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Risk Analysis in the Manufacturing and Transportation of precast concrete using PFMEA

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The study analyzes micro and small enterprises in Brazil, which represent 93% of all active companies, employ 62% of the workforce, and contribute 27% of the Gross Domestic Product (GDP). It was observed that these companies, especially one in the construction sector in the state of Rio de Janeiro, suffer from a lack of fault detection processes and high rework rates. The study sought to identify risks and implement responses to improve material preparation, manufacturing, and transportation of concrete parts. It used tools such as Process Mapping, PFMEA, and Porter's 5 Forces Analysis, where internal documentation and scientific literature were consulted. As a result, the critical steps of the processes were mapped, failure modes were identified, and actions were defined for risks with high RPN (Risk Prioritization Level). The actions resulted in process improvement, failure and cost reduction, and increased customer satisfaction. Although focused on one company, the study can be applied to other precast and precast concrete companies, impacting the practice and thinking of professionals in the industry.

KEYWORDS: Failure Mode and Effect Analysis; Transportation; Precast; Precast; Concrete Artifacts; Cracking; Hoisting, Pre-Slabs; Solid Slabs; Risk.

1 Introduction

The precast and precast concrete industry produces beams, columns, slabs, plates, blocks, and other structural elements. These elements are usually produced under controlled conditions using materials with greater selection control. Using has become increasingly common in constructing buildings, roads, bridges, and other infrastructure. This form of construction is faster, safer, and more economical than traditional forms. This segment has been expanding in recent years due to its advantages and flexibility, especially in the state of Rio de Janeiro, because several companies in the basic sanitation sector have been privatized. These companies demand these products to meet their contractual goals because these parts are used to build fast, durable, and economic structures with a lower execution cost. The pre-molding or prefabrication process begins with receiving the raw materials, which are checked against the invoice to ensure the correct quantities and specifications. If everything is in accordance, the materials are stocked. Next, the processing of these inputs begins.

The reinforcements are prepared and go through the cutting process, bending, and separation by type and size. In the assembly process, the tying or welding and the affixation of the spacers are performed. The molds are prepared for assembly. They must be clean without any residues, ensuring the surface is smooth where the mold release agents are applied to facilitate the removal of the components after the concreting. These additives prevent the adherence of the concrete to the molds. After this, the reinforcements are placed inside the molds, and the squaring, alignment, and locking process is performed. The concreting can be done in two ways, with a concrete mixer truck or on-site. In the case of receipt in the concrete mixer truck, the safety seal is checked to verify its integrity. This seal ensures that the concrete delivered is the same as the concrete plant produced and that there are no adulterations or mixtures with other materials during transportation. The concrete goes through a slump test to meet the project specifications. If not, it is dosed until it reaches the specification or rejected if that is the case. After the slump test, the concrete is molded into test specimens for laboratory testing and then released for application in the formwork to start concreting. Concrete vibration ensures that the concrete is spread evenly inside the formwork. After leveling, the concrete goes through the final finishing before the lifting pins are placed. The curing process is the natural one. The elements are left in a protected area until the concrete reaches the required strength level, never exposed to the sun. As the parts cure, the components are removed from the molds, where they go through a finishing process, which can be the removal of burrs, cleaning, paint application, or polishing, and then they are stored for final curing. Transporting precast concrete parts requires some specific care to ensure the integrity of the parts during transportation. We highlight some of the care that must be taken during transportation: Check the maximum weight allowed by the transport vehicle; excess weight can compromise the vehicle's safety; Use suitable vehicles. In addition, the vehicle must be in good mechanical condition, with the documentation up to date and meeting the guidelines of Regulatory Standard Nr 18; Use suitable equipment to tie the parts, such as straps or chains appropriate to the load; Maintain the stability of the parts during transport, avoid sudden movements that can compromise the integrity of the parts; Perform the unloading of the parts carefully, using suitable equipment and avoiding falls or damage during the process.

In conclusion, prefabrication involves specialized labor, selected materials, and technological control, with a refined and industrialized technique of concrete preparation and ideal curing, guaranteeing the standardization and quality of the finished product. The transportation of precast concrete parts requires specific care to ensure the safety and integrity of the parts during the entire process. Counting on trained professionals and adequate equipment is essential to ensure safe and efficient transportation. Many variables and risks are present in the process. When proper care is not taken, risks are not identified, and responses are not provided, the result is rework and waste.

The study aims to answer the following research questions:

Research question 1: How can material preparation, manufacturing, and transportation difficulties be overcome?
Research question 2: What are the risk factors present in manufacturing these materials?
Research question 3: What actions should be taken to correct production in response to the identified risks?
Research Question 4: What can impact the company's image, the rejection of materials?

The study is structured as follows: Section 2 addresses the Literature Review, presenting previous studies on Risk Assessment in manufacturing and the transportation of concrete products, PFMEA, and reliability. Section 3 discusses the Methodology. Section 4 presents the results. Section 5 discusses the results, and section 6 presents the conclusions.

2 Literature review

2.1 Standards applicable to precast and precast fabrication

The Brazilian Standard (NBR) 5738 establishes the criteria for the choice of materials and the concrete dosage, as well as for the mixing, casting, and compacting of the material. NBR 5739 deals with the compression test of cylindrical concrete specimens, allowing the determination of the material's compressive strength. NBR 6118 deals with the design and dimensioning of reinforced concrete structures and classifies the environments according to the degree of aggressiveness, and this classification considers factors such as exposure to chemical agents, humidity, and temperature variations, among others. NBR 7222 establishes the procedures for the execution and evaluation of flexural tests on concrete specimens. NBR 9062 in the curing process, the concrete must be protected against harmful agents such as sudden changes in temperature, drying, heavy rain, torrential water, chemical agents, as well as shock and vibrations of such intensity that can produce cracks in the concrete mass or damage its adherence to the reinforcement. NBR 12655 establishes the requirements for the production of centrally batched concrete. NBR 14931 establishes the procedures for the execution of reinforced and prestressed concrete structures. NBR 15116 establishes the requirements for using recycled aggregates in mortars, and Portland cement concretes and the test methods to evaluate their quality. NBR 16889 establishes the procedures for performing the slump test on fresh concrete samples, allowing the measurement of consistency and deformation capacity under load. NBR 16697 establishes the requirements for the receipt and sampling of ordinary Portland cement and compounds used in the production of concrete and mortar. NBR ISO 31000 establishes the guidelines and principles for risk management in organizations of all types and sizes. The standard deals with risk management, i.e., the process of identifying, assessing, and treating the risks that an organization may face in its internal and external environment.

2.2 Risk assessment in the manufacture and transportation of concrete products

Santos et al. (2018) stated that the processes in the factory are organized so that when the structural design is finalized, it is forwarded to the production team that starts the work, starting from the PCP (Production Planning and Control). Manikandan et al. (2021) identified the existing risks in the workplace, and the safety recommendations were given through a bow-tie tool analysis. Bow-tie tool analysis is one of the safety tools used to provide preventive measures for hazardous process health and safety issues in all industries. Hatmoko et al. (2019) stated that precast concrete typically has a long lead time from order placement and the production phase to delivery to the project site, which requires good supply chain management. Liu et al. (2022) determined the environmental impacts of three water-based drilling waste (WDC) recycling routes, namely cement, sintered bricks, and non-sintered bricks, based on the life cycle assessment (LCA) method. Elhag et al. (2008) explored the nature of the precast industry and discussed opportunities and challenges related to environmental improvement. A holistic view of the manufacture and procurement of precast concrete products is used to provide environmental improvement criteria with an improved status relative to the imperative of profitability. Paulina and Fernando (2008), concluded that prefabrication uses different construction techniques. Even analyzing the logistics of construction, agility, economy, and quality control the, prefabrication is still rejected in some areas of civil construction but essential in other sectors that bet on this technology; despite the higher cost in some cases, the prefabrication surpasses the conventional reinforced concrete in speed, economy, and quality control. Duarte et al. (2016) considered the advantages and disadvantages of using this construction technique, as well as market analysis and the economic feasibility of its implementation. Studies on the development of manufacturing processes were also considered, showing that it is a reality in civil engineering, and many companies have already adopted this construction standard. This shows that the technique is not just a market trend, but something that is here to stay, because the studies indicated that this technique would be one of the leading construction methods in the future. Stefanello (2021) highlighted the importance of constantly renewing concepts and points of view related to the construction site to add greater competence to the company and achieve goals and success in the organization. Silva (2015), presented the emergence and concept of precast, the advantages and disadvantages of this construction method, the rationale that led many people to opt for this type of construction, and also the hypothesis that the use of precast is an economical method, structurally safe and with architectural versatility. Serra et al. (2005) summarized that recent applications of prefabrication in civil construction, including the introduction of façade panels and "tilt up" technology, allow for savings in architectural versatility and a reduction in construction time.

2.3 Porter's 5 Competitive Forces Characteristics

According to Porter (1986), competitive strategy is the method a company uses to achieve favorable market positioning and long-term profitability. Researching and analyzing each competitive force is the key to developing a strategy. The set of five competitive forces influences the degree of competition in an industry. What will determine the company's ultimate profit potential is the strategy against the five competitive forces. The threat of New Entrants, In an industry, new entrants bring new capabilities, a desire to gain market share and substantial resources. This can lead to lower prices, or even entrants' costs can be inflated, decreasing profitability. Rivalry Among Competitors, with the dispute for market share, companies feel the need to improve their position concerning competitors. The Pressure of Substitute Products Substitute products is those that can perform the same function as those already on the market. They can be easily exchanged, satisfying consumer needs and competing for the same space in the market. Customers' bargaining power, customers can exert a huge influence on the industry, obtaining lower prices and demanding product quality or better services. In this way, the buyers play one competitor against the other, affecting the industry's profitability. Suppliers' bargaining power, suppliers can influence the industry with their bargaining power by increasing prices or reducing the quality of the supplied goods and services, reducing the profitability of an industry unable to pass on cost increases to their prices.

2.4 PFMEA and Reliability

Araujo and Camila (2019) reported that FMEA aims to evaluate possible risks and failures of a system, which is traditionally used in Production Engineering and has been adapted for Civil Engineering. Pantazopoulos and Tsinopoulos (2005) stated that failure modes and effects analysis (FMEA) is a potential tool with widespread use in reliability engineering for the field of electrical and electronic component manufacturing, as well as in complicated assemblies (aerospace and automotive industries). Plinta and Greń (2022) presented an example of a risk management approach in a cast iron foundry based on using qualitative tools to improve the identification and elimination of failures occurring in the process and their causes. Hatefi and Balilehvand (2023) proposed an improved version of the FMEA method by adding the risk controllability criterion. Murtopo and Chimayati (2023) stated that applying technology in the oil and gas industry can harm human safety, impact environmental pollution, and damage technology and equipment. Maulana and Pandria (2023) conducted a study to identify damage and repairs to Screw Press machine working tools. The study uses the method to identify risks and take preventive measures in advance. Ebadzadeh et al. (2023) conducted a study to evaluate the environmental risks caused by the ammonia and urea production process. Alves and Melo (2021), presented the results of pathology analysis in 6 precast reinforced concrete columns, selecting parameters of exposure conditions in a building with a reinforced concrete structural system. Barroso (2018), through the analysis of diagnosis trees of the SICCO program, identified the time that inspectors spend in each functional area of a company and in the respective processes and then made a comparison with the time spent in each of the program's processes. Moreira (2018), found the solutions to reduce the amount of waste arising from the concrete production process after the studies raised by the applied FMEA proved positive from the environmental point of view.

3 Methods

3.1 Population and sample selection

The study adopted the theory-building approach of Case Study Research (Eisenhardt, 1898) and Hancock et al. (2021). Files, interviews, and observations conducted in the manufacturing and transportation of precast concrete were combined. The sample for the study was precast concrete's manufacturing and transportation process. The number of local stakeholders who participated in the study is listed in Table 1.

Table 1. Study Collaborators

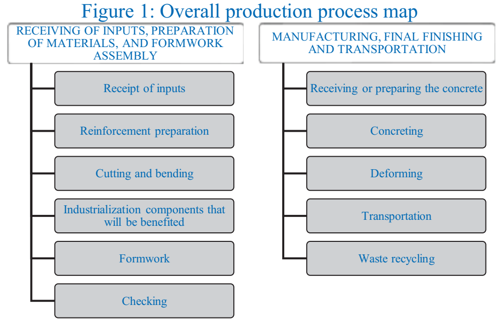
Area	Function	Number of participants	Time of experience (years)
Engineering	Engenheiro de manutenção	1	13
Production	Encarregado	1	6
Operator	Process Operator	3	1
Operator	Process Operator	3	0,5

These stakeholders were selected based on their expertise in a specific domain. The sample size is adequate and meaningful since all areas studied are covered.

3.2 Use of instruments and tools

A map of the overall process of manufacturing and transporting concrete products was prepared to understand the variables of the process. The macro flowchart in Figure 1 shows the manufacturing and transportation of concrete products.

Figure 1: Overall production process map



3.3 Data Collection

The most critical steps of the process flow diagram were identified and divided into stages. Then the potential effect (impact) of each failure mode was identified. The potential cause of each failure mode was analyzed based on how often (probability) the failure could occur and whether it could be detected (detection). The rating for impact, probability, and detectability was assigned, and the RPN was calculated.

3.4 Data Analysis and Actions

The documents created and the processes with increased monitoring raised data for the process analysis. These processes were mapped with the help of the process employees, and a thorough literature review on the manufacturing and transportation of precast and precast concrete was performed to identify risk factors.

4 Results

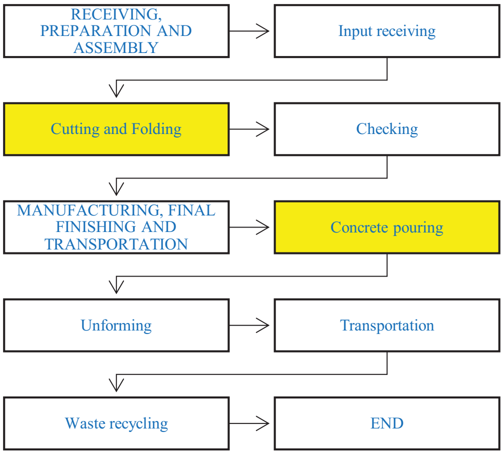
4.1 Operation process map

The concreting of precast and precast concrete starts with the planning and design of the structures to be manufactured. From there, molds, also known as formwork, are created to shape precast objects, which can be made of wood, steel, aluminum, or plastic. The concrete mixture, which may contain additives to improve its physical and chemical properties, is then prepared. The mixture goes to the production area, where the molds are

filled with concrete. The concrete is compacted to ensure that it is free of imperfections. After concreting, the parts are stored in a controlled environment to cure the concrete. Depending on project specifications, this can be done by hot or cold curing processes. After the initial curing, the molds are removed and cleaned to return to the new prefabrication process. Concrete is a material whose components have different natures and structures, and its main constituents are cement, aggregates, and water. Thus, concrete is a junction of solid materials (aggregates) with a viscous material (cement paste).

The cement paste, even being a material of glutinous consistency, is also characterized as a heterogeneous material because it is composed of solid particles (cement grains) and a liquid (water). In a general analysis, fresh concrete flows like a liquid (FERRARIS, 1996; 1999). The finished product is then examined to ensure it meets the quality and safety standards. After this evaluation and validation, it goes through complementary finishing, cleaning, sanding, and painting procedures. The most critical stage of the macro flowchart is part of cutting and bending the steel, and the part of concreting the parts. The critical steps marked in yellow are presented in Figure 2. This flowchart helped in the construction of the PFMEA.

Figure 2 - Operational Process Map



4.2 PFMEA (Process Failure Mode & Effect Analysis)

The failure modes identified in the detailed level process diagram steps were defined based on the study by Fuentes-Bargues et al. (2017). Each failure mode's potential effect (impact) on internal and external customers is identified and recorded in the PFMEA spreadsheet. The potential cause of each failure mode was analyzed based on how often (probability) the failure could occur and how it could be detected (detection). The information was also recorded in the FMEA Matrix shown in Figure 3. Impact, probability, and detectability ratings were assigned, and the RPN was calculated and recorded on the same spreadsheet. Risks with a high RPN (greater than 320) are marked in red, medium RPNs (80-240) in yellow, and the lowest RPNs (8-40) in green. The creation of fault detection processes was essential to reduce rework rates. This is because rework is a primary factor that negatively affects productivity and profitability and damages the company's customer image.

The non-conformities found are 4% of the total manufactured parts, and it is essential to emphasize that we must always reduce non-conformities to achieve the highest possible quality in manufactured products. To this end, internal quality goals were established, and measures were adopted to control and monitor production processes to identify and correct any flaws and reduce non-conformities. In addition, the company must know the criteria and requirements of the production standards. Non-compliance with these standards can increase the number of non-conformities and compromise the quality of the products. The justification for the creation of fault detection processes is related to the fact that the early identification of faults can prevent defective products from reaching customers, which reduces the number of complaints and dissatisfactions. In addition, by avoiding rework, labor, materials, and time costs can be reduced, increasing the company's efficiency and competitiveness. The importance of creating fault detection processes is related to the need to increase the quality of the products offered by the company, as well as to improve customer satisfaction, both internal and external; by implementing efficient fault detection processes, it is possible to ensure that all products meet the quality requirements established by the company and customers, which increases brand credibility and trust. The risks with a high RPN (greater than 320) are marked as red, and their actions are listed in Table 3 in the conclusion section.

4.3 Data recording, procurement, and procedures

As a result of the PFMEA, several actions and changes were implemented as detailed below:

Photo and video report - is used to visually record the progress of improvement of manufactured parts, as well as document possible problems or irregularities in some processes.

Surveillance cameras and microphones - The use of surveillance cameras and microphones in the production processes have helped to improve the safety, efficiency and quality of the products produced and provide a valuable record for legal and production process monitoring purposes.

Control of product withdrawal in the company - Many customers withdraw products without a receipt, so it was necessary to create a more careful control, with the identification of who delivers and who receives.

Control of production and material output via invoices - This control is essential to ensure that the production processes are carried out efficiently and on time.

Input control - It was essential to have precise control of several inputs. To ensure efficient management of stock and processes,

Control of arrival of products to industrialization - This control involves the receipt of parts that enter the processing process. They will be joined to molds and will form other products.

Delivery Schedule - Delivery control is critical to ensure that the products are delivered to the customers efficiently and on time.

Organization Chart - A company organization chart was assembled with the main attributions of each collaborator in this organizational structure, showing the hierarchical relationships. It served to aid in the understanding of the company structure, its responsibilities, and functions. The designation of the collaborators' attributions was fundamental to ensure that tasks were carried out efficiently and that each team member knew precisely his or her responsibilities and areas of activity. This helps to avoid duplication of effort, minimize errors, and increase productivity. In addition, clearly defining employees' roles was essential to ensure responsibility and accountability in case of problems or mistakes, allowing the company to take corrective action and improve its work processes.

Training - As far as training is concerned, training employees enables them to be more efficient in their roles, thus increasing the company's productivity.

Bonus and Goals - Forms of the bonus have been created, the production goal achieved, and the individual gratification by suggesting improvement in the processes. Work Plans - It is fed with the extra tasks so that we will have a documented history of the activities performed by the teams in the company.

Physical arrangement - Concerning the physical layout, a good layout of equipment and machines can contribute to the optimization and improvement of the production flow, reducing the waiting time between stages and increasing the efficiency of the production process.

Equipment - Finally, acquiring modern equipment adapted to the needs of the company can bring many advantages, such as increased productivity, cost reduction, and better quality of products and services, in more than allowing the company to stay in the market.

4.2.1 Failure Mode & Effect Analysis (FMEA)

Figure 3 – PFMEA Matrix

Frequency Scale	Severity Scale	Detectability Scale
10 – Frequent: May happen several times a year 7 – Occasional: May happen a few times a year 4 – Uncommon: May happen 2 to 5 times a year 1 – Remote: May happen sometimes in 5 to 30 years	10 – Failure that can result in death or serious harm 7 – Failure that can cause non-serious and/or harm significant patient dissatisfaction and/or resulting in expenditure of money for follow-up care 4 – Minor event; increased length of stay 1 – Failure not noticeable or would not affect the delivery of service	10 – Error likely to be discovered < 50% of the time before harming/reaching patient 7 – 50% of the time 4 – 70% of the time 1 – > 90% of the time

Step or Link in the process (e.g., machine part)	Potential Failure Mode (Identify the potential failures for each component step in process) *can be more than one per step*	Potential Effect of Failure Mode (Identify the potential outcome of the failure to patient)	Frequency (Likeliness Scale 1 – 10)	Severity (Potential for Harm 1 – 10)	Detect ability (Potential for Discovery 1 -10)	Risk Priority Number (RPN = Freq. x Sev. x Detect)	Remedial Action
Inputs Receiving	Incorrect or different from what was requested quality outside the established standards Difficulty in identifying problems with the supplier or correcting possible errors. Problems with payments, since invoices are used as proof for payment.	Financial losses Problems with the supplier and difficulties to correct possible errors; Delays in the production process and difficulties in meeting deadlines; Increased costs with rework or disposal of materials; Damages to the company's image, since problems with the quality of materials can affect customer satisfaction; Reduced efficiency and competitiveness of the company, since the receipt of correct materials is essential for the progress of the work and to maintain high quality standards	6	2	9	108	Training of the employees responsible for the reception of materials; Development of checklists Establishment of clear and objective protocols; Periodic verification of the quality of the materials received, with the objective of identifying possible problems and correcting them before they cause losses; Involvement of suppliers in problem solving; Establishment of performance indicators;
Preparing the materials	Improper choice of raw materials Inaccurate measurement of materials Inadequate storage of materials Lack of proper mixing	Manufacturing delays; Pathologies	8	9	5	360	Creation of showcases; Delegation of people responsible for each process; Improvement of the physical layout
Final check	Final check of formwork positions; Verification of interlocking; Verification of the centralization of the covers, if this is the case; Formwork preparation: the molds must be clean, dry and well lubricated to avoid adhesions and difficulties in removing the parts	Rejection of the parts produced; Increased costs with corrections and rework; Lost time and customer dissatisfaction. In addition, if parts with irregularities are installed, this can result in safety problems, such as accident risks. It is important to avoid these negative effects by carrying out a thorough check and ensuring the quality of the concrete precasts produced	9	7	5	315	Employee training; Establishment of clear and objective protocols;
Concrete pouring	Check the integrity of the concrete mixer truck's safety seal; Check the quantity requested x quantity received; Slump test check; Molding of the specimens.	Failure to check concrete strength requirements and other technical specifications can result in underperforming parts and safety problems; It is important to carefully and rigorously check the arrival of the concrete on site to ensure the quality of the material and avoid future problems;	7	10	8	560	Employee training; Establishment of clear and objective protocols;
Unform	Checking concrete humidity: it is important to ensure that the concrete has adequate humidity to ensure adherence of the pieces to the molds and to avoid the risk of breakage or deformation. Use of appropriate tools: It is important to use appropriate forming tools, such as hammers and spreaders, to avoid damaging the pieces or the molds. Time control: the forming time must be controlled to avoid the loss of plasticity of the concrete, which can harm the quality of the pieces. Surface treatment: after forming, it is important to treat the surfaces of the pieces to ensure their protection against external agents, such as humidity and the weather.	Without proper care during stripping, concrete parts can suffer damage such as cracking, deformation, or other types of malfunctions that affect their quality and structural integrity. In addition, time and resources can be lost to correct these problems, which can negatively impact the project's schedule and budget. It is important to follow the correct recommendations and procedures during stripping to ensure the quality and safety of the concrete part.	7	10	9	630	Employee training; Establishment of clear and objective protocols;
Transport of parts and waste	Damage to parts due to improper loading or unloading or improper handling; Breaks or cracks due to excessive vibration during transport; Shifting or deviations during transport, causing damage to the transport vehicle or other vehicles in transit; Safety problems due to lack of proper securing equipment or lack of training for transport staff Problems with logistics, such as transport delays or delivery to an inappropriate location.	Problems that can occur when transporting concrete artifacts include: breakage of pieces; damage to the surface of the pieces detachment of pieces; balance problems during transport, problems with the transport vehicle, among others. In addition, it is important to consider safety issues, such as the correct use of lifting and lashing equipment, to avoid accidents.	6	10	10	600	Checking the condition of the transport vehicle, to ensure that it is in good condition to make the delivery; Checking the cargo to ensure that it is properly secured and protected against impacts; Checking the transport route to ensure that it is as safe as possible. Verification of the transportation team, to ensure that they have the necessary training and knowledge to make the delivery safely

Source: Author (2023)

5 Discussion of the results

The contribution is significant because the actions carried out led to commitment, process improvement, failure reduction, and cost reduction, and, consequently, quality increase. The study can change the practice and thinking of professionals dealing with risk assessment in producing precast and precast concrete products. The proposed method revealed some exciting results that can help overcome the above problems. It provides a set of evaluation parameters and makes decision-makers more aware of the impact and probability of high-scoring risks. It was necessary to set up a strict control system and use tools that allow the recording and monitoring of the production process, from the choice of raw material to the delivery of the product to the customer. Training employees involved in all stages of the process was essential to ensure everyone was aware of the proper procedures and the importance of following the established control, safety, and quality standards. Per periodic equipment inspections and establishing clear and objective protocols for problem-solving and defect correction was also essential. In addition, it was essential to control logistics and transportation carefully, ensuring that the vehicles were in good condition and driven by trained drivers using the equipment. Optimized routes were established to avoid delays and damage to the vehicles and the transported products. Training the personnel responsible for handling materials and developing clear and objective checklists and protocols to identify and correct problems before they cause damage was necessary to avoid waste and standardize the tasks. In addition, it was essential to involve employees in problem-solving, establish performance indicators, and sample and delegate responsibility to each. The physical production layout could be improved to optimize efficiency and avoid problems. Training employees and establishing clear and objective protocols were essential to implement corrective actions efficiently and effectively.

In the diagnosis, it was detected that there was not adequate planning of the processes because, without adequate planning, the process may not be compatible with the customers' needs or not meet the manufacturing specifications. Some process steps that had relevance in the detection were:

1. Choosing inappropriate materials may result in low-quality products or products that do not meet design specifications;
2. Manufacturing errors can lead to quality and safety problems, such as cracks, splits, and imperfections;
3. Incorrect use of equipment, such as concrete vibrators, can result in defective parts, and assembly errors can cause great losses because concrete can leak and parts can be manufactured with varying dimensions and outside the customer's specifications;
4. During transportation, some care must be taken to avoid damage, checking the number of pieces stacked, the support at the bottom of the body, and if they are with the adequate equipment for tying, such as straps or chains, because the pieces may slide or vibrate, causing cracks and fissures;

5 The lack of projects for the execution of the reinforcements made it difficult to manufacture them. The objective of the study was to propose a method to prioritize the risks in the manufacture of precast and precast concrete and the risks of failure in the manufacture and transportation of manufactured parts.

As per Porter's five forces analysis, the introduction of the text and analysis of the results:

Threat of new entrants: Law 14.026/2020 brought several opportunities to the sanitation sector, which may encourage new companies to enter the market. In addition, the increase in the number of active companies in Rio de Janeiro has generated greater competition among companies, increasing the threat of new entrants.

Bargaining power of suppliers: Due to the large number of firms in the market, the bargaining power of suppliers is strengthened since supply is much greater than demand.

Bargaining power of customers: With increased competition, customers have more options to choose from, which can increase their bargaining power regarding product prices and quality.

The threat of substitute products or services: The practice of product price prostitution can generate inferior quality products that compete with similar or superior quality but fairly priced products, posing a threat of substitute products.

Rivalry among competitors: The increase in the number of active companies in Brazil generates greater competition among companies, increasing rivalry among competitors. In addition, the practice of product price prostitution can generate unfair competition with other companies that offer similar or superior quality products but at fair prices, further increasing rivalry among competitors. Porter's five forces are not directly applicable to the conclusion of the results in question since he addresses the improvement actions implemented in the company. However, it can be said that these actions are a response to the threat of substitute products and rivalry between competitors, as the company needs to differentiate itself and improve its processes to remain competitive in the market. The improvement actions taken included the establishment of a strict control system, the use of tools to record and monitor the production process, periodic equipment inspections, clear and objective protocols for problem-solving and defect correction, logistics and transportation control, employee training, employee involvement in problem-solving, and improvement of the physical production layout. These actions will contribute to reducing failures, reducing costs, and increasing product quality, generating more profitability for the company. The study can be generalized to other companies that produce substantial parts, which face similar problems of waste, rework, and unnecessary energy consumption.

6 Conclusion

A summary of the FMEA Matrix has been made, the risks with a high RPN (greater than 320) and marked as red, and their actions are listed in table 3:

Table 3: FMEA and Potential Failure Analysis

	Potential Failure Mode	Corrective Action
Materials	- Inadequate materials; - Inaccurate cutting and measuring; - Improper storage; - Lack of proper mixing;	- Creation of showcases; - Delegation of persons responsible for each process; - Improving the physical arrangement
Concrete pouring	- Check the integrity of the concrete mixer truck's safety seal; - Check the quantity requested x quantity received; - Slump test check; - Molding of the specimens.	- Employee training; - Clear and objective protocols;
Shapeshift	- Ensuring that the concrete is adequately humid to guarantee non-adherence of the pieces to the molds and to avoid the risk of breakage or deformation. - The use of adequate tools is important for the mold removal, avoiding damage to the pieces or the molds. - The forming time must be controlled to avoid the loss of plasticity of the concrete, which can harm the quality of the pieces.	- Employee training; - Establishment of clear and objective protocols;

Transportation	- Damage to parts due to improper loading or unloading or improper handling; - Breaks or cracks due to excessive vibration during transport; - Dislocation or deviations during transportation; - Safety problems due to lack of equipment and untrained operators; - Delays in transportation or delivery at an inadequate location. - Vehicle in good condition for delivery.	- Load tied up and protected against impacts; - Verification of the transportation route; - Training of operators.

In answer to Research Questions 1 and 2: *How can difficulties in material preparation, manufacturing, and transportation be overcome?* And *what are the risk factors present in the manufacturing of these materials?* The PFMEA matrix presents the risk factors and detailed information on overcoming the difficulties. Create a plan and have a well-elaborated project to guarantee that all dimensions and details are precise and adequate for the final use of the precast and precast element, select and choose quality materials such as cement, aggregates, and additives to guarantee the strength and durability of the parts, the molding of the elements must be done with good vibration techniques to guarantee a uniform surface and resistance to compression, where an effective curing process must be sought, essential for the strength of the concrete. It must be carried out under adequate conditions with curing control. To avoid damage and ensure safety, the transportation and installation of precast and precast concrete elements must be done carefully.

In response to research questions 3 and 4: *What actions should be taken to correct production in response to identified risks*? And *what can impact the company's image and the rejection of materials*? The advantages of creating controls are diverse and range from improving the efficiency of production processes to ensuring safety and increasing quality. As a tool for quick and efficient communication between employees, WhatsApp allows data and information to be recorded and shared quickly and easily. The photographic, video, and surveillance cameras report the progress of the improvement of the manufactured parts, as well as document possible problems or irregularities in some processes, providing a form of analysis for troubleshooting and monitoring the evolution of the production process and providing a valuable record for legal purposes and monitoring of the production process. The control of product withdrawal ensures greater control over the number of products withdrawn by customers, as well as the identification of who delivers and who receives, avoiding product loss and ensuring more efficient inventory management. The study showed the importance of implementing adequate and detailed controls in the different areas of the company. The examples cited in the text show how data can help improve processes, and production, ensuring the safety of employees and managers, and improving communication and relationships based on these experiences. One can conclude that data collection is a valuable tool for making strategic decisions and achieving goals and objectives.

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