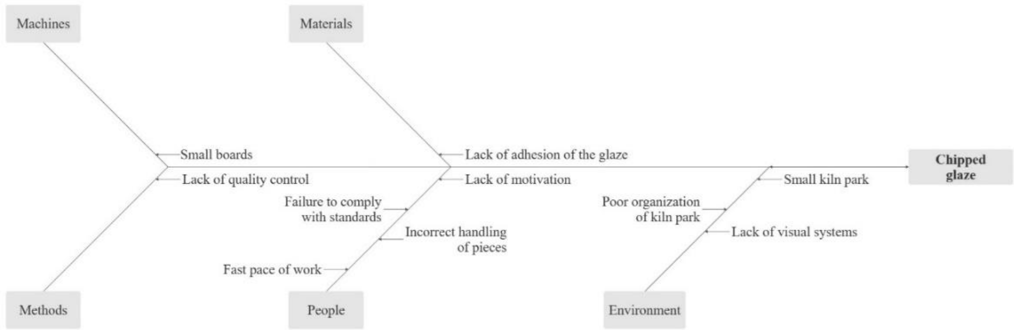

Figure 2. Ishikawa diagram for "chipped glaze" defect (Source: elaborated by the authors)

In order to prioritize the causes to act on, a GUT Matrix was used that considers three criteria: Gravity (G), Urgency (U) and Trend (T). Collecting feedback from various stakeholders, some causes were selected for inclusion in the GUT Matrix, among those found in the Ishikawa Diagrams and in the various Gemba Walks carried out, scoring them from 1 to 5, in each of the three criteria. The results are presented in Table 1. The causes are arranged in descending order according to the final classification obtained.

Table 1. GUT matrix for problem prioritization (Source: elaborated by the authors)

Problem	G	U	T	GxUxT
Lack of quality control	5	5	5	125
Incorrect handling of pieces	5	5	5	125
Poor organization of kiln park	5	5	4	100
Non-compliance with standards	5	4	4	80
Dirty kiln cars	5	4	3	60
Loading the kiln car in the wrong order	4	3	3	36
Lack of adhesion of the glaze	2	2	2	8
Small boards	3	2	1	6
Raw material with waste	2	1	1	2

The last three causes were excluded because they scored 3 or less on the three criteria.

Lack of quality control. The number of pieces analyzed during quality inspections was small when compared to the company's daily production. Inspections were carried out by a single person in three different zones (kiln park, kiln car and kiln exit), who analyzed a sample of twenty pieces per day from two references in each zone. In total, one hundred and twenty pieces were analyzed per day. Due to this, defects were not detected and corrected in a timely manner (before firing), which led to an increase in non-conforming pieces in the selection process and, consequently, an increase in the percentage of retouched pieces. Furthermore, the inspection database was not flexible enough to allow the introduction of new defects into the system and it was also not intuitive for new users, which made data analysis difficult. Another problem identified and related to the lack of quality control was the lack of a database to monitor, in a simplified way, the quantities and percentages of pieces of a specific reference that were sent annually for touch-up. Until then, this data was obtained by transferring, for each reference, an Excel file with data provided by the company's internal system and calculating the percentages individually. Considering that the manufacturing unit produces thousands of different references, it resulted in a huge waste of time and other resources.

Poor organization of the kiln park. The poor organization of the kiln park was one of the problems that most contributed to the number of pieces for refinishing and the time wasted by kiln operators, who spent a lot of time looking for the pieces to place on the kiln car. When operators finished glazing the number of pieces needed to fill a cart, they moved it to the kiln park and placed it in the first empty space. Considering that the pieces are fired according to the customer, the random placement of carts in the kiln park meant that carts with pieces for the same customer were not close to each other but dispersed throughout the kiln park. This required the movement of carts by the kiln operators, to identify which carts contained the pieces to be fired first, which contributed to the occurrence of some defects, as pieces can collide with each other when moved. Furthermore, as kiln operators only have nine minutes to load each kiln car, the time spent looking for the right pieces reduces the time available for firing and lead to some carelessness in handling pieces, contributing to the occurrence of even more defects.

Incorrect handling of pieces. Incorrect handling of pieces was one of the most common problems encountered when preparing pieces for firing. According to the standards established by the company, pieces with a diameter greater than 18 centimeters must be handled with both hands to avoid damaging the piece, while pieces with a diameter of less than 18 centimeters can be handled with just one hand. However, this rule was not being followed, which resulted in pieces with cracks after firing, although in some cases, as they were small, they could be repaired. Additionally, when placing the pieces on the kiln car, kiln workers dragged them, instead of placing them carefully on it, which damaged the bottom of the piece and contaminated the kiln cars. This led to more defects in the pieces, such as dirt, making it necessary to repair the pieces, which represented more waste of time and rework for the organization.

Non-compliance with standards. Other problems encountered were non-compliance with standards, namely the blowing of kiln cars in the dust removal area, cleaning of hands and the incorrect stacking of pieces on pallets when removing pieces from the kiln. The blowing of kiln cars in the dust removal area was often not carried out or was carried out without closing adjacent gates, which generated dust and residues that contaminated the pieces and nearby kiln cars. In addition, hands must be clean whenever a piece with a different glaze is handled, which was not being strictly followed by workers and was contributing to the increase of the number of contaminated pieces. Finally, regarding the stacking of pieces on pallet after firing, the pieces should not be stacked higher than 1.5 meters, as the pallet becomes unstable, and its weight can compromise the pieces located on the lower levels. This rule was also not being complied with by the workers.

Loading the kiln car in the wrong order. The pieces must be placed in the kiln cars from top to bottom. Loading kiln cars from the bottom up can result in residue contaminating pieces at lower levels. For the same reason, the pieces must be removed from the kiln cars from the bottom up to prevent residue from falling onto the remaining pieces. This practice was also not strictly followed by workers, as observed in the various Gemba Walks carried out.

Dirty kiln car. Another problem identified was the existence of dirty kiln carts, which can cause damage to the pieces placed in them and put kiln workers at risk, as the remains of the stoneware pieces can be extremely sharp.

A brainstorming was carried out to identify improvement actions to be implemented to address the selected causes (Table 2). The actions were selected considering the feasibility of their implementation in the short term and the potential impact on the percentage of defects.

Table 2. Improvement actions defined for selected problems (Source: elaborated by the authors)

Problem	Improvement action
Lack of quality control	Increasing inspection frequency and creating a defect library Redesigning the quality inspection database Creating a report to track product quality
Poor organization of kiln park	Implementing a visual system at the kiln park
Incorrect handling of pieces Non-compliance with standards Loading the kiln cars in the wrong order	Introducing new performance indicators Implementing a visual system for pallet stacking
Dirty kiln car	Implementing a system to identify contaminated kiln cars

4.3. Do

In a second phase (Do phase), the defined action plan was executed. Seven improvement actions were implemented to resolve the problems identified as priorities.

Increasing inspection frequency and creating a defect library. Considering the available human resources and following the ISO2859-1 standard for sampling procedures for inspection by attributes with an Acceptable Quality Limit of 2.5, the inspection frequency was increased to three references per zone. Moreover, to improve communication and adopt corrective measures more quickly, daily quality meetings began to be held with inspectors and the person responsible for Quality to report the main defects and problems detected throughout the day. Increasing the frequency of inspections and holding daily quality meetings made it possible to increase quality control and collect more data to enrich the database and thus support more informed and faster decision-making by the Quality Department. For example, if a reference has a high percentage of defects, it goes through the selection process first to give the organization time to react. Furthermore, a defect library (i.e., photographic record of defects), was created to help workers identify potential defects throughout the process and combat the lack of quality control. In the library, for each type of defect, a set of images is presented to facilitate the identification of the non-conformity, specially by new operators. More than 50 defects have been included. The existence of a defect library increases operators' awareness of the types of defects that can be found, encouraging them to take responsibility for identifying defects in pieces that pass through their workstation and contributing to tighter quality control.

Redesigning the quality inspection database. When quality inspections were carried out, a form was filled out on Google Forms and the data was subsequently exported to an Excel file to be processed in order to obtain information. A redesign of the database was necessary to allow automatic updating of Google Forms data, introduce new defects when necessary and facilitate the analysis and interpretation of results. To meet the first two objectives, a Power Query environment was used to change the way data is imported into the Excel file. Using the function "Update data" allowed the Excel file to be updated automatically. It also became possible to insert more defects in the form whenever necessary, as the table generated by Power Query incorporates a new column for this purpose. Finally, dynamic tables and graphs were used to facilitate the analysis and interpretation of results. With this reformulation, data can be segmented and filtered, allowing the analysis of defects according to various parameters, such as manufacturing unit, year, week, shift or team. Furthermore, it is possible to study the evolution of defects over time (or a defined period), with graphs being created automatically, according to the selected parameters.

Creating a report to track product quality. As mentioned previously, tracking a reference over time to analyze how pieces were classified after the selection process (i.e., first-class pieces, second-class pieces, pieces for refinishing or shard) was a time-consuming task. Power BI, a data visualization tool, was used to create an interactive report to monitor the various product references and check the number of pieces classified in each category. The report has three pages. On the first page, the overall results of the selection process can be consulted for a set of product references selected by the user, as well as the quantities produced over the years, as long as there are records. On a second page of the report, the evolution over the years of the percentage of pieces in each category is presented. Monitoring these values makes it possible to analyze the impact of changes in the factory layout, technology or methods used over the years on product quality (Figure 4).

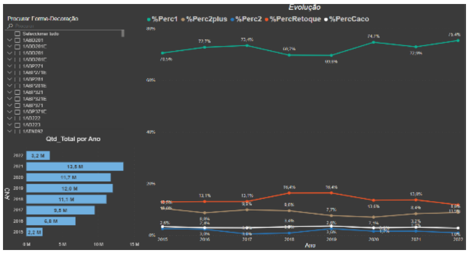

Figure 4. Page of the Power BI report with the evolution of the percentage of pieces classified in each category

Finally, to take advantage of all the data collected, a third page of the report presents the most recurring defects for each selected reference, which justify the classification of pieces for refinishing. The creation of this report aimed to monitor, improve and simplify the access to information on product quality by product reference, which can support decision-making. The report can be accessed by telephone, anywhere, which is an advantage and makes consulting information more convenient, as it is not necessary to be in front of a computer to do so.

Implementing a visual system at the kiln park. A visual system was introduced to overcome the lack of organization of the kiln park. A card with identification of the customer is placed on the top of each cart, using a flexible holder, to make it more visible from a greater distance. Glazing operators are responsible for placing the card on each cart and transporting it to the kiln park. If there is no other cart for the same customer in the park, the operator must place the cart in an unoccupied area and away from other carts. Otherwise, if there are already other carts for the same customer in the park, the operator must place the carts together to facilitate the kiln operator's work. This measure contributes to improving the organization of the park, placing the carts with pieces for the same customer close to each other. It facilitates the correct identification of carts by kiln operators, reducing excessive movement, increasing the time available for loading kiln cars and, consequently, reducing the probability of defects occurring.

Introducing new performance indicators. As result of several Gemba walks and monitoring of daily Kaizen meetings with kiln workers, a new performance indicator was proposed to evaluate the quality of the kiln workers' work and promote a greater commitment to product quality. The data from the quality inspection at the entrance to the kiln, when analyzed in Excel, did not reveal which defects were caused by the workers when placing the pieces in the kiln cars. To obtain better control of defects caused by the kiln workers, a new spreadsheet was created to be completed by quality inspectors, indicating the percentage of conforming pieces, considering only the defects caused by them. The results of this new performance indicator are printed monthly and placed on the kiln workers'

Kaizen board to be analyzed and discussed in meetings with kiln workers and support decision-making by managers and supervisors. In addition to this new performance indicator, another improvement opportunity was identified related to an existing practice in the organization. Supervisors conducted Gemba walks and evaluated the behavior of kiln workers according to various criteria, such as pieces handling, loading and unloading order of kiln cars, hand cleaning, scraping and blowing of kiln cars and stacking of pieces in pallets after firing. However, they did not do so regularly, which did not allow for a reliable analysis of the available data. Furthermore, the results of this analysis should be shared with the kiln workers so that they become aware of their mistakes and the need to correct their behavior. The results of this analysis began to be shared weekly through a bar graph, as illustrated in Figure 5.

Figure 5. Bar chart used to display assessment of kiln worker behavior

Each bar, corresponding to a kiln worker, can take two colors (green and/or red), according to percentage of fulfilment of all the previously mentioned criteria. For example, if they do not meet at least one of the criteria every time they are observed by the supervisor, the bar will turn red. To complement this information, another graph is provided detailing which criteria were not met. The introduction of new performance indicators aims to promote more transparency in inspections, as well as a greater commitment of kiln workers to product quality, reducing the number of non-conforming pieces.

Implementing a visual system for pallet stacking. Another measure implemented with the aim of reducing non-compliance with standards by kiln workers, especially those responsible for unloading kiln cars and stacking pieces on pallets, consisted of signage indicating the maximum height that pallets must have (Figure 6). The structure has three marks, corresponding to the maximum height allowed for different types of pieces. It is marked at 50 centimeters from the ground, which is the maximum height to be considered for stacking platters greater than 40 centimeters or plates with a diameter greater than 32 centimeters. The mark at 80 centimeters from the ground corresponds to the maximum height for stacking jugs, milk jugs, and tureen lids and the last mark (at 1.5 meters from the ground) must be considered for stacking the remaining pieces. In no case should stacking exceed this mark. Kiln workers were made aware of the importance of the measure and alerted to the consequences of non-compliance with this standard. This helps reduce the likelihood of pieces breaking.

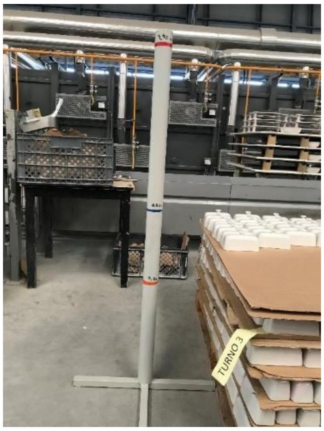

Figure 6. Visual system for pallet stacking (Source: property of the authors)

Implementing a system to identify contaminated kiln cars. The last measure implemented consisted of a system that allows the identification of kiln cars that are in poor condition and need to be replaced. Kiln cars are replaced periodically, every three weeks. Sometimes, they degrade or become contaminated before that, so there is a need to replace them sooner than usual. As the workers responsible for replacement are rarely at the shop floor, as they are in the workshop applying treatment to the kiln cars that will replace the old ones, there is a need to identify which kiln cars are damaged to replace them. An A3-sized sheet was placed next to the kilns with the number of each kiln car and a space for kiln workers to place a mark to indicate deteriorated or contaminated kiln cars (Figure 7). This way, when workers responsible for replacing kiln cars go to the shop floor, they can check whether there are kiln cars to be replaced. The ideal would be to automatically alert them to this signal, but at the time of project execution, there were no resources available to carry it out.

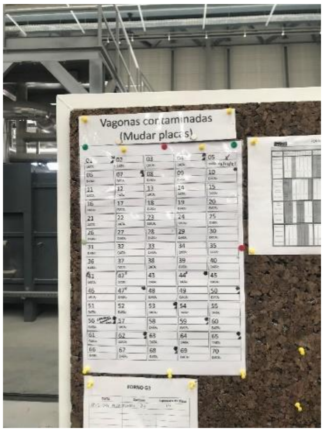

Figure 7. Sheet for signalling deteriorated and contaminated kiln cars (Source: property of the authors)

All the measures presented were implemented to solve each of the problems identified with a low financial investment. The following section presents the results of the implemented measures, with the aim of determining whether the measures had the desired impact, particularly in terms of reducing rework.

4.4. Check

After completing the Plan and Do phases of the PDCA cycle, in which problems were identified and measures implemented to resolve them, the results achieved were analyzed, to verify whether the objectives were met. All the measures implemented aimed to reduce the level of retouching in the manufacturing unit. Although the percentage of touch-up was considered the main way of evaluating the success of the interventions carried out, an attempt was made to evaluate, in the first instance, the results achieved with each measure.

Regarding the reformulation of databases, some feedback was collected from users, namely members from the Quality Department and R&D Department, responsible for the continuous process improvement. The reformulation aimed to facilitate the analysis and interpretation of inspection data and automate some analyses. According to the feedback provided by the users, the objectives were achieved. Some benefits they listed include the possibility of adding new defects whenever necessary; the ease of obtaining a representation of the evolution of defects, according to various parameters (e.g., by team or shift); a more intuitive and simple use of filters; faster and higher quality decision-making by the Quality and R&D Departments; and less time spent obtaining information. The new files present information in a simpler and more structured way, important for more sustained and faster decision-making and, consequently, with an impact on organizational performance. Feedback was also collected from the head of the Quality Department, the Production Director and the Manufacturing Unit Director on the report created to monitor the product quality. They identified some benefits associated with the report such as the reduction in the time spent obtaining information; an intuitive and easy-to-use report; decision-making based on reliable data; the possibility of monitoring the evolution of product quality and evaluating the discontinuity of products with a high rate of defects to reduce costs.

To evaluate the impact of implementing a visual system at the kiln park, the percentage of defects detected in the park was analyzed. As one of the quality inspections is carried out in the kiln park, it was easy to compare the percentage of defects before and after implementation. The analysis revealed that the percentage of defects in the kiln park decreased after the implementation of the visual system in December 2021 (Figure 8). However, there are other factors that can influence these results, such as an increase in the number of inspections.

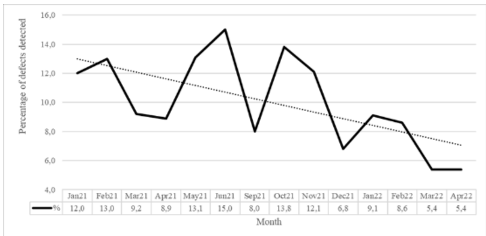

Figure 8. Percentage of defects detected in the kiln park (Source: elaborated by the authors)

Furthermore, and according to feedback from kiln workers, the visual system implemented facilitated the identification of pieces and made it possible to reduce movement, increasing the time available for loading the kiln cars.

The new performance indicators introduced were monitored over the months after the implementation. Data from inspections at the entrance to the kiln revealed an increase in product quality from 90.5% to 95.3% due to the reduction in defects caused by kiln workers when placing the pieces on the kiln cars. This result could be even more significant, however, over the months of analysis, there were several changes in the kiln workers' team, which led to the need for new employees to learn and adapt to kiln-related tasks. Additionally, sharing the results of inspections carried out by supervisors had a major impact on the performance of kiln workers. The improvement was visible, as most workers transitioned from red bars to predominantly green bars, meaning they met all criteria most of the time they were observed. The system implemented to identify contaminated kiln cars also had positive results, as the percentage of defects caused by dirt in kiln cars decreased after the intervention from 2.4% to 0.2% in four months.

All the improvement actions implemented aimed to reduce the number of pieces that needed to be reworked. Therefore, the best indicator to evaluate the impact of the intervention is to compare the percentage of pieces subjected to rework before and after implementation. There was a reduction in the percentage of rework over the months (Figure 9).

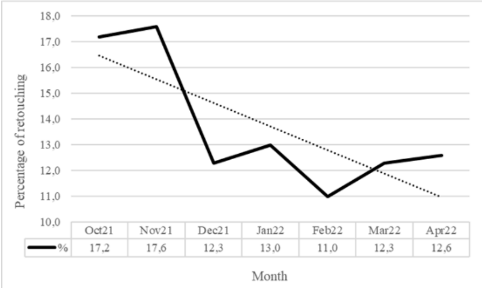

Figure 9. Percentage of retouching during the project (Source: elaborated by the authors)

Comparing the data collected with the objectives established by the company for the year, the maximum percentage of rework defined was not exceeded, presenting the lowest value in the last 5 years, which validates the work carried out to identify and implement improvement actions to the process. Regarding the financial savings resulting from the reduction in the percentage of rework, savings of 10600 euros were estimated in only four months, considering the estimated rework costs and that 67267 fewer pieces were subject to rework than in the previous year. If it were considered that for every piece that is not reworked, a new, defect-free piece is burned, revenues would increase by 200000 euros, as a piece is, on average, sold for 3 euros.

4.5. Act

After implementing the improvement actions described, the factory continued to invest efforts in continuous improvement. Quality inspections continue to be carried out, but now quality inspectors photograph defects found and make the images available weekly in the company's cloud for supervisors to analyze and define corrective measures. These corrective measures are shared with operators in daily Kaizen visual boards, along with the identification of defects, their occurrence percentages and representative images of each of them.

Furthermore, a Quality car was created in each of the four sections of the factory to place pieces with defects available to everyone for analysis. Only quality supervisors, team leaders or quality inspectors are authorized to place pieces on the car to maintain a certain rigor in pieces selection. Screens have also been installed in the glazing and kiln sections, which are showing educational videos (prepared by the quality team) on how to handle the pieces or the correct order in loading and unloading kiln cars. If operators have doubts about work standards, they can consult them quickly and visually through the screen.

5. Conclusions

TQM has been referred in the literature as one of the most popular quality improvement initiatives, with a proven impact on the performance of organizations. The work described in this case study used the PDCA methodology and a diverse set of tools to identify and address the root causes of the increasing number of non-conforming pieces in a factory that manufactures and designs fine stoneware tableware and accessories. Some solutions were offered for the problems identified as priorities and their impact was measured. The main objective of reducing the percentage of retouched pieces was achieved. However, the constant turnover of employees, a recurring problem in factories with a large number of employees, was highlighted as one of the reasons why the actions may not have had a greater impact. It is believed that the constant hiring of new employees has a direct impact on the number of non-conforming parts, as there is a phase of adaptation to the work, in which more errors are likely to occur. This highlights the importance of closely monitoring the processes and implement improvement actions to make them more standardized.

The work described can be a useful guide for researchers and professionals on how to adopt the TQM paradigm and PDCA methodology to improve the quality of processes and products in the ceramics industry or other industrial sectors, using the same or other tools. Case studies reporting the application of these concepts in the ceramics industry are still scarce in the literature. According to Ahire & Dreyfus (2000), greater familiarity with the implementation of TQM allows companies to use their resources more effectively and focus their attention on other areas, such as product design, maintaining good process performance with less effort.

Acknowledgment: This work was financially supported by the Research Unit on Governance, Competitiveness and Public Policies (UIDB/04058/2020) + (UIDP/04058/2020), funded by national funds through FCT - Fundação para a Ciência e a Tecnologia.

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