Implementation of Nonconformity and Rework Control in the Construction Execution Process – A Case Study

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Abstract. There is a significant culture of rework during the execution of the work in the civil construction. Given this scenario, construction companies that seek to be a differential in the market, providing a high standard of quality in their services and products, feel the need to standardize their processes and avoid waste by implementing a robust Quality Management System. The standardization is achieved by identifying factors that contribute to the incidence of rework in all stages of the construction process. The registration and analysis of nonconformities in processes and products are crucial. When nonconformities are not treated adequately, and processes are not standardized, waste and high-quality costs are generated. A construction company of high-standard residences in Brazil needs to analyze the impact of implementing the control of nonconformities and rework, since quality costs is high. This paper aims to demonstrate how implementing a robust nonconformity treatment method can reduce rework in this medium-sized construction company. As a methodological approach, a literature search was conducted to identify how companies deal with costs of quality through NC control and rework measurement. A case study was conducted in that construction company. As a result, data from the company shows the importance of effective control of nonconformities in reducing rework. The implementation of non-compliance control evidenced significant improvements and cost/waste reduction. This study is vital for engineers, professionals, and companies working in the civil construction area...

Keywords: Non-conformities. Rework. Construction industry. Quality.

1 Introduction

According to ISO 9000, nonconformity is defined as failure to meet requirements. Organizations must be aware of and promote a quality management system that identifies various stakeholders' requirements to avoid nonconforming outputs and products. Requirements are understood as a need or expectation that is stated generally implicit or mandatory. There are various requirements, such as those determined by customers and regulatory and statutory bodies. For the organization to have a

satisfactory quality level, still according to ISO 9000, its product or service must comply with the requirements.

Within this dynamic, Deming [1] states that quality must aim at the consumer's current and future needs. Singh [2] states that Juran provides two main definitions of the term quality: the first is that quality translates the characteristics of products that meet customer needs and consequently their satisfaction; the second is that quality means being free of defects and rework.

Quality Assurance is essential to ensure collaboration so that the final product meets the customers' requirements and provides them great satisfaction. It also acts directly on the internal and external processes of the organization, aiming to obtain a practical process approach in its inputs and outputs. Once the organization's main internal and external requirements are understood, and the company is managed to meet them by developing policies and strategies that originate the processes and their indicators, the identification of nonconformities in the processes becomes apparent. Nonconformity can be identified in different ways, such as a customer complaint, an inspection of finished products, internal and external audits, supplier evaluation, and customer satisfaction surveys. There are several possibilities for the entry of a nonconformity. However, how it is treated and controlled guarantees the continuous improvement of a company's processes, consequently reducing waste and rework.

Several authors define rework as the action performed so that defective or out-of-specification components conform to the established requirements. That is, efforts are used for correction. Rework means an actual waste of human and financial resources that, on a large scale, translates into a high cost of non-quality. The civil construction sector has always presented high rework rates in its processes. According to Grohmann [3], this waste is the consequence of a vast list of causes, among which we can highlight: project deficiencies and incompatibilities, inefficient administrative management, outdated methods and little development of technologies, and no study of past errors that culminate in their recurrence, low specialization of the workforce. Based on these data, the knowledge and application of quality tools are necessary for the effective treatment of nonconformities identified in the processes of execution of works so that the errors start to be known, understood, analyzed, and avoided with the constant improvement of processes.

A construction company of high-standard residences in Brazil needs to analyze the impact of implementing the control of nonconformities and rework since the value of quality costs is high. Given this context, a study was conducted in this organization to understand and report how the control of nonconformities and rework contributes to significant process improvement and waste reduction through a review of scientific literature and exploratory research. The civil construction sector presents many rework and waste in its processes. This problem causes several consequences to the organizations and their clients, such as delays in the delivery of the work, non-compliance with the initial budget, and reduced team productivity at the construction site. Therefore, rework is a significant problem in the sector, reaching up to 10% of the total cost of the work [4].

According to studies conducted by Lima [5], in companies that do not use management tools, 9.5% report that there is reworked and waste above 75% of the

activities, while those that use rework and waste do not exceed 50% of the activities. And in the companies that do not use a management tool, 9.5% report rework and waste exceeding 75% of the activities, while in those that use a management tool, rework and waste do not exceed 50% of the activities. And in companies that do not use management tools, 9.5% report that there is reworked and waste above 75% of the activities, while in those that do, rework and waste do not exceed 50% of the activities. This study proves that construction companies must invest in quality tools to improve their processes. The company on which this study is based has difficulties in controlling nonconformities and rework in its processes due to the lack of an effective methodology. These deficiencies are identified by analyzing the percentage of costs related to technical assistance, the number of errors in projects during the execution of works, and performance indicators recently implemented in the organization. Previous studies presented herein do not address specifically the practical problem faced by the construction company.

This study completes this gap and aims to analyze how quality and production engineering tools in the control and treatment of nonconformities in construction execution processes can impact rework in a construction company. It analyzes how Quality Management contributes to the efficiency of the construction execution processes, identifies the leading causes of rework in construction sites and how to monitor them, proposes the use of quality tools in construction execution processes, proposes a simple and effective method for dealing with nonconformities in the execution of construction work processes and analyzes how training provides the team's engagement in nonconformity records. Civil construction is one of the sectors that most present waste and rework in its processes, causing a relevant impact on the cost of the work, delay in the client's schedule, and low-quality indices. The wastes originate in several stages, such as planning, poor detailing of projects, materials, and execution [3]. It is known that waste in the execution stages of work is not accounted for and managed in many organizations. It reflects the lack of planning of operations, the non-alignment of the various stages of the project, and the lack of quality controls of the processes. Unlike other industries, in civil construction, the cost of rework is very high because it directly impacts the execution of other steps. The processes are very dependent on each other and require that for the next service to start, the last one must be completed and without non-compliance.

Edwards Deming [1] states that quality improvement transfers the waste of person-hours and machine-time to manufacturing a good product and better service delivery. For this reason, it is essential that nonconformities are identified during the execution of services, dealt with efficiently, and that the company adopts corrective actions to avoid their recurrence. In this scenario, it is necessary to implement and use the tools of the Quality Management System, guided by the NBR ISO 9001-2015 standard, in the company studied so that the work can be carried out in a leaner way without the need for constant rework.

The study responds to four research questions.

Research Question 1: What is the importance of implementing a quality management system in construction companies and the causes of rework?

Research Question 2: How can the treatment of nonconformities using quality tools influence the reduction of rework in construction processes?

Research Question 3: Which is the effective method to be used in the treatment of nonconformities?

Question 4: What are the challenges in maintaining quality in construction companies?

This study was structured as follows: The first section presents the introductory part of the research, with the determination of objectives, problem, justifications, importance of the study, delimitation of the research, and the questions to be addressed throughout the study. The second section presents previous studies on the challenges of the QMS in construction companies, the third studies on nonconformities in construction companies and the importance of identifying and treating nonconformities, and the consequences of rework in the construction processes. The third section defines the methodology used in the study, detailing the tools used to achieve the research objectives. In the fourth section, the methodology. The fifth section presents the results with details of the case study, with a description of the company under study, data collected in the company, and the theoretical framework. In the sixth section, the analysis and discussion of the results are presented to explain the interpretation of the data collected. Finally, the seventh section presents the study's conclusion and its final considerations with suggestions for future research.

2 Challenges of the QMS in construction companies

According to Verdan and Souza [6], the main difficulty he studied was the lack of commitment from the leadership (management), who did not effectively participate in the system because they only considered it a way to obtain financing for the company's ventures. This deficiency is common in several companies and does not meet the normative requirement on the leadership of ISO 9001, causing a big void in the system. With this behavior, it is challenging to keep the team engaged.

Barros [7] stated that the director of one of the companies he analyzed pointed out that the system requires much time to work because it is necessary to implement many changes in the way the company was used to working and the completion of several controls developed during the implementation. Resistance to change and excessive bureaucracy are considered the most significant difficulties in maintaining the system.

Almeida [8] states that the construction industry generally brings together professionals with low professional qualifications concerning other commercial and industrial sectors, which explains why the construction industry still maintains its processes considered primitive and without significant signs of evolution. He also points out that companies get lost after introducing a quality management program because many processes are adopted. The daily actions result in the understanding and perception of the system's benefits for those involved in the processes.

In general, construction companies and several organizations face the main challenge in implementing and maintaining the quality culture because it is essential for the

consolidation of quality programs. Paladini [9] stated that quality must be transformed into a value for all members so that their actions are guided by it. Hui
Hui and Tan [10] found that the leading causes of rework are poor quality management, improper planning, lack of communication, design changes, and poor subcontractor management. Some practical rework minimization approaches are also suggested to better manage and prevent rework toward enhanced project performance. Garg and Misra [11] evaluated available models' applicability for COQ calculations in the construction industry and presented a framework to estimate its components. The study also explored the interrelationship between the various components of COQ and presented a generalized relationship between COQ.

Egwunatum et al. [12] conducted a study that has assessed the practice level of TQM and the factors hindering TQM implementation on construction projects in Nigeria. This study took place in Imo state with records of periodic structural failure and building collapse.

3 Nonconformities in construction companies

According to Bernardes (1998), nonconformities in civil construction occur in three distinct phases, the first phase is during the execution of the work, the second is when the work is released, and the third is after the work is delivered. In the construction phase, the nonconforming outputs are controlled through service verification forms. Da Silva Santos [13] states that from the use of the sheets, it is possible to collect information and generate indicators such as services that generate most rework, stage of the work that generates most nonconformities, service suppliers' compliance with the work schedule, and suppliers' compliance with the quality of materials. In addition, with other tools such as the nonconformities report and internal and external audits, it is possible to identify several occurrences concerning the planning of the work, the projects, the controls used, and other production support processes. According to the PBQP-H standard [14], the construction company must keep documented information of the procedure for inspecting the final characteristics of the work before its delivery to confirm its conformity to the client's specifications and needs. To this end, the company must carry out the checks planned so that all arrangements are satisfactorily completed.

In their study, Machado and Vieira [15] demonstrated that in the post-work period, the pathologies that presented the highest incidence in the companies surveyed were related to the water and sanitary installations, which can be responsible for some cases, for infiltrations, leaks, and humidity. Many notes involving painting, cracks and fissures, and electrical installations were also verified, which may result from other pathologies. Dogan [16] reports that one of the aggravating factors in the construction industry concerning the recording of nonconformities is the construction team's lack of familiarity and experience in maintaining these records. Therefore, he proposed an automated operational model to alert nonconformities before their occurrence and provide an alert mechanism to those involved in quality. Thus actions are taken to prevent occurrences and not only for correction. Kumar's [17] study shows the

deficiencies and strengths of the companies when applying the project management techniques and tools; and prepared a guide to use them through specific recommendations to the construction sector.
Shaqour [18] study concluded that adopting lean construction approaches is essential in reducing waste and enhancing the Egyptian construction sector's performance. Kiani Mavi [19] found that the concept of sustainability should be included in construction projects from the early stages of design and feasibility studies and must be monitored throughout the project. Singh [20] studied the Visual Management tools that help improve the construction project's efficiency and value. Xing's [21] study found that project waiting times and defects can be reduced through implementing Lean Construction and that improving construction workflow along with project productivity and quality were the two most valuable benefits of using lean practices. Bottero [22] investigated the literature on the issues of construction costs in building production and urban development to identify the most relevant trends and describe the research context. The author shows the increasing importance of topics like BIM, LCA or Multicriteria analysis.

4 Methodology

This chapter presents the methodological structure used to prepare the study and its classification, the method, and the research design. The steps followed to obtain the responses to the questions are shown in the flowchart in Figure 1. Initially, the authors analyzed the theoretical framework and updated scientific literature on quality in civil construction, using the keywords: quality, civil construction, nonconformities, and rework. In the second step, they analyzed the construction company's data on rework in technical assistance requests before and after implementing nonconformities control. Data on costs with the technical assistance of the construction company under study were collected for analysis regarding the incidence of rework in the post-work phase and to observe whether the implementation of nonconformity control caused a decrease in these costs. In the third step, an interview was conducted at the construction site to validate the NC control process. In the fourth step, the authors surveyed employees on the relationship between nonconformities and rework in work execution. This survey was conducted to determine if a reduction of rework is being observed with the use of quality tools in the processes. It also allowed the analysis of the results of the methods and the proposal of improvements. In the fifth step, the survey results were reviewed. In the sixth, quality tools necessary to control nonconformities were identified. In the seventh, the actions for improvement and response to research questions were defined. The final step was implementing actions, issuing a Standard Procedure and revision of procedure for NC control.

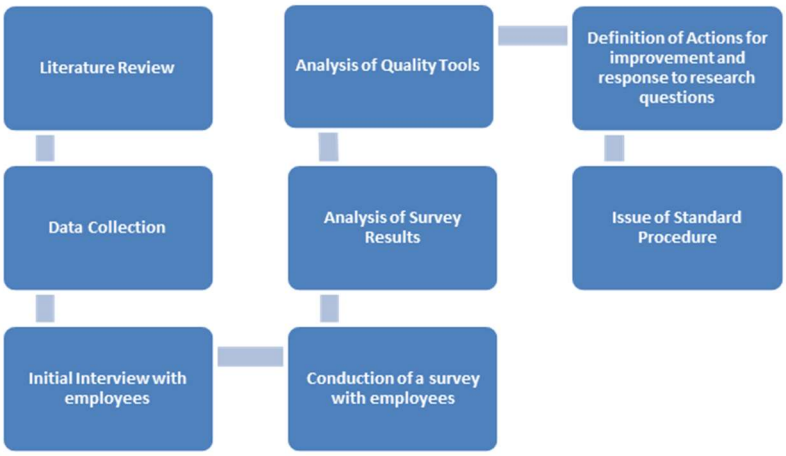

Fig. 1. Methodology Flowchart

5 Results

The company under study is a high-standard housing construction company located in Brazil. The company has been operating in the construction market for ten years. Approximately four years ago, it expanded its services to the high-standard construction segment, and since then, it has operated exclusively in this segment. The company offers the following services to its clients: project planning and execution, construction of high-standard houses, refurbishment of apartments, houses, and leisure areas with a refined finish, administration of the physical and financial resources of the works, administration of the documentation of the work during the construction period, and maintenance of the houses delivered. Searching to provide its clients with the best experience in the constructive process of their residence, the company started the implementation of the Quality Management System in 2019 based on the ISO 9001:2015 standard. Since then, the processes have been designed and described; there were several proposals for improvements, changes in habits, creation of standards, and training of employees, among other actions that allowed the certification in ISO 9001 in August 2021. According to the executive director, the end customer's certification is not required. However, it is a way to ensure that the company will keep its processes organized and controlled with the validation of an external body. All these dynamics are directed to the company's vision of expansion, of becoming a reference in the market for high-standard construction in Brazil. To this end, a strategic plan is developed and followed to achieve this vision, where the quality assurance of services and products provided through a functioning QMS was one of the first steps determined and achieved.

During the implementation of ISO 9001:2015, the company's processes were described in operational procedures to establish the standards to be followed. Besides the procedures, service instructions and control sheets also help execute the processes. Nonconformity controls and rework processes did not exist in the company before implementing the quality system. Then, it was necessary to develop and implement it to apply the continuous improvement methodology. The control of nonconformities is

described in an internal procedure named Improvement Management. The NC process flowchart is shown in Figure 2.

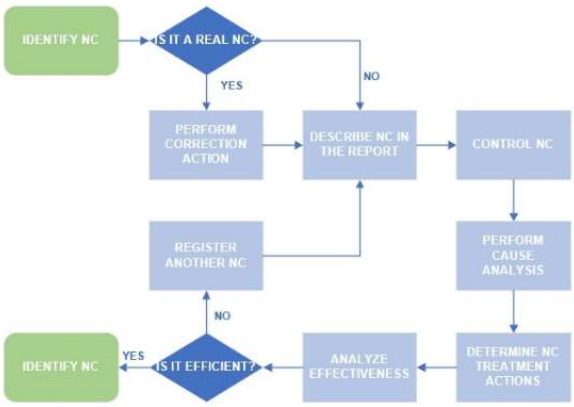

Fig. 2. Flowchart of the nonconformities control process

When identifying an NC, the employee identifies what type of nonconformity: actual, potential, or improvement action. If it is a real NC, it means that it has already occurred/is occurring, and it is necessary to minimize the impacts generated by performing corrective action. Then it is necessary to fill out the nonconformity report

In the first step of report completion, the place of occurrence and classification of the NC is described, as shown in Figure 6. There are three options for NC occurrences: process, product, or service, detected in different situations, from the performance of activities to external audits. The report completion shows how much the team has identified NC in executing its processes, thus demonstrating an acute sense and desire for continuous improvement by employees. The second step describes the nonconformity, classifying it as actual, potential, or an opportunity for improvement. The last entry refers to a suggestion for change in the process. The description explains what happened, and what might happen or improve. The cause analysis and subsequent action are not compulsory answers. If a collaborator does not immediately identify the cause of this NC, he/she does not have to answer when registering the RNC. The quality sector receives this information from the RNC record, analyzes whether such a record corresponds to a non-compliance, and records this information to control non-compliance. At this point, the root cause analysis is performed using the five whys tool with the sector in which the NC was identified, and, based on the cause, corrective action is determined to prevent its recurrence. When the nonconformities are more critical or very recurrent, a deeper analysis through the Ishikawa diagram tool is used to identify the causes. A prioritization comprises at least 20% of the causes that most impact the process. An action plan is elaborated for such nonconformity.

When all actions are completed, there is an effectiveness analysis to verify the improvement. If it is effective, the NC is considered completed; if not, another NC is opened so that the other causes are treated. The performance indicator of the process

Improvement management is obtained by closures of nonconformities. The target specified was to close a minor NC in 25 days on average and a major NC in 60 days. At the time of the study, this indicator stands at 76.21% (i.e., 76.21% of the NCs recorded were closed within the stipulated goals) with an average of 25.45 days to close an NC. This indicator aims to stimulate the sense of urgency in the quality team to take action as soon as possible to treat a nonconformity. This motivation within a construction company is valid since the same process is repeated in other construction sites in a short period. The sooner the root cause is identified, treated systematically, and communicated to other construction managers, the lower the probability of recurrence. The quality sector monitors the effectiveness of the adopted actions, and the criteria adopted for such analysis vary according to the NC. This analysis can be either passive (evaluation by recurrence criteria) or active (evaluation by interviews, samples, simulations), being the department manager's responsibility to define what best applies in each case. Improvements were made in the NC process based on the employee survey results.

Figure shows the trend of costs with techncal assistance after implementation of improvement actions , in the first year of delivery of high-end residences there was the highest cost with technical assistance, a result that was expected since the company was new in the sector, there were no defined processes and no operational experience in the industry. At the end of 2019, the Quality Management System was implemented. However, the system was only used in all its aspects in 2020, when there was a noticeable drop in requests for technical assistance. In 2020, the preventive maintenance plan started to be adopted in the homes delivered. The control of nonconformities caused an even more significant drop in assistance costs, reflecting the result of the first half of 2021, which is 1.47% of the monthly billing.

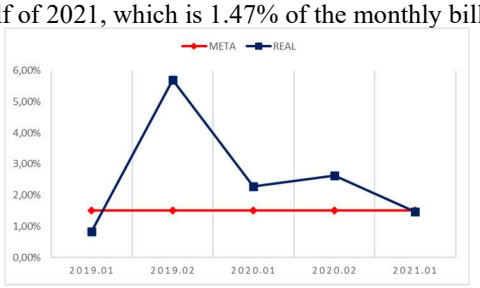

Fig. 3. Costs with technical assistance

Aiming to identify the relationship between Nonconformities and Rework, a survey was conducted with employees to assess the team's awareness of the importance of nonconformity records and their participation in the process. The survey was conducted using a Google form and was responded to by 24 direct employees. The research sample population was 60 employees, not considering service providers. Most participants have been with the company for more than a year. They are from the engineering and construction sectors, as shown in Figures 4 and 5, which means that they have followed the implementation process of the quality sector since its beginning.

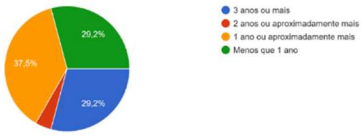

Fig. 4. Respondents time in the company

The survey also identifies the participants' sector of activity n the studied company.

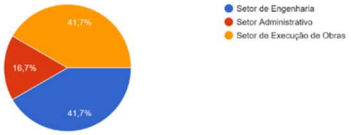

Fig. 5. Participants' sector of activity

Figure 5 shows that 62.5% said they have already registered a nonconformity concerning their process. Of this population, 60.9% said they had a positive experience with treating a registered nonconformity. However, more than half of the interviewees are collaborating with process improvement from the records of nonconformities. This number needed to be improved because it indicated that people still did not understand the importance of such records. Another critical factor is that approximately 39.1% of respondents who have already registered a nonconformity did not have a positive experience regarding the treatment adopted, indicating that it was necessary to communicate more about the actions adopted and engage the whole team in determining these actions. A tool that could be used to improve this aspect would be the adoption of brainstorming at this stage. The survey questions were used to identify opportunities for improvement, as shown in Table 1.

Table 1. Survey Questions

Factors	Questions
IMPORTANCE OF NC CONTROL	Do you understand the importance of controlling nonconformities?
IMPROVEMENT IN PROCESSES FROM NC CONTROL	Do you believe that the register of nonconformities in your operational process improves the process?
CHANGES IN METHODS STARTING WITH NC	Have you witnessed changes in the company's methods from registering a nonconformity?
IMPORTANCE OF REWORK REDUCTION	Do you understand the importance of avoiding rework in the processes?

EFFECTIVENESS OF NC CONTROL	Do you believe that it will be treated when you register a nonconformity so that it does not happen again?
REDUCTION OF REWORK STARTING WITH NC	Do you believe that the control of nonconformities can reduce the operational rework in the company?

Figure 6 shows the survey results. The participants had the following response options: very, enough, not enough, and very little. The results from the survey shows that: 1 - Most of the participants understand the importance of controlling nonconformities; 2 - Most of the participants believe that there is improvement in processes from the control of nonconformities, but there are still people who do not believe; 3 - The number of those who have witnessed many changes in methods is lower than those who strongly believe that there are process improvements, indicating a particular discrepancy between what is believed and what occurs; 4 - Everyone understands the importance of reducing rework; 5 - Few believe very much that a nonconformity will not occur again and many believe that NC control can reduce process rework. The survey clarified the team's awareness and level of understanding and participation regarding the control of nonconformities and rework. The company has an effective nonconformity control. Most of the team participates in this process, contributing by recording the nonconformities. However, it is noticeable that there are still people who do not understand such importance and have not yet registered a nonconformity. As a suggestion for improvement, we can highlight the following actions: 1 - Carry out more training on NC and rework with the team; 2 - Increase the communication of improvements made from the nonconformities; 3 - Present to the employees which nonconformities had the most impact on their process; 4 - Orient the company's leadership as to the incentive and engagement of their subordinates in the quality processes.

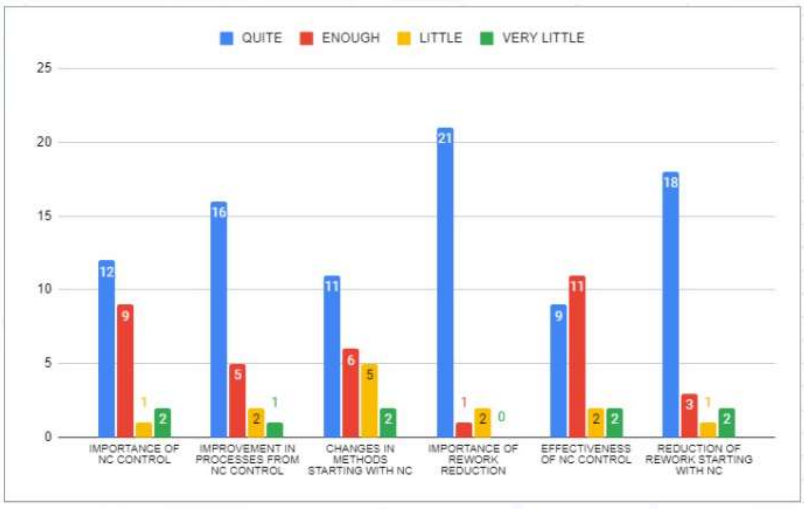

Fig. 6. Survey results.

6 Discussion of Results

The results show that the company managed to reduce its cost with technical assistance even with the increase in the number of projects delivered and consequently a higher probability of requests for technical assistance. This results from improvements applied to the process, such as the structuring of construction processes and improvements from the control of nonconformities and new proposals adopted as the use of a preventive maintenance plan in the first year after the delivery of a residence.

It can be seen that the rework rate is still low in the initial phase of construction, but the rate of nonconforming outputs is not so high. The sheets are essential tools for identifying flaws in the execution of each stage of the process and, therefore, should be used in all inspections carried out on site. Because it is a new process, it is understood that although the indexes indicate that rework is within the expected levels, there are risks related to this inspection, such as the company's lack of experience in using such a document. There is a possible lack of clarity in the criteria to be inspected and the definition of acceptable levels.

The data show the maturity level and knowledge of the team regarding the control of nonconformities and their relationship with the company's rework. It can be seen that the team understands the importance of the existing controls and that it is still necessary to improve the process of nonconformity control. It is necessary to engage better participation in the nonconformity records of the processes. Most of the team believes in this correlation regarding the relationship between nonconformity control and reduction of rework. Thus, the team's engagement in the nonconformity registry occurs more easily since they understand the main consequence of an effective process of nonconformity control, which is the reduction of rework..

7 Conclusion

According to the results and considering the methodological guidelines and analyzing the literature, it was possible to conclude that quality tools in the control of nonconformities directly influence the rework. It generates a mentality of continuous improvement in those involved in the processes and analyzing the actions taken to treat the nonconformities.

In response to the first research question, *"What is the importance of implementing a quality management system in construction companies and the cause of rework?"*. The conclusion is that on meeting the requirements of ISO 9001:2015, the construction company developed a culture that directly influences the efficiency of its processes once it developed continuous improvement, nonconformities analysis, process performance monitoring, and team engagement. In addition, the ISO 9001:2015 certification promoted a sense of commitment from all employees to maintain the application of the methodologies proposed by quality. The fact that internal and external audits are carried out periodically signals which aspects of the processes still

need to be improved, ensuring that the processes are efficient. As for rework, many factors directly influence it, such as the lack of a defined stage execution process, project flaws, and flaws in the execution process that culminate in requests for technical assistance, among others.

Regarding the second research question: *"How does the treatment of non-conformities influence the reduction of rework in the construction processes?"*. The conclusion is that monitoring technical assistance is vital, and it allows the maintenance of the improvement cycle of the work. Service instructions ensure that such execution failures do not happen again. Another critical factor is monitoring each stage of work execution using Service Verification Sheets, which bring actual parameters for the rework indicators and show improvements to be adopted. Thus, both the technical assistance and the service check sheets raise critical nonconformities in the execution process. Once controlled and treated with the adoption of a corrective action plan, it reduces the incidence of such nonconformities in the assistance and the execution of the work and directly reduces rework. Therefore, these processes complement each other and generate a cycle of constant improvement.

In response to the third research question, *"What is the effective method for handling nonconformities?"*. The conclusion is that using some quality tools such as root cause analysis based on the five whys and the development of the Ishikawa diagram allows the identification of the root causes that most impact the occurrence of such nonconformity. From this, it is necessary to prioritize the causes and perform brainstorming to determine the action plan. Finally, after the actions are completed, it is necessary to analyze the effectiveness of the treatment. It was observed that many team members do not realize the results of the process. It is suggested the integration of all involved in the process. It is crucial to determine the action and analysis of effectiveness so that everyone is aware of what was effective or not, thus improving the internal communication regarding the nonconformities and increasing the effectiveness of this control.

In response to the fourth research question, *"What are the challenges to maintaining quality in construction companies?"*. The main factor raised from the survey with employees is the team's involvement in the quality management process. Quality can only be maintained if everyone involved participates effectively in the proposed improvement processes. The participation happens with the registration of nonconformity, the knowledge and use of the service instructions and operational procedures, participation in training, and suggestion of process improvements. The awareness of trying to perform their services in the best possible way with a critical sense capable of identifying bottlenecks and suggesting changes is also critical.

Based on this work, several future studies can be carried out, such as: 1 - the analysis of the risks tied to the control of nonconformities in the processes of execution of works; 2 - the implementation of Lean Construction in small construction companies to reduce waste; 3 automation of the Quality Management System in construction companies to ensure the effectiveness of records and maintenance of controls.

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