INTEGRATING HOUSE OF RISK (HOR) AND ROOT CAUSE ANALYSIS (RCA) WITH KEY PERFORMANCE INDICATOR (KPI) FOR ENHANCED RISK MANAGEMENT AND OPERATIONAL EFFICIENCY IN MANUFACTURING OPERATIONS

UNDERGRADUATE THESIS

Submitted to the International Undergraduate Program in Industrial Engineering in Partial Fulfilment of Requirement for the Degree of Sarjana Teknik at the Faculty of Industrial Technology
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2025

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DEDICATION PAGE

Alhamdulillahirabbil'alamiin
I extend my deepest gratitude and praise to Allah SWT, whose grace has enabled me to successfully complete this undergraduate thesis.

I dedicate this undergraduate thesis to my beloved parents, brother and sister, those whom I classify as 'family', and to Ir. Muhammad Ridwan Andi Purnomo, S.T., M.Sc., Ph.D., IPM. as a testament to my academic journey, who have continuously provided unwavering support, motivation, and endless prayers, both morally and materially.

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MOTTO

"Except what Allah should will. Indeed, He knows what is declared and what is hidden." (Q.S. Al-A'la 7)

"What is with Allah is better than diversion and than a transaction, and Allah is the best of providers." (Q.S. Al-Jumu'ah 11)

PREFACE

Assalamu'alaikum Warahmatullahi Wabarakatuh

Alhamdulillah, all praise be to Allah SWT, the Most Abundant in blessings and wisdom. Endless gratitude is expressed to Him for His mercy and grace, which have enabled the author to complete this undergraduate thesis, titled **"Integrating House of Risk (HOR) and Root Cause Analysis (RCA) with Key Performance Indicator (KPI) For Enhanced Risk Management and Operational Efficiency in Manufacturing Operations (Case Study: PT. Sinar Semesta)".** The author extends gratitude to the ultimate Murabbi, Prophet Muhammad SAW, who has guided humanity from ignorance to a world illuminated by knowledge.

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11. All parties that cannot be mentioned here one by one that have helped the writer finish this undergraduate thesis.

The author acknowledges that this undergraduate thesis still has several shortcomings and welcomes constructive criticism and suggestions from various parties for future improvements.

This thesis has been prepared as part of the requirements for obtaining a Bachelor's Degree in Industrial Engineering International Undergraduate Program at the Industrial Technology Faculty, Islamic Universitas Islam Indonesia.

Wassalamu'alaikum Warahmatullahi Wabarakatuh.

Yogyakarta, March 21st, 2025



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ABSTRACT

Manufacturing industries encounter substantial challenges due to operational inefficiencies and risks that affect productivity and profitability. To mitigate these issues, this research integrates the House of Risk (HOR) method, Root Cause Analysis (RCA), and Key Performance Indicators (KPI) to enhance risk management and streamline operations. The study focuses on PT. Sinar Semesta, a metal casting company in Indonesia, which deals with production delays, machine failures, and inconsistent product quality. The research begins by applying HOR to identify and prioritize risk agents based on their severity and likelihood. RCA is then utilized to determine the root causes of critical risks, enabling the development of targeted mitigation strategies. Subsequently, KPIs are used to assess the effectiveness of risk management measures, focusing on key metrics such as defect rates, production cycle times, and downtime reduction. The findings highlight the effectiveness of integrating HOR and RCA in establishing a structured and proactive risk mitigation approach. Implementing prioritized corrective actions is shown to significantly reduce operational risks and enhance production performance. KPI validation confirms measurable improvements, demonstrating the feasibility of this integrated framework as a tool for continuous process optimization. This research contributes to industrial engineering by presenting a comprehensive model that strengthens risk management in manufacturing. The integration of HOR, RCA, and KPI offers a data-driven methodology that allows companies to systematically identify, address, and evaluate risks, ensuring long-term operational sustainability.

Keywords: House of Risk (HOR), Root Cause Analysis (RCA), Key Performance Indicator (KPI), Risk Management, Operational Efficiency, Manufacturing

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CHAPTER I
INTRODUCTION

1.1 Background

Manufacturing industries play a pivotal role in economic growth, contributing significantly to employment and GDP. However, they face challenges related to operational inefficiencies and risks that can hinder productivity and profitability. A 2022 report by the International Labor Organization (ILO) revealed that over 20% of manufacturing firms globally experience frequent downtime due to unmitigated risks, leading to losses amounting to billions annually. In Indonesia, the manufacturing sector contributes approximately 19.7% to the GDP, as per the Ministry of Industry's 2024 data. Yet, inefficiencies in production processes remain a significant hurdle. PT. Sinar Semesta has encountered similar issues, including delays, machine breakdowns, and inconsistent production quality. Addressing these challenges requires a robust risk management framework that not only identifies and prioritizes risks but also ensures effective mitigation strategies and validation through measurable outcomes. The table below represents the defective products at PT. Sinar Semesta during the January – April 2024 period. The company faced challenges mainly regarding its production efficiency caused by ineffective production hurdles. Rejected products are products that are being thrown away immediately after production while repaired products are products that are revamped so that they can then be distributed to clients.

Table 1. 1 Defective Products at PT. Sinar Semesta

Month	Defects	
	Quantity (Pcs)	Weight (KGs)
January	767	20.749,8
February	653	19.912,0
March	529	11.506,2
April	426	9.705,6
Total	2375	61.873,6

One of the key frameworks used to manage risks in manufacturing is the House of Risk (HOR). HOR provides a systematic approach to identifying and prioritizing risk agents based on their severity and likelihood of occurrence. By calculating the Aggregate Risk Priority

(ARP), HOR enables organizations to focus their resources on addressing the most critical risks. Despite its effectiveness, HOR primarily focuses on risk prioritization and does not delve deeply into the underlying causes of these risks. For instance, while HOR can identify that "frequent machine breakdowns" pose a high risk, it does not specify why these breakdowns occur or how to address their root causes effectively.

This is where Root Cause Analysis (RCA) becomes a valuable tool. RCA, particularly through methods like the Fishbone Diagram or the 5 Whys, helps organizations uncover the underlying causes of identified risks. Integrating RCA with HOR creates a complementary framework where HOR prioritizes risks, and RCA provides actionable insights to mitigate them. For example, if HOR identifies "low-quality spare parts" as a significant risk agent, RCA can reveal specific procurement or supplier-related issues contributing to this risk. However, while the integration of HOR and RCA provides a structured approach to risk management, it still requires a mechanism to validate whether the implemented strategies effectively improve operational efficiency.

Key Performance Indicators (KPIs) serve as a validation tool to measure the success of integrating HOR and RCA. KPIs offer quantifiable metrics that reflect the performance of production systems and the effectiveness of risk mitigation strategies. Common KPIs in manufacturing include downtime reduction, defect rates, production throughput, and cost savings. For instance, after addressing "frequent machine breakdowns" using insights from HOR and RCA, a significant reduction in downtime or maintenance costs would validate the effectiveness of the risk management framework. In the context of PT. Sinar Semesta, KPIs such as on-time delivery rates, production cycle time, and defect rates can provide measurable evidence of improvements in operational efficiency.

The integration of HOR, RCA, and KPI validation presents a holistic framework for enhancing productivity and streamlining operations. HOR’s prioritization capabilities ensure that critical risks are addressed first, RCA’s analytical methods pinpoint actionable solutions, and KPIs provide continuous feedback to measure and sustain improvements. This approach is particularly relevant for PT. Sinar Semesta, where recurring issues like inconsistent production schedules and equipment failures demand an integrated solution. By adopting this framework, PT. Sinar Semesta can not only address immediate risks but also create a proactive risk management culture that drives long-term efficiency and competitiveness.

Despite the potential benefits, the integration of HOR, RCA, and KPI validation is not without challenges. One key challenge is ensuring accurate and reliable data collection for each stage of the framework. For HOR, this involves gathering data on the frequency and impact of risks; for RCA, it requires detailed analysis of operational processes; and for KPIs, it demands consistent monitoring and measurement. Furthermore, aligning the outputs of HOR and RCA with organizational goals and KPIs requires effective coordination and communication among stakeholders. Addressing these challenges is essential to fully realize the benefits of this integrated approach.

The proposed research focuses on implementing and validating this integrated framework in the production system of PT. Sinar Semesta. The research aims to demonstrate how the combination of HOR and RCA can enhance risk management processes and how KPI validation can ensure that these improvements translate into measurable operational benefits. By applying this framework, PT. Sinar Semesta can identify critical risks, uncover their root causes, and implement targeted strategies that are continuously validated and refined using KPIs. This study not only addresses specific challenges faced by PT. Sinar Semesta but also contributes to the broader body of knowledge on integrated risk management in manufacturing.

In conclusion, the integration of HOR, RCA, and KPI validation offers a comprehensive solution to address the complex challenges of risk management and operational efficiency in manufacturing. By prioritizing risks through HOR, analyzing their root causes with RCA, and validating improvements using KPIs, this framework ensures a structured and measurable approach to enhancing productivity. For PT. Sinar Semesta, adopting this integrated approach can lead to significant improvements in production processes, helping the company achieve its operational and strategic goals while setting a benchmark for the best practices in the industry. This research seeks to validate the effectiveness of this framework and provide actionable recommendations for its implementation.

1.2 Problem Formulation

Drawing from the background discussed, the problem statements are as follows:

1. How can the House of Risk method be applied to identify and prioritize risks in PT. Sinar Semesta's production line?

2. What are the mitigation strategies that should be taken by PT. Sinar Semesta to minimize the risks within their production line?
3. How can Key Performance Indicators (KPIs) validate the effectiveness of integrating HOR and RCA in improving operational efficiency?

1.3 Research Objectives

1. To implement the House of Risk (HOR) method to identify and prioritize risks in PT. Sinar Semesta's production system effectively.
2. To determine the preventive actions needed to minimize the risks at PT. Sinar Semesta's production line.
3. To validate the integration of HOR and RCA using Key Performance Indicator (KPIs) to measure their impact on operational efficiency.

1.4 Benefits of research

Many benefits are to be achieved for several parties, which are mentioned below:

1. For the company, the result of this undergraduate research can provide further information and future consideration regarding the company's productivity and operational efficiency. The company also supports students by applying real-world problems.
2. For students, practical application of risk management and process improvement in a real manufacturing setting. It can also be used as a measure of the student's capability in converting knowledge received on campus into the real world.

1.5 Research Limitations

Several limitations are assigned for this undergraduate research. The limitations are as follows:

1. The methods used for this undergraduate research are House of Risk (HOR), Root Cause Analysis (RCA), and Key Performance Indicator (KPI).
2. The research was conducted on the Production Facilities at PT. Sinar Semesta is located in Klaten, Central Java, Indonesia from January – February 2025.
3. The object of this study is PT. Sinar Semesta. The data used within this undergraduate research awas collected during the data collection time and cannot be disclosed or shared with third parties.

1.6 Systematic research

The research is structured into several chapters, and each chapter will be described as follows:

CHAPTER 1 INTRODUCTION

Chapter I contains background, problem formulation, research objectives, research benefits, research limitations, and systematic research for the undergraduate thesis.

CHAPTER II LITERATURE REVIEW

Chapter II contains the findings of literature that are accumulated based on earlier studies and studies that are also significant and associated with this research.

CHAPTER III RESEARCH METHODOLOGY

Chapter III comprises the research object, research subject, data collection method, data processing method, and the research flowchart to explain the research flow from scratch until completion.

CHAPTER IV DATA COLLECTION AND PROCESSING

Chapter IV describes the details of the data that has been collected with the visualization including identifying the risk events, risk agents, risk probabilities, and risk mitigations that will be further analyzed by the House of Risk method as well as finalizing it by setting up the Key Performance Indicator.

CHAPTER V DISCUSSION

Chapter V describes the outcome of the data that was acquired from data research processing that has been analyzed subjectively using theoretical expressions that were supported by research findings and studies that were associated with the problem.

CHAPTER VI CONCLUSIONS AND RECOMMENDATIONS

Chapter VI consists of certain results and suggestions for this undergraduate research. The conclusion was created following the results and discussion that were obtained from the research which could resolve the purpose of this research.

CHAPTER II
LITERATURE REVIEW

2.1 Deductive Review

2.1.1 House of Risk (HOR)

The House of Risk (HOR) model is a structured approach to risk management that focuses on identifying and mitigating risk agents that lead to various risk events. Unlike other risk tools that primarily focus on the effect of risks, HOR emphasizes preventive actions determining the main risk agents and the priority of preventive actions (Wibowo & Ahyudanari, 2020). This enables organizations to address the root causes of potential disruptions, especially in complex environments such as supply chains. A study done by Hadi et al., 2020 found that HOR was successful in identifying five critical risk events and 28 risk agents, emphasizing how this tool can help companies allocate resources to the most significant threats. This is particularly useful in industries with interdependent processes, such as manufacturing, where a single risk agent can trigger multiple failures.

One of the main advantages of HOR is its structured approach to prioritization, which ensures that resources are allocated effectively to mitigate the most critical risks. Unlike other risk management tools that may only identify risks, HOR provides a clear framework for ranking and addressing them systematically. However, HOR also has its limitations; while it excels at identifying and prioritizing risks, it does not delve deeply into the root causes of each risk. Furthermore, HOR can be resource intensive as it requires detailed data collection and analysis. Therefore, integrating HOR with other methods like Root Cause Analysis (RCA) allows for a more systematic identification of risks associated with specific root causes. This combination enhances the ability to assess potential failures in processes or systems, leading to more effective risk mitigation strategies (Deswandri et al., 2024). Moreover, the HOR framework provides a structured approach to prioritizing risks based on their potential impact, while RCA focuses on understanding the underlying causes of those risks. Together, they create a holistic view that helps organizations address both symptoms and root issues (Erdil & Erbiyik, 2023).

2.1.2 Root Cause Analysis (RCA)

Root Cause Analysis (RCA) is a process used to understand, solve, and find out when problems occur from the start and it is useful for avoiding future failures by pinpointing the cause of the problem (Holifahtus Sakdiyah et al., 2022). Its primary goal is to address root causes rather than superficial symptoms, ensuring that corrective actions lead to long-term solutions rather than temporary fixes. RCA employs a systematic approach, often using tools such as the "5 Whys", Fishbone Diagram (Ishikawa), or Fault Tree Analysis to analyze incidents and uncover their origins. Moreover, RCA effectively resolves quality control issues in consumer product manufacturing by utilizing Industry 4.0 tools and collaborative problem-solving processes (Vo et al., 2020).

a. Fishbone Diagram

   Fishbone Diagram is also known as the Ishikawa Diagrams, are visual tools used to illustrate the relationship between a specific problem and its potential causes. Prof. Kaoru Ishikawa introduced this diagram at Tokyo University in 1953 (Handayani et al., 2021). Fishbone diagrams help to identify the primary factors that influence the quality, contribute to the occurrence of problems, and allow for a more detailed examination of the elements that affect these main factors and how they are interrelated in the context of the issue being analyzed. The main causal factors in this causal diagram are material (raw materials), machine (machinery), man (labor), method (method), and environment (environment) (Holifahtus Sakdiyah et al., 2022).

   The stages in making a Fishbone Diagram are as follows ((Hisprastin & Musfiroh, 2020):

   1. Determine the problems.
   2. Determining the main categories or factors that cause the pain.
   3. Identify the cause of the problem.
   4. Analyze the problem with a diagram.

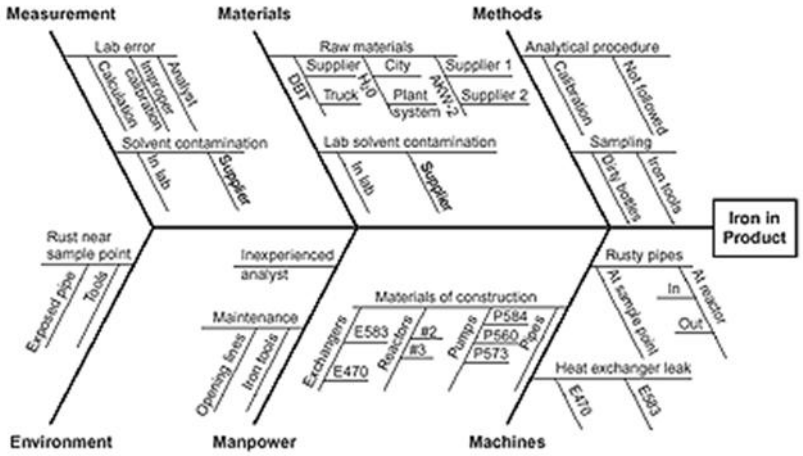


Figure 2. 1 Fishbone Diagram

2.1.3 Key Performance Indicator (KPI)

Key Performance Indicators (KPIs) are management tool or instrument so that an activity or process can be followed, controlled (if it deviates, can be recognized for correction), and ensured to achieve the desired performance (Setiawan & Purba, 2020). By setting specific, measurable, attainable, relevant, and time-bound (SMART) KPIs, businesses can align their operational activities with strategic goals, allowing for effective decision-making. KPIs enable organizations to track performance across various domains like customer satisfaction, financial health, and operational efficiency, ensuring alignment with overall strategic priorities (Berg, 2020).

The effectiveness of KPI relies heavily on their selection and implementation. Furthermore, balancing and weighting multiple KPIs to reflect organizational priorities can be complex as it includes multiple integrations, and the aggregation is random, so that it becomes complex (Setiawan & Purba, 2020). For example, performance systems in utilities have used weighted KPIs to ensure a balanced approach to financial and service-related outcomes (Berg, 2020).

2.2 Inductive Study

An inductive study involves examining prior literature relevant to current research. This approach allows the author to gain deeper insights into previously used methods and related topics that have already been explored.

A study conducted by Gozali et al., (2020) titled "Root Cause Analysis and Overall Equipment Effectiveness of Press Machine in Line H and HIRAC at PT. XYZ" underscores the importance of systematic maintenance and risk assessment in achieving optimal manufacturing performance. The methodologies used within this study are RCA, OEE, and HIRAC to identify inefficiencies and risks, ultimately suggesting improvements in maintenance strategies and operational procedures to enhance productivity and safety. These methods collectively enhance the effectiveness of RCA at PT. XYZ, enabling the company to improve machine reliability and operational efficiency in its production processes.

Hadi et al., (2020) conducted a study titled "*Identifikasi Risiko Rantai Pasok dengan Metode* House of Risk (HOR)" that focuses on identifying and analyzing risks within the supply chain of a textile company. FMEA and HOR were the methodologies used in this research. FMEA assesses risks based on two key variables; likelihood of occurrence and the severity of impact while HOR is used to analyze potential risks during production, evaluating both the probability of risks and their impact on decision-making processes. The study identifies five risk events and 28 risk agents that contribute to supply chain risks and highlights the importance of understanding these risks to mitigate negative outcomes. Furthermore, the study then concludes with several recommendations for mitigating identified risks which include enhancement of information systems, training and evaluation, and technological upgrade with the aim of improving productivity by ensuring that the output exceeds the input and thereby minimizing risks as well as potential losses for the company.

The study done by Wibowo & Ahyudanari, (2020) titled "Application of House of Risk (HOR) Models for Risk Mitigation of Procurement in The Balikpapan Samarinda Toll Road Project" employs the HOR method, which integrates FMEA and QFD to identify and prioritize risks in the supply chain. The research identifies 14 risk events and 15 risk agents that could potentially delay material procurement. Moreover, the study emphasizes the importance of proactive risk management strategies in ensuring the smooth procurement of materials, which is vital for the overall success of the project. By implementing the recommended preventive actions, project management can enhance the efficiency of the procurement process, thereby minimizing the risk of delays and ensuring timely project completion. In conclusion, this comprehensive approach not only addresses immediate

risks but also contributes to the development of a more resilient supply chain for future projects.

A study titled “Production Line Improvement Analysis with Lean Manufacturing Approach to Reduce Waste at CV. TMJ uses Value Stream Mapping (VSM) and Root Cause Analysis (RCA) Methods” conducted by Yanti et al., (2022) identifies various forms of waste in the production process, including excessive processes, delays, defective products, and transportation issues. The Lean Manufacturing approach was used to address these inefficiencies, utilizing tools such as VSM to visualize material flow and RCA to identify the underlying causes of waste. Proposed improvements include regular machine inspection, the creation of maintenance report cards, and the establishment of production control cards to ensure ongoing efficiency. The methodologies used indicate a reduction in lead time from 2490 to 1959, and an increase in process efficiency from 69.40% to 88.20% after the recommended changes were implemented. Overall, the research concludes that by systematically identifying and eliminating waste, the company can enhance productivity and maintain competitiveness in the manufacturing industry.

Meanwhile, a study done by Roy et al., (2021) titled “Investigation of Production Line Defects Using Root Cause Analysis: A Case Study on an Automobile Industry in Bangladesh” focuses on Root Cause Analysis (RCA) applied in an automobile industry in Bangladesh. The analysis revealed that the implementation of RCA could reduce production line defects by approximately 56.66%, leading to improved product quality and productivity. The study concludes that RCA is a straightforward yet effective method for enhancing production quality in the automobile industry as it emphasizes the importance of using various process tools to achieve a significant improvement in output. The application of countermeasures based on the identified root causes resulted in notable improvements in productivity, achieving scores of 96% in the first phase, 90.6% in the second, and 96.2% in the third phase of the target score.

A separate study conducted by Saifuddin et al., (2021) titled “Production Machine Effectiveness Analysis Using Overall Equipment Effectiveness (OEE) and Root Cause Analysis” focuses on evaluating the performance of machinery at Company XYZ, which is involved in manufacturing White Crystal Sugar. The study employs OEE and RCA to assess machine reliability and identify areas for improvement. The analysis revealed that idling and minor stoppages were significant contributors to the low OEE values in the

underperforming machines, with losses ranging from 13.15% to 16.98%. The highest machine effectiveness recorded was 87.39% while the lowest was 77.98%, highlighting the need for targeted improvements in specific machines to enhance overall productivity. In conclusion, the production process is competitive and can be classified as world-class, suggesting that the company is on a positive trajectory towards achieving long-term operational goals.

A study done by Setiawan & Purba, (2020) titled "A Systematic Literature Review of Key Performance Indicators (KPIs) Implementation" emphasizes review regarding Human Resources development within companies. The paper shows that the study focuses on KPIs to improve organizational performance, increase customer satisfaction, improve service, determine safety indicators, and even monitor system dashboards. Readers can then apply KPIs in contexts other than HR performance measurements such as machine performance measurements, sales target measurement, and productivity measurements.

A separate study conducted by Partiwi et al., (2023) with the title "House of Risk (HOR) Approach to Manage Risk Involving Multi-stakeholders: The Case of Automotive Industry Cluster of Multifunctional Rural Mechanized Tool (MRMT)" discusses the HOR approach to managing risks involving multiple stakeholders in the automotive industry cluster of MRMT. The application of HOR 1 led to the identification of the Combined Aggregate Risk Potential (CARP) and the selection of six priority risk potentials. Among these, inaccurate demand forecasting was identified as the risk factor with the highest CARP value. This highlights the significance of accurate forecasting in mitigating risks. A total of 13 mitigation actions were determined based on the identified risks. These actions were further assessed using HOR 2 to evaluate their effectiveness and difficulty for each stakeholder involved. In conclusion, the HOR approach provides a structured method for identifying and mitigating risks in the automotive industry cluster of MRMT. By fostering collaboration among stakeholders, implementing effective risk management strategies, and addressing quality control issues, the industry can enhance its resilience and operational efficiency.

Moreover, the paper titled "*Penilaian Kinerja* (Performance Appraisal) *Pegawai Negeri Sipil dengan Menggunakan Kombinasi Metode* Key Performance Indicator *dan* 360 Degree Feedback" by Arisandy et al., (2017) discusses the performance appraisal of civil servants in Indonesia, highlighting the limitations of existing evaluation systems that often rely on

subjective assessments by superiors. It emphasizes the need for a more objective and measurable approach to performance evaluation, proposing a combination of Key Performance Indicators (KPI) and 360-degree feedback as a solution. This dual-method approach aims to enhance the effectiveness of performance appraisals by providing a comprehensive view of an employee's performance from multiple perspectives, thus reducing bias, and increasing accountability. In conclusion, the integration of KPI and 360-degree feedback is posited as a necessary reform to improve the performance appraisal process for civil servants, ensuring that evaluations are fair, transparent, and conducive to professional development.

In a separate study done by Gusnadi & Hermawan, (2020) titled “Designing Employee Performance Monitoring Dashboard Using Key Performance Indicator (KPI)” discusses the development and implementation of a dashboard monitoring application designed to enhance employee performance tracking within organizations. The proposed dashboard utilizes Key Performance Indicators (KPIs) to provide a visual representation of employee performance, making it easier for division heads and managers to analyze, monitor, and evaluate performance against set targets. In conclusion, the dashboard monitoring system significantly improves the ability of management to oversee employee performance by providing timely and clear information. The research indicates a high level of user satisfaction with the application, suggesting that it meets the operational needs of organizations effectively. Overall, the implementation of such a system is essential for companies aiming to thrive in the digital age by optimizing their performance management processes.

A study titled “Key Performance Indicator (KPI) Design of Bamboo Creative Industry in Godean Sleman District Area” written by Zabidi, (2019) focuses on designing Key Performance Indicators (KPIs) for the bamboo creative industry in the Godean district of Sleman. It emphasizes the importance of performance evaluation not only for large companies but also for Small and Medium Enterprises (SMEs) like the bamboo crafts industry. The conclusion highlights the necessity of these KPIs in enhancing the operational efficiency and overall success of the bamboo creative industry, suggesting that proper KPI implementation can lead to improved business processes and increased competitiveness in the market.

Furthermore, Mesra et al., (2019) conducted research titled "*Penentuan* Key Performance Indicators *dengan Metode* Performance Prism *(Studi Kasus Program Studi Teknik Industri Sekolah Tinggi Teknologi Dumai)*" that emphasizes the importance of performance measurement in educational institutions, particularly in the Industrial Engineering Study Program at Dumai Technology College. It utilizes the Performance Prism method and KPI validation to assess stakeholder satisfaction and contributions, aiming to enhance overall program quality and effectiveness. The study identifies key performance indicators and recommends systematic evaluation processes to ensure continuous improvement.

The study done by Mohd et al., (2023) titled "Implementation of Root Cause Analysis (RCA) in Painting Process for Malaysian Automotive Industries" focuses on the implementation of Root Cause Analysis (RCA) in the painting process within the Malaysian automotive industry, addressing significant quality issues that arise during production. It identifies seven common defects, including watermarking, blistering, and dust contamination, which can severely impact product quality. By employing tools such as Pareto analysis and the Ishikawa diagram, the research reveals that a small percentage of causes (20%) are responsible for the majority (80%) of defects, adhering to the 80:20 rule. By implementing corrective measures based on the findings, companies can enhance productivity and ensure the production of high-quality automotive parts at competitive prices.

Moreover, Oktarina & Gunawan, (2022) conducted research titled "House of Risk Analysis as a Supply Chain Risk Mitigation Method at CV. XYZ," which aimed to identify and mitigate risks within its supply chain using the House of Risk (HOR) method, which consists of two stages. In the first stage, 23 risk events were identified, leading to the recognition of 36 risk agents, from which 12 priority risk agents were selected for further analysis. The second stage resulted in the development of 11 preventive actions to address these priority risks, including regular maintenance of machinery, machine repairs, increasing production hours, and evaluating supplier performance. The implementation of these actions is expected to significantly mitigate the identified risks and enhance the overall efficiency and reliability of the supply chain at CV. XYZ. The study emphasizes the importance of proactive risk management in maintaining productivity and customer satisfaction in a competitive market.

On the other hand, a paper titled “Mitigation of Supply Chain Risk using HOR Model at PT. Sumber Karya Indah” done by (Ahmad et al., 2020) explores the critical risks associated with the supply chain activities of PT. Sumber Karya Indah, identified a total of 28 risk events and 32 risk agents that impact the company's operations. The research highlights seven key mitigation actions aimed at addressing the identified risks, such as improving raw material procurement procedures and conducting supplier performance evaluations, each with specific estimated time durations (ETD) for implementation. The findings emphasize the importance of effective risk management strategies to enhance the resilience of the supply chain, ultimately aiming to reduce disruptions and improve overall operational efficiency. The study concludes that implementing these mitigation actions can significantly help PT. Sumber Karya Indah manages supply chain risks more effectively, thereby safeguarding the company's interests and ensuring smoother operations in the face of uncertainties.

Table 2. 1 Inductive Study

No.	Authors	Methods			Study Objectives
		HOR	RCA	KPIs	
1	(Gozali et al., 2020)		√		Operational efficiency
2	(Hadi et al., 2020)	√			Risk mitigation
3	(Wibowo & Ahyudanari, 2020)	√			Supply chain development and risks addressing
4	(Yanti et al., 2022)		√		Productivity enhancement
5	(Roy et al., 2021)		√		Production quality enhancement
6	(Saifuddin et al., 2021)		√		Productivity enhancement
7	(Setiawan & Purba, 2020)			√	Organizational improvement
8	(Partiwi et al., 2023)	√			Operational efficiency
9	(Arisandy et al., 2017)			√	Professional development of employees
10	(Gusnadi & Hermawan, 2020)			√	Management's ability to oversee employees' performance

11	(Zabidi, 2019)			√	Improved business processes and increased competitiveness within market
12	(Mesra et al., 2019)			√	Continuous improvement
13	(Mohd et al., 2023)		√		Productivity enhancement
14	(Oktarina & Gunawan, 2022)	√			Productivity maintenance and customer satisfaction
15	(Ahmad et al., 2020)	√			Operational efficiency
16	(Muhammad Alifian Fauzannasa Nawawi, 2025)	√	√	√	Enhanced risk management and operational efficiency

CHAPTER III
RESEARCH METHOD

3.1 Research Subject and Object

The research subject is PT. Sinar Semesta located in *Jalan Raya Solo - Jogja KM.26 Penggung, Jetis, Klepu, Kec. Ceper, Kabupaten Klaten, Jawa Tengah*, Indonesia. The object of this research is the production system within the company, where they have a foundry with a capacity of 1,500 tons/year and can produce several flagship products in which among them are components for railway facilities and infrastructure, agro product components such as sugar factory components and palm oil factories, cement factory components, mining and heavy equipment, oil, and gas industry as well as shipyards and ports. This research is focused on production lines and systems to evaluate the current state of the company's production system in order to improve operational efficiency.

3.2 Data Collection Method

The author carried out several data collection methods in this research. The methods being used are mentioned as follows.

3.2.1 Primary Data

Primary data is the data given directly to the author based on observation, test, interview, etc. (Hikmawati, 2020).

3.2.2 Secondary Data

Secondary data is the data given indirectly to the author that is usually used to fulfill the author's knowledge and information based on journals, articles, thesis, etc. (Hikmawati, 2020). Within this research, the author used journals, books, and articles from existing sources.

3.3 Research Flow

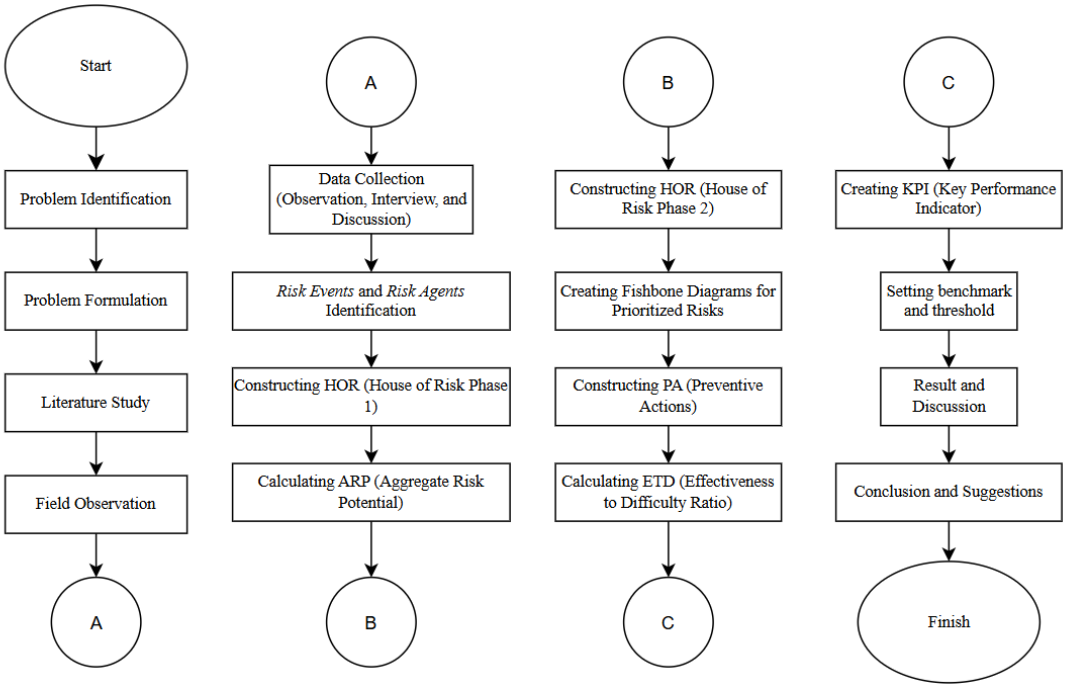


Figure 3. 1 Research Flow

The research flow mentioned in Figure 3.1 is explained below:

1. Problem Identification

Observing the issues faced by the company during its production process. Within this research, the author identifies the problem to be analyzed and formulates the problem statements, objectives, and limitations.

2. Literature Study

The author performs a literature review to acknowledge the problem, and the methods used, while also gathering references in support of the research being conducted.

3. Problem Formulation

Formulating the details of the problem that has been identified aims to determine the direction of the discussion. The problem formulation contains questions that will be answered within the

research and thus, a formulation of the problem is obtained that aims to reduce and mitigate risks for the production line at PT. Sinar Semesta as well as creating performance indicators.

4. Field Observation

The author made direct observations in the field to find out the real condition of the object to be observed, namely the production line of PT. Sinar Semesta.

5. Data Collection

The author obtains relevant data from the company exclusively that is related to the observed problems. The data collected is later used to conduct House of Risk, such as activities within the company's production line, risk events, risk events, severity assessment, occurrence assessment, and HOR correlation assessment as well as preventive actions or mitigation strategy needed for the company to reduce or prevent risks from happening. The data collection techniques used within this study are as follows:

a. Observation

   Observations were made with the field supervisor related to production conditions at the production line of PT. Sinar Semesta.

b. Interview

   Interviews were conducted with Mr. Fadil as the Production Planning and Inventory Control Supervisor of PT. Sinar Semesta to identify risks to the production line, the severity and occurrence of the risks, the correlations of the risks, risk map probability, as well as the preventive actions needed.

6. Data Processing

After obtaining the results of the interviews and discussions, data processing is performed, which includes risk events and their cause, the frequency of events that contribute to the risks, the impact if the risk occurs, and the correlation between risk causes and risk events. After the data is complete, the House of Risk (HOR) Phase 1 can be used to identify and prioritize risk events, followed by the development of risk mitigation recommendations based on the generated Pareto diagram.

The prioritized risk events are then processed in HOR Phase 2 to determine appropriate mitigation strategies, considering actual field conditions. After selecting potential mitigation actions, they are further analyzed to establish priority actions by evaluating their feasibility for implementation. Finally, decision-making in both HOR Phase 1 and Phase 2 is guided by Pareto analysis to ensure effective risk management.

Following up on the results gained at HOR Phase 1 and Phase 2, the Key Performance Indicator was formed. KPI allows further actions to be taken by the company to construct an enhanced risk management framework. Benchmarks and thresholds will be applied in order to track the company's effort to mitigate identified risks.

7. Results and Discussion

The author evaluates the effectiveness of implemented strategies in mitigating risks and improving operational efficiency.

8. Conclusion and Suggestion

The author provides a conclusion based on the analysis and discussion of the research problem and objectives. Moreover, suggestions for the company are also provided based on the conclusion. The proposed suggestions and recommendations are intended to serve as input or considerations for the company.

CHAPTER IV
DATA COLLECTION AND PROCESSING

4.1 Data collection

4.2.1 Company Profile

PT. Sinar Semesta, a prominent metal casting company, was established on November 12th, 2002, in Ceper, Klaten, Central Java. The company specializes in producing high-quality cast metal components, leveraging the expertise of a highly skilled and experienced workforce. Supported by state-of-the-art equipment and cutting-edge tools, PT. Sinar Semesta has positioned itself as one of the leading companies in the foundry and machining industry. The company's commitment to innovation and continuous development has enabled it to adopt advanced manufacturing technologies, significantly enhancing production efficiency and precision to meet and exceed the expectations of its growing customer base.

Along with an impressive annual foundry capacity of 1,500 tons/year, the company manufactures a diverse range of critical components for various industries. These include railway infrastructure systems, agro-industrial machinery such as components for sugar and palm oil mills, equipment for cement plants, mining and heavy machinery, as well as essential parts for the oil and gas sectors. Additionally, the company supplies components for shipyard operations and port facilities, underscoring its versatility and capability in serving multiple industrial sectors. Located strategically on *Jalan Raya Solo-Yogya KM. 26*, PT. Sinar Semesta operates under ISO 9001:2015 certification, ensuring adherence to rigorous standards and reinforcing its commitment to excellence and legal compliance in all aspects of its operations. Moreover, the certification was obtained legally through:

1. Deed of Establishment, Notary Triniken Tiyas Tirlin, S.H., No. 16 dated November 12, 2002, legalized by the Minister of Justice and Human Rights on February 13, 2003.
2. First Amendment Deed, Notary Susanto, S.H., No. 32 dated December 15, 2003, legalized by the Minister of Justice and Human Rights on June 16, 2004.
3. Second Amendment Deed, Notary Budi Yojanti Ningrum, S.H., No. 01 dated September 1 and September 17, 2005, legalized by the Minister of Law and Human Rights on January 16, 2002.

4. Third Amendment Deed, Notary Budi Yojanti Ningrum, S.H., No. 02 dated December 2, 2008, legalized by the Minister of Law and Human Rights on December 30, 2008.

4.2.2 Company Vision and Mission

The following statements are the vision and mission of PT. Sinar Semesta.

4.1.2.1 Vision

Establishing a competitive iron and steel industry that harnesses technology and thrives on national resources.

4.1.2.2 Mission

1. Establish a strong and reliable partnership with customers and suppliers.
2. Evolve into a company that fosters prosperity and delivers meaningful benefits to its stakeholders, employees, and the surrounding environment.

4.2.3 Company Location

PT. Sinar Semesta is located at Jl. Raya Solo-Yogya Km. 26, Klepu, Ceper, Klaten, Central Java, 57465. The company occupies a sprawling land area of 40,000 m^2, encompassing two primary production zones: a raw material warehouse and a dedicated production facility. Below is the specific location of PT. Sinar Semesta according to Google Maps along with its facility layout:

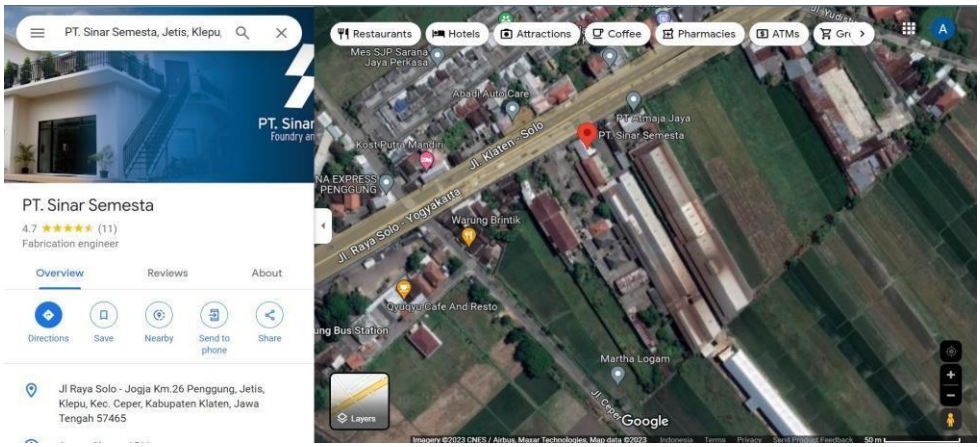


Figure 4. 1 Company Location

Source: Google Maps, 2025

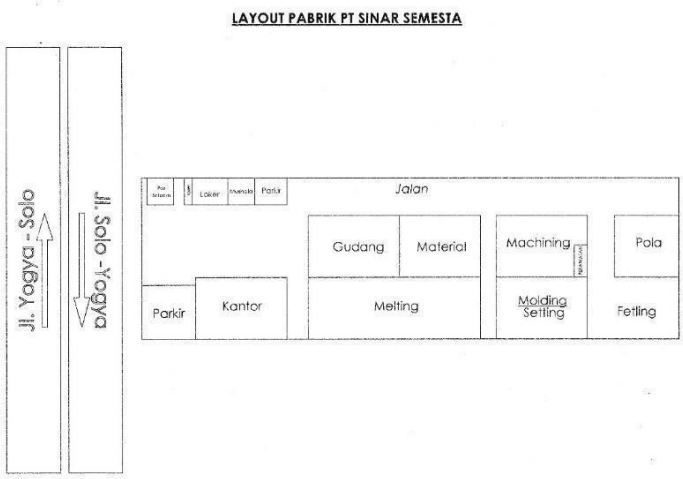


Figure 4. 2 Facility Layout of PT. Sinar Semesta

4.2.4 Production Line

A production line is a systematic sequence of operations in a manufacturing process where a product moves through different stages, with each station performing a specific task. It is designed to maximize efficiency, consistency, and speed by dividing the production process into smaller, specialized steps. Whereas at PT. Sinar Semesta itself, production follows a structured six-step process to ensure high-quality and precise products. The following is an elaboration on each stage:

1. Patterning

The process begins with the creation of a pattern, which serves as a replica of the final product. Made from wood, metal, or plastic, the pattern accounts for shrinkage and machining allowances, ensuring accuracy in the casting process. However, in some cases, customers bring their own patterning product for the company to process from then on.

2. Molding

Molding involves forming a cavity with silica sand or other molding materials around the pattern. Once the pattern is removed, a negative impression remains, ready to receive molten metal during casting.

3. Setting

The mold is carefully assembled, and if necessary, cores are placed to create a hollow section. The gating system which controls the flow of molten metal is also prepared to ensure smooth filling and proper venting.

4. Fettling

After solidification and cooling, the mold is broken apart to extract the casting. Excess material, such as runners and risers, is removed, and surface cleaning processes like grinding, shot blasting, or sandblasting are performed to enhance the final finish.

5. Melting

Raw materials, such as pig iron and scrap metal, are subjected to high temperatures in a furnace for melting. The molten metal is refined to achieve the desired chemical composition before being poured into the prepared molds.

6. Machining

The final stage involves precision machining, where the cast product undergoes milling, drilling, grinding, and other finishing operations to achieve the required dimensions and surface quality. A thorough quality inspection is conducted before the product is delivered.

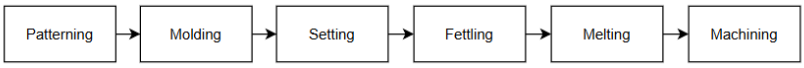


Figure 4. 3 PT. Sinar Semesta Production Process

The production strategy employed at PT. Sinar Semesta is make-to-order, allowing customers to specify their preferences for how their future products should be designed. Hence, the agreement between the customers and the company's representative is agreed upon by the *Memorandum of Understanding*. The production line implemented by the

company has produced a considerable number of products for a variety of customers. The products listed below are manufactured by PT. Sinar Semesta:

Table 4. 1 Accumulated Production (January – April 2024 Period)

Month	Production (KG)
January	40.485,1
February	20.078,4
March	39.885,0
April	25.647,3
Total	126.095,8

4.2 House of Risk Phase 1

House of Risk Phase 1 is the preliminary stage focused on identifying potential risks within PT. Sinar Semesta's production line. This phase requires data collection, including risk event identification, severity assessment, risk agent identification, occurrence evaluation, and correlation assessment. Based on interviews and questionnaires that had been given to the company's expert, namely Mr. Fadil as the supervisor of Production Planning and Inventory Control, 33 risk events and 33 risk agents were obtained on the production line at PT. Sinar Semesta. The following are risk events that were identified within the production line:

Table 4. 2 Identified Risk Events

Process	E(i)	Risk Events
PATTERNING	E1	Dimensional inaccuracies in patterns
	E2	Shrinkage miscalculations
	E3	Pattern surface damage
	E4	Pattern distortion
	E5	Inconsistent pattern replication
MOLDING	E6	Weak mold strength
	E7	Mold cracking or leakage
	E8	Improper core placement
	E9	Inconsistent sand composition
	E10	Mold cavity contamination
	E11	Premature mold degradation
SETTING	E12	Misalignment of mold halves
	E13	Faulty gating system design
	E14	Poor gating and riser design
	E15	Unstable mold positioning

Process	E(i)	Risk Events
	E16	Inconsistent mold closure pressure
FETTLING	E17	Casting breakage
	E18	Excessive material removal during grinding
	E19	Residual sand or slag adhesion
	E20	Inconsistent burr removal
MELTING	E21	Inconsistent metal quality
	E22	Chemical composition errors
	E23	Improper charge mix
	E24	Metal temperature fluctuations
MACHINING	E25	Tool wear and tears
	E26	Workpiece misalignment
	E27	Incorrect machining parameters
	E28	Cutting fluid contamination
	E29	Over-machining
OTHERS	E30	Human errors
	E31	Material defects
	E32	Production bottlenecks
	E33	Lack of equipment maintenance

Hence, the table below shows the 33 risk agents identified on the company's production line:

Table 4. 3 Identified Risk Agents

Code	Risk Agents
A1	Inaccurate pattern measurement
A2	Incorrect shrinkage factor estimation
A3	Low-quality pattern material
A4	Improper storage or handling
A5	Inconsistent replication process
A6	Inadequate sand mixing process
A7	Low-quality or contaminated sand
A8	Poor core setting procedures
A9	Improper mold handling and transportation
A10	Weak mold compression or binding force
A11	Misalignment during mold assembly
A12	Incorrect gating and riser design
A13	Defective venting system
A14	Unstable mold positioning during pouring
A15	Variations in mold closure pressure
A16	Improper handling during fettling
A17	Overaggressive grinding process
A18	Insufficient cleaning process
A19	Inconsistent burr removal techniques
A20	Furnace overheating or failure

Code	Risk Agents
A21	Inconsistent chemical composition of molten metal
A22	Incorrect charge mix ratio
A23	Variability in metal pouring temperature
A24	Tool wear and tear
A25	Workpiece misalignment
A26	Incorrect machining parameter settings
A27	Cutting fluid contamination
A28	Excessive cutting depth
A29	Human errors in handling, processing, and decision making
A30	Defective or low-quality raw materials
A31	Unbalanced workflow
A32	Machine downtime
A33	Poor coordination between production stages

4.2.1 Risk Event Identification

A risk event (Ei), refers to any incident that disrupts ongoing production activities, leading to losses in time, energy, and finances for the company. The impact of these events is measured using a severity scale, which evaluates the intensity of disruption they cause in production. Severity assessment is the first step in risk analysis, determining the extent to which a risk event affects operations. This assessment is conducted using a scoring system from 1 to 5, where a higher score indicates a more significant impact on the production process. Below are the severity assessment criteria:

Table 4. 4 Scale of Severity

Rank	Severity	Description	Criteria
1	Insignificant	Minimal impact, no disruption to production	Minor defects or short delays with no impact on production
2	Minor	Slight disruption, but production continues smoothly	Slight disruptions, small rework, or brief machine issues without major effects
3	Moderate	Noticeable impact, requiring adjustments	Noticeable delays, moderate rework, or equipment issues requiring adjustments
4	Major	Significant disruption, affecting production targets	Significant defects, production halts, or equipment failures affecting targets
5	Critical	Severe impact, leading to major losses	Severe breakdowns, high scrap rates, safety incidents, or major financial losses

Based on the criteria mentioned above, the following is a risk event table and severity scale obtained from the production line at PT. Sinar Semesta:

Table 4. 5 Risk Event Table

Process	E(i)	Risk Events	Severity
PATTERNING	E1	Dimensional inaccuracies in patterns	3
	E2	Shrinkage miscalculations	3
	E3	Pattern surface damage	2
	E4	Pattern distortion	3
	E5	Inconsistent pattern replication	3
MOLDING	E6	Weak mold strength	4
	E7	Mold cracking or leakage	4
	E8	Improper core placement	4
	E9	Inconsistent sand composition	3
	E10	Mold cavity contamination	4
	E11	Premature mold degradation	3
SETTING	E12	Misalignment of mold halves	4
	E13	Faulty gating system design	4
	E14	Poor gating and riser design	4
	E15	Unstable mold positioning	3
	E16	Inconsistent mold closure pressure	3
FETTLING	E17	Casting breakage	5
	E18	Excessive material removal during grinding	2
	E19	Residual sand or slag adhesion	3
	E20	Inconsistent burr removal	2
MELTING	E21	Inconsistent metal quality	5
	E22	Chemical composition errors	5
	E23	Improper charge mix	4
	E24	Metal temperature fluctuations	4
MACHINING	E25	Tool wear and tears	3
	E26	Workpiece misalignment	3
	E27	Incorrect machining parameters	3
	E28	Cutting fluid contamination	2
	E29	Over-machining	3
OTHERS	E30	Human errors	3
	E31	Material defects	4
	E32	Production bottlenecks	4
	E33	Lack of equipment maintenance	4

4.2.2 Risk Agent Identification

During this stage, the root causes of risks within PT. Sinar Semesta's production line will be identified and analyzed. This evaluation will be conducted using a structured assessment, assigning severity scores on a scale of 1 to 5. The following are the occurrence assessment criteria:

Table 4. 6 Scale of Occurrence

Rank	Occurrence	Description	Criteria
1	Rare	Risk agent is almost non-existent	Occurs < 2 times per month
2	Uncommon	Risk agent happens infrequently	Occurs 2-4 times per month
3	Moderate	Risk agent occurs occasionally	Occurs 5-7 times per month
4	Frequent	Risk agent happens regularly	Occurs 8-12 times per month
5	Very Frequent	Risk agent is nearly inevitable	Occurs > 12 times per month

Based on the criteria mentioned in the table above, the following is a table of risk agents and occurrence scale obtained from the production line of PT. Sinar Semesta:

Table 4. 7 Risk Agent Table

Code	Risk Agents	Occurrence
A1	Inaccurate pattern measurement	3
A2	Incorrect shrinkage factor estimation	2
A3	Low-quality pattern material	2
A4	Improper storage or handling	3
A5	Inconsistent replication process	3
A6	Inadequate sand mixing process	4
A7	Low-quality or contaminated sand	3
A8	Poor core setting procedures	3
A9	Improper mold handling and transportation	3
A10	Weak mold compression or binding force	4
A11	Misalignment during mold assembly	3
A12	Incorrect gating and riser design	3
A13	Defective venting system	3
A14	Unstable mold positioning during pouring	4
A15	Variations in mold closure pressure	3
A16	Improper handling during fettling	3
A17	Overaggressive grinding process	3

Code	Risk Agents	Occurrence
A18	Insufficient cleaning process	4
A19	Inconsistent burr removal techniques	3
A20	Furnace overheating or failure	2
A21	Inconsistent chemical composition of molten metal	2
A22	Incorrect charge mix ratio	2
A23	Variability in metal pouring temperature	3
A24	Tool wear and tear	4
A25	Workpiece misalignment	3
A26	Incorrect machining parameter settings	3
A27	Cutting fluid contamination	2
A28	Excessive cutting depth	3
A29	Human errors in handling, processing, and decision making	4
A30	Defective or low-quality raw materials	2
A31	Unbalanced workflow	3
A32	Machine downtime	3
A33	Poor coordination between production stages	3

4.2.3 Correlation Identification

The subsequent assessment involves identifying the correlation between risk events and risk agents. The relationship between these factors is evaluated and assigned a value of 0, 1, 3, or 9, representing the significance of each relationship or combination as determined by expert analysis. The correlation levels table is described as follows:

Table 4. 8 Correlation Level

Weight	Criteria
0	No Relation
1	Low Relation
3	Moderate Relation
9	High Relation

The table below presents the results of identifying the correlation level between each risk event and risk agent in PT. Sinar Semesta's production line:

Table 4. 9 Risk Correlation Table

Risk Event	Correlation	Risk Agent
E1	1	A2, A5
	3	A3
	9	A1
E2	1	
	3	A4
	9	A2, A5
E3	1	

Risk Event	Correlation	Risk Agent
	3	A4
	9	A3
	1	A4, A5
E4	3	A6
	9	A3
	1	A2, A3, A4
E5	3	A1
	9	A5
	1	A7, A9
E6	3	A6
	9	A10
	1	A6, A9, A11
E7	3	A7, A10
	9	A8
	1	A9
E8	3	A11
	9	A8
	1	A9
E9	3	A6
	9	A7
	1	A8, A12
E10	3	A7, A9
	9	A10, A18
	1	A6, A12
E11	3	A7, A10
	9	A11
	1	A14
E12	3	A15
	9	A11
	1	A11, A14, A15
E13	3	A13
	9	A12
	1	A15, A16
E14	3	A14
	9	A12
	1	A16
E15	3	A10
	9	A14
	1	A17, A18
E16	3	A16
	9	A15
	1	
E17	3	A10, A16
	9	A17
	1	A19
E18	3	A18

Risk Event	Correlation	Risk Agent
	9	A17
E19	1	
	3	A19
	9	A18
E20	1	A20
	3	A18
	9	A19
E21	1	A23
	3	A22
	9	A20, A21
E22	1	A20, A24
	3	A22, A23
	9	A21
E23	1	
	3	A21, A23, A31
	9	A22
E24	1	A24
	3	A20
	9	A23
E25	1	A25, A27
	3	A26
	9	A24
E26	1	
	3	A29
	9	A25
E27	1	A29
	3	A28
	9	A26
E28	1	A30
	3	A29
	9	A27
E29	1	A26
	3	A24, A29
	9	A28
E30	1	A4, A14, A17, A26, A31
	3	A1, A2, A28, A33
	9	A29
E31	1	A33
	3	
	9	A30
E32	1	A33
	3	A5, A29
	9	A31, A32
E33	1	A5
	3	A13, 29, A33
	9	A20, A24, A32

4.2.4 Aggregate Risk Potential Calculation

After assessing severity, occurrence, and the correlation between risk events and risk agents, the subsequent step is to calculate the Aggregate Risk Potential (ARP) values. ARP calculations aim to find out the priority risks that will be given treatment or mitigation. The formula for determining the ARP values is as follows:

$$ARPj = (Oj)(\Sigma Si \text{ x } Rij) \quad (4.1)$$

Description:

ARPj = Aggregate Risk Potential
Oj = Possibility occurrence of risk agent
Si = Severity of risk event
Rij = Correlation between risk events and risk agents

Hence, the Aggregate Risk Potential (ARP) calculations are as follows:

Table 4. 10 Aggregate Risk Potential Calculation

Aggregate Risk Potential (ARP)	Calculation Result
ARP_1	= (O1) x (ΣS_i x R_{i1}) = (3) x [(9x3) + (3x3) + (3x3)] = **135**
ARP_2	= (O2) x (ΣS_i x R_{i2}) = (2) x [(1x3) + (9x3) + (1x3) + (3x3)] = **84**
ARP_3	= (O3) x (ΣS_i x R_{i3}) = (2) x [(3x3) + (9x2) + (9x3) + (1x3) + (1x3)] = **120**
ARP_4	= (O4) x (ΣS_i x R_{i4}) = (3) x [(3x3) + (3x2) + (1x3) + (1x3)] = **63**
	= (O5) x (ΣS_i x R_{i5})

Aggregate Risk Potential (ARP)	Calculation Result
ARP_5	= (3) x [(1x3) + (1x3) + (9x3) + (3x4) + (1x4)]
	= **147**
	= (O6) x (ΣS_i x R_{i6})
ARP_6	= (4) x [(3x3) + (3x4) + (1x4) + (3x3) + (1x3)]
	= **148**
	= (O7) x (ΣS_i x R_{i7})
ARP_7	= (3) x [(1x4) + (3x4) + (9x3) + (3x4) + (3x3)]
	= **192**
	= (O8) x (ΣS_i x R_{i8})
ARP_8	= (3) x [(9x4) + (9x4) + (1x4)]
	= **228**
	= (O9) x (ΣS_i x R_{i9})
ARP_9	= (3) x [(1x4) + (1x4) + (1x4) + (1x3) + (3x4)]
	= **81**
	= (O10) x (ΣS_i x R_{i10})
ARP_{10}	= (4) x [9x4) + (3x4) + (9x4) + (3x3) + (3x3) + (3x5)]
	= **468**
	= (O11) x (ΣS_i x R_{i11})
ARP_{11}	= (3) x [(1x4) + (3x4) + (9x3) + (9x4) + (1x4)]
	= **249**
	= (O12) x (ΣS_i x R_{i12})
ARP_{12}	= (3) x [(1x4) + (1x3) + (9x4) + (9x4)]
	= **237**
	= (O13) x (ΣS_i x R_{i13})

Aggregate Risk Potential (ARP)	Calculation Result
ARP_{13}	= (3) x [(3x4) + (3x4)]
	= **72**
	= (O14) x (ΣS_i x R_{i14})
ARP_{14}	= (4) x [(1x4) + (1x4) + (3x4) + (9x3) + (1x3)]
	= **200**
	= (O15) x (ΣS_i x R_{i15})
ARP_{15}	= (3) x [(3x4) + (1x4) + (1x4) + (3x3) + (9x3)]
	= **168**
	= (O16) x (ΣS_i x R_{i16})
ARP_{16}	= (3) x [(1x4) + (1x3) + (3x3) + (3x5)]
	= **93**
	= (O17) x (ΣS_i x R_{i17})
ARP_{17}	= (3) x [(1x3) + (9x5) + (9x2) + (1x3)]
	= **207**
	= (O18) x (ΣS_i x R_{i18})
ARP_{18}	= (4) x [(9x4) + (1x3) + (3x2) + (9X3) + (3x2)]
	= **312**
	= (O19) x (ΣS_i x R_{i19})
ARP_{19}	= (3) x [(1x2) + (3x3) + (9x2)]
	= **87**
	= (O20) x (ΣS_i x R_{i20})
ARP_{20}	= (2) x [(1x2) + (9x5) + (1x5) + (3x4) + (9x4)]
	= **200**
	= (O21) x (ΣS_i x R_{i21})
ARP_{21}	= (2) x [(9x5) + (9x5) + (3x4)]

Aggregate Risk Potential (ARP)	Calculation Result
	= **204**
	= (O22) x (ΣS_i x R_{i22})
ARP_{22}	= (2) x [(3x5) + (3x5) + (9x4)]
	= **132**
	= (O23) x (ΣS_i x R_{i23})
ARP_{23}	= (3) x [(1x5) + (3x5) + (3x4) + (9x4)]
	= **204**
	= (O24) x (ΣS_i x R_{i24})
ARP_{24}	= (4) x [(1x5) + (1x4) + (9x3) + (3x3) + (9x4)]
	= **324**
	= (O25) x (ΣS_i x R_{i25})
ARP_{25}	= (3) x [(1x3) + (9x3)]
	= **90**
	= (O26) x (ΣS_i x R_{i26})
ARP_{26}	= (3) x [(3X3) + (9x3) + (1x3) + (1x3)]
	= **126**
	= (O27) x (ΣS_i x R_{i27})
ARP_{27}	= (2) x [(1x3) + (9x2)]
	= **42**
	= (O28) x (ΣS_i x R_{i28})
ARP_{28}	= (3) x [(3x3) + (9x3) + (3x3)]
	= **135**
	= (O29) x (ΣS_i x R_{i29})
ARP_{29}	= (4) x [(3x3) + (1x3) + (3x2) + (3x3) + (9x3) + (3x4) + (3x4)]
	= **312**
	= (O30) x (ΣS_i x R_{i30})
ARP_{30}	= (2) x [(3x4) + (1x2) + (9x4)]

Aggregate Risk Potential (ARP)	Calculation Result
	= **100**
	= (O31) x (ΣS_i x R_{i31})
ARP_{31}	= (3) x [(1x3) + (9x4)]
	= **117**
	= (O32) x (ΣS_i x R_{i32})
ARP_{32}	= (3) x [(9x4) + (9x4)]
	= **216**
	= (O33) x (ΣS_i x R_{i33})
ARP_{33}	= (3) x [(3x3) + (1x4) + (1x4) + (3x4)]
	= **87**

In House of Risk Phase 1, a table is used for ARP calculations, marking the last step in risk identification. This table includes the severity of risk events, the occurrence rate of risk agents, and the correlation between risk agents and risk events, derived from interviews with the related department experts. Additionally, it ranks risk agents based on priority for mitigation strategies.

The following is the HOR Phase 1 table which performs calculations to obtain risk agent priority based on the highest to lowest value of the aggregate risk potential:

Table 4. 11 House of Risk Phase 1

Risk Event (Ei)	**Risk Agent (Aj)**																															Severity of Risk (Si)
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	A21	A22	A23	A24	A25	A26	A27	A28	A29	A30	A31	A32	A33	
E1	9	1	3	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E2	0	9	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E3	0	0	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
E4	0	0	9	1	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E5	3	1	1	1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E6	0	0	0	0	0	3	1	0	1	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E7	0	0	0	0	0	1	3	9	1	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E8	0	0	0	0	0	0	0	9	1	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E9	0	0	0	0	0	3	9	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E10	0	0	0	0	0	0	3	1	3	9	0	1	0	0	0	0	0	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E11	0	0	0	0	0	1	3	0	0	3	9	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E12	0	0	0	0	0	0	0	0	0	0	9	0	0	1	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E13	0	0	0	0	0	0	0	0	0	0	1	9	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E14	0	0	0	0	0	0	0	0	0	0	0	9	0	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
E15	0	0	0	0	0	0	0	0	0	3	0	0	0	9	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

E17	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	3	9	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5
E18	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
E19	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	3	0	0	0	0	0	0	0	0	0	0	0	0	0	3
E20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	9	1	0	0	0	0	0	0	0	0	0	0	0	0	2
E21	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	9	3	1	0	0	0	0	0	0	0	0	0	5
E22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	9	3	3	1	0	0	0	0	0	0	0	0	5
E23	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	9	3	0	0	0	0	0	0	3	0	0	4
E24	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	9	1	0	0	0	0	0	0	0	0	4
E25	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	1	3	1	0	0	0	0	0	3
E26	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	0	3	0	0	0	3
E27	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	3	1	0	0	0	3
E28	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	3	1	0	0	2
E29	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	1	0	9	3	0	0	0	3
E30	3	3	1	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	0	3	9	0	1	0	3	3
E31	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	9	0	0	1	4
E32	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	9	9	1	4
E33	0	0	0	0	1	0	0	0	0	0	0	0	3	0	0	0	0	0	0	9	0	0	0	9	0	0	0	0	3	0	0	9	3	4
Occurrence of Agent (Oj)	3	2	2	3	3	4	3	3	3	4	3	3	3	4	3	3	3	4	3	2	2	2	3	4	3	3	2	3	4	2	3	3	3	
ARPj	135	84	120	63	147	148	192	228	81	468	249	237	72	200	168	93	207	312	87	200	204	132	204	324	90	126	42	135	312	100	117	216	87	
Agent Priority Rank	18	29	22	32	17	16	14	7	30	1	5	6	31	12	15	25	9	3	27	12	10	20	10	2	26	21	33	18	3	24	23	8	27	

Based on the table above, the following is the sequence of results from the Aggregate Risk Potential calculation:

Table 4. 12 Aggregate Risk Potential Rank

Rank	Risk Agent	ARP
1	A10	468
2	A24	324
3	A29	312
3	A18	312
5	A11	249
6	A12	237
7	A8	228
8	A32	216
9	A17	207
10	A21	204
10	A23	204
12	A20	200
12	A14	200
14	A7	192
15	A15	168
16	A6	148
17	A5	147
18	A1	135
18	A28	135
20	A22	132
21	A26	126
22	A3	120
23	A31	117
24	A30	100
25	A16	93
26	A25	90
27	A19	87
27	A33	87
29	A2	84
30	A9	81
31	A13	72
32	A4	63
33	A27	42

4.2.5 Risk Evaluation Prioritization using the Pareto Diagram

Risk evaluation aims to determine the dominant risk agent to be handled based on the aggregate risk potential value that has been previously assessed. The risk evaluation will be carried out using a Pareto Diagram. Within the diagram, a data classification will be sorted

from left to right based on the highest order to the lowest. The Pareto Diagram itself is created using the cumulative percentage of each ARP, derived from the risk agents. By implementing the 80:20 concept, it is expected that by improving 20% of the dominant risk sources, it can minimize the other 80% risk sources. The following is a Pareto Diagram showing the most dominant risk agents:

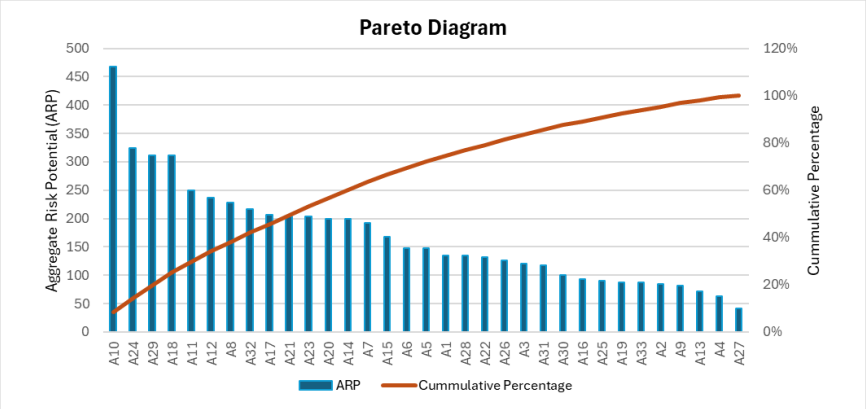


Figure 4. 4 Pareto Diagram

Table 4. 13 Risk Agent Category

Risk Agent	ARP	ARP Percentage	Cumulative Percentage	Category
A10	468	8%	8%	Priority
A24	324	6%	14%	
A29	312	6%	20%	
A18	312	6%	25%	
A11	249	4%	30%	Non-Priority
A12	237	4%	34%	
A8	228	4%	38%	
A32	216	4%	42%	
A17	207	4%	46%	
A21	204	4%	49%	
A23	204	4%	53%	
A20	200	4%	57%	
A14	200	4%	60%	
A7	192	3%	64%	
A15	168	3%	67%	
A6	148	3%	69%	
A5	147	3%	72%	
A1	135	2%	74%	
A28	135	2%	77%	
A22	132	2%	79%	

Risk Agent	ARP	ARP Percentage	Cumulative Percentage	Category
A26	126	2%	81%	
A3	120	2%	84%	
A31	117	2%	86%	
A30	100	2%	87%	
A16	93	2%	89%	
A25	90	2%	91%	
A19	87	2%	92%	
A33	87	2%	94%	
A2	84	2%	95%	
A9	81	1%	97%	
A13	72	1%	98%	
A4	63	1%	99%	
A27	42	1%	100%	

Based on the figure above, 4 of the identified 33 risk agents, namely (A10) Weak mold compression or binding force, (A24) Tool wear and tear, (A29) Human errors in handling, processing, and decision making, and (A18) Insufficient cleaning process are the main causes of the potential risks. They have a cumulative percentage of 25% combined respectively. Hence, based on the Pareto principle that 80% of consequences come from the 20% of causes, this study will proceed with risk agents A10, A24, A29, and A18 as the focus of improvement. The four risk agents can be seen on the table below along with their occurrence and severity values.

Table 4. 14 Risk Agent Dominant

Rank	Code	Risk Agent	ARP	Oj	Si
1	A10	Weak mold compression or binding force	468	3	4
2	A24	Tool wear and tear	324	4	4
3	A29	Human errors in handling, processing, and decision making	312	4	3
3	A18	Insufficient cleaning process	312	4	4

The next step is to create a risk mitigation strategy using the House of Risk Phase 2 after acquiring the dominant risk agents. Taking the risk appetite into consideration helps balance the company's willingness to accept risk with the prioritization and management of identified risks in determining the most appropriate course of actions to achieve operational efficiency. Risk mapping will be handled first to illustrate the condition of the dominant risk agent before handling the treatment. The following are potential risks from the dominant risk agents:

Table 4. 15 Risk Map

Likelihood of Consequences	Potential Consequences				
	Insignificant	Minor	Moderate	Major	Catastrophic
	1	2	3	4	5
Almost Certain					
Likely			**A29**	**A24, A18**	
Moderate				**A10**	
Unlikely					
Rare					

The risk mapping above is carried out based on the following levels:

Table 4. 16 Risk Map Category

Risk Assessment Level		
Level	**Severity**	**Occurrence**
Insignificant	1	1
Minor	2	2
Moderate	3	3
Major	4	4
Catastrophic	5	5

4.3 House of Risk Phase 2

Based on the risk assessments performed using House of Risk Phase 1 and the Pareto Diagram, four risk agents were identified as the highest priority. Following their identification, each risk agent is examined using a fishbone diagram. This approach enables detailed cause analysis through the fishbone diagram methodology, providing a deeper insight into developing an effective mitigation strategy. The figures below are the fishbone diagrams for risk agents A10, A24, A29, and A18:

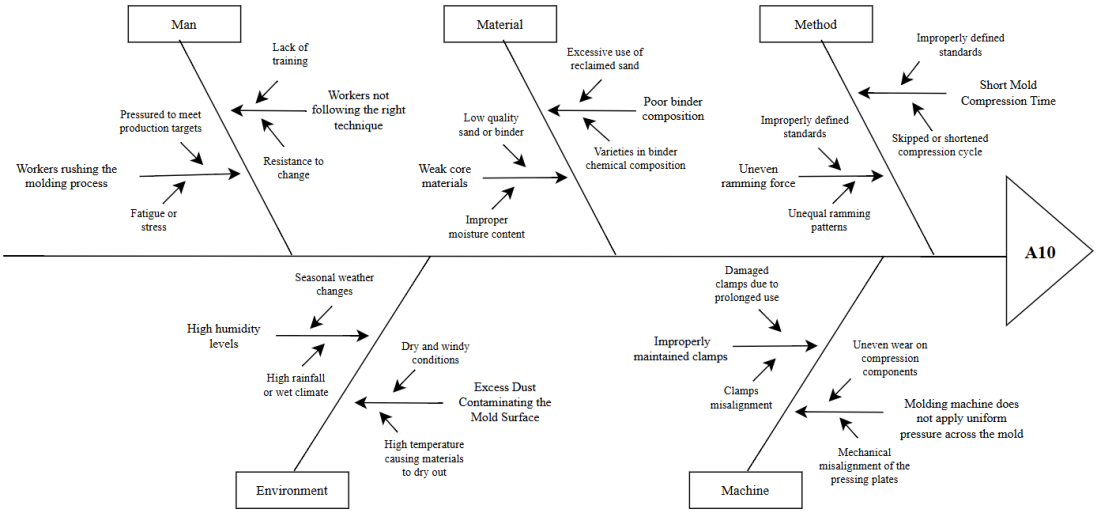


Figure 4. 5 Fishbone Diagram of Risk Agent A10 – Weak Mold Compression of Binding Force

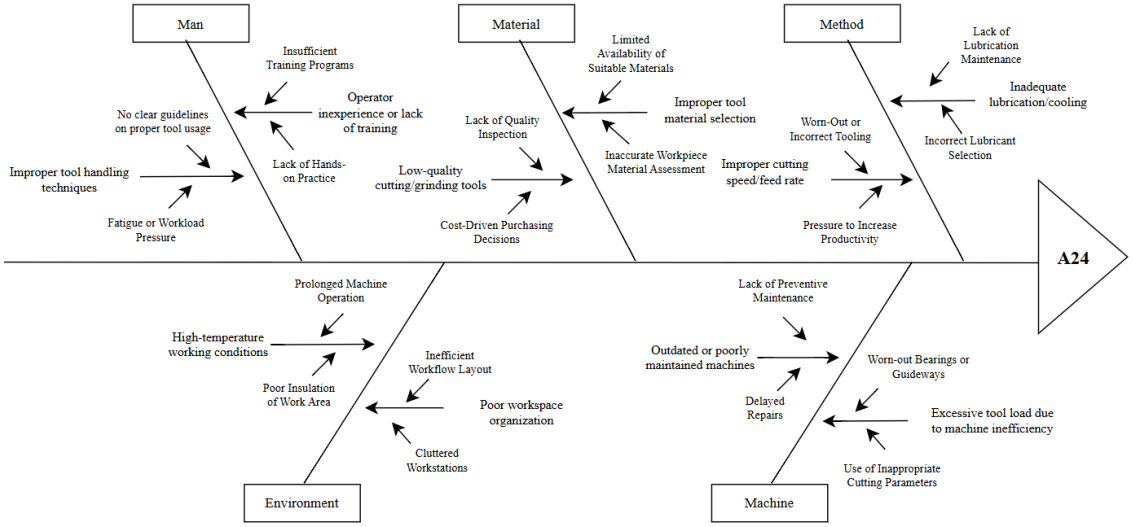


Figure 4. 6 Fishbone Diagram of Risk Agent A24 – Tool Wear and Tear

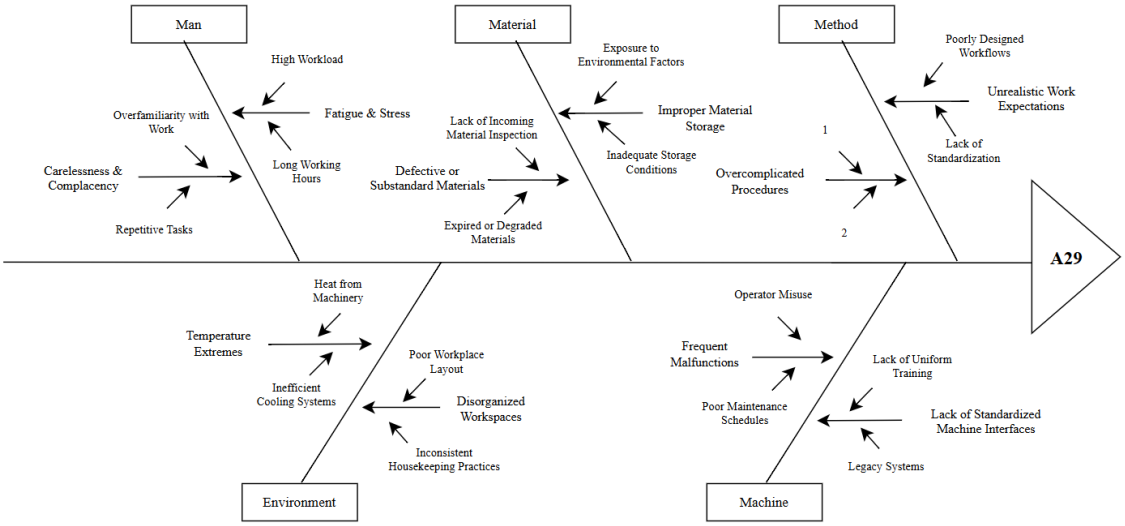


Figure 4. 7 Fishbone Diagram of Risk Agent A29 - Human Errors in handling, processing, and decision-making

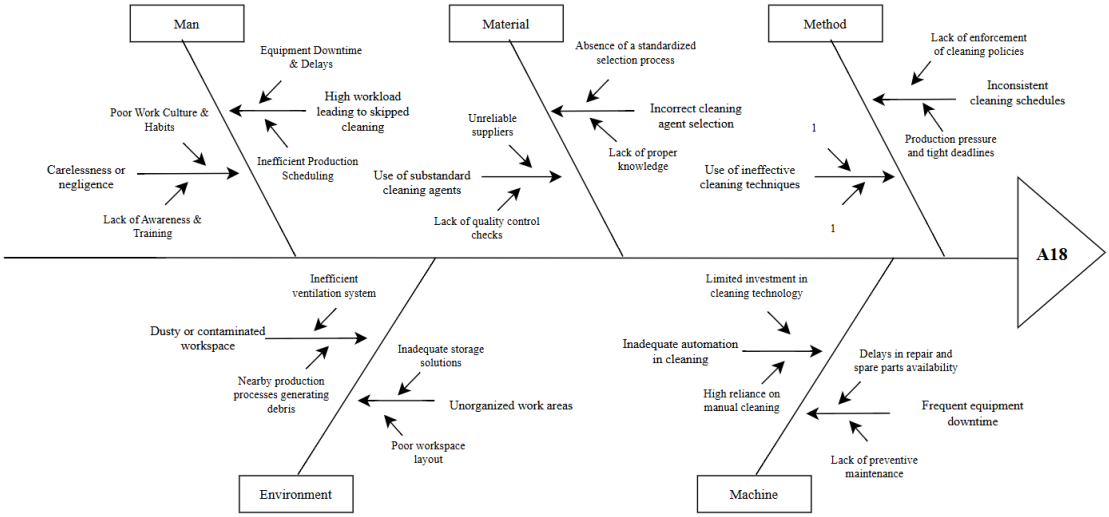


Figure 4. 8 Fishbone Diagram of Risk Agent A18 – Insufficient Cleaning Process

The second stage of the House of Risk is used to determine the most effective risk mitigation to minimize the possibility of risk events based on risk agents. In the previous stage, based on the Pareto Diagram above, there are four dominant risk agents that will be handled, and a search for handling strategies using the Fishbone Diagram. Based on these risk agents, 6 mitigation actions were obtained. The following is a table of proposed risk mitigation strategies:

Table 4. 17 Preventive Action Table

Preventive Action	Code
Operator training	PA1
Work standardization & simplified procedures	PA2
Ergonomic & fatigue management strategies	PA3
Regular cleaning audits & performance monitoring	PA4
Regular mold inspection	PA5
Optimize cutting speed, feed rate & lubrication	PA6

After establishing the preventive action table, the next step is to identify the correlation between the prioritized risk agents and the corresponding preventive action agents. This relationship will be presented in the table below.

Table 4. 18 Risk Agent and Preventive Action Correlation

Risk Agent	Correlation	Code
A10	1	PA4
	3	PA1
	9	PA2, PA5
A24	1	
	3	PA1, PA2
	9	PA6
A29	1	
	3	PA2
	9	PA1, PA3
A18	1	PA3
	3	PA1
	9	PA2, PA4

The next step involves measuring the correlation between the mitigation strategies and the selected risk agents. The following table presents the degrees of difficulty, along with corresponding weighting values and descriptions of the mitigation actions to be implemented, categorized as follows:

Table 4. 19 Degree of Difficulty Explanation

Quality	Explanation
3	Preventive action is easily applied
4	Preventive action is quite difficult to be applied
5	Preventive action is difficult to be applied

Hence, the following table lists the treatment strategies obtained according to the priority of the risk agent determined from the aggregate risk potential value:

Table 4. 20 Preventive Action Degree of Difficulty

Preventive Action	Code	Degree of Difficulty (Dk)
Operator training	PA1	3
Work standardization & simplified procedures	PA2	3
Ergonomic & fatigue management strategies	PA3	4
Regular cleaning audits & performance monitoring	PA4	4
Regular mold inspection	PA5	4
Optimize cutting speed, feed rate & lubrication	PA6	5

After defining the treatment strategy and evaluating the Degree of Difficulty (Dk), the next step is to establish a strong correlation between the treatment strategy and the identified risk sources. Once the strength of this relationship is determined, the Total Effectiveness (Tek) value is calculated to measure how effectively the treatment strategy can be applied. Following this, the Efficiency to Difficulty (ETDk) ratio is obtained by dividing the Total Effectiveness (Tek) by the Degree of Difficulty (Dk). By determining the ETDk value, the priority ranking of the treatment strategies can be established. The formula for calculating the total effectiveness value is presented below:

$$TEk = \Sigma \text{ARPj x Ejk} \quad (4.2)$$

$$ETDk = TEk/Dk \quad (4.3)$$

Description:

TEk = Sum of the effectiveness of each action

ARPj = Aggregate Risk Potential

Ejk = Correlation between each prevention action and each risk agent

Dk = Degree of Difficulty

The following is an example of calculating *Tek* (total effectiveness) and *ETDk* (effectiveness to difficulty). Complete results can be seen below.

$TEk = \Sigma ARPj \; x \; Ejk$

$TE_1 = (468 \text{ x } 3) + (324 \text{ x } 3) + (312 \text{ x } 9) + (312 \text{ x } 3)$

$= 6120$

$ETDk = TEk / Dk$

$ETDk = 6120 / 3$

$= 2040$

The complete calculations of the House of Risk Phase 2 for the production line at PT. Sinar Semesta can be seen on the table below.

Table 4. 21 House of Risk Phase 2

Risk Agent (Ei)	Preventive Action (PA)						ARP
	PA1	PA2	PA3	PA4	PA5	PA6	
A10	3	9	0	1	9	0	468
A24	3	3	0	0	0	9	324
A29	9	3	9	0	0	0	312
A18	3	9	1	9	0	0	312
Total Effectiveness of Action k	6120	8928	3120	3276	4212	2916	
PA Degree of Difficulty	3	3	4	4	4	5	
Effectiveness of Difficulty Ratio	2040	2976	780	819	1053	583,2	
Rank of Priority	2	1	5	4	3	6	

After arranging the House of Risk Phase 2 table, we can now determine the rank of preventive action to be prioritized as shown below:

Table 4. 22 Sequence of Mitigation Priorities

Code	Preventive Action	ETDs	Priority Rank
PA2	Work standardization & simplified procedures	2976	1
PA1	Operator training	2040	2
PA5	Regular mold inspection	1053	3
PA4	Regular cleaning audits & performance monitoring	819	4
PA3	Ergonomic & fatigue management strategies	780	5
PA6	Optimize cutting speed, feed rate & lubrication	583,2	6

Based on the table above, it is identified that from the 6 mitigation strategies that will be applied, it can be obtained that conducting work standardization & simplified procedures has the highest score of ETD with 2976, followed by operator training with ETD of 2040, then regular mold inspection with ETD of 1053, regular cleaning audits & performance monitoring with ETD of

819, ergonomic & fatigue management strategies with ETD of 780, and lastly, optimize cutting speed, feed rate & lubrication with ETD of 583.2.

4.4 Key Performance Indicator

After conducting House of Risk Phase 1 and Phase 2, the final step will be setting the company's Key Performance Indicator (KPI) which will be based mainly on the identified risks and preventive actions suggested. Furthermore, the KPI should be based on or support the company's vision and mission. Therefore, the determined KPI are listed on the table below:

Table 4. 23 Determined Key Performance Indicators

No.	Key Performance Indicators (KPIs)	Related Risk Agent
1	Compression pressure consistency	A10
2	Mold strength test pass rate	A10
3	Defect rate due to compression issue	A10
4	Tool change frequency (cycles per tool)	A24
5	Unplanned downtime due to tool failure	A24
6	Machining accuracy	A24
7	Error rate	A29
8	Rework rate	A29
9	Cleaning adequacy score	A18
10	Defect rate due to contamination	A18

After determining the KPIs, it is important to set benchmarks and thresholds for KPIs to ensure process stability, quality control, and more importantly, continuous improvement. Benchmarks define the ideal performance levels, while thresholds serve as early warning indicators, allowing proactive intervention before issues escalate. The table below indicates the threshold and benchmarking for the determined KPIs:

Table 4. 24 KPI Benchmark and Threshold

Key Performance Indicators	Benchmark	Threshold		Period
		Warning	Critical	
Compression pressure consistency *(%)*	≥ 95%	90 - 94%	< 90%	Monthly
Mold strength test pass rate *(%)*	≥ 98%	95 - 97%	< 95%	
Defect rate due to compression issue *(%)*	≤ 2%	2 - 4%	> 4%	
Machining accuracy *(%)*	≥ 98%	95 - 97%	< 95%	
Tool change frequency *(cycles per tool)*	≥ 10000	8000 - 10000	< 8000	
Unplanned downtime due to tool failure *(hours/month)*	≤ 5	5 - 10	> 10	

Key Performance Indicators	Benchmark	Threshold		Period
		Warning	Critical	
Error rate *(%)*	≤ 2%	2 - 4%	> 4%	
Rework rate *(%)*	≤ 2%	2 - 4%	> 4%	
Cleaning adequacy score *(1-5 scale)*	≥ 4,5	4,0 - 4,4	< 4,0	
Defect rate due to contamination *(%)*	≤ 1,5%	1,5 - 3%	> 3%	

According to the table above, the benchmark for each KPI has been set as well as the thresholds which have two classifications of warning and critical thresholds. Moreover, the period for all KPIs is set to monthly based with different parameters such as in percentages, 1-5 scale, cycles per tool, and hours/month.

CHAPTER V
DISCUSSION

5.1 Risk Identification Analysis at PT. Sinar Semesta

On the production line at PT. Sinar Semesta, there are 7 stages of production namely patterning, molding, setting, fettling, melting, and machining. The production process begins with patterning where a replica of the final product is created using wood, metal, or even plastic, accounting for shrinkage and machining allowances. Some customers provide their own patterns, reducing this step. Next, in the molding stage, a cavity is formed by packing silica sand or other molding materials around the pattern, leaving a negative impression after its removal. This is followed by the setting, where the mold is assembled, including core placement for hollow sections and the preparation of the gating system to control molten metal flow. Once the mold is ready, the melting process begins, where raw materials such as pig iron and scrap metal are heated in a furnace until they reach the desired chemical composition and temperature. The molten metal is then poured into the mold and allowed to solidify. After cooling, the fettling stage involves removing the solidified casting from the mold, trimming excess material (runners and risers), and performing surface cleaning through grinding, shot blasting, or sandblasting. Finally, the machining stage ensures precision by milling, drilling, and grinding the cast product to meet required dimensions and surface quality, followed by a final inspection before delivery. After carrying out observations and collecting data regarding the operational workflow along with interviews with the company's experts, there are some issues regarding their production line as a whole that may affect operational efficiency at PT. Sinar Semesta. The highlighted issue was regarding their production/operational efficiency, as when they produce a few products (for example, 40 products), they are producing 80 products. 40 products are actually the goods that passed the quality control check while the other 40 are products that are defective/rejected.

5.2 House of Risk (HOR) Phase 1

The risk identification process at PT. Sinar Semesta was carried out from January – February through observations, interviews, and discussion with experts. According to this, there are 33 risk events and 33 risk agents that were identified within the production line of the company. In House of Risk Phase 1, the input obtained is risk event and severity values, risk agents and

occurrence values, and correlation values. Furthermore, the output obtained is the rank of the risk agent, which is obtained from the largest to the smallest aggregate risk potential (ARP) value, with a further assessment of risk sources using the Pareto Diagram. The principle of the Pareot Diagram itself is to use a ratio of 80:20, which means that 80% of risk events come from 20% of risk agents. According to this principle, the research findings indicate that there were originally 3 risk agents that should be prioritized; however, the third agent accumulated the exact same ARP as its next agent, and therefore, it is also prioritized. The cumulative ARP percentage of the 4 risk agents is 25%. Therefore, there are 4 dominant risk agents that were selected to handle risks. Prioritized risk agents that need to be handled are as follows:

1. Weak mold compression or binding force (A10)

   The aggregate risk potential (ARP) value for this risk agent is 468. Weak mold compression or binding force occurs when the applied force during molding is insufficient, leading to poor mold integrity. This can result in defects such as incomplete castings, excessive porosity, or dimensional inaccuracies. Causes may include improper ramming techniques, worn-out equipment, or variations in sand properties affecting compaction.
2. Tool wear and tears (A24)

   The aggregate risk potential (ARP) of this risk agent is 324. Continuous use of tools in production leads to gradual wear and degradation, reducing their effectiveness and precision. Worn-out tools can cause defects in cast products, increase rejection rates, and slow down machine efficiency. Factors contributing to excessive tool wear include improper maintenance substandard tool materials, and high operating temperatures.
3. Human errors in handling, processing, and decision making (A29)

   The aggregate risk potential (ARP) value for this risk agent is 312. Errors made by workers during production, such as incorrect handling of materials, improper machine operation, or misjudgment in decision-making, can lead to defects and inefficiencies. These errors may stem from inadequate training, fatigue, lack of supervision, or unclear work instructions, impacting both productivity and product quality.
4. Insufficient cleaning process (A18)

   The aggregate risk potential (ARP) of this risk agent is 312, the same as (A29). A poorly executed cleaning process results in residual contaminants such as sand, slag, or metal debris remaining on cast products. This can compromise surface quality, increase rejection

rates, and affect downstream machining. Causes include inadequate cleaning procedures, improper use of cleaning equipment, and rushed fettling operations.

5.3 Pareto Diagram Analysis

According to the Pareto Diagram, it is found that the risk agent Weak mold compression or binding force (A10) with ARP of 468 has the highest percentage of ARP with 8%, followed by Tool wear and tears (A24), Human errors in handling, processing, and decision-making (A29), and Insufficient cleaning process (A18) with ARP of 324 and 312 respectively at 6%. It is then followed by Misalignment during mold assembly (A11), Incorrect gating and riser design (A12), Poor core setting procedures (A8), Machine downtime (A32), Overaggressive grinding process (A17), Inconsistent chemical composition of molten metal (A21), Variability in metal pouring temperature (A23), Furnace overheating or failure (A20), and Unstable mold positioning (A14) with ARP of 249, 237, 216, 207, 204, 204, 200, and 200 respectively at 4%. Then, risk agents Low-quality or contaminated sand (A7), Variations in mold closure pressure (A15), Inadequate sand mixing process (A6), and Inconsistent replication process (A5) with ARP of 192, 168, 148, and 147 respectively are next at 3%. Moreover, risk agents Inaccurate pattern measurement (A1), Excessive cutting depth (A28), Incorrect charge mix ratio (A22), Incorrect machining parameter settings (A26), Low-quality pattern material (A3), Unbalanced workflow (A31), Defective or low-quality raw materials (A30), Improper handling during fettling (A16), Workpiece misalignment (A25), Inconsistent burr removal techniques (A19), Poor coordination between production stages (A33), and Incorrect shrinkage factor estimation (A2) with ARP of 135, 135, 132, 126, 120, 117, 100, 93, 90, 87, 87, and 84 respectively are next with 2%. Finally, risk agents Improper mold handling and transportation (A9), Defective venting system (A13), Improper storage or handling (A4), and Cutting fluid contamination (A27) are next with an ARP of 81, 72, 63, and 42 respectively at 1%.

5.4 Fishbone Diagram Analysis

After identifying the percentages of the Pareto Diagram, the root causes of the problem are then analyzed using a Fishbone Diagram. It can be seen that the prioritized risk agents are (A10), (A24), (A29), and (A18). There are 5 factors that are affecting these agents, namely, human, machine, method, material, and mother nature. The following are the factors that are causing the risk agents, discussed and explained using the fishbone diagrams:

a. *A10 – Weak mold compression or binding force*

- Man

  Human factors (Man) contribute significantly, as workers may rush the molding process due to production pressure, fatigue, or stress, leading to improper techniques, often worsened by inadequate training and resistance to change.

- Machine

  Equipment-related issues stem from improperly maintained or misaligned clamps, uneven wear on compression components, and mechanical misalignment of pressing plates, causing the molding machine to apply uneven pressure.

- Method

  Process-related factors include short mold compression time, skipped or shortened compression cycles, and inconsistent ramming patterns due to undefined or poorly implemented standards.

- Material

  Material-related issues such as low-quality sand or binder, weak core materials, excessive use of reclaimed sand, and improper moisture content weaken mold integrity.

- Mother Nature (Environment)

  Environmental conditions such as high humidity, seasonal weather changes, and excessive dust contamination further compromise mold strength by affecting material properties.

b. *A24 – Tool wear and tears*

- Man

  Human-related issues arise from a lack of clear guidelines on proper tool usage, insufficient training, operator inexperience, and improper tool handling due to fatigue or workload pressure, leading to faster tool degradation.

- Machine

  Machine-related causes stem from poor maintenance practices, outdated or poorly maintained machines, delayed repairs, worn-out bearings or guideways, and excessive tool load due to inefficiencies or incorrect cutting parameters.

- Method

  Process inefficiencies contribute to tool wear through improper material selection, inaccurate workpiece assessments, incorrect cutting speeds, and the use of worn-out tooling, often driven by production pressure.

- Material

  Material-related causes include low-quality cutting or grinding tools, poor-quality inspection, and cost-driven purchasing decisions that prioritize affordability over durability.

- Mother Nature (Environment)

  Environmental factors such as prolonged machine operation, high temperature working conditions, poor insulation, inefficient workflow layout, and cluttered workstations further accelerate tool wear

c. *A29 – Human errors in handling, processing, and decision-making*

- Man

  This factor includes overfamiliarity with work leading to complacency, carelessness from repetitive tasks, long working hours, high workloads, and stress, all of which increase the likelihood of human error.

- Machine

  The Machine factor contributes through frequent malfunctions, operator misuse, lack of maintenance schedules, and outdated systems with non-standardized interfaces, making operations more prone to human errors.

- Method

  The Method factor emphasizes issues like poorly designed workflows, unrealistic work expectations, overcomplicated procedures, and a lack of standardization, all of which create confusion and inefficiencies.

- Material

  The Material factor focuses on poor material management, such as the lack of proper inspection, the use of defective or expired materials, and improper storage, which can lead to incorrect decisions during processing.

- Mother Nature (Environment)

  The Environment factor includes temperature extremes, heat from machinery, inefficient cooling, poor workplace layout, disorganized workspaces, and inconsistent housekeeping, all of which create distractions and unsafe conditions that increase the likelihood of errors.

d. *A18 – Insufficient cleaning process*

- Man

The Man factor highlights negligence, lack of awareness and training, poor work habits, inefficient production scheduling, and high workload leading to skipped cleaning.

- Machine

  The Machine factor highlights limited investment in cleaning technology, excessive reliance on manual cleaning, frequent equipment downtime, and delays in repairs, which all hinder effective cleaning.

- Method

  The Method factor includes improper cleaning techniques, inconsistent cleaning schedules, production pressure causing cleaning to be overlooked, and weak enforcement of cleaning policies.

- Material

  The Material factor focuses on unreliable suppliers, the use of substandard cleaning agents, a lack of quality control checks, and the absence of a standardized selection process for cleaning materials.

- Mother Nature (Environment)

  The Environment factor includes dusty and contaminated workspaces due to inefficient ventilation, poor workspace organization, inadequate storage solutions, and debris from nearby production processes.

5.5 House of Risk (HOR) Phase 2

House of Risk (HOR) Phase 2 builds upon the findings from Phase 1 by developing mitigation strategies for the most crucial critical risk agents. Within this phase, a structured approach is used to formulate risk-handling strategies, focusing on the most significant risk sources. The outcome of the HOR Phase 2 is a prioritized set of risk management actions, derived from expert consultations and discussions. These strategies are specifically designed to address four high-priority risk agents, ensuring effective risk mitigation within the production process. Based on the data processing of HOR Phase 2, 6 preventive actions or risk mitigations were obtained with codes PA1 – PA6. The following are the handling strategies:

1. Operator training (PA1)

   PA1 – Operator Training aims to enhance workers' skills and knowledge, ensuring they follow best practices in handling equipment and materials to minimize errors and

improve efficiency. This preventive action has a degree of difficulty of 3 which indicates that the action is easily applied.

2. Work standardization & simplified procedures (PA2)

   PA2 – Work standardization & simplified procedures seek to establish clear, standardized workflows and procedures to reduce variability, enhance consistency, and streamline operations. This preventive action has a degree of difficulty of 4, which indicates that the action is quite difficult to apply or implement.

3. Ergonomic & fatigue management strategies (PA3)

   PA3 – Ergonomic & fatigue management strategies focus on reducing worker fatigue and physical strain through ergonomic improvements, optimized work schedules, and proper rest intervals to maintain productivity and safety. This preventive action has a degree of difficulty of 4 which indicates that the action is quite difficult to apply or implement.

4. Regular cleaning audits & performance monitoring (PA4)

   PA4 – Regular cleaning audits & performance monitoring ensure cleanliness and maintenance standards are met by conducting scheduled audits, reducing contamination risks, and improving equipment reliability. This preventive action has a degree of difficulty of 4 which indicates that the action is quite difficult to apply or implement.

5. Regular mold inspection (PA5)

   PA5 – Regular mold inspection aims to detect and prevent defects in molds early by implementing routine inspections, thereby reducing production errors and ensuring high-quality outputs. This preventive action has a degree of difficulty of 5 which indicates that the action is difficult to implement.

6. Optimize cutting speed, feed rate, & lubrication (PA6)

   PA6 – Optimize cutting speed, feed rate, & lubrication. Focus on optimizing machining parameters to minimize tool wear, improve surface quality, and enhance operational efficiency while prolonging equipment life. This preventive action has a degree of difficulty of 5 which indicates that the action is difficult to implement.

The following is the priority ranking of the 6 mitigation strategies, namely in order from the highest to the lowest treatment priority ranking:

1. PA2, with an *ETD* value of 2976.
2. PA1, with an *ETD* value of 2040.

3. PA5, with an *ETD* value of 1053.
4. PA4, with an *ETD* value of 819.
5. PA3, with an *ETD* value of 780.
6. PA6, with an *ETD* value of 583,2.

5.6 Key Performance Indicators

Key Performance Indicators (KPIs) are determined to validate the House of Risk Phase 1 and the House of Risk Phase 2. Integrating HOR and KPI while also aligning it with the company's vision and mission will give the company guidelines in keeping track of the preventive actions in the form of performance indicators as well as for continuous improvement. The benchmark indicates the safety measure that is in place at the company, while the threshold was created as a sign of warning if the company does not fulfill its benchmark. The threshold itself is separated into two namely 'Warning' and 'Critical', to signal early warning and a dangerous warning of the benchmark not being met. The following are the KPIs that were created:

Key Performance Indicators	Benchmark	Threshold		Period
		Warning	Critical	
Compression pressure consistency *(%)*	≥ 95%	90 - 94%	< 90%	Monthly
Mold strength test pass rate *(%)*	≥ 98%	95 - 97%	< 95%	
Defect rate due to compression issue *(%)*	≤ 2%	2 - 4%	> 4%	
Machining accuracy *(%)*	≥ 98%	95 - 97%	< 95%	
Tool change frequency *(cycles per tool)*	≥ 10000	8000 - 10000	< 8000	
Unplanned downtime due to tool failure *(hours/month)*	≤ 5	5 - 10..	> 10	
Error rate *(%)*	≤ 2%	2 - 4%	> 4%	
Rework rate *(%)*	≤ 2%	2 - 4%	> 4%	
Cleaning adequacy score *(1-5 scale)*	≥ 4,5	4,0 - 4,4	< 4,0	
Defect rate due to contamination *(%)*	≤ 1,5%	1,5 - 3%	> 3%	

Figure 4. 9 Key Performance Indicator

CHAPTER VI
CLOSING

6.1 Conclusion

1. There are a total of 33 risk events and 33 risk agents identified in PT. Sinar Semesta's production line. After conducting further research using the Pareto Diagram, 4 risk agents were prioritized, namely (A10) Weak mold compression or binding force, (A24) Tool wear and tears, (A29) Human errors in handling, processing, and decision-making, and (A18) Insufficient cleaning process.
2. A fishbone diagram was implemented when trying to extract deeper into the prioritized risks that were identified in the House of Risk Phase 1. Moreover, the mitigation strategies that should be taken to minimize the risks at PT. Sinar Semesta is:
    a. Operator training (PA1)
    b. Work standardization & simplified procedures (PA2)
    c. Ergonomic & fatigue management strategies (PA3)
    d. Regular cleaning audits & performance monitoring (PA4)
    e. Regular mold inspection (PA5)
    f. Optimize cutting speed, feed rate, & lubrication (PA6)
3. Key Performance Indicators were created in accordance with House of Risk Phase 1 and Phase 2, Pareto Diagram, Fishbone Diagram as well as the company's vision and mission. The KPIs are as follows:
    a. Compression Pressure Consistency (%) – Benchmark of ≥95%, warning threshold at 90 – 94%, and critical threshold at <90%.
    b. Mold Strength Test Pass Rate (%) – Benchmark of ≥98%, warning threshold at 95 – 97%, and critical threshold at <95%.
    c. Defect Rate Due to Compression Issue (%) – Benchmark of ≤2%, warning threshold at 2 – 4%, and critical threshold at >4%.
    d. Tool Change Frequency (cycles/tool) – Benchmark of 10000, warning threshold at 8000 – 10000, and critical threshold at <8000
    e. Unplanned Downtime Due to Tool Failure (hours/month) – Benchmark of ≤5, warning threshold at 5 – 10, and critical threshold at >10.
    f. Error Rate (%) – Benchmark of ≤2%, warning threshold at 2 – 4%, and critical threshold at >4%.

g. Rework Rate (%) – Benchmark of ≤2%, warning threshold at 2 – 4%, and critical threshold at >4%.
h. Cleaning Adequacy Score (1-5 scale) – Benchmark of ≥4,5%, warning threshold at 4,0 – 4,4, and critical threshold at <4,0.
i. Defect rate Due to Contamination (%) – Benchmark of ≤1,5%, warning threshold at 1,5 – 3%, and critical threshold at >3%.

6.2 Suggestion

The suggestions that can be given for future research and PT. Sinar Semesta are as follows:

1. The suggestion for the company is to implement and take the proposed mitigation strategy into consideration and to also pay attention as well as make careful improvements to the risks that may occur.
2. A suggestion for future researchers is to be recommended to conduct research on all departments to visualize the impact as one whole company.
3. There was only one company expert interviewed during this study. In order to achieve more accurate results, future research can use more personnel to be interviewed, have discussions and observe, as well as add fuzzy logic to uphold research findings.

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APPENDIX

JANUARY									
No.	Product	Material	Weight	Rejected Products		Repaired Products		Total Defect	
				Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)
1	Steel Support Block Hole	SC 450	23,8		0	2	47,6	2	47,6
2	Steel ball	SC 450	10,85		0	2	21,7	2	21,7
3	EQ Spacing 1360 TTC	SC 450	33	3	99	410	13530	413	13629
4	Axle Seat 6"	SC 450	8,15	2	16,3	262	2135,3	264	2151,6
5	Flange OD 720 x ID 550	SS 400 / SCW 480	43,2		0	5	216	5	216
6	Disc Holder CMT	SC 450	18,89		0		0	0	0
7	Sleeve O Ring 140	FCD 500	3,19	12	38,28		0	12	38,28
8	Will on Gum 120-160	ARS	212,5		0	10	2125	10	2125
9	Bearing Housing Part	FCD 500	790		0	1	790	1	790
10	Gyrator 160 x 90 x 30	SUS 304	1,21		0	24	29,04	24	29,04
11	Fan 390 x 130 F	SUS 304	8,55		0	2	17,1	2	17,1
12	Fan 390 x 130 R	SUS 304	8,55		0	1	8,55	1	8,55
13	Tray Carburizing (1100 x 700 mm)	SCH 12	57,6		0	6	345,6	6	345,6
14	Cover SUS 316	SUS 304	30		0	1	30	1	30
15	Screen Plate	SUS 304	390		0	1	390	1	390

16	Casting Wing Shroud 40	ARS	30,08		0	10	300,8	10	300,8
17	Isen CW 10	FC 250	67		0		0	0	0
18	Pulley OD 820	FC 450	264		0	2	528	2	528
19	Corner L	FC 450	4		0	6	24	6	24
20	Trial Uji Tarik Browen	Browen	1,15		0		0	0	0
21	Counter Weight 10	FC 250	388		0		0	0	0
22	Casting Cylinder Sample 16	FC 250	0,52		0		0	0	0
23	Casting Cylinder Sample 22	FC 250	0,69		0		0	0	0
24	Specimen Uji Tarik FC 300	FC 300	1,93		0		0	0	0
25	Housing Bearing CMT Tipe Lama 45	SC 450	11,5		0	5	57,5	5	57,5
26	Sleeve Cycle Block	FCD 500	18,8		0			0	0
			Total					**767**	**20749,77**

FEBRUARY

No.	Product	Material	Weight	Rejected Products		Repaired Products		Total Production	
				Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)
1	Fix Torque ARM 525	SC 450	7		0	53	371	53	371
2	Spacing Kecil SCH (polos)	SC 450	34		0	147	4998	147	4998
3	Rantai SC 450	SC 450	1,16		0	11	12,76	11	12,76
4	Housing Tail Bearing TB-3A (M 4410)	FCD 500	68,15		0	3	204,45	3	204,45
5	Housing Wristpin	FCD 500	36,27	4	145,08	6	217,62	10	362,7

6	WPB - 3 M77 (M0405) Housing Saddle Bearing SB-3A (M35)	FCD 500	147,25		0	4	589	4	589
7	EQ Spacing 1360 TTC	SC 450	33		0	234	7722	234	7722
8	Pipe Bracket Out Board	FC 250	39		0		0	0	0
9	Base Plate R54	FCD 500	7,2		0	7	50,4	7	50,4
10	Spacing Besar SCH	SC 450	47,7		0	31	1478,7	31	1478,7
11	Fix Torque ARM 620	SC 450	9,13		0	5	45,65	5	45,65
12	Rear Hanger	SC 450	13,28		0	63	836,64	63	836,64
13	Pin Lock	SC 450	1,1		0		0	0	0
14	Counter Weight 10	FC 250	389,67		0	3	1169,01	3	1169,01
15	Counter Weight 16	FC 250	690		0	1	690	1	690
16	Equalizer Hanger SCH	SC 450	22,5	1	22,5		0	1	22,5
17	Ring Gear	SC 450	133		0	2	266	2	266
18	Sleeve Cycle Block	FCD 500	18,8		0		0	0	0
19	Tutup Holder 323	FCD 500	27,8		0		0	0	0
20	Axle Seat 6"	SC 450	8,15	1	8,15	36	293,4	37	301,55
21	ND Box-80	FCD 500	6		0		0	0	0
22	Fix Torque ARM 380	SC 450	6,02		0	26	156,52	26	156,52
23	Propeller Screw	SC 450	191,85		0	2	383,7	2	383,7
24	Specimen Uji Tarik ScSi Mn 2H	ScSi Mn 2H	2,38		0		0	0	0
25	Bearing Housing OD.420	SCN 440	39,67		0		0	0	0

26	Ring OD 555 x T65	SC 450	10,9	0		0	0	0
27	Specimen Uji Tarik FCD 500 (SS)	FCD 500	2,5	0		0	0	0
28	Specimen Uji Tarik FCD 400 (SS)	FCD 400	2,25	0		0	0	0
29	Casting Pump Turo 3"	ScMnCr4 Cr 5%	76	0		0	0	0
30	Block Sampling SC 4030	SC 450	12,38	0	11	136,18	11	136,18
31	Bearing Housing Padestal (Atas)	FC 250	17,5	0		0	0	0
32	Bearing Housing Padestal (Bawah)	FC 250	29	0		0	0	0
33	Sleeve Bearing out Board Fill - 2421 Atas	FC 250	22,5	0		0	0	0
34	Sleeve Bearing out Board Fill - 2421 Bawah	FC 250	23,13	0		0	0	0
35	Sleeve Bearing in Board Fill - 2421 Atas	FC 250	22,5	0		0	0	0
36	Sleeve Bearing in Board Fill - 2421 Bawah	FC 250	23,33	0		0	0	0
37	Sleeve Bearing out Board Fill - 2321 Atas	FC 250	20,4	0		0	0	0
38	Sleeve Bearing out Board Fill - 2321 Bawah	FC 250	20,5	0		0	0	0

39	Sleeve Bearing in Board Fill - 2321 Atas	FC 250	22,05	0		0	0	0
40	Sleeve Bearing in Board Fill - 2321 Bawah	FC 250	23,87	0		0	0	0
41	Specimen Uji Tarik SS 400	SS 400	0,9	0		0	0	0
42	Casting Pump Turo 6"	ScMnCr4 Cr 5%	215,2	0		0	0	0
43	Tray Carburizing (1100 x 700 mm)	SCH 12	57,6	0	2	115,2	2	115,2
44	Cover Saddle Bearing SB-3A (M35)	FCD 500	16	0		0	0	0
45	Cover Wristpin WPB-3 (M 0405-004-C-000)	FCD 500	8,65	0		0	0	0
46	Cover Tail-bearing TB-3A (M 0412-002-B-000)	FCD 500	11,94	0		0	0	0
47	Top Clamp Plate	SC 450	8,5	0		0	0	0
48	Specimen Uji Tarik SC 480	SC 480	0,6	0		0	0	
			Total				653	19911,96

MARCH

No.	Product	Material	Weight	Rejected Products		Repaired Products		Total Production	
				Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)
1	Middle Bar Grate	RTSi5	0,58	25	14,5		0	25	14,5
2	Rear Hanger	SC 450	13,28	5	66,4	70	929,6	75	996

3	Fix Torque ARM 620	SC 450	9,13	1	9,13	16	146,08	17	155,21
4	Fix Torque ARM 525	SC 450	7		0	108	756	108	756
5	Equalizer Hanger SCH	SC 450	22,5		0	20	450	20	450
6	Tanegata Fitting Plate	FC 250	35,87		0		0	0	0
7	Spacing Kecil SCH (polos)	SC 450	34		0	151	5134	151	5134
8	EQ Spacing 1360 TTC	SC 450	33		0		0	0	0
9	Grinder Crusher	ScMnH11	46,22		0	8	369,76	8	369,76
10	Specimen Uji Tarik RTSi5	RTSi5	1,75		0		0	0	0
11	Tray Carburizing (1100 x 700 mm)	SCH 12	57,6		0	9	518,4	9	518,4
12	Specimen Uji Tarik SCM 440	SCM 440	1,1		0		0	0	0
13	Roda Gila SC 4050	FC 250	107,02		0	2	214,04	2	214,04
14	Cooper	SC 450	9,65		0	20	193	20	193
15	Axle Seat 6"	SC 450	8,15		0	48	391,2	48	391,2
16	Side Block WTT 76,5 M	SCW 480 N	32,3		0	8	258,4	8	258,4
17	Housing Tail Bearing TB-3A (M 4410)	FCD 500	68,15	2	136,3		0	2	136,3
18	Sleeve O Ring 140	FCD 450	3,19	1	3,19		0	1	3,19
19	Tutup Holder 323	FCD 500	27,8		0		0	0	0
20	Rumah Keong Pompa DCS	FC 250	620		0		0	0	0

21	Top Plate Move WTT 76,5 m	SCW 480 N	451,5		0	2	903	2	903
22	Roda 180	SC 450	2,98		0	9	26,82	9	26,82
23	Hub Roda Fuso LB 8	FCD 500	33,75		0		0	0	0
24	Pulley 295	SCM 440	34,05		0	2	68,1	2	68,1
25	Casting Wing Shroud 40	ARS	30,08		0	10	300,8	10	300,8
26	Casting Wing Shroud 65	ARS	47,25		0	10	472,5	10	472,5
27	Upper Plate UB-03-12	A532-IIIA	5,8		0		0	0	0
28	Side Linner NS.35.100 S	A532-IIIA	8,17		0		0	0	0
29	Side Linner RB 90-11S (Linner MT-11S)	A532-IIIA	2,85		0		0	0	0
30	Side Linner RB 90-11L (Linner MT-11L)	A532-IIIA	3,75		0		0	0	0
31	Side Linner MT-120	A532-IIIA	8		0		0	0	0
32	Cover Wristpin WPB 2 (M28)	FCD 500	4,05		0		0	0	0
33	Cover Tail Bearing TB 2B (M28)	FCD 500	5,63		0		0	0	0
34	Bushing Chok std 1-3	AISI 4140 C1% / SCM 440	13		0		0	0	0
35	Bearing Housing OD.420	SCM 440	39,67		0		0	0	0
36	Pulley 500	FCD 500	36		0		0	0	0
37	Nozzel SC 450	SC 450	274,5		0		0	0	0
38	Return Rail D	FC 250	72,5	2	145		0	2	145
39	Housing Wristpin WPB 2 (M28)	FCD 500	21,11		0		0	0	0

40	Housing Tail Bearing SB-2A (M28)	FCD 500	32,45		0		0	0	0
41	Housing Saddle Bearing SB-2A (M28)	FCD 500	57,25		0		0	0	0
			Total					**529**	**11506,22**

APRIL

No.	Product	Material	Weight	Rejected Products		Repaired Products		Total Production	
				Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)	Qty (pcs)	Weight (Kg)
1	Bolt L435	SC 450	7,5		0		0	0	0
2	Nut L75	SC 450	2,75		0	2	5,5	2	5,5
3	Pulley Hino PTD	SC 450	11,9		0	2	23,8	2	23,8
4	Shaft Neco	SC 450	6,5		0	5	32,5	5	32,5
5	Lock Nut	SUS 410	6		0		0	0	0
6	End Cup	SUS 410	11		0		0	0	0
7	Spacer No.4	SUS 410	12,5		0	1	12,5	1	12,5
8	Spacer No.6	SUS 410	10		0		0	0	0
9	Spacer No.8	SUS 410	9		0	1	9	1	9
10	Spacer No. 10	SUS 410	5,5		0		0	0	0
11	Screw No. 5	SUS 410	10,6		0	1	10,6	1	10,6
12	Screw No. 7	SUS 410	10,5		0	1	10,5	1	10,5
13	Screw No. 9	SUS 410	9,5		0	1	9,5	1	9,5
14	Shaft Screw	SUS 410	124,5		0	1	124,5	1	124,5
15	Tray Carburizing (1100 x 700 mm)	SCH 12	57,6		0	4	230,4	4	230,4
16	Middle Bar Gate	RTSi5	0,58	34	19,72		0	34	19,72
17	Sleeve O Ring 140	FCD 500	3,5	12	42		0	12	42

18	Spacing Kecil SCH (polos)	SC 450	34		0	165	5610	165	5610
19	Specimen Uji Tarik ScMn H11	ScMnH11	2,7		0		0	0	0
20	Big Cover Flange 300	FC 250	4,2		0		0	0	0
21	Small Cover Flange	FC 250	1,3		0		0	0	0
22	Bearing Cup 300	FC 250	13		0		0	0	0
23	Specimen Uji Tarik RTSi5	RTSi5	1,75		0		0	0	0
24	ND Box-80	FCD 500	6		0		0	0	0
25	Bushing 316 PJG 210	SUS 316	12,5		0		0	0	0
26	Bushing 316 PJG 340	SUS 316	21,38		0		0	0	0
27	Chain Axis (revisi)	FCD 500	4,26		0	16	68,16	16	68,16
28	Cover / Flange Impeller	FCD 500	11		0		0	0	0
29	Pamp TV Casting Base Tee 20"	FC 250 + Cr	837,2		0	1	837,2	1	837,2
30	Emitting Rapping Inner Arm (new)	SC 450	3,57		0	144	514,08	144	514,08
31	Return Rail D	FC 250	72,5		0		0	0	0
32	Housing Impeller for Pamp TV 61-100	FCD 500	73	1	73		0	1	73
33	Twist Lock (ASTM)	ASTM	1,7		0		0	0	0
34	Pin Lock (ASTM)	ASTM	1		0	10	10	10	10
35	Corner L (ASTM)	ASTM	4		0	10	40	10	40
36	Corner R (ASTM)	ASTM	4		0	10	40	10	40

37	Specimen Uji Tarik ASTM A27 70-36	ASTM A 27 70-36	2,3	0		0	0	0
38	Primary Grinder Crusher	ScMnH11	52,5	0		0	0	0
39	Bearing Housing OD 420	SCM 440	39,67	0	1	39,67	1	39,67
40	Waritsutsu Baffu (K91010	FCD 500	33,5	0		0	0	0
41	Top Plate Fix WTT 76.5m	SCW 480 N	406,5	0		0	0	0
42	Top Plate Move WTT 76.5 m	SCW 480 N	451,5	0	2	903	2	903
43	Specimen Uji Tarik Browen (AS)	Browen	1,2	0		0	0	0
44	Casting Reducer Tea 24" x 18"	FC 250 + Cr	1040	0	1	1040	1	1040
Total							**426**	**9705,63**
Accumulated Total of Defected Products							**2375**	**61873,58**

JANUARY

No	Product Name	Material	Total Production Qty (pcs)	Total Production Weight (Kg)
1	Steel Support Block Hole	SC 450	4	95,2
2	Steel ball	SC 450	4	43,4
3	EQ Spacing 1360 TTC	SC 450	731	24123,0
4	Axle Seat 6"	SC 450	529	4311,4
5	Flange OD 720 x ID 550	SS 400 / SCW 480	10	432,0
6	Disc Holder CMT	SC 450	25	472,3
7	Sleeve O Ring 140	FCD 500	240	765,6

8	Will on Gum 120-160	ARS	20	4250,0
9	Bearing Housing	FCD 500	2	1580,0
10	Part Gyrator 160 x 90 x 30	SUS 304	60	72,6
11	Fan 390 x 130 F	SUS 304	4	34,2
12	Fan 390 x 130 R	SUS 304	3	25,7
13	Tray Carburizing (1100 x 700 mm)	SCH 12	12	691,2
14	Cover SUS 316	SUS 304	2	60,0
15	Screen Plate	SUS 304	2	780,0
16	Casting Wing Shroud 40	ARS	20	601,6
17	Isen CW 10	FC 250	4	268,0
18	Pulley OD 820	FC 450	4	1056,0
19	Corner L	FC 450	12	48,0
20	Trial Uji Tarik Browen	Browen	2	2,3
21	Counter Weight 10	FC 250	1	388,0
22	Casting Cylinder Sample 16	FC 250	25	13,0
23	Casting Cylinder Sample 22	FC 250	8	5,5
24	Specimen Uji Tarik FC 300	FC 300	4	7,7
25	Housing Bearing CMT Tipe Lama 45	SC 450	23	264,5
26	Sleeve Cycle Block	FCD 500	5	94,0
	Accumulated Production			40391,09 KG

FEBRUARY

No	Product Name	Material	Total Production	
			Qty (pcs)	Weight (Kg)
1	Fix Torque ARM 525	SC 450	163	1141,0
2	Spacing Kecil SCH (polos)	SC 450	294	9996,0
3	Rantai SC 450	SC 450	211	244,8
4	Housing Tail Bearing TB-3A (M 4410)	FCD 500	23	1567,5
5	Housing Wristpin WPB - 3 M77 (M0405)	FCD 500	50	1813,5
6	Housing Saddle Bearing SB-3A (M35)	FCD 500	24	3534,0
7	EQ Spacing 1360 TTC	SC 450	575	18975,0
8	Pipe Bracket Out Board	FC 250	10	390,0
9	Base Plate R54	FCD 500	41	295,2
10	Spacing Besar SCH	SC 450	64	3052,8
11	Fix Torque ARM 620	SC 450	25	228,3
12	Rear Hanger	SC 450	143	1899,0
13	Pin Lock	SC 450	8	8,8
14	Counter Weight 10	FC 250	6	2338,0
15	Counter Weight 16	FC 250	2	1380,0
16	Equalizer Hanger SCH	SC 450	14	315,0
17	Ring Gear	SC 450	4	532,0
18	Sleeve Cycle Block	FCD 500	10	188,0
19	Tutup Holder 323	FCD 500	16	444,8
20	Axle Seat 6"	SC 450	73	595,0

21	ND Box-80	FCD 500	50	300,0
22	Fix Torque ARM 380	SC 450	142	854,8
23	Propeller Screw	SC 450	4	767,4
24	Specimen Uji Tarik ScSi Mn 2H	ScSi Mn 2H	18	42,8
25	Bearing Housing OD.420	SCN 440	3	119,0
26	Ring OD 555 x T65	SC 450	1	10,9
27	Specimen Uji Tarik FCD 500 (SS)	FCD 500	10	25,0
28	Specimen Uji Tarik FCD 400 (SS)	FCD 400	4	9,0
29	Casting Pump Turo 3"	ScMnCr4 Cr 5%	5	380,0
30	Block Sampling SC 4030	SC 450	27	334,3
31	Bearing Housing Padestal (Atas)	FC 250	10	175,0
32	Bearing Housing Padestal (Bawah)	FC 250	10	290,0
33	Sleeve Bearing out Board Fill - 2421 Atas	FC 250	5	112,5
34	Sleeve Bearing out Board Fill - 2421 Bawah	FC 250	5	115,7
35	Sleeve Bearing in Board Fill - 2421 Atas	FC 250	10	225,0
36	Sleeve Bearing in Board Fill -2421 Bawah	FC 250	10	233,3
37	Sleeve Bearing out Board Fill - 2321 Atas	FC 250	15	306,0
38	Sleeve Bearing out Board Fill - 2321 Bawah	FC 250	15	307,5
39	Sleeve Bearing in Board Fill - 2321 Atas	FC 250	15	330,8
40	Sleeve Bearing in Board Fill - 2321 Bawah	FC 250	15	358,1
41	Specimen Uji Tarik SS 400	SS 400	3	2,7
42	Casting Pump Turo 6"	ScMnCr4 Cr 5%	5	1076,0
43	Tray Carburizing (1100 x 700 mm)	SCH 12	4	230,4
44	Cover Saddle Bearing SB-3A (M35)	FCD 500	40	640,0
45	Cover Wristpin WPB-3 (M 0405-004-C-000)	FCD 500	40	346,0
46	Cover Tail-bearing TB-3A (M 0412-002-B-000)	FCD 500	40	477,6
47	Top Clamp Plate	SC 450	40	340,0
48	Specimen Uji Tarik SC 480	SC 480	3	1,8
	Accumulated Production			39051,56 KG

MARCH

No	Product Name	Material	Total Production	
			Qty (pcs)	Weight (Kg)
1	Middle Bar Grate	RTSi5	2200	1276
2	Rear Hanger	SC 450	181	2403,68
3	Fix Torque ARM 620	SC 450	67	611,71
4	Fix Torque ARM 525	SC 450	252	1764
5	Equalizer Hanger SCH	SC 450	40	900
6	Tanegata Fitting Plate	FC 250	18	645,66
7	Spacing Kecil SCH (polos)	SC 450	308	10472
8	EQ Spacing 1360 TTC	SC 450	99	3267
9	Grinder Crusher	ScMnH11	68	3142,96
10	Specimen Uji Tarik RTSi5	RTSi5	8	14
11	Tray Carburizing (1100 x 700 mm)	SCH 12	18	1036,8

12	Specimen Uji Tarik SCM 440	SCM 440	2	2,2
13	Roda Gila SC 4050	FC 250	10	1070,2
14	Cooper	SC 450	40	386
15	Axle Seat 6"	SC 450	96	782,4
16	Side Block WTT 76,5 M	SCW 480 N	16	516,8
17	Housing Tail Bearing TB-3A (M 4410)	FCD 500	22	1499,3
18	Sleeve O Ring 140	FCD 450	60	191,4
19	Tutup Holder 323	FCD 500	20	556
20	Rumah Keong Pompa DCS	FC 250	1	620
21	Top Plate Move WTT 76,5 m	SCW 480 N	2	903
22	Roda 180	SC 450	19	56,62
23	Hub Roda Fuso LB 8	FCD 500	50	1687,5
24	Pulley 295	SCM 440	4	136,2
25	Casting Wing Shroud 40	ARS	20	601,6
26	Casting Wing Shroud 65	ARS	20	945
27	Upper Plate UB-03-12	A532-IIIA	12	69,6
28	Side Linner NS.35.100S	A532-IIIA	4	32,68
29	Side Linner RB 90-11S (Linner MT-11S)	A532-IIIA	12	34,2
30	Side Linner RB 90-11L (Linner MT-11L)	A532-IIIA	10	37,5
31	Side Linner MT-120	A532-IIIA	5	40
32	Cover Wristpin WPB 2 (M28)	FCD 500	40	162
33	Cover Tail Bearing TB 2B (M28)	FCD 500	30	168,9
34	Bushing Chok std 1-3	AISI 4140 C1% / SCM 440	8	104
35	Bearing Housing OD.420	SCM 440	1	39,67
36	Pulley 500	FCD 500	1	36
37	Nozzel SC 450	SC 450	1	274,5
38	Return Rail D	FC 250	6	435
39	Housing Wristpin WPB 2 (M28)	FCD 500	40	844,4
40	Housing Tail Bearing SB-2A (M28)	FCD 500	30	973,5
41	Housing Saddle Bearing SB-2A (M28)	FCD 500	20	1145
	Accumulated Production			38739,98 KG

APRIL

No	Product Name	Material	Total Production	
			Qty (pcs)	Weight (Kg)
1	Bolt L435	SC 450	2	15,0
2	Nut L75	SC 450	4	11,0
3	Pulley Hino PTD	SC 450	7	83,3
4	Shaft Neco	SC 450	10	65,0
5	Lock Nut	SUS 410	1	6,0
6	End Cup	SUS 410	1	11,0
7	Spacer No.4	SUS 410	2	25,0
8	Spacer No.6	SUS 410	1	10,0
9	Spacer No.8	SUS 410	2	18,0

10	Spacer No. 10	SUS 410	1	5,5
11	Screw No. 5	SUS 410	2	21,2
12	Screw No. 7	SUS 410	2	21,0
13	Screw No. 9	SUS 410	2	19,0
14	Shaft Screw	SUS 410	2	249,0
15	Tray Carburizing (1100 x 700 mm)	SCH 12	8	460,8
16	Middle Bar Gate	RTSi5	1894	1098,5
17	Sleeve O Ring 140	FCD 500	420	1470,0
18	Spacing Kecil SCH (polos)	SC 450	379	12886,0
19	Specimen Uji Tarik ScMn H11	ScMnH11	1	2,7
20	Big Cover Flange 300	FC 250	3	12,6
21	Small Cover Flange	FC 250	1	1,3
22	Bearing Cup 300	FC 250	1	13,0
23	Specimen Uji Tarik RTSi5	RTSi5	4	7,0
24	ND Box-80	FCD 500	1	6,0
25	Bushing 316 PJG 210	SUS 316	4	50,0
26	Bushing 316 PJG 340	SUS 316	4	85,5
27	Chain Axis (revisi)	FCD 500	46	196,0
28	Cover / Flange Impeller Pamp TV	FCD 500	1	11,0
29	Casting Base Tee 20"	FC 250 + Cr	2	1674,4
30	Emitting Rapping Inner Arm (new)	SC 450	344	1228,1
31	Return Rail D	FC 250	2	145,0
32	Housing Impeller for Pamp TV 61-100	FCD 500	5	365,0
33	Twist Lock (ASTM)	ASTM	20	34,0
34	Pin Lock (ASTM)	ASTM	30	30,0
35	Corner L (ASTM)	ASTM	20	80,0
36	Corner R (ASTM)	ASTM	20	80,0
37	Specimen Uji Tarik ASTM A27 70-36	ASTM A 27 70-36	12	27,6
38	Primary Grinder Crusher	ScMnH11	6	315,0
39	Bearing Housing OD 420	SCM 440	2	79,3
40	Waritsutsu Baffu (K91010	FCD 500	4	134,0
41	Top Plate Fix WTT 76.5m	SCW 480 N	2	813,0
42	Top Plate Move WTT 76.5 m	SCW 480 N	4	1806,0
43	Specimen Uji Tarik Browen (AS)	Browen	4	4,8
44	Casting Reducer Tea 24" x 18"	FC 250 + Cr	2	2080,0
	Accumulated Production			23650,62 KG
	Total			126.095,8 KG