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Practical Risk Management for Aeroengine Maintenance: An Industry 5.0 Approach

Jose Pereira

Engineering Centre, Petropolis Catholic University, Petropolis, Brazil. E-mail: josecristiano.pereira@ucp.br

Flavio Frade

Engineering Centre, Petropolis Catholic University, Petropolis, Brazil. E-mail: flavio.frade@ucp.br

Giovane Quadrelli

Engineering Centre, Petropolis Catholic University, Petropolis, Brazil. E-mail: giovane.quadrelli@ucp.br

Vanessa Santos

Business Administ. Centre, Petropolis Catholic University, Petropolis, Brazil. E-mail: vanessa.santos@ucp.br

Flavio Almeida

Engineering Centre,. Centre, Petropolis Catholic University, Petropolis, Brazil. E-mail: flavio.book@gmail.com

This study presents a method for identifying and managing risks in the aeronautical engine overhaul process. It emphasizes integrating this process with the Operational Safety Management System (SMS) to enhance quality and meet regulatory requirements. The study also introduces an optimized risk prioritization process using Bayesian Belief Networks (BBN) and Fuzzy Logic. As technology evolves, it brings both advancements and new risks. Effective risk identification and response are vital in aircraft engine maintenance due to the potentially catastrophic consequences of engine failure during flight. The study combines a literature review on probabilistic risk analysis with a case study of aircraft and engine overhaul process, presenting a method for integrating risks from various sources into a unified model. The mathematical method, employing BBN and Fuzzy Logic, aids in prioritizing risk mitigation actions. By integrating the overhaul process with SMS, aero engine operations can enhance quality and operational safety while reducing costs. The approach aligns with industry standards and regulations. In conclusion, this method offers significant potential for optimizing risk management, especially in aeronautical engine maintenance. It contributes to the knowledge of process and aero engine maintenance, can aid safety professionals, and its implications can extend to industries where safety and risk management are paramount.

Keywords: Bayesian Belief Networks (BBN), Fuzzy Logic, Risk Management. Operational Safety, Probabilistic Risk Assessment, Aeroengine Overhaul. Quality and Safety, Industry 5.0.

1. Introduction

Technological advancements have significantly improved aero-engine performance, efficiency, and reliability. However, these innovations introduce complexities in manufacturing and maintenance, requiring robust risk identification and mitigation strategies. In-flight engine failures, once frequent, have drastically declined from 40 per 100,000 flight hours in the 1960s to less than 1 per 100,000 today. Despite this progress, emerging technologies demand continuous risk assessment and resource optimization to maintain safety and compliance with Civil Aviation Regulations and AS9100D standards. Effective risk management is crucial, as failures can lead to quality issues, operational inefficiencies, and regulatory non-compliance, resulting in fines and restrictions. Prioritizing risks remains challenging due to the wide range of potential issues. Previous studies, such as Pereira (2017), combined Bayesian networks with bow-tie diagrams for risk assessment in aero-engine manufacturing, while Di Maio (2020) applied similar models in the oil and gas industry. However, research is lacking on using Bayesian Belief Networks (BBN) and Fuzzy Logic in aero-engine repair stations. This study addresses that gap by developing a risk assessment model that consolidates various risks into a single operational risk score. Using BBN and Fuzzy Logic, the study evaluates risks in the overhaul process and integrates them into a Safety Management System (SMS) to enhance compliance with AS9100D standards. A case study of an aero-engine repair station is conducted to identify gaps and improve safety, quality, and risk prioritization. Additionally, the study explores how Industry 5.0 concepts can support SMS integration in aero-engine maintenance. The research aims to answer the following questions: 1 - How can the overhaul process be integrated with SMS using Bayesian Networks to improve quality and regulatory compliance? 2 - How can Bayesian Networks and Fuzzy Logic prioritize risks in the overhaul process? 3 - How can an organization optimize its SMS to reduce quality costs amid continuous operational changes? 4 - How can Industry 5.0 support the integration of aero-engine overhaul with SMS?

This study contributes to probabilistic risk analysis in aero-engine maintenance. The paper is structured as follows: Section 2 reviews literature on Operational Safety, SMS, Probabilistic Risk Analysis, BBN, regulatory compliance, AS9100, and Fuzzy Logic. Section 3 outlines the methodology, Section 4 presents results, Section 5 discusses findings, and Section 6 concludes the study..

2. Literature Review

The literature review is divided into four sections. The first section encompasses publications related to aeronautical maintenance and change management. The second section presents operational safety and risk management studies within aviation maintenance. The third section compiles recent research on probabilistic risk assessment using Bayesian Belief Networks (BBN). The fourth section presents current studies on fuzzy logic, and the fifth section is dedicated to studies examining quality within aviation maintenance.

2.1 Aeroengine Maintenance and Change Management

Pang, Aziz, and Pang et al. (2020) stress the essential role of integrated risk analysis in planning and controlling risks and hazards resulting from proposed changes. Considering the current trends and developments, the literature indicates that (1) there is a growing number of publications addressing change management issues and applications; (2) researchers are not solely focusing on small and medium-sized changes but are also examining significant changes, and (3) optimizing the change management process is crucial for mitigating risks that could result in substantial financial losses for organizations. Moretti et al. (2021) conducted a case study in a manufacturing industry to assess the trade-off between efficiency and quality, discussing managerial implications of solutions with various approaches. Assad et al. (2021) investigated the decision-making process in a highly flexible and subjective environment, proposing a decision support system to guide supply.

2.2 Operational Safety and Risk Management

Santhosh and Patelli (2020) stated that major accidents in the industry and critical infrastructure failures have generated an absolute need for new and efficient approaches to risk assessment and security management. Risk management starts by reviewing all relevant information, particularly the combined risk assessment, consisting of risk and concern assessments. Together with the judgments made in the risk characterization and assessment phase, this information forms the input material on which management options are evaluated and selected (Aven, 2012).

2.3 Probabilistic risk Assessment using Bayesian Belief Networks (BBN)

A Bayesian Belief Network (BBN) is a probabilistic graphical model that represents variables and their conditional dependencies using a directed acyclic graph. It is used for reasoning under uncertainty by applying Bayesian inference, allowing decision-makers to update probabilities as new data becomes available. BBNs are widely used in risk assessment, diagnostics, and decision-making, particularly in complex aviation, healthcare, and engineering systems. Delen, Topuz, and Eryarsoy (2020) highlight the

Methodology's success in capturing probabilistic interactions between the dependent and related variables using a large, feature-rich dataset, revealing underlying, potentially complex/non-linear relationships. Dang et al. (2020) note that Bayesian Belief Networks (BBN) can quantify various types of supplies, demands, and budgets, serving as a decision-support tool in risk analysis.

2.4 Probabilistic risk Assessment using Fuzzy Logic

Kundu and Adhikari (2022) formulated a mathematical model to evade response bias latent in the quantification process in any decision-making by applying intuitionistic fuzzy logic. He et al. (2022) conducted a case study that showed the fuzzy analytic hierarchy process and Bayesian Network for gas overrun control and treatment in coal mines to ensure safe and efficient mining. Wang et al. (2021) concluded that Fuzzy evaluation provided the risk interval and membership degree, contained more parameter information, quantified and reduced parameter uncertainty, provided more comprehensive results, and compensated for the deficiency.

2.5 Industry 5.0 in Aviation Maintenance

Industry 5.0 is an evolution of Industry 4.0 that emphasizes human-centric, resilient, and sustainable manufacturing by integrating advanced technologies like artificial intelligence (AI), robotics, and the Internet of Things (IoT) with human expertise. It focuses on collaboration between humans and intelligent machines, enhancing efficiency, customization, and environmental responsibility while ensuring ethical and social considerations in industrial processes. Reviewing the advancements in Industry 5.0, recent studies have highlighted various advancements in Industry 5.0, including dual resource-constrained job shop problems (Chang et al., 2024), unsupervised anomaly detection (Zajec et al., 2024), and human-centric manufacturing (Horvat et al., 2024). Regarding AI in Enterprise Engineering, Tortorella et al. (2024) investigated the impact of AI on enterprise engineering in lean organizations. This research can be applied to aviation maintenance to optimize processes and improve decision-making. Considering Autonomy Models, Goujon et al. (2024) proposed a framework for designing autonomy models, which can be adapted to aviation maintenance to automate routine tasks and enhance efficiency. Concerning Dynamic Scheduling, Zhao et al. (2024) developed a hierarchical reinforcement learning framework for dynamic scheduling, applicable to aviation maintenance planning and resource allocation deficiency.

This literature review outlines the evolution of risk management in aero-engine maintenance, progressing from traditional methods to advanced Industry 5.0 solutions. The first section on aero-engine maintenance and change management highlights the need for structured risk assessment when implementing operational changes. Studies emphasize the importance of balancing efficiency and quality while mitigating risks from process modifications. Next, operational safety and risk management reinforce the necessity of structured frameworks to prevent failures and ensure compliance. This section connects risk assessment to safety standards, establishing a foundation for more advanced methodologies. Bayesian Belief Networks (BBN) introduce a probabilistic approach to managing uncertainty, enhancing predictive capabilities by analyzing dependencies among risk factors. Similarly, fuzzy logic refines risk assessment by incorporating qualitative and uncertain data, offering a flexible decision-making framework for maintenance operations. Finally, Industry 5.0 in aviation maintenance explores AI-driven enterprise engineering, automation, and dynamic scheduling to optimize workflows and resource allocation. These advancements support predictive maintenance and enhance decision-making, aligning with the principles of intelligent risk management. This structured review demonstrates the transition from conventional risk management to modern, data-driven methodologies, supporting the research on Practical Risk Management for Aeroengine Maintenance: An Industry 5.0 Approach by showing how emerging technologies improve safety, efficiency, and reliability.

4. Methodology

This study employs a structured approach, integrating Bayesian Networks, Fuzzy Logic, and Industry 5.0 concepts to enhance risk management in aero-engine maintenance. Using both qualitative and quantitative methods, it combines real-world observations with statistical analysis for objectivity. For Research Question 1, the study examines how the aero-engine overhaul process can be integrated into a Safety Management System (SMS) using Bayesian Networks to improve compliance with Civil Aviation Agency regulations and AS9100 standards. A case study approach (Eisenhardt, 1989; Hancock et al., 2021) involved experienced Quality, Manufacturing, and Process Engineers and Operators. Unstructured interviews and document analysis led to the development of a conceptual flow diagram and an SMS framework aligned with regulatory and industry best practices. For Research Question 2, the study explores Bayesian Networks combined with Fuzzy Logic for risk prioritization in engine overhaul. Risk assessment diagrams were created using historical data, industry standards, and expert input, identifying hazards and their probabilistic interactions. Fuzzy Logic principles quantified uncertainties, refining risk assessment for improved decision-making under uncertain conditions. For Research Question 3, Bayesian Networks were applied to optimize SMS by prioritizing risks and reducing quality costs. Data from archival records, regulations, and expert interviews were analyzed to assess safety measures, defect rates, and cost implications. Simulations using Bayesian models provided data-driven decision-making insights, enhancing safety and cost efficiency. For Research Question 4, the study assesses how Industry 5.0 concepts integrate with SMS in aero-engine overhaul. A literature review on AI-driven risk management, digital twins, and automation evaluated their impact on risk identification and mitigation. Findings suggest that AI-based anomaly detection, predictive maintenance, and human-centric automation enhance SMS implementation. The study ensures a comprehensive analysis by triangulating industry standards, technical documentation, and expert insights. The results reinforce the effectiveness of Bayesian Networks, Fuzzy Logic, and Industry 5.0 in optimizing risk management for aero-engine maintenance.e.

4. Results

Integrating the aero-engine overhaul process with the operational Safety Management System using BBN-Fuzzy to improve quality performance and compliance with Civil Aviation Agency Regulations and the requirements AS9100 is challenging. This section shows the Integration of the Aero-engine Overhaul Process and SMS, the prioritization risks in the aero-engine overhaul process with BBN and Fuzzy, the Optimization of the organization's operational safety management with BBN and Fuzzy Analysis and the Industry 5.0 concepts that can help the aero-engine overhaul process be integrated with an operational Safety Management System.

4.1 Integration of Aero-engine Overhaul Process and SMS.

SMS elements are structured to enable aviation organizations to systematically detect, evaluate, and mitigate safety risks, promoting a strong safety culture across the industry. Compliance with ICAO's SMS requirements is essential for maintaining safety standards and ensuring the well-being of passengers, employees, and the public. ICAO regulations about Safety Management Systems have been instituted with the primary objective of bolstering safety standards within the aviation industry. Airlines are mandated to adhere to these regulations as a means of ensuring the safety of their operations. Moreover, they are also responsible for ensuring that their vendors and partners adhere to these regulations. Aeroengine repair stations provide essential engine services to airlines, and they must comply with these ICAO regulations to uphold safety standards. It is worth noting that certain aviation authorities have devised specific SMS regulations that pertain to repair stations. Figure 1 illustrates the flow-down process.

Figure 1 - Regulatory flow-down process

Figure 1 illustrates the interaction between aviation stakeholders within a Safety Management System (SMS). Aviation authorities, such as FAA, EASA, ANAC, GACA, TCCA, and CAAC, regulate compliance with safety standards. Airlines, including FedEx, Avianca, Azul, GOL, LATAM, Ryanair, Emirates, Air France, and Etihad, rely on SMS for operational safety. Aero-engine repair stations play a crucial role in maintaining airworthiness. The figure highlights how aviation authorities oversee airlines and repair stations, ensuring compliance with regulations. ICAO serves as the central body aligning these entities within a global safety framework. Appendix 1 details the integration of aero-engine overhaul into SMS. The first element emphasizes the importance of a strong safety culture, driven by senior management's commitment to policies and objectives. The second focuses on risk management, including hazard identification, assessment, and mitigation. The third mandates verification of operational safety performance and risk controls. The fourth highlights safety promotion, fostering a proactive safety culture to achieve operational safety objectives. Appendix 2 presents the structured risk management process within the SMS. It outlines a systematic approach to identifying, assessing, and mitigating risks in aero-engine maintenance. The first step involves data collection from maintenance records, incident reports, and expert evaluations. Next, Bayesian Networks and Fuzzy Logic are applied to quantify and prioritize risks based on probability and impact. The model allows dynamic risk assessment, adapting to new data and operational conditions. The final step integrates findings into decision-making, enabling preventive actions, optimized resource allocation, and regulatory compliance. This structured approach enhances safety, efficiency, and cost-effectiveness in aero-engine maintenance..

4.2 Prioritization risks in the aero-engine overhaul process with BBN and Fuzzy

The number of hazards raised is substantial. Treatment prioritization is critical because it can cause a disaster with a high human and financial impact if it is not done adequately. A node with a high probability will indicate a high probability of failure. The Bayesian Belief Network (BBN) in Figure 3 represents the relationships between different failure causes in the aero-engine maintenance process, ultimately leading to "Failure in Operation." The diagram visually maps various factors contributing to failures, illustrating dependencies between different processes and their associated risks. Root causes, such as incorrect tools, manuals, processes, or preparation errors, are highlighted as key risk factors occurring across multiple maintenance stages, including Inspection, Cleaning, Repair, Assembly and Modulation, and Preparation for Testing and shipping. Intermediate causes, such as incorrect material handling, improper inspections, and transportation damage, link these root causes to the final outcome, showing how minor errors can propagate and compromise operational safety. The final outcome, represented by "Failure in Operation," results from accumulating these contributing factors, demonstrating how poor maintenance practices—such as incorrect procedures, tool selection errors, and lack of traceability—can lead to safety-critical failures. This BBN serves as a valuable tool for risk prioritization by identifying the most critical failure points in the aero-engine overhaul process. By analyzing probability dependencies, maintenance teams can focus on mitigating high-impact risks, improving operational safety, and ensuring compliance with regulatory standards. The BBN is shown in Figure 3.

Figure 3 – BBN Model

4.3 Optimization of the organization's operational safety management with BBN and Fuzzy Analysis

The organization's operational safety management system can be optimized to prioritize risks using Bayesian Networks to reduce quality costs by the changes shown in the red arrows in Appendix 2, which shows the Integration of BBN and Fuzzy Method into the SMS. The integration details are explained in detail in the following items: (I) In the operational safety policy and objectives: Preparation of documentation that addresses the combination of risks using Bayesian Belief Networks (BBN) - Fuzzy and sensitivity analysis. The policy and objectives should include BBN and sensitivity analysis to enhance integrated risk analysis. (II) In managing operational safety risks: Storage data related to the BBN and fuzzy network in a database for utilization across the entire organization. (III) Operational safety Assurance: Development of a metric for assessing the Risk Priority Number (RPN) reduction through BBN-Fuzzy. In other words, creating indicators demonstrating the safety improvements achieved using BBN-Fuzzy aids in risk prioritization and action planning. Measuring the effectiveness of BBN-Fuzzy through SMS audits and employing BBN to survey and analyze risks introduced by New Products Introduction/Management of Change (NPI/MOC), thus enhancing the change management process. As part of the continuous improvement process, establishing periodic metrics to evaluate new overall risk values when using BBN-Fuzzy, thereby managing increased global risks associated with BBN usage. (IV) To promote operational safety: Designing training programs for using BBN-Fuzzy in integrated risk analysis, communicating the outcomes of sensitivity analysis conducted with BBN-Fuzzy.

4.4 Industry 5.0 concepts that can help the aero-engine overhaul process be integrated with an operational Safety Management System

The selected Quality, Manufacturing, Process Engineers, and Process Operators with extensive experience in aviation maintenance and SMS were interviewed on how Industry 5.0, focusing on human-machine collaboration and advanced technologies, could enhance the effectiveness and efficiency of Repair Station Safety Management Systems (SMS). Table 1 shows the actions necessary for improvement:

Table 1 - Actions for improvement:

Category	Actions
Data-Driven Risk Assessment and Management:	Real-time data analysis: Utilize AI-powered analytics to continuously monitor operational data, identify emerging risks, and proactively implement mitigation measures.
	Predictive maintenance: Employ data-driven models to predict potential equipment failures, enabling preventative maintenance and reducing downtime.
Enhanced Operational Safety Assurance:	Automated monitoring: Implement automated systems to monitor safety performance indicators, identify trends, and detect anomalies.
	AI-powered incident analysis: Use AI to analyze incident data, identify root causes, and develop targeted prevention strategies.
	Digitalized documentation: Store safety-related documentation and records in a centralized digital repository for easy access and analysis.
Optimized Safety Promotion and Training:	Personalized training: Leverage AI to tailor training programs to individual employees' needs and learning styles.
	Gamified learning: Incorporate interactive elements and gamification to make safety training more engaging and effective.
	Virtual reality simulations: Use VR to provide realistic training scenarios and improve knowledge retention.
Improved Communication and Collaboration:	AI-powered communication platforms: Use AI-driven tools to facilitate efficient communication and stakeholder collaboration.
	Real-time information sharing: Enable real-time sharing of safety information and alerts to ensure timely response.
Enhanced Decision-Making:	AI-assisted decision support: Employ AI algorithms to analyse complex data and provide recommendations for decision-making.
	Scenario planning: Use AI to simulate various scenarios and assess potential risks and outcomes.
Increased Efficiency and Productivity:	Automation of routine tasks: Automate repetitive tasks to free up resources for more strategic activities.
	Optimized workflows: Use data analytics to identify inefficiencies and optimize workflows for improved productivity.

5. Discussion of Results

The study confirms the proposed risk assessment method's effectiveness in aero-engine overhaul. It demonstrates how integrating the overhaul process into an Operational Safety Management System enhances quality, ensures compliance with aviation regulations, and optimizes risk management. The case study validates the model’s ability to unify risk factors using Bayesian networks and fuzzy logic, prioritizing critical risks to improve workshop operations. The model enables strategic resource allocation by estimating failure probabilities and conducting sensitivity analyses, reducing quality-related costs. It advances risk analysis beyond traditional methods by offering a comprehensive framework for mitigating non-conformities and improving decision-making. The findings align with existing literature on prioritizing risks based on detectability and severity while addressing gaps through quantitative methods like Bayesian belief networks. Additionally, the study highlights how improved communication and a data-driven risk management approach enhance operational efficiency. Integrating Industry 5.0 technologies into SMS processes further strengthens safety, efficiency, and compliance, leading to better performance and higher customer satisfaction.

6. Conclusion

This study confirms that integrating Bayesian Networks and Fuzzy Logic into an Operational Safety Management System (OSMS) significantly enhances risk management, reduces operational failures, and ensures compliance with National Civil Aviation Agency regulations and AS9100D standards. By systematically identifying, consolidating, and prioritizing risks, the proposed approach improves resource allocation for risk mitigation, ultimately reducing quality-related costs while maintaining safety and efficiency in the aero-engine maintenance process. Our findings highlight the critical role of Bayesian Networks in optimizing risk assessment, offering a structured and data-driven method to evaluate uncertainties in complex maintenance environments. Simulations demonstrated that combining Bayesian Networks with Fuzzy Logic enhances accuracy in assessing and prioritizing risks from multiple sources, leading to more effective decision-making and proactive failure prevention. Additionally, the integration of Industry 5.0 concepts into Repair Station Safety Management Systems presents significant advancements in risk assessment, operational safety, workforce training, communication, and efficiency. Organizations that adopt these innovations can improve safety outcomes, streamline operations, and enhance customer satisfaction. Investing in emerging technologies, fostering innovation, and strengthening collaboration with technology partners will be essential for long-term success in the aviation sector. Beyond aviation, the proposed methodology provides a structured framework that can be adapted to other industries seeking to improve risk management practices. This research identifies key risk factors affecting workshop operations and offers practical insights for managers, engineers, and industry stakeholders. Future studies should explore broader applications of this methodology through additional case studies, further refining risk identification and mitigation strategies. The validation of this study by industry experts shows its practical relevance and effectiveness, reinforcing its potential to enhance risk management, regulatory compliance, and operational performance in aviation and beyond.

References

Assad Neto, A., Sampaio, J., Detro, S.P. et al. Reconciling Process Flexibility And Standardization: A Case Study In The Automotive Industry. Operations Management Research, v. 14, n. 3-4, p. 507-524, 2021. https://doi.org/10.1007/s12063-021-00230-y

Aven T. Foundations of Risk Analysis. 2. ed. Stavanger: Jonh Wiley and Sons, 2012.

Dang, Kinh Bac et al. Potential, flow and demand of rice provisioning ecosystem services–Case study in Sapa district, Vietnam. Ecological Indicators, v. 118, p. 106731,

Delen, Dursun; Topuz, Kazim; Eryarsoy, Enes. Development of a Bayesian Belief Network-based DSS for predicting and understanding freshmen student attrition. European journal of Operational Research, v. 281, n. 3, p. 575-587, 2020.

Eisenhardt, Kathleen M. Building Theories from Case Study Research. Academy of Management Review, v. 14, n. 4, p. 532-550, 1989.

Hancock, Dawson R.; Algozzine, Bob; Lim, Jae Hoon. Doing Case Study Research: A practical guide for beginning researchers. 2021. ICAO - International Civil Aviation Organization. Doc 9859 Safety Management Manual, 2018.

Moretti, Emilio et al. Exploring the Application of Machine Learning To the Assembly Line Feeding Problem. Operations Management Research, v. 14, p. 403-419, 2021. Disponível em:

Pang, Kar Kei; AZIZ, Hanida Abdul; PATAH, Abir Abdul. Management of Change System with Integrated Risk Analysis for Temporary and Emergency Cases. Pertanika Journal of Science & Technology, v. 28, n. 101, 2020.

Pereira J. C. Modelo causal para análise probabilística de risco de falhas de motores a jato em situação operacional de fabricação. Univ. Federal Fluminense, 2017. Accessed May 05, 2021, https://app.uff.br/riuff/handle/1/4078.

Pereira, José Cristiano et al. Probabilistic Risk Analysis Of Safety Management System Failure And Impact On Economic Performance: The Case Of Jet Engine Manufacturing. International Journal of Management and Decision Making, v. 14, n. 4, p. 345-372,2015.

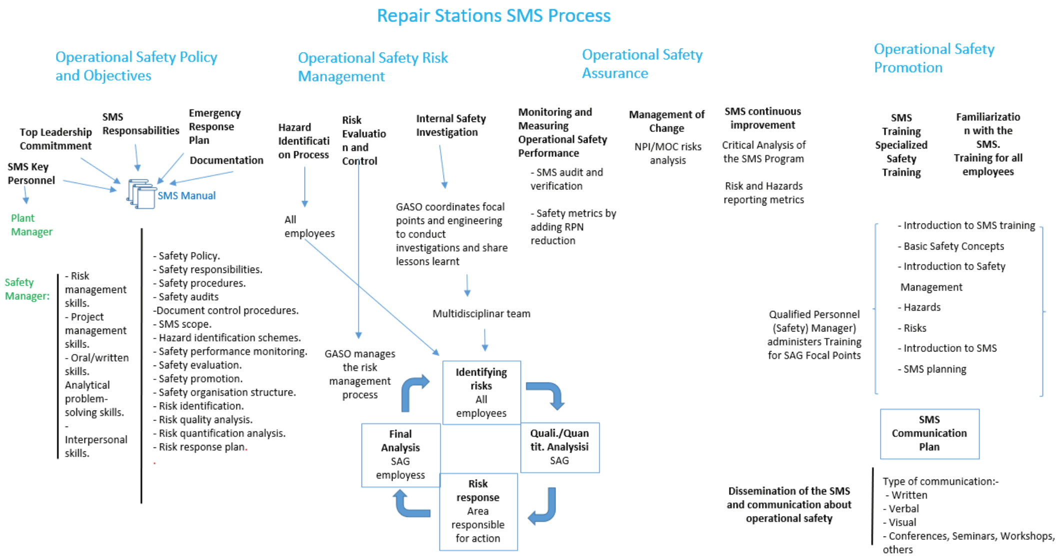
Pereira, José Cristiano. Modelo Causal Para Análise Probabilística De Risco De Falhas De Motores A Jato Em Situação Operacional De Fabricação. Univ. Federal Fluminense, 2017.

Pereira, José Cristiano; Fayer, Geane Cristina. Strategic Decision Making to Maximise the Efficiency of Water Usage in Steel Manufacturing Process via AHP and BBN: A Case Study. International Journal of Information and Decision Sciences, v. 12, n.4, p. 328-347, 2020.

Santhosh, T.V., Patelli E., A bayesian network approach for the quantitative assessment of resilience of critical systems, ESREL, London, 2020. Accessed April 29, 2021,

Yin, robert k. Case Study Research: Design And Methods. United States: Sage Publications, 1989.

Appendix 1. Repair Station SMS Process



Appendix 2. Integration of BBN and Fuzzy Method into the SMS