WEATHER RADAR SYSTEM FAILURE ANALYSIS ON AN AIRBUS 320-200 AIRCRAFT AT PT GMF AEROASIA USING FMEA AND RCA TO IMPROVE RELIABILITY AND SAFETY

Alfina Rahmawati[1]; Bhima Shakti Arrafat[2]; Muhamad Faridh Al Farisy[3]; Muchammad Furqon[4]; Muqdhatas[5], Tia Tsania[6]

[1]Indonesian Aviation Polytechnic; [2]Indonesian Aviation Polytechnic; [3]Indonesian Aviation Polytechnic;[4]National Air And Space Power Center Of Indonesia
[1]alfinarahmawati541@gmail.com;[2]bhima.shakti@ppicurug.ac.id;[3]faridhalfarisy@ppicurug.ac.id [4]muchammadfurqon10@gmail.com
[5,6]ikeo.santai@gmail.com;

Abstrak — *This study aims to analyze the failure of the Weather Radar System using a mixed-methods sequential explanatory approach. Flight safety is highly dependent on the reliability of avionics systems, one of which is the Weather Radar System that functions to detect extreme weather phenomena. Damage to this system is categorized as a no-go item in the MEL and based on data from the Top Delay Report of PT GMF Aero Asia Tbk for the period 2020–2024, it ranks fifth as the highest cause of delays on the Airbus A320-200, with 341 failure reports. The quantitative stage uses Failure Mode and Effects Analysis (FMEA) and Pareto Diagrams to identify critical components, while the qualitative stage uses Root Cause Analysis (RCA) and Fishbone Diagrams to explore the root causes of failure. The results show that the Transceiver is the most problematic component with 39% of unscheduled removals with the dominant failure mode being Intermittent Signal with an RPN value of 336. RCA reveals the main causal factors including human error, non-compliance with procedures, limited tools, low material quality, and exposure to extreme environments. Recommendations for improvement include improving technician competency, tool procurement and calibration, stringent material vendor selection, and system protection from extreme weather. This research is expected to support increased maintenance effectiveness, reduce delays, and strengthen the safety culture at GMF.*

Keywords: *Weather Radar System, Airbus A320-200, Failure Mode and Effects Analysis (FMEA), Root Cause Analysis (RCA), Transceiver, Intermittent Signal, Airworthiness*

1. INTRODUCTION

In the aviation industry, aircraft component maintenance and upkeep must be carried out in accordance with strict standards to ensure safety and optimal performance (Law No. 1 of 2009, 2009). Safety and airworthiness are top priorities in the aviation industry, as stipulated in national regulations and ICAO standards. ICAO regulations stipulate that aircraft certification must ensure that its systems and components meet airworthiness standards (ICAO, 2018). One avionics system that plays a crucial role is the

Weather Radar System, which detects hazardous weather phenomena such as storms, turbulence, and heavy rainfall. This system plays a crucial role in detecting hazardous weather phenomena such as thunderstorms, turbulence, and heavy rainfall, which can threaten flight safety if not properly anticipated by the flight crew (Renata et al., 2023). Given this critical role, the Minimum Equipment List (MEL) on the A320-200 aircraft stipulates that the aircraft must not operate if this system is malfunctioning. Based on data from the Top Delay Report of PT. According to GMF Aero Asia Tbk's 2020–2024 report,

Weather Radar System failures ranked fifth as the leading cause of delays on the Airbus A320-200. Furthermore, 341 failure reports were recorded in Pilot Reports during the same period. Another study analyzing five years of data in Norwegian airspace found that of the 124 reported incidents, 76 were related to surveillance functions, and 34 were caused by radar system failures (Ali et al., 2015). This fact indicates the presence of recurring problems that can have serious opera tional impacts, including delays, flight cancellations, and potential threats to flight safety. Observations and interviews with licensed A320-200 technicians identified several critical components, particularly the transceiver and control unit, that are susceptible to damage due to exposure to high temperatures, humidity, and dust contamination. These environmental condi tions accelerate component degradation and increase the risk of system failure. Therefore, this study was conducted with the aim of analyzing Weather Radar System failures on the Airbus A320-200. The methods used are Failure Mode and Effects Analysis (FMEA) to prioritize failure risks based on the Risk Priority Number (RPN) value, and Root Cause Analysis (RCA) to trace the root causes of critical component failures. Through this appro ach, it is hoped that recommendations for improvement can be formulated that can increase the effectiveness of maintenance programs, reduce delays, and maintain flight operational safety.

2. RESEARCH METHOD

This research uses a mixed-methods approach with a sequential explanatory model, integrating quantitative and quali tative analysis sequentially. This approach is typically used when researchers want to delve deeper into initial quantitative findings or confirm and explain quantitative research results with qualitative data (Nasution et al., 2024). The initial stage of quantitative analysis was conducted using the Failure Mode and Effects Analysis (FMEA) method. Failure Modes and Effects Analysis (FMEA) is a technical method for defining, identifying, and analyzing potential failures, problems, and errors in systems, designs, production processes, and services before they reach consumers (Ramadhana, 2021). In this FMEA method, the Risk Priority Number is calculated to determine the greatest potential failure rate. The Risk Priority Number is calculated by multiplying the ratings for three factors (severity x occurrence x detection) (McDermott, 2008). The next stage is qualitative analysis using Root Cause Analysis (RCA). RCA requires researchers to find solutions to pressing problems, unders tand the root causes of the situation, and address them appropriately to prevent similar problems from recurring (Zani & Supriyanto, 2021). The RCA method is very useful for analyzing a system failure regarding unexpected events that occurred, how they could have occurred, and why they could have occurred (Nursyanti & Partisia, 2024). The data sources for this study came from primary and secondary data. This data was collected as an open-ended narrative without trying to match a symptom to a predetermined standard category, such as the answers to questions in the questionnaire (Sitorus, 1998). Primary data were obtained through interviews and questionnaires completed by technicians and engineers licensed A320-200 at PT GMF Aero Asia Tbk. Meanwhile, secondary data was collected from histo rical documents in the form of unscheduled component removal reports, Pilot Reports, Top Delay Reports for the 2020–2024 period, as well as references from the Aircraft Maintenance Manual (AMM), Component Maintenance Manual (CMM), and A320-Series Training Manual.

2.1. Research Model

In the first stage, a quantitative analysis was conducted using the Failure Mode and Effects Analysis (FMEA) method to identify components with the highest failure rate, analyze failure modes, and calculate Risk Priority Number (RPN) values based on severity, occurrence, and detection para meters. This stage employed a Pareto diagram approach. Pareto diagrams are used to compare various categories of incidents arranged according to their size, from the largest on the left to the smallest on the right (Auliandri & Kurniastuti, 2016). Pareto diagrams can be used for various purposes, such as identifying the root cause of a problem, prioritizing corrective actions, and measuring the effectiveness of corrective actions (Putra et al., 2024). The second stage was a qualitative analysis using the Root Cause Analysis (RCA) method. The failure modes with the highest RPN values obtained from the previous stage were further analyzed to identify the root causes. In this stage, a Fishbone Diagram was used to group the causal factors into five main categories. A fishbone diagram is an analytical tool that has the basic function of identifying and organizing the possible causes of a specific effect and then isolating the root causes. To find these various causes, a brainstorming technique can be used by all personnel involved in the process being analyzed (Nursyanti & Partisia, 2024). The fishbone diagram explains the main sources of causes, namely humans, methods, machines, materials, measurements, the environ ment, and other causes. To find these various causes, a brainstorming technique can be used by all personnel involved in the process being analyzed (Nursyanti & Partisia, 2024). This research model is systematically designed to assess the causes of failure. This research model was chosen because it provides the advantage of combining quantitative risk analysis with an in-depth understanding of the causal

factors of failure. The sequential explana tory approach allows the FMEA results to be enriched with RCA findings, thus providing a more comprehensive picture of the Weather Radar System failure problem on the Airbus A320-200. This method combines quantitative and qualitative research sequentially, starting with a quantitative approach in the first stage, followed by a qualitative approach in the second stage. This approach is typically used when researchers want to delve deeper into initial quantitative findings or confirm and explain quantitative research results with qualitative data (Nasution et al., 2024). Thus, this model is capable of not only mapping risk levels but also generating targeted improvement recom mendations to enhance the effectiveness of the maintenance program at PT GMF Aero Asia Tbk.
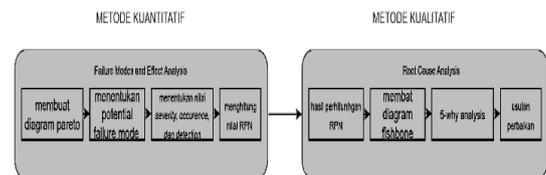
Weather Radar System Failure Research Model
Source: Author's Work

2.2. Research Time and Location

The research was conducted at Hangar 4 of PT GMF Aeroasia, located on Jl. GMF Aeroasia, RT.001/RW.010, Pajang, Benda District, Tangerang City, Banten 15126. The research was conducted over a six-month period, from October 2024 to March 2025.

2.3. Research Data Collection

- *To obtain the data required for this study, the researcher used various data collection techniques. Documents were collected as the primary data source.*
- *Literature Review. A literature review is a section of a scientific paper that includes discussions of previous research and scientific references*

related to the research described by the author in the paper (Hermawan, 2019). In this study, the author sought and studied references related to the Weather Radar System through the Aircraft Maintenance Manual (AMM), Training Manual, engineering informa tion, journals, and other references.

- *Documents. The author used operator operational documents as the primary source of information for the study. The obtained data was processed and developed based on the applied research method. The document used was The failure of the weather radar system on the A320-200 aircraft in 2020-2024.*

- *Interviews. Interviews are used as a data collection technique when researchers want to conduct a prelimi nary study to identify research problems and when they want to learn more in-depth information from respon dents (Sugiyono, 2013). In interviews, researchers can select several infor 1mants deemed to have relevant knowledge and experience related to the phenomenon being studied, which can include two or more informants. In this study, the author interviewed an Airbus 320-200 type rating engineer for the A320-200 aircraft's weather radar system.*

- *Questionnaires. Questionnaires are an efficient data collection technique if researchers know precisely which varia bles to measure and what to expect from respondents (Sugiyono, 2013). The author will distribute question naires to six technicians/engineers with an Airbus 330-300 type rating. The ideal team size is between four and six people (Mcdermott et al., 2013).*

3. RESEARCH RESULTS AND DISCUSSION

This research was conducted to obtain significant results related to the analysis of *weather radar system failures on Airbus A320-200 aircraft, including:*

- *What is the failure rate of Weather Radar System components on the Airbus A320-200 at PT GMF Aero Asia Tbk?*

- *What is the Risk Priority Number (RPN) value for each failure mode on the Weather Radar Transceiver?*

- *What are the root causes of the failure mode with the highest RPN value?*

3.1 Design Stage

The required data has been collected; the next step is data processing and analysis. In this stage, the author analyzed the Airbus A320-200 Weather Radar System to determine the failure mode with the highest risk value and its root cause. To achieve this objective, the collected data will be processed and analyzed according to the following established procedures:

- *Collection of historical data. Data was obtained from unscheduled removal reports for the Airbus A320-200 Wea ther Radar System component for the 2020–2024 period, Top Delay Reports, and Pilot Reports at PT GMF Aero Asia Tbk.*

- *Unscheduled removal data was compil ed into a table to identify components with the highest failure rates. Initial analysis used a Pareto Diagram to determine the critical components that experienced the most frequent failu res.*

- *Failure modes for critical components (especially the transceiver and control unit) were identified based on field data, reference manuals (AMM, CMM), and interviews with licensed Airbus A320-200 technicians.*

- *RPN values were calculated. Severity, occurrence, and detection parameters were determined through technician questionnaires and then calculated to obtain the RPN value for each failure mode using the FMEA method.*

- *The failure mode with the highest RPN*

value was selected as the top priority for in-depth analysis. In this study, the Intermittent Signal failure mode on the transceiver had the highest RPN value.

- *Priority failure modes were analyzed using a Fishbone Diagram to identify the root cause of the failure. Causal factors were grouped into five cate gories: man, method, machine, mate rial, and mother nature.*
- *FMEA and RCA results were interpreted to determine the relation ship between technical and non-technical factors in causing the Wea ther Radar System failure.*
- *Determining improvement recommen dations for the Weather Radar System on the A320-200*.

3.2. Research Results
3.2.1 *Historical Data Analysis*
Based on unscheduled removal data for the Airbus A320-200 Weather Radar System component from 2020–2024, 341 failures were recorded.
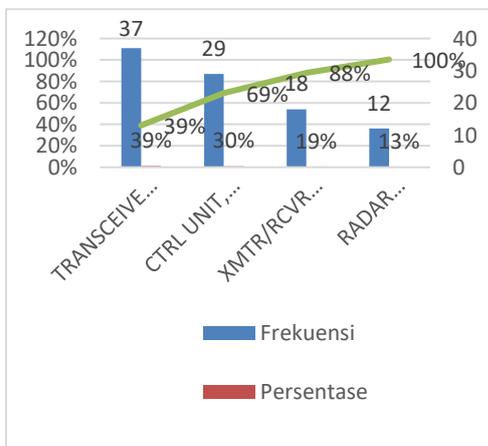
Pareto Chart of Airbus A320 Weather Radar System FailureSource: Author's Work

The Pareto diagram shows the causes of failure. The diagram identifies the highest to lowest percentages of failures between 2020 and 2024. These causes are as follows:

- *Weather Radar Transceiver RTA-4B with a weight of 39%*
- *Weather Radar Control Unit with a*

weight of 30%

- *XMTR/RCVR- Weather Radar 1 / WX Radar XCVR with a weight of 19%*
- *Radar Antenna Drive Unit (SINGLE) with a weight of 13%*
- *Based on the results of component removal data processing on the Airbus A320-200 aircraft Weather Radar system, it was found that the transceiver was the component that failed most frequently, with a higher frequency of 39% compared to other components in the system during the 2020–2024 period.*

3.2.2 *Failure Mode Analysis (FMEA)*
The identification results indicated four main failure modes in the transceiver:

- *No Data Return*
- *Intermittent Signal*
- *No Data Output*
- *Failed BITE Test*

Komponen	Bentuk Kerusakan	S	O	D	RPN
Transceiver	*No Data Return*	8	8	3	192
	Intermitten Signal	8	7	6	336
	No Output Data	8	7	4	224
	Failed Bite Test	7	7	5	245

Risk Priority Number Calculation Results
*Source: Author's Processed Results*

The Risk Priority Number (RPN) is calcu lated by combining severity, occurrence, and detection parameters based on the technician questionnaire results. Of the four failure modes, Inter mittent Signal has the highest RPN value, at 336. This value indicates that the failure is significant, occurs frequently, and is difficult to detect in its early stages.

3.2.3. *Root Cause Analysis*
The Intermittent Signal failure mode was further analyzed using the RCA method with the aid of a Fishbone Diagram. The results indicated that the root causes of the failure stemmed from various factors,

including:
- *Human: technician complacency, poor inter-shift communication.*
- *Method: non-compliance with the AMM, lack of internal troubleshooting procedures.*
- *Machine: use of incomplete or uncalibrated tools.*
- *Material: limited spare parts inventory and the practice of robbing parts.*
- *Mother Nature: exposure to high temperatures, extreme humidity, and dust contamination during prolonged aircraft stays on the apron.*
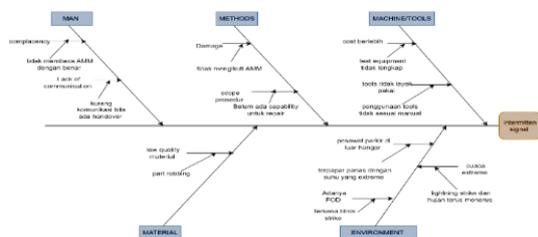
Fishbone Diagram of RCA Failure Mode "Intermittent Signal"
Source: Author's Work

3.2.4. Key Research Findings
Based on the analysis, the following conclu sions can be drawn:
- *The transceiver component is the largest contributor to Airbus A320-200 Weather Radar System failures, accoun ting for 39%.*
- *The Intermittent Signal failure mode has the highest RPN value (336) and is prioritized for further analysis.*
- *The root causes of failure are multifac torial, encompassing both technical (equipment, materials) and non-technical (human, methods, and environ ment) aspects.*
- *Improvement efforts must be compre hensive, encompassing not only compo nent replacement but also improving technician competency, adherence to procedures, equipment calibration, material management, and mitigating environmental factors.*

3.2.5. Interpretation
- *The results show that the transceiver is*

the component with the highest failure rate in the Airbus A320-200 Weather Radar System. The failure rate of 39% indicates that this component has a relatively low level of reliability compared to other components. This condition aligns with the characte ristics of the transceiver as a radar signal processing center that operates continuously and is highly influenced by operating environmental factors.
- *The Intermittent Signal failure mode, which has the highest RPN value (336), reflects complex issues, not only technical but also managerial. From a reliability perspective, a high RPN value indicates a significant risk to flight delays and operational safety. This is consistent with research (Ali et al., 2015), which found that more than 25% of radar incidents in Europe were related to system failures in detecting weather phenomena, primarily due to environmental factors.*
- *The RCA analysis indicates that the root cause of failure is not a single factor, but rather the result of an interaction between human factors, methods, equipment, materials, and the environment. This reinforces the theory that avionics system failures are rarely caused by a single factor, but rather result from latent failures within the maintenance system. For example, the practice of robbing parts not only degrades material quality but also increases the risk of recurring failures, impacting airline operational sche dules.*
- *Practically, the results of this study emphasize the importance of integra ting preventive maintenance and human resource management. Techni cians' adherence to the AMM and internal troubleshooting procedures proved crucial in mitigating risks. Furthermore, identified environmental factors such as high temperature, humidity, and dust contamination*

indicate the need for additional mitiga tion strategies, such as shortening inspection intervals during extreme weather conditions or providing aircraft cover on the apron.

- Therefore, the interpretation of the results of this study indicates that improving the reliability of the Weather Radar System depends not only on component replacement but also on holistic maintenance management, encompassing technical, procedural, and work environment aspects.

3.2.6. Implications
This study has important theoretical and practical implications. Academically, the research results strengthen the study that FMEA and RCA methods can be used in an integrated manner to analyze complex avionics system failures. Meanwhile, practically, the findings regarding the dominance of transceiver failures and the multifactorial causes provide a basis for PT GMF Aero Asia Tbk to strengthen preven tive main tenance programs, improve techni cian compliance with procedures, opti mize spare parts management, and develop mitigation measures against environ mental factors to improve flight relia bility and safety.

4. CONCLUSIONS AND RECOMMENDATIONS
4.1. Conclusions
Based on the results of the research on the Weather Radar System failure analysis on the Airbus A320-200 at PT GMF Aero Asia Tbk using the FMEA and RCA methods, the following key conclusions can be drawn:

- The transceiver component has the highest failure rate in the Weather Radar System, contributing 39% of the total unscheduled removals for the 2020–2024 period.

- The FMEA analysis identified four main failure modes: No Data Return, Intermittent Signal, No Output Data, and Failed BITE Test. The Intermittent Signal failure mode had the highest Risk Priority Number (RPN) value, 336, and was therefore prioritized for further analysis.

- The RCA analysis of the Intermittent Signal failure mode indicated that the root cause of the failure was multifac torial, including:
  o Human factors: technician compla cent behavior, poor inter-shift communication.
  o Method factors: non-compliance with AMM, lack of internal trouble shooting procedures.
  o Equipment factors: incomplete or uncalibrated tools.
  o Material factors: limited spare parts inventory and the practice of robbing parts.
  o Environmental factors: high tempera ture, extreme humidity, and dust contamination on the apron.
  o Weather Radar System failures are not only caused by technical factors, but also organizational and environ mental factors, so handling them requires a holistic approach.

4.2. Recommendations
- PT GMF Aero Asia Tbk needs to prio ritize transceivers in its preventive main tenance program, with stricter routine inspection intervals and a focus on analyzing Weather Radar system failu res on Airbus A320-200 aircraft in the aviation industry, which is a crucial topic related to operational safety and relia bility.

- Identification of critical components (transceivers) and their multifactorial causes, along with concrete improve ment recommendations, demonstrates a practical contribution and can improve maintenance processes and flight safety.

- *Technician competency improvement can be achieved through ongoing trai ning, and enforcement of AMM com pliance is necessary to reduce the risk of recurrent failures.*

- *Spare parts and equipment manage ment must be strengthened through adequate material procure ment, regular tool calibration, and control of environmental factors that could accele rate component degra dation.*

5. REFERENCES

[1] A. Fadhil dan H. Abu Bakar, Analisis Terjadinya Apu Auto Shutdown di Pesawat Airbus A320-200, *Indept*, vol. 5, No. 1.

[2] A. Faizal dan S. Arifin, Analisis Keandalan Instrumentasi pada Unit Central Mechanical Electrical menggu nakan Metode Failure Mode and Effect Analysis (FMEA) (Studi kasus PT. Telkom Area Network Riau Daratan Pekanbaru), Panam.

[3] F. Hakim Nasution, M. Syahran Jailani, and R. Junaidi, Kombinasi (Mixed-Methods) Dalam Praktis Penelitian Ilmiah,J. Genta Mulia, vol. 15, No. 2, pp. 251–256, 2024, [Online]. Available: https://ejournal.stkipbbm.ac.id/index.ph p/gm

[4] F. Rafsyan Zani and H. Supriyanto, Analisis Perbaikan Proses Pengema san Menggunakan *Metode Root Cause Analysis dan Failure Mode And Effect Analysis* Dalam Upaya Meningkatkan Kualitas Produk Pada CV. XYZ, *Semin. Nas. Sains dan Teknol. Terap. IX*, pp. 140–146, 2021.

[5] ICAO, *Annex 8 Aircraft Airworthiness*, July. 2018. [Online]. Available: www.icao.int

[6] L. N. Widyastuti, Analisis Gangguan Sistem Transmisi Listrik Menggunakan Metode Root Cause Analysis (RCA), Fakultas Teknik – Universitas Dipone goro, Semarang.

[7] L. S. Silaban and F. E. Sitorus, Hubungan Karakteristik Model Praktek Keperawatan Profesional Dengan Kinerja Perawat, *BEST J. (Biology Educ. Sains Technol.*, vol. 4, No. 2, pp. 130–137, 2021, doi:10.30743/ best. v4i2.4573.

[8] Renata Salma Ramadhanty, Bambang Bagus Hariyanto, and Teguh Imam Suharto, Desain Antena Mikrostrip Radar Cuaca Pesawat Pada Frekuensi 9,4 GHZ, *J. Public Transp. Community*, vol. 03, Apr. 2023.

[9] R. M. M. B. Robin McDermott, *Basics of Fmea, 2Nd Edition*.

[10] R. B. Abernethy, *Reliability &statistical analysis for predicting life, safety, risk, support costs, failures, and forecasting warranty claims, substantiation and accelerated testing, using Weibull, Log normal, Crow-AMSAA, Probit, and Kaplan-Meier models*, 5 ed. North Palm Beach: R.B. Abernethy.

[11] Sugiyono.157152-ID-wawancara-sebagai-salah-satu-metode-peng, 2013.

[12] T. A. Auliandri and M. Kurniastuti, *Evaluasi On-Time Performance Pada Maskapai Tiger Airways Rute* Sura baya-Singapura dengan Mengguna kan Diagram Pareto, dan Diagram Sebab-Akibat, *J.Manaj. dan Bisnis Indones.*, vol. 3, No. 3, pp. 334–346, doi:10.31843/jmbi.v3i3.89. Diagram Kontrol

[13] UU Nomor 1 Tahun 2009, *No Title*, Indonesia, Pemerintah Pusat. [Online]. Available: https://peraturan.bpk.go.id/Details/54656/uu-no-1-tahun-2009

[14] W. A. S. Putra, E. M. Saputra, M. Miftakhurrohman, and W. D. Lestari, Analisa Kecacatan pada Produk Hasil Pengelasan dengan Metode FMEA dan Diagram Pareto Studi Kasus di Perusahaan PT. Aneka Jasa Teknik Gresik, *J. Tek. Mesin*, vol. 21, No. 1, pp. 21–28, 2024, doi: 10.9744/jtm.21.1.21-28.

[15] W. S. and T. K. C. Busyairah Syd Ali, Arnab Majumdar, Washington Yotto Ochieng, *A causal factors analysis of aircraft incidents due to radar limitations: The Norway case study*, J. Air Transp. Manag., doi: 10.1016/j.jairtraman.2015.03.004.

[16] Yevita Nursyanti and R. Partisia, *Analisis Discrepancy Inventaris di Gudang Menggunakan Root Cause Analysis*,J. Teknol. dan Manaj. Ind. Terap., vol. 3, No. 3, pp. 313–323, 2024, doi: 10.55826/jtmit.v3i3.478.

[17] Y. K. Sakti, I. A. S. W, and D. Zuhroh, Analisis Faktor-Faktor Penyebab Ter hambatnya Perkembangan Umkm Sentra Ikan Bulak (SIB) Kenjeran Dengan Pendekatan Metode Fishbone Diagram,*Semin. Nas. Has. Penelit. dan Pengabdi. 2020*, pp. 92–99, 2020.

[18] Z. Ramadhana, *Modifikasi Failure Modes And Effect Analysis (FMEA) pada Rotor Turbin Pesawat Terbang Untuk Meningkatkan Efisiensi Manaje men Resiko* dan Keandalan, Institut Teknologi Sepuluh Nopember, Surabaya, 2021. Accessed: Mar. 09, 2025. [Online]. Available: http://reposi tory.its.ac.id/id/eprint/83215