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Non-Compliance in Civil Construction Projects: A Case Study In the "My House My Life" Program

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ABSTRACT
The use of the method allows achieving both the improvement of the performance of the processes, in the execution phase of the work, as in the subsequent phase, as it presupposes the concept of correction of non-conformities as a continuous process, analytically based and subsidiary to the corrective measures adopted. Permanent control allows not only to avoid new non-compliant situations, but also to develop a database that enables the constant improvement of performance monitoring processes and methods. In this way, through the feedback of the process to other projects, it is intended to reduce the rate of construction pathologies in order to encourage the continuous improvement of quality in housing projects in Civil Construction. The research demonstrates that the use of the DMAIC method allows to improve procedures and techniques in a project, resulting in continuous learning, which is one of the bases for improving the quality of processes and a requirement for their reproducibility.
Keywords Improvement, Development, Lawsuit.

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I. INTRODUCTION

The Six Sigma methodology proposes performance improvement through the use of tools for designing and monitoring your routine activities, from basic activities to highly complex activities. As a result of this control, process variability is eliminated, reducing costs, wasted resources, inputs and labor and, above all, leverages the results of customer satisfaction.

The Six Sigma methodology proposes methods for process redesign, so that errors and defects do not exist, thus improving communication with the customer, work team and other interested parties.

This methodology presents the DMAIC as a tool, the steps of defining, measuring, analyzing, improving and controlling, developed for one of the housing constructions processes of the My Home My Life. (PMCMV).

In civil construction, there is a concern with the waste of materials and the quality of services provided to the population. The non-compliance of the processes, can, in a way, compromise the safety of the prone residents of the. Residencial Parque Poranga II, in Itacoatiara, AM and Residencial Manacapuru, in Manacapuru, AM. Non-conformities are one of the main problems related to process failures, in addition to not meeting quality requirements and standards, they represent risks to the work, establish critical vulnerabilities with regard to safety and reliability standards in project execution.

II. LITERATURE REVIEW

II.1 QUALITY IN ITS VARIOUS DIMENSIONS

The concern with quality is not new. Four different phases of quality can be identified: era of inspection; statistical quality control; quality assurance; and strategic quality management [11].

The development of quality-oriented work processes and methods only came to be accompanied by in-depth theoretical studies in the 1940s and 1950s in the United States, highlighting the Cost of Quality Theory (COQ) and the theory of Joseph Juran's reliability engineering, as well as Armand Feigenbaum's total quality control and Phillip Crosby's zero defect approach. They jointly established tools that basically aimed to highlight the possibility of reducing total quality costs with greater investment in preventing errors and defects in the production process [6].

The costs with quality can be situated in two dimensions: costs for obtaining quality in order to meet the demands and demands of customers (quality control processes), and the costs of non-quality, resulting from failures or errors in quality control [3].

This conception can be expanded when considering a quality product or service as the result of a process in which there is an absence of failures, linked to low cost [3].

From this point of view, quality is more than the characteristic of the product or service itself, or the customer's perception of what is offered to him, as it covers aspects intrinsic to the generation of the product or service, involving the management of different processes and activities along the path from its idealization or planning to the final delivery [19].

II.2 QUALITY ASSURANCE BASED ON PROCESS MONITORING

A concept of quality cannot be formed from the use of the word in everyday life. Usually, the term refers to the characteristic of an object or service in isolation. But, in a broader sense, quality can be considered as a result of the interaction between the organization and its customers [10].

Consumer satisfaction tends to be seen as one of the points aimed at quality management, however, it is difficult, if not impossible, to effectively understand the whole set of perceptions, feelings, expectations of each customer to offer him fully what he expects or presupposes to want, because it is difficult to control or achieve the precise meaning of the expectation formulated subjectively by him. As a result, companies must define what they can effectively offer, and how it should be achieved, so that they can deliver only what they promise [1].

Therefore, quality management must focus on obtaining satisfactory performance at all stages of creating a product or service, in order to achieve a result defined in terms of final quality. But these results are only achieved if all organizational processes are coordinated from a management process capable of defining common objectives, to be shared by everyone in the various sectors, processes and activities [10].

Therefore, quality indicators make it possible to obtain qualitative and quantitative data on the characteristics of processes and products [31], and the analysis of the results provides subsidies for decision making on what can be improved or the which must be maintained if the quality is considered satisfactory.

Three groups of quality indicators must be considered when analyzing a process, according to its purpose or applicability [8]:

– Indicators to assess product quality: both the quality of the product, resulting from the production chain as a whole, and the intermediate products, generated in the various processes, involving the following items: specific characteristics; price; availability; expenses with the offered guarantee; number of products returned by units sold; evaluation of consumers and specialized magazines;

– Indicators to assess the quality of the production process: defect index at the end of the process; rework in relation to the total produced; rejected products in relation to the total produced; days of production lost due to unforeseen interruptions;

– Supplier quality: supplier quality rate (parameters to be defined according to the characteristics of each supplier, in the various links in the chain).

II.3 QUALITY IN SERVICES

The concern with quality is not only in the field of the production of goods, but also in the provision of services, whose nature is essentially intangible, that is, they are not usually physical products, although they can be associated with a material item [14].

Services take different forms in terms of their provision or destination, which allows distinguishing their characteristics: simultaneity (they are consumed almost simultaneously when they are produced); intangibility (they are not material, physical as a product, so they cannot be transported or stored); heterogeneity (they can take many forms, making standardization difficult [23].

The management of quality in services implies considering that these are not added to inventories, like products. Although they are not material, they can be evaluated in terms of quality, as they have visible and measurable repercussions for final consumers [24].

Service quality must be prioritized as a way of adding value to the offer, an essential strategic objective because it is related to the perception and satisfaction of consumers, and can be identified in the delivery or provision, depending directly on the performance of the frontline staff, that is, those responsible for these processes [12].

The subjectivity issue has a strong influence on the provision of services, as quality is linked to the person who performs it. Therefore, quality management in this case depends on a detailed analysis of the specific processes involved, being indirectly assessed based on the perception of the final recipients (consumers) [8].

In the search for quality, the so-called tools that can be understood as instruments for quality management have gained prominence, involving techniques and methods applied to tasks or processes that make it possible to obtain improvements and positive effects [35].

II.4 QUALITY IN CIVIL CONSTRUCTION

A milestone in the establishment of quality standards for civil construction in Brazil was the integration of Caixa Econômica Federal into the Brazilian-CEF Habitat Quality and Productivity Program (PBQP-H) in 2000. Construction companies were now required to obtain certification quality as a requirement for access to finance. As a result, construction companies began to worry about developing their own programs and standards to ensure the alignment of their activities and results with compliance requirements and performance standards [15].

The Qualification System for Civil Construction Service and Construction Companies - SiQ, transformed in 2005 into the Conformity Assessment System for Civil Construction Service and Construction Companies - SIAC, defines the general certification rules, with deployment to different specifications in the area of civil construction, with the National Institute of Metrology, Quality and Technology - INMETRO, defining the list of controlled materials and services and establishing rules to qualify auditors and specialist technicians.

Generally, the implantation of a quality system starts with the definition of the processes, in order to define previously the procedures to be observed in the execution of the PES services - Service Execution Procedure, which will base the verification and the work of validation of activities based on the technical standards in force responsible for the standardization of construction processes. The team responsible for the inspection must be fully aware of the PES, and those in charge of execution must also know the requirements or requirements in the execution of the service [17].

Here, the concept of process is adopted in the sense of work activities organized in time and space, with well-defined inputs and outputs that delimit the structural set of all actions within the scope of the execution of planning decisions and formulations [14].

II.5 GUT MATRIX

The GUT matrix is a tool widely used by companies to prioritize the problems that must be tackled by management, as well as to analyze the priority that certain activities must be carried out and developed [9].

The great advantage of using the GUT Matrix is that it helps the manager to quantitatively assess the company's problems, making it possible to prioritize corrective and preventive actions [9].

As for the main aspects, [9] makes the following classification: − Severity: It says how much is the weight of the difficulty analyzed in case it occurs. Certain characteristics are analyzed, such as: tasks, people, results, 34 processes, organizations, etc. studying the results in the medium and long term, if it is not solved beforehand; − Urgency: The amount of time you have or need to resolve the task. The greater the urgency, the less time available to remedy the problem. It is recommended to ask: "Can the solution of this cause wait or does it need to be done immediately?"; − Trend: Refers to the possibility of increasing the problem, the circumstance of the issue growing over time.

It is recommended to ask: "If you don't solve this problem soon, will it worsen gradually or suddenly?". To obtain the value of the priorities, just make the product between the assigned grades as follows: (G) x (U) x (T). This score goes from 1 to 5, the result of the multiplication will give the level of action that the problem must have, that is, from the biggest to the smallest.

II.6 SIX SIGMA (6σ)

According to [36], Six Sigma is a disciplined and quantitative management strategy, with the objective of maximizing the performance and profitability of companies, by improving the quality of products and processes and increasing customer and consumer satisfaction.

The Six Sigma approach speaks of quality gains, calculated based on the results of the Six Sigma projects. This assessment is generally carried out by accounting sectors, based on techniques of economic evaluation of projects such as present value analysis [27].

For authors like [22], Six Sigma is more than a methodology, being considered a benchmarking tool, a goal, a measure, a philosophy, a statistic, a strategy, a value and a mission.

According to [16], Six Sigma is a standard for measuring product variations studied since the 1920s by Walter Shewart, which demonstrated that the processes with necessary corrections, presented a variation greater than or equal to three sigmas of your correction average.

According to [20], Six Sigma: A broad and flexible system for achieving, sustaining and maximizing business success. Six Sigma is solely guided by a good understanding of customer requirements, by the disciplined use of facts, data and statistical analysis, and by diligent attention to the management, improvement and reinvention of business processes.

The Six Sigma methodology is linked to indicators on the capacity of the process under analysis. The Greek letter σ (sigma) expresses the measure of process capacity, relative to the number of standard deviations from the process that deviate from the limits of the tolerable value of defects [29].

The effectiveness of operational actions aimed at quality depends first of all on the choice of tools and techniques for the improvement of processes and quality, followed by the definition of reliability goals and, finally, the analysis of failures or execution errors, to establish new quality indexes, in addition to defining programs and methods so that improvement is continuous. [18].

More effective processes can be achieved through the use of tools and procedures related to the Six Sigma methodology, as it presupposes the focus on changes and results, reducing variations in the process resulting in a performance lower than what can be achieved [25].

[21] They mention some benefits brought by Six Sigma that make companies adopt this methodology:

– generates sustained success - the method creates skills and cultures for constant reinvigoration;

– determines a performance goal for everyone - uses the process and the client as a common basis to create a consistent goal, the performance level should be as close to perfect as people can imagine;

Intensifies value for customers - according to the author, focus on the customer is the priority of the method, it means learning the meaning of value for customers and planning how it will become profitable;

– accelerates the rate of improvement - with market competition, the method assists in improving performance and continuous improvement;

– promotes learning and "cross-pollination" - the method accelerates the training and development of employees and shares new knowledge throughout the organization;

– executes strategic changes - investments in new markets, products and the launch of new ventures become more reliable with the understanding and analysis through this method.

II.7 THE DMAIC TECHNIQUE AS A TOOL OF THE SIX SIGMA METHODOLOGY

DMAIC is used to improve existing products and services, being structured to achieve the capacity goals of the Six Sigma program through five phases: Define - define, Measure - measure, Analyze - analyze, Improve - improve and Control – control (DMAIC). This method is also called the "Performance Improvement Model" and is the most widespread in companies. In the defining phase, customers and their needs are identified; in the phase measuring processes are measured and performance is analyzed; in the analysis phase, the causes of the main defects are verified; in the improve phase, ways to eliminate the causes of defects are analyzed; and in the control phase, it is verified whether the improvements implemented are under control in order to maintain the benefits achieved [4].

DMAIC can be considered as a continuous effort to optimize the performance of processes and establish new ways of controlling operational performance, based on the identification and analysis of results considered inadequate or undesirable, with priority in solving problems [26].

The use of the DMAIC model is very useful, not only to find the causes of performance problems and define corrective actions, but also to improve the performance of processes and people over time, since it is not focused only on the statistical analysis of process variations and effects on operational performance, but prioritizes the search for the most adequate means of sustainability of the suggested improvements [28].

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According to [34], "all work is a process, all processes have variations and all processes create data that explains such variations". To improve services and product quality, continuous improvement is used through the DMAIC process, where:

– Define - definition of the project scope;
– Measure - definition of the location and / or focus on the problem;
– Analyze - Determination of the priority causes of the problem;
– Improve - Propose / implement solutions to a specific problem;
– Control - Guarantee the achievement of the stipulated goal.

II.8 DMAIC EMPLOYMENT IN CIVIL CONSTRUCTION

Civil construction processes are not equated with industrial processes, an area for which the Six Sigma methodology and DMAIC were created. It is an outdoor activity, which is affected by external conditions and is less repetitive than the manufacturing process [13].

A problem arises when there is a distinction between what "should be" and what "is"; between the optimum and definitive situation, that is, the difference between the expected and the actual situation realized. It is directly or indirectly related to an expected result or pattern of behavior. The clear and accurate description of the problem is the first step in implementing process improvement actions [30].

The necessary analyzes and decision-making about the changes can be carried out using the Six Sigma DMAIC model. Its application allows to know the factors and effects related to the civil construction processes that affect its quality, to then design actions that will allow to correct and improve the processes [32].

The importance of using the DMAIC methodology in the management of civil construction processes is in the fact that in this area, when a problem is found only after the actions have been carried out, the price of its correction is high, which makes quality management essential. based on the concern with the quality of all processes, and not only in relation to the final product (results), in order to avoid costs, improve safety and ensure the effective adaptation to the technical requirements from the beginning to the end of the project execution [33].

Lean construction refers to the projection and operation of processes correctly, in the same way that lean manufacturing refers to the control of resources according to the needs of the client, reducing waste with additional activities that do not add value (wasting time) [2].

III. METHODS

This research was developed using the Six Sigma method, through the DMAIC technique, consisting of a structured instrument, of systematic, proactive and quantitative application, which allowed, from the data collection to determine the critical problems of non-conformities in civil construction, the its causes and the possibilities of improvement from a corrective, and also proactive, point of view, since the results achieved provide references and action criteria that allow for the improvement of continuous control and ensure the compliance of processes with technical requirements, which can be considered in new ventures.

In general, the investigation was carried out in a qualitative and quantitative way, adopting an analytical procedure through personal observations, application of forms and data collection, having been used in the theoretical foundation of the research, the bibliographic technique that consists of tracking significant content , available from different sources, and which contain material that is relevant from the point of view of knowledge production, such as books, magazines or periodicals, among other sources.

For this research, the bibliographic technique consisted of visiting libraries to select books of interest for their relevance to the theme of this work, in addition to consulting sources (databases) on the electronic network (Internet), such as Scientific Electronic Library Online (SCIELO) and Google Scholar, as well as sites and articles not attached, in Portuguese and English.

The bibliographical research involved the contact with the bibliographic production in the area of quality management, techniques and methodologies, making it possible to obtain data to present the theoretical bases of this research from the selected literature.

The following descriptors were used to screen the publications: quality; constructive quality; non-conformities in construction projects; continuous improvement; Six Sigma; DMAIC methodology and DMAIC methodology applied in civil construction.

Based on the DMAIC methodology, we use its tools to develop the work, following the steps and tools below:

– Define - Project charter, data collection instrument, process mapping - SIPOC, CTC tree;

– Measure – Record of non-conformities (data collected);

– Analyze - Process analysis to determine the root causes of problems, ishikawa chart, logical tree defining critical problems;

– Improve- Action Plan;

– Control - Training and monitoring of the action plan.

Mapping and fieldwork were carried out between the months of January/2019 to December/2020, important to observe and collect data relevant to the research.

In order to obtain the official data, the documents provided by the construction companies and by Caixa Econômica Federal, the government financing agency for the works, were considered. Information that was important for the development of the research.

The descriptive scope for this research was defined based on the processes related to the execution of the works of the aforementioned residential buildings, delimiting the central issues to be investigated:

– Know the root causes of problems (non-conformities) identified;

– Identify possible solutions to correct detected non-conformities and avoid new occurrences, ensuring the reliability of processes;

– Determine what benefits can be achieved with the correction or elimination of non-conformities in the processes.

Following the approach and steps of DMAIC, the construction of the work was carried out as follows:

III.1 Problem Definition (Define)

Following the DMAIC approach, the first step in data collection was to determine the root problem. Through a meeting, in the form of brainstorming, held with the engineers of two projects of the "My home, My life" Program in the state of Amazonas, pertaining to the construction of Residencial Parque Poranga II, in Itacoatiara, AM, and Residencial Manacapuru, in Manacapuru, AM, a critical analysis of the problems registered in the execution phase of the works was carried out, based on the following questions:

– Does the execution of the works meet all technical specifications at the time of completion/delivery?

– Are the processes being carried out properly from the standpoint of effectiveness of actions?

– Are there variations in process outcomes that denote the need for change or corrective action?

From these questions, we carried out the initial mapping of the process through SIPOC, and determined the non-conformities and the most critical problems, with the help of the engineers responsible for the works, the processes to be analyzed related to these constructive non-conformities were defined, leading to account the following aspects:

– What are the process?

– How are process inputs turned into outputs? Set in four or more steps maximum.

– What are the entries?

– Who are the suppliers?

– Who are the final customers/recipients.

It is only possible to promote continuous improvement by analyzing all the factors that make up its processes. Often, a problem identified at the end of the production line originates from the first step of the process. It is necessary to know the process well, understand the inputs, outputs and the order in which things happen to act on the fault points. From that moment on, we defined the key indicators for the monitoring and analysis of the processes, CTC tree.

III.2 Measurement (Measuring)

In this phase, detailed data was gathered to identify the dimension of the problem, which would subsequently allow for a direct comparison of the performance of the processes, before and after the implementation of the improvements.

For this purpose, brainstorming was carried out in order to gather information about non-compliance events, with the support of engineers and data sheets obtained from the non-compliance reports prepared during the execution of the projects, which made it possible to identify the different events characterizing situations not compatible with the technical requirements and specifications.

In this way, it was possible to determine the quantity (number of registered events) and the types of non-conformities verified in the execution of the projects, obtaining the description of the types of non-conforming occurrences and their respective quantities in each project, thus determining their absolute frequency and its relative frequency.

III.3 Analysis (Analyze)

Using a stratification tool, it was possible to quantify and statistically represent the non-compliance events in the project execution phase, and through the Pareto chart the most important causes of these problems were delimited in order to identify the defects that most contributed to the non-compliance with technical specifications and had a greater impact on construction quality.

After surveying the main problems, using the Ishikawa diagram, the causes and their repercussions were delimited. Through this analysis tool, the probable causes of each of the most recurrent non-conformities were listed, enabling a quick view of the factors and respective effects.

Once the various problems and their effects on the processes were defined, a logical tree was created to delimit the most critical problems to be corrected.

III.4 Implementation of Improvements (Improve)

Once the most critical problems were identified, an action plan, 5W2H, was drawn up to detail the corrective measures and their purpose (justification), with the aim of eliminating the main causes of problems related to the most recurrent non-conformities , to reach a satisfactory level of quality, compatible with the requirements and technical specifications of the constructions.

In this case, the focus was not only on the correction of non-conformities with the greatest impact on the construction process, but also on the definition of corrective actions, taking into account that they are measures that are not confused. Fixing the non-compliance prioritizes the non-recurrence of problems.

Therefore, once the causes and effects of non-conformities were identified, the actions to correct the non-conformity were defined, to make the necessary changes feasible, not only to solve the identified problems, but also to avoid their repetition in new projects.

III.5 Control

The definition of a control plan is essential to verify the various preventive measures that will help to achieve the desired result, that is, the elimination of non-conformities in projects and also in new ventures.

For this, we elaborate an action plan for the necessary training, after all, it is necessary to establish which procedures, checks or activities must be carried out considering the specifications and expected performance of the processes.

Having defined the most frequent non-conformities or those with the greatest impact on the projects that were the object of the research, corrective criteria were established, such as solving the problems identified, to improve the quality of construction and ensure the alignment of processes and activities related to the execution of projects with the specifications and the technical requirements.

Since the corrective actions related to the projects under analysis constitute the final phase of intervention in the construction elements that were already in the final phase for the delivery of the work, it was not possible to establish a statistical control to continue the analysis of the results obtained in terms of results involving the same critical problems that were the target of improvement actions.

Chapter 4 presents the results of the research, the analysis of the results obtained with the application of the data collection instrument covering all phases of the DMAIC method and the quality tools used according to the methodology presented in this dissertation.

IV. RESULTS AND DISCUSSION

IV.1 CASE STUDY: RESIDENTIAL PARQUE PORANGA II AND RESIDENTIAL MANACAPURU

IV.1.1 Define Phase

Following the described methodology, an Opening Term for the Project of Residencial Parque Poranga II and Residencial Manacapuru was drawn up, where the macro gram, restrictions to the project, with pre-established objectives and targets was established. It is an agreement between the project's executing team, the person responsible for the actions and the construction company's managers. The objective is to keep the team aligned with the project's focus, formalizing the main definitions of the work through the schedule.

The initial mapping of processes – SIPOC (Appendix A), in turn, consisted of better clarifying the stages of the process, while the CTC tree made it possible to transform the customer's needs into indicators of the improvement project.

IV.1.2 SIPOC Mapping

After defining the processes to be analyzed and answered the questions regarding non-conformities, the following questions were asked:

– What are the outputs of the process?

– How are process inputs turned into outputs?

– What are the entries?

– Who are the suppliers?

– Who are the final customers/recipients.

It is only possible to promote continuous improvement by analyzing all the factors that make up its processes. Often, a problem identified at the end of the production line originates from the first step of the process. It is necessary to know the process well, understand the inputs, outputs and the order in which things happen to act on the fault points.

IV.1.3 Voice of Customer – CTC Tree

Using the CTC Tree, it was defined as transforming what the customer needs into Improvement Project indicators, making it possible to define the key indicators for monitoring and analyzing processes. As shown in Fig. 4.1.

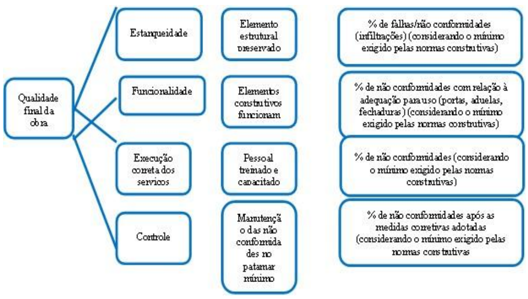

Figure 4.1 – CTC tree. Introducing indicators to assess the drivers of customer needs

Fig. 4.1 shows the measures adopted to correct non-conformities, based on the final quality of the work. Tightness was presented as preserved constructive elements, in addition to the % of failures/nonconformities (leakage), considering the minimum required by the standards.

Functionalities, correct execution of services and control were analyzed, observing the need for training of personnel involved in the process and considering the % of non-conformities after the corrective measures adopted, considering the minimum required by construction standards. In this way, it is possible to implement corrections and improvements in the execution of the process.

IV.2 CASE STUDY 1- RESIDENTIAL PARQUE PORANGA II

IV.2.1 Measure Phase

Access to the records provided by the engineers at Residencial Parque Poranga II, allowed us to determine the type and amount of non-conformities recorded during the project's execution.

Among the non-conformities found in the execution phase of Residencial Parque Poranga, those with the highest number of occurrences stand out, such as loose tiles and cracks with 54 occurrences of non-conformity, the peeling of ceramics due to mortar with 32 occurrences and infiltration due to poor execution in the pipe or cracks with 25 occurrences, with 189 being the general total of occurrences due to non-conformity in the process.

The data collection instrument with the main items of non-compliance recorded in the execution phase of the Parque Poranga II project are described in Table 4.1.

Table 4.1 -Non-conformities recorded in the execution phase of the Residencial Parque Poranga II project.

Não conformidades na fase de execução dos projetos e execução	Freqüência Absoluta	Freqüência Relativa %
Total de Não Conformidades Registradas	189	100
Telhas soltas e fissuradas	54	29,00
Desplacamento de cerâmica por conta da argamassa	32	17,00
Infiltrações por conta de má execução na tubulação ou trincas	25	13,50
Pisos trincados, manchados	19	10,50
Trincas e fissuras nas paredes	18	9,89
Contra piso e cerâmica - caimento com queda fora do ralo	13	6,88
Forros de PVC	12	6,35
Portas, aduelas e fechaduras	8	4,23
Pintura - empolamentos, descascamento ou alteração de cor	5	2,65
Ensaios de graute, argamassa e prismas não-conformes com os lotes	NA	NA
Compressão do concreto não atingiu a resistência mínima 28 dias	NA	NA
Impermeabilização do WC	NA	NA
Sistema de aquecimento solar	NA	NA
Instalações embutidas e vedações	NA	NA

Source: Authors

IV.2.2 Analyze Phase

Once the non-conformities and the number of events (number of occurrences) in the execution of the project have been identified, it is necessary to measure the impact of the data on the whole. in descending order, as well as identifying the most critical problems in the construction process that should be tackled as a priority due to the greatest impact on project execution results in terms of costs, time and rework. In the specific case, despite the Pareto rule having 80/20 as a principle, that is, 80% of the errors come from 20% of the items, due to the large dispersion of non-conformities, the maximum possible number of treatment was prioritized and that generate a strong impact on the result, therefore loose or cracked tiles; Ceramic peeling; Infiltrations were the three most frequent problems in the execution of the Residencial Parque Poranga II project and correspond to 58.72% of the total non-conformities. That's why they were prioritized. As shown in Fig. 4.2.

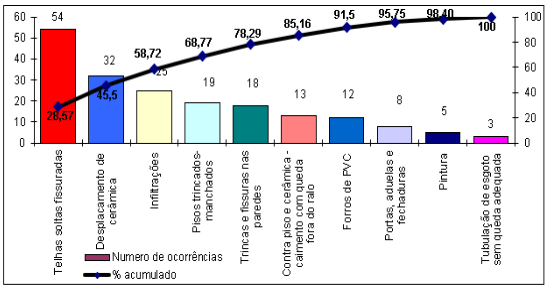

Figure 4.2 - Pareto Chart - Most frequent non-conformities recorded in the execution of the works of Residencial Parque Poranga II.

In Fig. 4.2, it is possible to clearly visualize the non-conformities that had the highest number of occurrences, thus demonstrating the need for correction in these steps.

Also based on data collected from non-conformities at Residencial Parque Poranga II in Itacoatiara, the NP letter of occurrence was drawn up. As shown in Fig. 4.3.

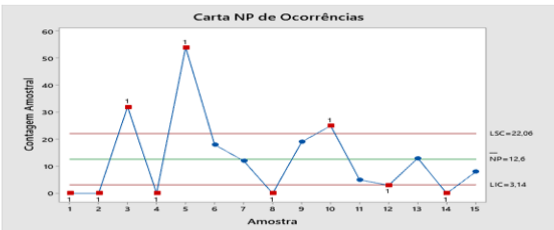

Figure 4.3 – NP letter of occurrences of non-conformities registered in the execution of the works of Residencial Parque Poranga II.

In Fig. 4.3 it is possible to observe the test results for the NP letter of occurrences. The test fails at points 1;2;3;4;5;8;10;12 and 14.

This chart was used in order to know the number of non-conforming items, instead of knowing the proportion of defective items. It transparently demonstrates the variability of the process, making visible the points that need to be addressed with priority. The visualization of the result of the NP letter corroborates and validates the Pareto results, making even clearer the items that must be worked on immediately.

From the validation, by measurement tools mentioned above, of the most frequent events of non-conformity to be primarily attacked, the analysis was carried out, using the stratification tool, to determine the causes of failures or errors in the execution of the construction process and its effects, and the variables to be considered for the quality and alignment of the process, with the technical specifications of the Residencial Parque Poranga II projects for non-conformities of loose or cracked tiles. As shown in Fig. 4.4.

Figure 4.4 – Ishikawa for loose or cracked tiles.

Fig. 4.4 shows the Ishikawa graph for non-conformities of loose or cracked tiles regarding material, personnel, environment, methods and machines.

The Ishikawa chart was also used to analyze the non-conformity of the removal of ceramics with regard to the material used and the personnel involved in the process. To the environment, methods and machines. Several non-conformities can be observed in the graph, allowing correction in the process of execution of the work at Residencial Parque Poranga II in Itacoatiara in Amazonas. As shown in Fig. 4.5.

Fig. 4.5 shows the Ishikawa graph for the non-conformity of the peeling of the ceramic regarding the material used as excess water in the sticky mixture. It also presents the failures in the settlement, errors in the specification, among others, enabling the necessary corrections for the quality in the execution of the process.

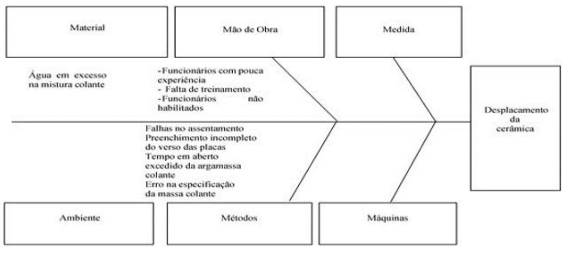

Figure 4.5 – Ishikawa for ceramic removal.

The non-conformities of the infiltrations can be observed in the Ishikawa graph, enabling the correction in the process of execution of the work at Residencial Parque Poranga II in the municipality of Itacoatiara in the State of Amazonas. As shown in Fig. 4.6.

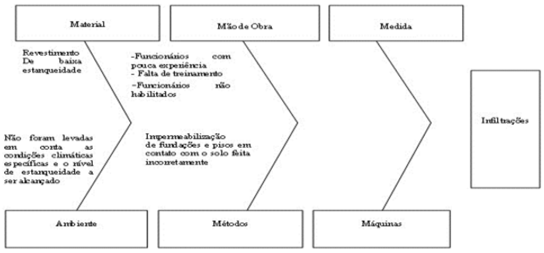

Figure 4.6 – Ishikawa for Infiltrations.

The analysis of infiltrations by the Ishikawa method, presents as one of the non-conformities of the material the low tightness coating and the specific climatic conditions, taking into account the tightness level to be achieved.

The analysis of the Ishikawa graph also shows that employees have little experience, do not have any training or skills to perform the work, in addition to the fact that the waterproofing of foundations and floors in contact with the ground was done incorrectly. The infiltration analysis took into account the material used, the personnel involved in the process and their deficiencies. Also analyzing the environment, methods and machines.

The analysis of infiltrations by the Ishikawa method, presents as one of the non-conformities of the material the low tightness coating and the specific climatic conditions, taking into account the tightness level to be achieved.

IV.3 CASE STUDY 2- RESIDENTIAL MANACAPURU

In the records provided by the engineers at Residencial Manacapuru, located in the municipality of Manacapuru in the State of Amazonas, it was possible to visualize and determine the non-conformities that occurred and recorded during the execution of the process.

IV.3.1 Measure Phase

Among the non-conformities found in the execution phase of Residencial Manacapuru, we highlight those with the highest number of occurrences, such as loose tiles and cracks with 39 occurrences of non-conformity, infiltrations due to poor execution in the pipe or cracks with 26 occurrences and nonconformity in doors, staves and locks with 31 nonconformities. Totaling 182 non-conformities found in the execution of the process. Taking into account the other non-conformities described. As shown in Table 4.2. Where it is NA, it means that there was no non-compliance with the item.

Table 4.2 -Non-conformities registered in the execution phase of the Residencial Manacapuru project.

Não conformidades na fase de execução dos projetos e execução	Freqüência Absoluta	Freqüência Relativa %
Total de Não Conformidades Registradas	182	100
Telhas soltas e fissuradas	39	21,43
Portas, aduelas e fechaduras	31	17,03
Infiltrações por conta de má execução na tubulação ou trincas	26	14,29
Contra piso e cerâmica - caimento com queda fora do ralo	21	11,54
Pisos trincados, manchados	18	9,89
Desplacamento de cerâmica por conta da argamassa	14	7,69
Instalações embutidas e vedações	13	7,14
Trincas e fissuras nas paredes	9	4,95
Sistema de aquecimento solar	5	2,75
Tubulação de esgoto sem queda adequada	4	2,20
Pintura - empolamentos, descascamento ou alteração de cor	2	1,10
Ensaios de graute, argamassa e prismas não-conformes com os lotes	NA	NA
Impermeabilização do wc	NA	NA
Compressão do concreto não atingiu a resistência mínima 28 dias	NA	NA
Forros de PVC	NA	NA

Source: Authors

After surveying the non-conformities and the number of occurrences in the execution of the construction process of Residencial Manacapuru, it is necessary to measure the data. the most critical problems in the construction process that should be tackled as a matter of priority due to the greatest impact on project execution results in terms of costs, time and rework.

IV.3.2 Analyze Phase

As explained above, the 80/20 principle was not followed due to the pulverization of results and the need to prioritize a smaller number of items in order to achieve the highest result in the shortest time possible. Priority is knowing how to differentiate between the urgent and the important.

It was found that the non-conformities of Residencial Manacapuru were loose or cracked tiles; Doors, staves and locks and infiltrations. Presenting a non-conformity different from those raised in Residencial Parque Poranga II. In addition to some different non-compliances between the two residentials, the percentage also differs from each other. While the residential Parque Poranga II, which presents a percentage of 58.72% of the total of non-conformities, the residential Manacapuru presents a percentage of 52.73%. It is clear that this percentage is not considered adequate for the acceptance of non-conformities, since in the original project, the percentage of up to 10% of non-conformities is considered satisfactory. In Parque Poranga, 58.72% of the result was in 30% of the occurrences. And there was a need to focus efforts on a smaller number of occurrences (30%) in order to maximize the result. In residential Manacapuru, concentrating energies in 27% of occurrences, they would solve 52.73% of non-compliances.

The non-conformities of Residencial Manacapuru are presented in the data. As shown in Fig. 4.7.

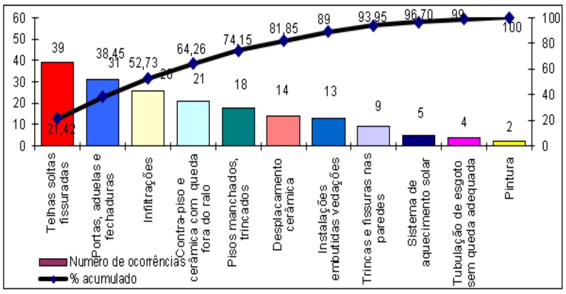

Figure 4.7 - Pareto Chart - Most frequent non-conformities recorded in the execution of the works at Residencial Manacapuru.

In Fig. 4.7, it is possible to clearly visualize the non-conformities of Residencial Manacapuru that had the highest number of occurrences, thus demonstrating the need for correction in these steps.

Also based on data collected from non-conformities at Residencial Manacapuru in the municipality of Manacapuru, in the State of Amazonas, the NP letter of occurrence was prepared. As shown in Fig. 4.8.

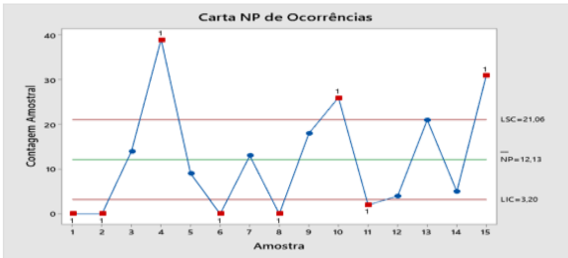

Figure 4.8 – Letter NP of occurrences of non-conformities registered in the execution of the works of Residencial Manacapuru.

In Fig. 4.8 it is possible to observe the test results for the NP letter of occurrences. The test fails at points 1;2;4;6;8;10;11 and 15.

The chart above was used to monitor process variation, identifying common (intrinsic to the process) and special (random) causes.

Common causes are related to the functioning of the system itself (eg project and equipment).

In turn, the special causes, which are the object of our further analysis, reflect occurrences outside the control limits (eg, human error and non-conforming raw material).

The variability of the process is demonstrated in a simple analysis of the NP chart, these points outside the lower and upper limits, which are the same with the highest incidence in the Pareto chart, need to be treated with priority.

Focusing on the most frequent events of non-compliance to be primarily attacked, the analysis was carried out, using the stratification tool, to determine the causes of failures or errors in the execution of the construction process and their effects, and the variables to be considered for the quality and alignment of the process, to the technical specifications of the processes of Residencial Manacapuru for non-conformities of loose or cracked tiles. As shown in Fig. 4.9.

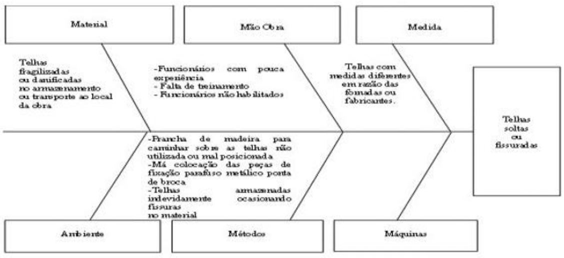

Figure 4.9 – Ishikawa for loose or cracked tiles at Residencial Manacapuru.

Fig. 4.9 shows the Ishikawa graph for non-compliance of loose or cracked tiles with regard to material, personnel, environment, methods and machines.

The Ishikawa chart was also used to analyze the non-compliance of Doors, staves and locks that do not work correctly in terms of the material used, the personnel involved in the process, the environment, the methods and the machines. Several non-conformities can be observed in the graph, allowing correction in the process of carrying out the work at Residencial Manacapuru. As shown in Fig. 4.10.

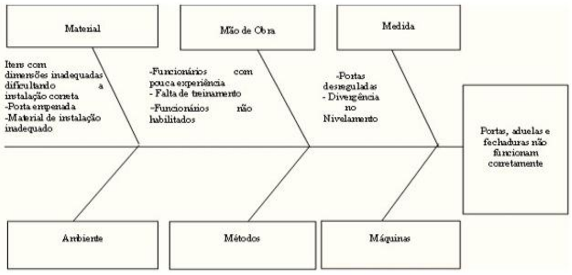

Figure 4.10 – Ishikawa for Doors, Staves and Locks at Residencial Manacapuru.

Fig. 4.10 presents the Ishikawa graph for non-compliance of doors, staves and locks that do not work correctly. As for the material, it presents non-conformities in the dimensions that are inadequate, warped door and inadequate installation material. As for the methods, it presents non-conformities in the installation of the doors that did not follow the technical specifications.

The graph also shows that the employees who work at the construction site have little experience, do not have any type of training and are not qualified to develop quality in the execution of the work.

The analysis of the infiltrations by the Ishikawa method, present the same non-conformities detected in the construction process of the residential Parque Poranga II, such as low-watertight coating and specific climatic conditions, taking into account the watertight level to be achieved.

The material used, the personnel involved in the process and their shortcomings were taken into account. Also analyzing the environment, methods and machines.

The non-conformities of the infiltrations can be observed in the Ishikawa graph, allowing the correction in the process of execution of the work at Residencial Manacapuru in the municipality of Manacapuru in the State of Amazonas. As shown in Fig. 4.11.

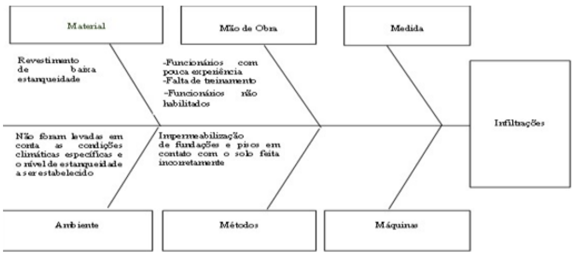

Figure 4.11 – Ishikawa for Infiltration of Residential Manacapuru.

Fig. 4.11 shows the Ishikawa graph for the non-conformities of infiltrations in the process of building Residencial Manacapuru.

IV.3.3 Implementation of Improvements (Corrective Actions)

The cause and effect diagrams of Residencial Parque Poranga II and Residencial Manacapuru showed that the human factor (staff), inadequate materials and methods were the main causes (root causes) of non-compliances. Based on this finding, a logical tree was created to delimit the applicable corrections. As shown in Fig. 4.12.

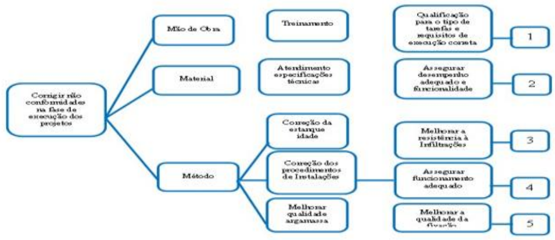

Figure 4.12 – Logical tree defining the critical problems to be corrected in the execution of the Project – Residencial Parque Poranga II.

Fig. 4.12 shows the correction of non-conformities in the project execution phase. From the preliminary analysis carried out using the logical tree, action plans were drawn up, for greater detailing of corrective measures and delimitation of their purposes (justifications), enabling intervention on the causes of critical problems (most recurrent nonconformities in each Project), in search of a level of quality compatible with the requirements and technical specifications.

IV.3.4 Improve Phase (Improve)

A prioritization matrix was elaborated to deal with the processes in order of importance, according to Table 4.3, in which the priority problems found were: Loose and cracked tiles, ceramic peeling due to mortar and infiltrations.

Table 4.3 - GUT matrix of priorities.

Processos identificados	Gravidade	Urgência	Tendência	GUT	Ordem calculada
Telhas soltas e fissuradas	5	5	5	125	1
Desplacamento da cerâmica por conta da argamassa	5	5	4	100	2
Portas aduelas e fechaduras	4	4	4	64	3
Infiltrações	5	4	3	60	4
Contrapiso e cerâmica	3	3	2	18	5
Pisos trincados, manchados	2	2	2	8	6
Tenicas e fissuras na parede	2	2	1	4	7

Source: Adapted from FAVERI (2016).

Knowing the most critical non-compliance problems of the researched projects, the project and process improvement plan was defined, aiming to remedy the deficiencies, establishing goals, criteria, schedules and changes in the execution of corrective actions, serving as a guiding instrument for the execution of the necessary improvement actions.

Regarding the non-conformities identified as more frequent or with greater impact on the projects under analysis in terms of the need for rework (infiltration; doors, staves and locks do not work correctly, and ceramic removal), it was found that there is a need to establish corrective criteria focusing on three key elements of the processes: human resources, materials and methods.

The instruction of the trainees was carried out in the workplace, which facilitated learning, as the instructed feel more secure and willing to learn. The learning was absolutely experiential and allowed for the integration between theory and practice.

The training was carried out by an engineer assisted by a supervisor, and the procedures were reviewed when the registered non-conformities were checked.

Step-by-step work instructions were elaborated, detailing information about the procedures with registration of trained employees, beginning and end of training, with identification of each worker's qualifications. According to Table 4.4.

Table 4.4 - Register of trained employees.

O QUE	PORQUE	QUEM	ONDE	QUANDO	COMO	QUANTO
Registro dos funcionários treinados	Para identificar a qualificação de cada trabalhador	Engenheiro e Supervisores	Na sede da Empresa	5 dias	Através de Relação de presença com assinatura dos funcionários treinados e carga horária	Não serão informados devido à solicitação da empresa

The training focused on the critical points and the correct methods for the adequacy of procedures to the technical requirements and standards on construction quality, with the following objectives:

– Develop skills and knowledge to the employee about the methodology or operational procedure in accordance with;

– Reduce rates of non-compliance due to the responsibility of the direct performers of services at the construction site.

The training was built according to the action plan below:

IV.3.5 Action Plan – Training (5W2H).

Table 4.5 - Action plan.

5W					2H	
O que	Por que	Quem	Onde	Quando	Como	Quanto
Ação problema, desafio	Justificativa explicação, motivo	Responsável	Local	Prazo, cronograma	Procedimento, etapas	Custo, desembolsos
Definição do plano de ação para os treinamentos	Para solicitar a direção e gerencia a aprovação	Engenheiro da Obra	Na sede da Empresa	3 dias	Requisições de treinamento	Não serão informados devido à solicitação da empresa
Levantamento das Necessidades de Treinamentos	Para assegurar um processo de aprendizagem contínua alinhado as normas de qualidade adotadas pela Construtora	RH	Na sede da Empresa e nas Obras	5 dias	O RH encaminha solicitação de necessidade de Treinamento aos Engenheiros e Supervisores das Obras	Não serão informados devido à solicitação da empresa
Rever os procedimentos registrados como não conformidades	Para correção dos problemas diagnósticos	Engenheiro e supervisores	Canteiro da obra	15 dias		Não serão informados devido à solicitação da empresa
Registro dos funcionários treinados	Para identificar a qualificação de cada trabalhador	Engenheiro e Supervisores	Na sede da Empresa	5 dias	Através de Relação de presença com assinatura dos funcionários treinados e carga horária	Não serão informados devido à solicitação da empresa

Source: Authors

IV.3.6 Control Phase

The definition of a control plan is essential to verify the various preventive measures that will help to achieve the desired result, that is, the elimination of non-conformities in the projects described and, also, in new projects.

For this, the procedures, verifications or activities to be carried out must be determined based on the technical specifications and the expected performance regarding the constructive quality.

Once the training is completed, the engineering sector must monitor daily, through an audit recorded in a checklist.

The training carried out based on the RT's must be evaluated by the person responsible for the sector, in the period identified in the form itself. After this analysis, you must register the evaluation in field 5 of the RT, close it and send it to the Personnel Department to file it. If it is found that the training was not effective, take the appropriate actions, such as requesting a new training or repositioning the employee based on their real skills. The person responsible for the Personnel Sector will receive the registration (copy of certificates, diplomas and others) for filing in the employees' folders for further proof of the employees' competence.

Internal training will be evaluated by the Engineer or responsible for the sector within one month after its completion, who will register in a specific field in the LPT - Training Attendance List. The effectiveness of training can also be verified by monitoring the professional's activities (for example, from the FVS). Checking that the training was not effective, take the appropriate actions, such as scheduling a new training or repositioning the employee based on their real skills. The person responsible for the Personnel Sector will receive from the instructor a record of the attendance list in training for filing in the department for further proof of the employee's competence.

V. CONCLUSIONS

These quality management tools can be useful in processes related to the construction industry. They are essential for improving performance and eliminating problems in the form of non-conformities that, in addition to being incompatible with the standards and technical requirements of the services performed, also have an impact on the projects by implying greater losses, costs and rework.

By enabling the identification of problems and their causes, as well as offering an intervention script adjusted to the processes according to their nature or form in the context of the project, these tools allow for adjustments and to avoid them in the future, so that the proposed methods and solutions can be implemented at other construction sites that carry out similar processes.

In this case study, it was verified the applicability of the DMAIC model for the survey and definition of corrective actions related to non-conformities in the execution phase of civil construction projects in the “My home My Life” Program in Amazonas.

The model allowed the tracking of several problems that characterized non-compliances in this phase of the construction projects of Residencial Parque Poranga II, in Itacoatiara, AM and Residencial Manacapuru, in Manacapuru, AM. In this preliminary phase of detection, the consulted reports provided quantitative indicators on the number of occurrences and the type.

Taking these factors as a reference, the necessary measures were defined as the basis for changes in processes and their execution according to non-conformities: qualification for the type of task and requirements for correct execution; ensure proper performance and functionality of facilities; improve resistance to infiltration; ensure proper functioning and improve the quality of fixing the ceramic.

This prior analysis carried out using the logical tree allowed the elaboration of an action plan, aiming at the implementation of corrective actions in the processes in the execution phase of the work, presenting the solutions to be adopted to correct the detected non-conformities and avoid new occurrences, ensuring the reliability of the processes.

With regard to control, the need to focus on key aspects of the processes is highlighted, such as staff training and a focus on mapping their competencies to expand the qualification base and permanent response capacity to the challenges of quality as a continuous process.

In terms of materials and methods, it is important to change risk management procedures, with the adoption of procedures and techniques that will allow for an increase in the capacity to respond to the probability of occurrence of non-conformities. Anticipating these events, through preventive control actions based on improving the reliability of processes, will allow for greater alignment of processes and activities with the objectives of total quality and continuous improvement.

Regarding the benefits that can be achieved with these measures, within the scope of the correction and elimination of non-conformities in the processes, the qualitative and quantitative gains stand out, represented by indicators such as lower costs due to the elimination of rework, compliance with deadlines and project goals, as well as improving the capacity of planning and reproducing results in new projects through the analysis of records and documentation with a history of corrective actions, critical points of occurrence of non-conformities and results obtained with corrective measures.

In this sense, it can be said that the use of the DMAIC model leads to continuous learning, which is one of the bases for improving the quality of processes and their necessary reproducibility.

Due to the complexity of the topic addressed in this study, the following are some suggestions for the continuation of this work:

– Carry out a study on the applicability of risk management and analysis as a tool to improve the alignment of processes with technical requirements and requirements, in the execution phase of the work;

– Develop a detailed analysis of a civil construction process, to map the way it is carried out, in view of the possibilities for improvement in execution and its possible repercussions, in terms of cost reduction or greater adequacy of results to economic and financial criteria as expected and defined results in the project design phase;

– Apply the DMAIC method to carry out analyzes related to the improvement of civil construction processes in other phases of the project, such as planning, a crucial step, where in addition to defining the scope, the activities that will be necessary, the processes, the refinement of objectives, sequencing of actions and respective deadlines, among other aspects.

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