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Integrating the Failure Mode Analysis Tool and Effect on Risk Reduction into an APQP Management Process in a Medium-Sized Company in the National Automotive Sector

Flávio Roberto Néris Oliveira[1*]

[1]Institute for Technological Research, São Paulo, Brazil. E-mail: flavrob22@yahoo.com.br

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Abstract

The research investigates the use of the Failure Mode and Effects Analysis (FMEA) methodology in the context of Advanced Product Quality Management (APQP) in the automotive industry. It explores how FMEA is used to detect, assess and reduce risks in projects, highlighting its positive impact on preventing failures and mitigating damage. The research analyzes the role of multidisciplinary teams in preparing the FMEA, highlighting how different perspectives enrich the analyses. Furthermore, it examines the adaptation of FMEA criteria for project management and the classification of risks by priority. The paper highlights how FMEA improves feasibility and risk assessment, promoting informed decisions and improved quality, while also evaluating your compliance with the IATF 16949 standard and your commitment to quality.

Keywords: *Product development, Risk management, FMEA*

1. Introduction

Product development is a complex and challenging undertaking, requiring a diverse set of skills and knowledge. It starts with identifying customer needs and extends to the final implementation of the product. Cooper (2001) highlights that this strategic activity requires not only technical expertise, but also creativity and management skills, promoting an integrated and collaborative approach. To ensure the success of the project, the practice of risk management is essential, which involves identifying, evaluating and mitigating the risks associated with both the product and the development process. This is crucial to avoid unpleasant surprises, such as delays and unforeseen costs.

Risk management, according to Lehner (2015), is a systematic and proactive approach that aims to maximize the benefits of the project while minimizing the risks involved. It is a vital tool to ensure that projects are delivered on time, within budget and with the desired quality, thus meeting stakeholder expectations. Failure Mode and Effect Analysis (FMEA) stands out as a widely adopted methodology in risk management. This method allows the identification of potential failure modes, their effects and causes, prioritizing critical failures and developing action plans to mitigate them. As described by Sadeghi (2016), FMEA is a valuable planning tool that assists in identifying and prioritizing critical failures, as well as developing action plans for their prevention or correction.

**Corresponding author: Flávio Roberto Néris Oliveira, Institute for Technological Research, São Paulo, Brazil. E-mail: flavrob22@yahoo.com.br*

The relevance of FMEA extends to several industries, as mentioned by Laurenti *et al*. (2012). It is widely used as a tool for preventing failures and improving products and processes. FMEA enables the detailed analysis of possible failure modes in a process, system or product, including their effects, and offers guidelines for adopting preventive or corrective measures in order to minimize risks. Industries as varied as aerospace, automotive and electronics have successfully applied FMEA to improve the quality and reliability of their products.

The main objective of this research is to apply the FMEA methodology to identify failure modes and their main causes in a product development process. The research will focus on best risk assessment practices based on Advanced Product Quality Planning (APQP) management procedures and processes in a medium-sized national company, specializing in the manufacture of cast and machined parts. The purpose is to identify possible failures and implement preventive measures to minimize risks, thus ensuring the quality and effectiveness of the process. The study will also provide conclusions and recommendations for future research, contributing to the continuous improvement of production processes and risk reduction.

2. Product Development and Project Management: Strategies and Tools to Ensure Quality in the Automotive Industry

The product development process, as discussed by Slack *et al.* (2002), it is crucial for customer satisfaction and to increase the competitiveness of companies. This involves understanding the needs and expectations of the market, following steps such as concept generation, screening, preliminary design, evaluation, improvement and prototype development. Rozenfeld *et al.* (2006) highlights the importance of this process in a globalized and diversified market, highlighting challenges such as adapting to new technologies and emerging social standards.

Project management plays a crucial role in product development, as pointed out by Valle *et al.* (2007) and Souza and Rodrigues (2012). It allows for a structured approach to achieving goals and objectives, ensuring efficiency and quality. Furthermore, the use of tools such as APQP, mentioned by Rocha (2009), is essential to guarantee product quality and compliance with standards and regulations. These systematic approaches help keep everyone involved in the project aligned, increasing the efficiency and quality of the process.

In the current environment, with increasingly complex requirements, it is essential to develop strategies for decentralization and centralization of activities, involving customers and suppliers, as highlighted by Toledo *et al.* (2003). The use of APQP, a methodology widely used in the automotive industry, can provide guidelines to ensure the quality of product development, avoiding waste and bringing benefits to various sectors. Therefore, structured product development management is crucial to meet market demands and ensure customer satisfaction. Advanced Product Quality Planning (APQP), as defined by the reference manual by Chrysler *et al.* (2008), it is an essential project management tool for the development of new products and processes. Its main objective is to coordinate and organize the activities necessary to validate both the product and the project. APQP, as pointed out by Lynn *et al*. (2000), serves as a comprehensive guide for all phases of development, offering means for documentation, review, planning, retrieval and analysis. It is a methodology widely adopted in the automotive industry, ensuring the quality of design and production, as well as meeting customer specifications.

Raicu *et al.* (2021) emphasize the importance of APQP as a fundamental tool for understanding customer needs, providing resources necessary to achieve the objectives established by both the company and the customer. Within the automotive industry, APQP follows a cyclical Plan, Do, Check and Act (PDCA) process, with a pre-planning phase and five simultaneous collaboration phases. This method aims to minimize risks associated with the project, ensuring that the client's needs and specifications are fully met.

The APQP is made up of 23 main topics that must be addressed before production begins, covering areas such as design robustness, testing, compliance with specifications, production process, quality inspection, process capability, production, packaging, product testing and operator training. Furthermore, APQP is supported by a manual that offers guidance and recommendations for executing the product development plan, as well as form templates and monitoring tools. The process is carried out by a multifunctional and collaborative team, led by the project manager, including members from engineering, manufacturing, quality and purchasing.

The APQP management model is highly adaptable to the specific needs of each organization, allowing the customization of elements such as nomenclature, monitoring systems, team agreements and meetings according to the individual characteristics of each company. APQP is a comprehensive approach that ranges from requirements definition to final product quality verification, providing a solid framework for the development of new products and processes in the automotive industry.

The PDCA cycle, as discussed by Wani *et al.* (2019), it is a fundamental tool for continuous improvement in several areas, including manufacturing, medicine and agriculture. Developed by Walter Shewhart in the 1920s and popularized by Edward Deming in the 1950s, this cycle is a structured approach that involves four stages: planning, executing, checking, and acting. Werkema (1995) highlights that PDCA promotes incremental improvements and helps in the standardization of management processes, in addition to assisting in decision making.

Campos (1992) emphasizes that PDCA is the essence of management at all levels of the company, as it allows understanding the relationship between cause and effect in processes. The Japanese recognized the importance of distinguishing causes from effects in management and created the cause and effect diagram. Pereira (2004) highlights that PDCA is a management tool widely used to control internal and external processes, ensuring compliance with defined objectives and assisting in decision making.

The PDCA method is composed of four sequential steps: Plan, Do, Check and Act. In the Planning stage, the necessary activities, goals and resources are defined. In Do, activities are carried out as planned. The Verify stage involves analyzing results against defined goals, while the Act stage implements corrective actions based on the verified results. The PDCA cycle provides a systematic approach to improving the quality of processes and products, allowing organizations to adapt and stand out in the market.

Sokovic *et al*. (2010) and Moen *et al.* (2009) highlight the ability of the PDCA cycle to implement temporary and permanent corrective actions, preventing the recurrence of problems. Furthermore, they emphasize the importance of the historical record of actions as a reference for future improvements.

3. The Risk Management Process in Projects: Minimizing Impacts And Maximizing Opportunities

Risk management, as discussed by authors such as Kerzner (2017), is a continuous process that aims to identify, evaluate and control elements that may affect an organization or project. It is essential to find a balance between the costs of controlling these elements and the expected benefits of safe operation, as highlighted by Lam (2014). The *PMBOK Guide* (2017) describes risk management as the identification, assessment, prioritization and implementation of measures to mitigate impacts. This approach is applicable to various organizations and aspects of management, helping to minimize risks and maximize opportunities.

Hillson (2013) emphasizes the importance of risk management to identify, evaluate and mitigate threats and opportunities in projects. It ensures that threats are adequately addressed to minimize negative impacts, while also seeking to identify and seize beneficial opportunities for the project. In projects, this process is vital to identify, evaluate and control elements that can influence success. It involves steps such as identification, probability and impact analysis, implementation of measures and constant monitoring. Understanding and applying this technique is essential for making informed decisions, effective resource allocation and project success within established deadline, budget and quality parameters.

4. FMEA: A Preventive Tool For Risk Calculation

Fattahi and Khalilzadeh (2018) highlight that Failure Modes and Effects Analysis (FMEA) is a preventive tool that assesses the risks of failure in systems, subsystems or components. It addresses any potential way in which a material, machine or system may fail to function as expected. Initially adopted by NASA in 1963 for non-military purposes, FMEA was later incorporated by the automotive industry in 1964. Its application involves identifying failure modes and their effects, contributing to improving quality in projects, services and processes.

FMEA is widely used in industry to minimize the risk of failure and maximize the quality of products, services and processes. It is valuable in identifying and eliminating failure modes before quality problems occur, through brainstorming, discussions and evaluations. Analyzing potential failures and mitigating their effects are essential FMEA practices, providing crucial information about the most critical parts of failures and helping to identify preventive actions.

A common approach to risk analysis is the *VDA Manual* (2019) in the automotive sector, which guides the application of FMEA in two aspects: the Product FMEA (DFMEA) and the Process FMEA (PFMEA). The first focuses on identifying failures in components and subsystems, while the second evaluates failures in the planning and execution of processes. FMEA is a logical approach based on previous studies and common failure physics, allowing the identification of potential failure modes and their effects on the system.

It is crucial to carry out a comprehensive risk assessment considering the specific requirements of the product or process in question. Based on the severity and occurrence of each cause of failure, appropriate preventive and detection measures must be adopted. Cross-functional teams play an important role in developing FMEAs, addressing each potential failure effect and defining appropriate controls. The FMEA development process involves six keysteps, including identification of flaws, prioritization analysis, implementation of preventive measures, verification of the effectiveness of actions, continuous monitoring and final evaluation.

Critical control point analysis (APCC) is an integral part of FMEA, evaluating the severity, occurrence and detection of failures during the execution of a process. This systematic process helps to quantify the risks involved, ensuring the quality and reliability of the products or processes analyzed.

The role of the Failure Modes and Effects Analysis (FMEA) facilitator is extremely important to ensure that the FMEA process is conducted in accordance with established guidelines. The facilitator plays a multifaceted role, which includes ensuring that all team members understand the guidelines, follow each important step, and receive necessary feedback and support. Key skills include promoting creative thinking, encouraging active participation from all members, maintaining control of the discussion, making fair decisions, managing time effectively, and supporting the team in identifying, evaluating, and correcting failure modes. Ultimately, the facilitator plays a crucial role in ensuring the success of the failure and effects analysis, collaborating with the team to achieve the best possible results.

Additionally, the facilitator helps establish the objective of the analysis, identifies failure modes, effects and causes, assesses the severity, probability and detectability of each failure mode, calculates the potential risk associated with each, prioritizes critical failure modes and supports the development and implementation of corrective actions. The facilitator also plays an important role in monitoring and evaluating the results of corrective actions. In summary, the FMEA facilitator plays a crucial role in ensuring the success of the process, collaborating with the team to identify and mitigate risks associated with failure modes and ensure the quality and safety of the products or processes analyzed.

Failure is a term widely used in various fields, such as engineering, psychology and political science, and its definition varies depending on the context. In engineering, it refers to the failure of a component or system to perform its functions correctly. In psychology, it is related to the inability to deal with stressful situations. In political science, it involves the collapse of governments or political systems. The specific definition of the failure is crucial to identifying and understanding the problem, considering aspects such as its nature and geographic location. Furthermore, some perspectives consider failure as an opportunity for progress and evolution.

The root cause plays a crucial role in resolving problems and improving systems and processes. It involves identifying the primary causes underlying unwanted symptoms or effects.

When corrected, the root cause prevents the problem from recurring, eliminating or reducing its effects. Identifying the root cause is not always obvious, requiring systematic analysis and the application of appropriate techniques.

Corrective action is a measure to correct problems or deviations in systems or processes, while preventive action seeks to prevent such problems from occurring. Both are essential for quality management, allowing you to identify, resolve and prevent problems effectively. Corrective action metrics help measure problem-solving performance, while preventative action metrics monitor success in preventing similar problems.

The development of an FMEA begins with the selection of the object of analysis, the formation of a multidisciplinary team and the identification of failure modes. Then, the effects of failures are evaluated, the root causes are determined and preventive or corrective actions are implemented.

Proper selection of criteria in FMEA is crucial. The traditional Risk Priority Number (RPN) classification has limitations, and alternatives consider the relative importance of severity, occurrence and detection. The VDA-FMEA criterion, for example, prioritizes actions based on priority categories.

The risk matrix is a valuable tool for risk analysis and management, allowing you to identify and evaluate potential risks associated with decisions or actions. It uses a two- dimensional approach to classify risks based on probability and impact, helping to identify critical areas that require immediate attention.

5. Materials and Methods

The methodological approach adopted for this dissertation is applied research, which aims to apply accumulated theoretical knowledge to solve real-world problems. This approach, according to Marconi and Lakatos (2017), is characterized by its focus on immediate practical solutions to real problems. Appolinário (2011) also defines applied research as that which aims to solve concrete problems through the application of scientific knowledge. Adams (2016) emphasizes the dynamics of this approach, requiring the adaptation of traditional research methods to practical contexts and highlighting the importance of constant critical analysis to ensure reliable and relevant results. Chen (2018) proposes a multidisciplinary approach to applied research, highlighting the need to integrate knowledge from different areas to develop comprehensive and effective solutions.

In this context, the applied research carried out was based on an automotive company in the metropolitan region of São Paulo. The company's expertise in using FMEA to manage risks in production processes was applied to solve a real problem. The main objective was to develop a methodology that improved a process, focusing on preventive measures and promoting continuous improvement, all within the project risk assessment parameters. This applied research exemplifies the practical application of theoretical knowledge to solve real-world problems in a specific industrial context, highlighting the importance of applied research as a valuable approach to solving real-world challenges.

6. Application of the Proposed Methodology

The research in question took place in a company specializing in the manufacture of cast and machined parts for the automotive industry. This medium-sized company has approximately 400 employees on its team and more than six decades of experience in the automotive market. Its trajectory began in the 1970s, initially supplying machine tools to the automotive industry, but, due to growing demand for high-quality cast iron parts, it expanded its operations to include its own foundry in the following decade. Since then, the company has been dedicated to adopting advanced technologies and continuous improvement programs to produce highly technical and precise parts that meet customer needs.

Currently, the company has a broad portfolio of products that range from light to heavy vehicles, including passenger cars, trucks and tractors. Among the services provided, cast iron foundries stand out, with an emphasis on exhaust manifolds, automotive engine supports, gearbox components and engines. Its ability to offer these services and products results from its flexibility and adaptability, as well as the presence of its own foundry facilities, a painting area and a machining center. The company manufactures more than two hundred different cast and machined products for fifteen OEMs and tier-one companies.

The research focused on establishing a multidisciplinary and collaborative team to develop the FMEA. This team was made up of experts from different areas, such as engineering, production, quality and maintenance, who collaborated in the identification and evaluation of potential failure modes, their consequences and control strategies. The variety of experiences and perspectives was essential for a complete and effective analysis.

During the development of the FMEA, the multidisciplinary team worked collaboratively to identify failure modes, analyze their effects, identify root causes of failures, and propose control strategies. Furthermore, the research adapted the severity, occurrence and detection criteria to meet the specificities of the company and the project management process.

The risk classification was established based on the Priority of Action (PA), using a matrix that combined severity, occurrence and detection (Figure 1). This matrix helped determine the urgency of action needed to mitigate the risks associated with failures. The research also addressed feasibility and risk analysis in the context of Advanced Product Quality Planning (APQP) (Table 1), emphasizing the importance of ensuring that project requirements are met from the planning phase to production.

Finally, the research described the development of FMEA and the prioritization of actions based on risk priority in the context of project management. This involved using techniques such as brainstorming and Microsoft Excel to identify failure modes, assess their risk and calculate the priority for action. The objective was to promote preventive analyzes and guide strategic decisions during feasibility assessments and risk analysis.

In the process of constructing and classifying severities, the cross-functional team's focus was to analyze failure modes in terms of their potential impact on the customer, quality, cost and schedule. The results revealed that the majority (70.6%) of failure modes were classified as having a high level of severity, while 29.4% were considered moderate. The occurrence analysis evaluated the probability of failures based on historical data from similar projects, showing that 42.8% of occurrences were classified as low and 22.9% as very low. Regarding detection, all cases were classified as moderate, considering factors such as previous experience, system characteristics and risk associated with identifying failures (Table 2).

The VDA-FMEA approach was adopted for risk analysis in projects, with the aim of evaluating the causes of failure at different risk levels. The results indicated that 54% of the causes were categorized as moderate risk, while 46% were considered low risk. This served as the basis for implementing preventive and corrective measures. FMEA stands out as a proactive tool in risk management, allowing organizations to identify potential points of failure and take action before substantial problems occur.

Severity		Occurrence 1	2 -3	4 -- 5	6 - 7	8 - 10	Detection
1		L	L	L	L	L	1
		L	L	L	L	L	2 - 4
		L	L	L	L	L	5 - 6
		L	L	L	L	L	7 - 10
2 - 3		L	L	L	L	L	1
		L	L	L	L	L	2 - 4
		L	L	L	L	M	5 - 6
		L	L	L	L	M	7 - 10
4 - 6		L	L	L	L	M	1
		L	L	L	M	M	2 - 4
		L	L	L	M	H	5 - 6
		L	L	M	M	H	7 - 10
7 - 8		L	L	M	M	H	1
		L	L	M	H	H	2 - 4
		L	M	M	H	H	5 - 6
		L	M	H	H	H	7 - 10
9 - 10		L	L	M	H	H	1
		L	L	H	H	H	2 - 4
		L	M	H	H	H	5 - 6
		L	H	H	H	H	7 - 10

Figure 1: Action Priority

Table 1: Severity APQP

SEVERITY	CRITERIA	
Very Low	1	The failure has no impact (none).
	2	The failure causes a disagreement among team members about the best way to proceed with an important task but can be resolved through discussion and collective decision-making.
Low	3	The failure that can be easily resolved.
	4	The failure does not cause project delays but can be easily mitigated with contingency measures.
Moderate	5	The failure causes a minor project delay but can be easily mitigated with contingency measures.
	6	The failure causes project delays but does not compromise the final delivery, resulting in a slight budget loss.
High	7	Changes in customer needs or requirements that require significant changes to the project scope, compromising the final delivery and part of the budget.
	8	Changes in customer needs or requirements that require some adjustments to the project scope, significantly affecting the schedule or budget.
Very High	9	Non-compliance with government or client regulations.
	10	Loss of a customer.

Table 2: Failure Rate

FAILURE POSSIBILITY	FAILURE RATE	SCORE
Very High: Failure is inevitable	1 em 10	10
	1 em 20	9
High: Constant failures	1 em 50	8
	1 em 100	7
Moderate: Occasional failures	1 em 500	6
	1 em 2.000	5
	1 em 10.000	4
Low: Few failures	1 em 100.000	3
	1 em 1000.000	2
Very Low	Failure is eliminated through preventive controls.	1

To address the moderate risks identified, the team carried out a specific analysis, resulting in 55% of cases classified as low risk and 45% as moderate risk after implementing new preventive measures. This demonstrated a substantial improvement in risk identification. Additionally, the team used a risk matrix to assess the potential impact of moderate risks, considering the financial, operational and reputational areas, and prioritized mitigation strategies based on these impacts.

7. Results Analysis

The research carried out aimed to deepen the understanding of the application of the FMEA methodology (Failure Mode and Effect Analysis) as a tool for risk analysis during the management of Advanced Product Quality Planning (APQP) in a company in the automotive sector (Figure 4). The results obtained from the application of the FMEA methodology in risk mapping for project management revealed a series of valuable patterns and insights.

Table 3: Detection of APQP

DETECTION	CRITERIA	SCORE
Absolute Uncertainty	Project control cannot detect the cause and subsequent mode of failure or there is no control.	10
Very Remote	The chances of detecting the cause and subsequent mode of failure are very remote.	9
Remote	The chances of detecting the cause and subsequent mode of failure are remote.	8
Very Low	The chances of detecting the cause and subsequent mode of failure are very low.	7
Low	The chances of detecting the cause and subsequent mode of failure are low.	6
Moderate	The chances of detecting the cause and subsequent mode of failure are moderate.	5
Likely	The chances of detecting the cause and subsequent mode of failure are likely.	4
High	The chances of detecting the cause and subsequent mode of failure are high.	3
Very High	The chances of detecting the cause and subsequent mode of failure are very high.	2
Certainly	Certainly, the control will detect the cause and subsequent mode of failure.	1

The FMEA methodology was adopted as the main approach to risk analysis, providing a structured and proactive approach to identifying and evaluating potential failure modes, their effects and the control strategies necessary to mitigate associated risks. Its application as an integral part of the APQP management process allowed the company to anticipate possible problems and take preventive measures to minimize negative impacts.

The composition of a multidisciplinary team played a crucial role in the elaboration of the FMEA. Collaboration between specialists from different areas, such as engineering, production, quality and maintenance, contributed to a more complete and effective analysis of the risks inherent to the process in question. This collaborative approach highlighted the importance of diversity of perspectives in identifying and evaluating failure modes.

The flexibility of the FMEA methodology was evidenced by the adaptation of the severity, occurrence and detection criteria for project management, taking into account financial, operational and regulatory aspects. This resulted in a more accurate risk assessment and contributed to a thorough analysis of the potential impacts of failures.

Classifying risks based on the risk priority approach allowed the company to prioritize actions to mitigate identified risks, directing its efforts towards the most critical failure modes. This facilitated the implementation of appropriate strategies to reduce the occurrence and impacts of these failures.

The implementation of the FMEA methodology as part of the risk analysis during the APQP management resulted in a significant improvement in the identification of risks and the application of preventive measures. FMEA's proactive approach allowed the company to anticipate problems, reduce rework and prevent negative impacts on projects. Furthermore, multidisciplinary collaboration, customization of criteria and objective risk classification (Table 4) contributed to a more comprehensive and accurate risk analysis, culminating in a process of continuous improvement.

At the end of the process, an analysis of strengths and weaknesses in the FMEA for APQP was carried out, involving the entire team involved in developing the methodology, with indirect interaction from the company's management. This analysis provided valuable insights to further improve the application of FMEA and strengthen risk management in the company.

As recommended by the IATF (International Automotive Task Force), feasibility and risk analysis plays a central role in preventing problems and continuously improving processes in the automotive industry. The assessment of viability

Table 4: FMEA Example

Process Item	Process Step	Process Step Function and Requirement	Failure Mode	Potential Failure Effect	Severity	Failure Cause	Current Prevention Method	Occurrence	Current Detection Method	Detection	Action Priority	Prevention Action	Detection Action	Target Date	Status	Completion Date	Severity	Occurrence	Detection	Action Priority
Process Item	APQP Phase 01 / 02	Meeting the criteria of APQP (Advanced Product Quality Planning) for planning and developing the manufacturing process.	Absence of Deadlines and Quantities for Prototype and Pilot Batch Parts.	Production Process Delay: If the deadlines and quantities for prototype and pilot batch parts are not defined, it can be challenging to ensure the progress of the production process according to the established schedule.	7	Lack of Resources: If the company does not have the necessary resources to produce the prototype and pilot batch parts according to the established deadlines and quantities, there may be delays in the production process.	-	3	Critical Analysis of Product Development Input Data: "Analyzing whether all stages of the production process have been taken into account in the planning: If any significant stage has been omitted or under-estimated, it may indicate a lack of planning. Additionally, it is important to verify whether there has been sufficient time allocated to each stage of the process and whether the necessary resources have been appropriately allocated."	5	M	Create a contingency plan to deal with unforeseen events or delays.	-	-	-	-	-	-	-	-

Table 4 (Cont.)

Process Item	Process Step	Process Step Function and Requirement	Failure Mode	Potential Failure Effect	Severity	Failure Cause	Current Prevention Method	Occurrence	Current Detection Method	Detection	Action Priority	Prevention Action	Detection Action	Target Date	Status	Completion Date	Severity	Occurrence	Detection	Action Priority
Process Item	APQP Phase 01 / 02	Meeting the criteria of APQP (Advanced Product Quality Planning) for planning and developing the manufacturing process.	Absence of Deadlines and Quantities for Prototype and Pilot Batch Parts.	Production Process Delay: If the deadlines and quantities for prototype and pilot batch parts are not defined, it can be challenging to ensure the progress of the production process according to the established schedule.	7	Lack of Resources: If the company does not have the necessary resources to produce the prototype and pilot batch parts according to the established deadlines and quantities, there may be delays in the production process.	-	2	Critical Analysis of Product Development Input Data: Analyzing whether all stages of the production process have been taken into account in the planning: If any significant stage has been omitted or underestimated, it may indicate a lack of planning. Additionally, it is important to verify whether there has been sufficient time allocated to each stage of the process and whether the necessary resources have been appropriately allocated.	5	M	Create a contingency plan to deal with unforeseen events or delays.	Create a contingency plan to deal with unforeseen events or delays.	Done	Done	NA	7	2	4	L

and risk is critical both before and during the establishment of supply contracts, and the adoption of these principles demonstrates the company's commitment to quality and customer satisfaction, consolidating a proactive approach to risk management and search for continuous improvement in the automotive scenario.

8. Conclusion

The research demonstrated that the application of the FMEA methodology in risk analysis during APQP management can offer advantages to companies in the automotive sector. The structuring of the FMEA, multidisciplinary collaboration, customization of criteria and objective risk classification contributed to accurate analysis, a proactive approach to risk mitigation and informed decision-making.

The integration of FMEA into the APQP process allowed the company to anticipate problems, implement preventive measures and promote excellence in the quality of projects developed. Furthermore, the FMEA approach aligned with the requirements of the IATF 16949 standard reinforced the company's commitment to regulatory compliance and continuous improvement.

For future research, it would be interesting to explore cases from other companies in different sectors to evaluate the applicability of the FMEA methodology in risk analysis and project management. Furthermore, investigating the challenges and limitations faced by companies when adopting FMEA as a risk analysis tool could also enrich the understanding of this approach.

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