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# Mitigating Supply Chain Risks of Concentrate Feed for the Dairy Cows through Smart Supply Chain Implementation

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***Abstract:***

***Purpose:*** This research aims to mitigate risks within the MAKO (concentrate feed for the dairy cows) supply chain by integrating the House of Risk (HOR) method with the application of smart supply chain technologies based on the Internet of Things (IoT). The objective is to enhance operational efficiency, reduce risks throughout the supply chain, and strengthen the company's competitiveness by leveraging technology at every stage of supply chain management.

***Design/methodology/approach:*** This research was conducted using the House of Risk (HOR) method to identify, evaluate, mitigate, and manage risks within the MAKO supply chain. Mitigation actions for prioritized risk agents were implemented through the application of smart supply chain technologies, including e-procurement systems, barcode systems, and a website-based database utilizing the Internet of Things (IoT) to monitor supply chain flows in real time.

***Findings:*** The research identified 28 risk events and 25 risk agents within the supply chain, with 12 risk agents prioritized for mitigation. Based on the results of proactive action design, 13 risk mitigation actions were proposed. The priority mitigation actions included training on the use of smart supply chain technologies, developing website-based databases to integrate internal and external data, implementing barcode technology for warehouse management, and adopting e-procurement technology for procurement processes.

***Research limitations/implications:*** This research is limited to identifying risks in the MAKO supply chain and designing the user interface for smart supply chain technologies based on the Internet of Things (IoT), without full-scale system implementation.

***Practical implications:*** The findings contribute to the development of smart supply chain management systems tailored for businesses operating within the livestock sector.

***Social implications:*** This research encourages improved digital literacy and technological transformation readiness among livestock sector entrepreneurs.

***Originality/value:*** This research integrates the House of Risk (HOR) method for risk mitigation with the application of smart supply chain technologies, including e-procurement systems, barcode systems, and website-based database using Internet of Things (IoT), within the specific context of the livestock sector.

***Keywords:*** HOR, IoT, risk mitigation, smart supply chain, supply chain

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## 1. Introduction

The Sustainable Development Goals (SDGs) established by the United Nations include 17 major targets, one of which is to eliminate hunger, achieve food security and improved nutrition, and promote sustainable agriculture (Ishatono & Raharjo, 2016). Enhancing food availability, particularly within the livestock sector, requires focused attention on the production capacities of livestock outputs such as eggs, milk, and meat (Varijakshapanicker et al., 2019). In Indonesia, the Ministry of Agriculture continues to implement strategic policies to develop the national dairy industry. Strengthening the dairy industry is considered crucial for driving economic growth towards an Advanced Indonesia and for promoting more progressive, independent, and modern livestock farmers. Increasing milk productivity requires the provision of supplementary feed to optimize both the quality and quantity of milk production (Rusdiana & Sejati, 2016). The quality and composition of concentrate feed have a significant impact on milk production, as the nutritional characteristics such as energy content, protein concentration, and digestibility directly influence the volume and composition of the milk produced (Lawrence, 2015). According to the Decree of the Minister of Agriculture No. 242/Kpts/OT.210/4/2003, concentrate feed is defined as a feed rich in protein sources, low in fiber, and containing high nutritional value.

XYZ Cooperative is a primary dairy cooperative established in 1971. The cooperative currently has more than 3,466 active members out of a total of 7,144 members and manages approximately 18,612 dairy cows. The cooperative operates various business units, including MAKO, dairy partnerships, non-dairy business ventures, and service operations. MAKO is a supplementary dairy cows feed product composed of eight types of raw materials. MAKO is a supplementary feed product composed of eight types of raw materials. Its production process follows a make-to-order system, and distribution is carried out using trucks. In managing the MAKO business, XYZ Cooperative carries out the production process starting from ordering raw materials, receiving raw materials, processing raw materials into finished goods, and finally delivering products to customers.

However, in the implementation of these processes, XYZ Cooperative encounters significant challenges in achieving MAKO production targets, despite MAKO's critical role in supporting milk productivity. These challenges primarily stem from the raw material procurement system. The reliance on short-term contracts with local raw material suppliers frequently leads to the rejection of supplied materials when they fail to meet established quality standards. Conversely, the use of long-term contracts with imported raw material suppliers also entails considerable risks, particularly delivery delays caused by restrictions on livestock feed raw material shipments triggered by ongoing geopolitical conflicts. Although XYZ Cooperative is able to procure raw materials from alternative suppliers, higher procurement costs and limited supply availability prevent the cooperative from fully satisfying its production requirements. Furthermore, raw materials stored for periods exceeding two weeks experience shrinkage of up to 10%. Quality degradation occurs as a result of pest contamination that damages the raw materials, while quantitative losses are attributed to the inherent characteristics of bran pollard and soybean meal (SBM), which possess high moisture content and are therefore susceptible to evaporation during storage. These conditions adversely affect operational efficiency, lead to a decline in final product quality, and increase production costs due to the necessity of replacing lost or non-conforming raw materials. This issue is of particular importance, as the availability of well-formulated, high-protein concentrate feed directly influences both milk quality and yield, there by contributing to the achievement of Sustainable Development Goal (SDG) 2 on food security through the provision of essential nutrients, including protein, calcium, and vitamins, which are fundamental to public health and well-being (Syabira et al., 2025).

All processes are closely related to supply chain processes. The supply chain can be understood as a series of interconnected processes that starts with sourcing raw materials, moves through their transformation into finished goods, and ultimately ends with delivering those goods to customers (Nainggolan, 2018). Within this system, the supply chain network brings together activities across procurement, manufacturing, and distribution, each of which requires careful management of materials, finances, labor, and information flows (Shukla et al., 2011).

Despite the comprehensive structure, XYZ Dairy Cooperative faces several operational challenges and risks across the supply chain stages, from upstream procurement to downstream distribution. Identified problems include dependency on imported raw material suppliers, the inability to meet production targets, inaccuracies in warehouse stock recording for incoming and outgoing goods, and mistakes during the delivery of finished goods to consumers. Dependency on imported suppliers arises from permanent contracts established to secure high-quality raw materials at viable production costs. However, disruptions such as international conflicts have led to delays in raw material deliveries. Furthermore, failure to meet production targets is frequently caused by the absence of prompt supplier confirmations regarding delays and variations in raw material quality. Manual stock recording, carried out separately by several warehouse staff using different recording books, has led to inaccuracies between recorded and actual inventory levels. Mistakes in delivering finished products are often caused by a lack of data integration between internal and external parties, resulting in miscommunication with consumers and discrepancies between the goods ordered and delivered. The absence of a system to confirm shipment schedules and expected delivery times further complicates customer preparation for receiving goods.

Based on the issues that occurred at the XYZ Dairy Cooperative, the implementation of integrated supply chain management is crucial. Supply chain risk management involves a systematic approach encompassing the communication, assessment, mitigation, monitoring, documentation, and reporting of risks (Medina-Serrano et al., 2021). Integrated supply chain management offers significant benefits, including increased productivity, improved customer satisfaction, and enhanced long-term service quality (Dzogbewu et al., 2021). To achieve an integrated supply chain, this research focuses on the application of supply chain risk management to mitigate risks within the MAKO supply chain. The objectives of this research are to enhance operational efficiency, minimize supply chain risks, and secure the availability of raw materials for MAKO production. Risk management in supply chains is the process of identifying and addressing risk factors that impact organizational performance, enabling improvements in customer satisfaction, profitability, and business growth (Aljabhan, 2023). Therefore, this research aims to identify supply chain risk events and risk agents, prioritize critical risk agents, and apply smart supply chain technologies at every stage of supply chain management.

To mitigate risks, it is essential to undertake systematic steps to identify risks occurring within supply chain activities. Risks in the supply chain can be classified into supply risks, process risks, demand risks, and network/control risks (Christopher & Peck, 2004). Several risks and constraints faced in the MAKO supply chain have led to decreased production outcomes and even failures to achieve production targets. Based on the identified problems, risk mitigation is carried out by integrating the House of Risk (HOR) method with the implementation of smart supply chain technologies, including e-procurement, barcoding, and a website-based database utilizing the Internet of Things (IoT). The House of Risk (HOR) method focuses on identifying and addressing risks by designing strategies to reduce risk agents, with the primary goal of minimizing the occurrence of risks through proactive actions targeting the root causes (Suriandi et al., 2022). The smart supply chain represents a complex and interconnected system, implemented at individual, regional, and intercompany levels. It is also adopted in broader and more complex business networks, such as online supply chains, smart factories, the Internet of Things (IoT), and the industrial internet (Du, 2022). Various supporting technologies such as e-procurement, barcoding, information systems, Global Positioning System (GPS) and the Internet of Things (IoT) are essential components in designing a smart supply chain.

The e-procurement system refers to the electronic management and integration of all procurement activities, covering the entire process from purchase requests to payment between buyers and suppliers (Chaffey, 2004). The e-procurement process consists of two stages: pre-purchase activities and post-purchase activities, each involving different operations (Turban et al., 2008). A barcode is a collection of optical data read by machines, represented either by parallel lines (1D) or geometric patterns such as squares and dots (2D), commonly known as barcodes or matrix codes (Panjaitan & Utama, 2024). The barcode system is designed to manage the movement and storage of stock within warehouses and to process transactions related to the receipt, selection, retrieval, and delivery of goods using codes printed in the form of barcodes (Putri & Nurcaya, 2019). In this regard, warehouse operations are critical elements of the supply chain and support the smooth running of a company's business processes (Madhani et al., 2024). Organizations rely on information systems to bring together different parts of their operations, helping them collect, manage, and process data into useful information (Lim & Ridho, 2021). One example is a Management Information System (MIS), which plays a critical role in turning raw data into insights that support daily activities, management oversight, and important decision-making processes (O'Brien & Marakas, 2010). Meanwhile, the Internet of Things (IoT) is reshaping the way people, devices, and systems connect, creating a network where information can flow seamlessly across different platforms in real time. Through this connection, all physical and social elements become interconnected, forming an IoT network that functions to collect, share, and interact with data among various components (Lee & Lee, 2015).

Several studies related to the application of the House of Risk method have been conducted. One study successfully identified 19 risk events and 29 risk agents, with 13 risk agents prioritized for mitigation in a crumb rubber company (Immawan & Putri, 2018). The use of the House of Risk method also led to the identification of 24 risk events and 20 risk agents, with 2 risks categorized as red and 6 risks categorized as orange, prioritized for mitigation efforts in a newspaper company (Ratnasari et al., 2018). In addition, several studies have explored the application of technologies and tools in smart supply chains. One study applied the Internet of Things (IoT) in a logistics company, resulting in a 30% reduction in goods loss, a 20% reduction in vehicle downtime through predictive maintenance using IoT data, and an 18% reduction in incident risks through the use of risk analytics (Usanto et al., 2024). The implementation of website technology and barcode scanning to support tracking processes in the fruit import supply chain was also shown to significantly improve supply chain performance (Burhani et al., 2023). Furthermore, a study on the heavy equipment procurement supply chain demonstrated that the use of an e-procurement system and website-based procurement processes accelerated procurement activities and reduced operational costs (Utama & Prabiyanto, 2019). A study conducted on the palm oil supply chain by implementing Global Positioning System (GPS) technology demonstrated that the application successfully detected dump truck locations with a delay of 15 seconds and displayed the information in real time through a digital map interface (Harahap et al., 2024). In addition, blockchain technology has been shown to improve transparency and operational efficiency within supply chains. Previous research has specifically examined the use of blockchain to enhance the sustainability of food supply chains (Cao et al., 2023).

Based on previous studies highlighting the importance of technology in improving supply chain performance, this study is systematically structured to illustrate the analysis and system design process, with the overall structure of the paper presented in Figure 1. This study produces a smart supply chain system design that encompasses process flows, key features, and mock-up interfaces to support improvements in the MAKO supply chain at XYZ Dairy Cooperative. The proposed design provides a practical contribution as an initial blueprint for the development of afunctional IoT-based system. However, this study has certain limitations, as it focuses solely on interface design and does not yet include full system implementation.

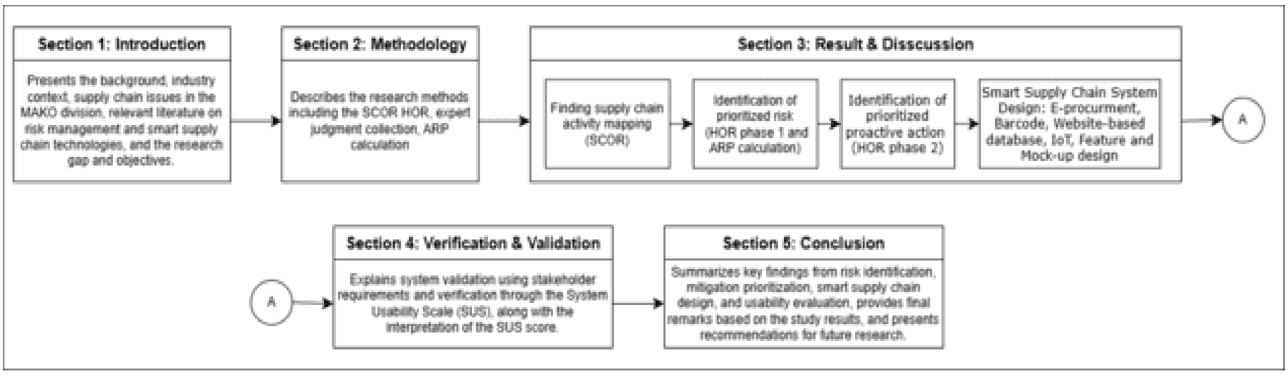


*Figure 1. Paper Organization*

## 2. Methodology

Data collection in this research was conducted through interviews, which were subsequently mapped using the Supply Chain Operations Reference (SCOR) model. The SCOR approach encompasses five key elements: Plan, Source, Make, Deliver, and Return. Following this, the first phase of the House of Risk (HOR) method was carried out, which involved identifying supply chain risks including risk events and risk agents. The HOR framework was applied using the mapped supply chain activities based on the SCOR approach. Risk identification covered procurement, production, finished goods delivery, and return activities, focusing on potential risks that could cause disruptions and losses for the company throughout the supply chain process (Dvaipayana et al., 2024).

After identifying risk events and risk agents, a questionnaire was developed and distributed to four selected experts. The questionnaire assessed the severity score of each risk event, the occurrence score of each risk agent, and the correlation score between risk agents and risk events. The collected data were then processed to calculate the Aggregate Risk Potential (ARP) value using Formula 1:

$$\text{ARPj} = 0j \sum SiRij \tag{1}$$

Based on the ARP calculation results, the most critical risks were identified for mitigation. In the second phase of the House of Risk analysis, various proactive mitigation strategies were designed to reduce or eliminate the impacts of prioritized risks. Several identified strategies were evaluated through another questionnaire distributed to five experts. This second questionnaire assessed the level of correlation, effectiveness, and implementation difficulty of each mitigation strategy. The Total Effectiveness (TEk) was calculated using Formula 2, and the Effectiveness to Difficulty Ratio (ETDk) was calculated using Formula 3:

$$\text{TEk} = \sum \text{ARP}j\ \text{E}jk \tag{2}$$

$$\text{ETD}k = \frac{\text{TE}k}{\text{D}k} \tag{3}$$

The results obtained from the second phase of HOR analysis were used to design the application of a smart supply chain system. In this stage, an analysis of the existing supply chain workflow was conducted to determine critical points requiring the application of smart supply chain technologies. Once critical points were identified, stakeholders who would be involved or affected by the system either directly or indirectly were identified. These stakeholders provided input, approval, and specification of system requirement. After the stakeholder requirements were identified, then the system design can be developed by using several modelling tools, including Use Case Diagrams, Activity Diagrams, Entity-Relationship Diagrams (ERD), and Sequence Diagrams. These models were used to define system needs and establish system boundaries. Then mockup was created as a visual representation which allowing stakeholders and developers to evaluate and provide feedback.

The final stage focused on verifying and validating the mockup. Verification was done using the System Usability Scale (SUS) method to evaluate how effectively users could interact with the system. While the validation was done using a checklist based on the previously identified stakeholder requirements, allowing stakeholders to provide feedback and confirm that the system design met their expectations. The SUS score was then calculated according to Formula 4:

$$\text{SUS Score} = ((Q1\text{-}1) + (5\text{-}Q2) + (Q3\text{-}1) + (5\text{-}Q4) + (Q5\text{-}1) + (5\text{-}Q6) + (Q7\text{-}1) + (5\text{-}Q8) + (Q9\text{-}1) + (5\text{-}Q10)) \times 2.5 \tag{4}$$

To clarifies the relationship between theory and method, the conceptual framework illustrated in Figure 2 integrates supply chain and risk management theories with the House of Risk (HOR) methodology, smart supply chain, and IoT-based technologies.

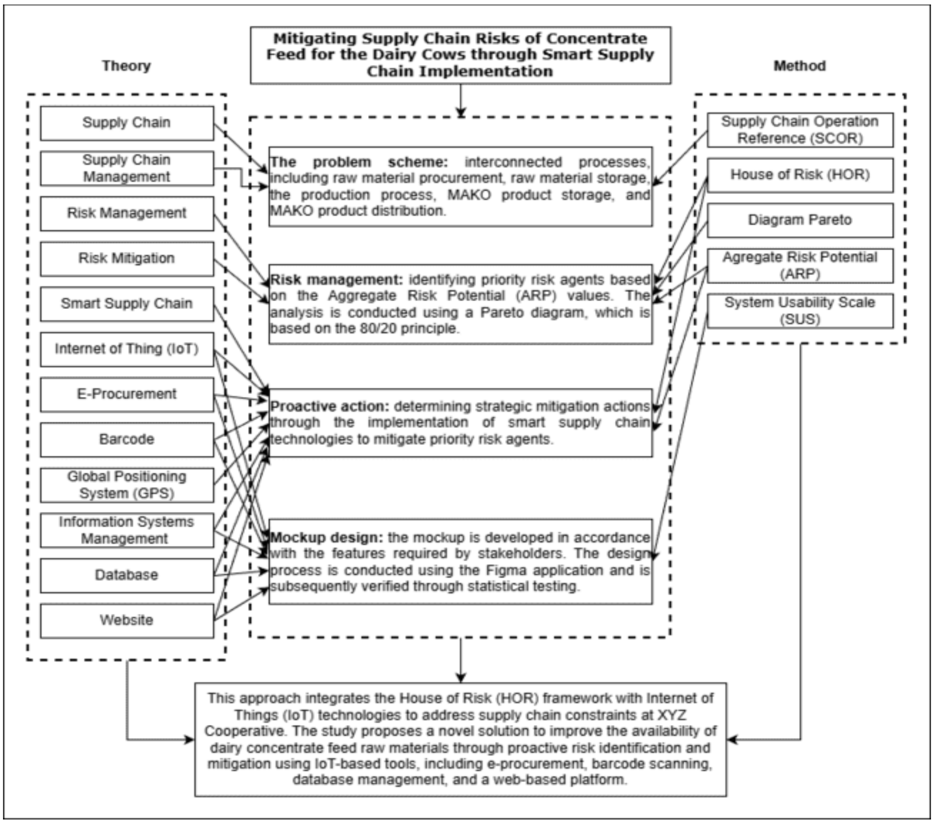


*Figure 2. Conceptual Framework*

## 3. Findings and Discussion

### 3.1. Supply Chain Activities

At XYZ Dairy Cooperative, the supply chain for MAKO are includes the procurement of raw materials, the production process, and the delivery of goods to customers. To map these activities, the Supply Chain Operations Reference (SCOR) model is used, which organizes the supply chain into five key stages: Plan, Source, Make, Deliver, and Return. The details of the supply chain activities for MAKO production are presented in Table 1.

| Business Process | Sub-process | Risk Actor |
|---|---|---|
| Plan | Production planning | Head of MAKO division |
| | Raw material procurement planning | |
| Source | Selection of local raw material suppliers | Procurement staff |
| | Ordering of imported and local raw materials | |
| | Scheduling of raw material deliveries | |
| | Receipt of raw materials | |
| | Storage of raw materials | |
| Make | Production process | Production staff |
| | Inspection of finished products | |
| | Packaging process | |
| | Storage of finished products | |
| Delivery | Delivery of finished products to customers | Logistics staff |
| Return | Aftersales process | Logistics staff & Head of MAKO division |

*Table 1. Supply Chain Activities*

### 3.2. Risks Identification

Based on the detailed identification of supply chain activities, the next step was identifying the risks associated with each business process. Risk events were identified for every sub-process, and risk agents, as the causes of those risks, were determined. Risk identification was carried out through expert interviews to ensure that the risks captured aligned with real operational conditions. The validation of identified risk events and risk agents was conducted by distributing questionnaires to experts. In the questionnaire, experts evaluated the severity level of each risk event and the occurrence level of each risk agent. The results of risk identification and validation revealed 28 risk events and 25 risk agents. The complete list of risk events is presented in Table 2, and the identified risk agents are shown in Table 3.

| Business Process | Sub-process | Code (Ej) | Risk Event |
|---|---|---|---|
| Plan | Production planning | E1 | Changes in production targets |
| | Procurement planning | E2 | Raw material shortages |
| | | E3 | Errors in forecasting raw material requirements |
| Source | Selection of local suppliers | E4 | Errors in selecting local raw material suppliers |
| | Ordering of raw materials | E5 | Errors in determining order quantities |
| | | E6 | System errors in the ordering process |
| | | E7 | Limited availability of materials from suppliers |
| | Scheduling deliveries | E8 | Delay in delivery of raw materials by suppliers |
| | Receipt of raw materials | E9 | Raw materials failing quality control |
| | | E10 | Rejection of raw materials |
| | | E11 | Errors in recording incoming raw materials |
| Source | Storage of raw materials | E12 | Damage to raw materials during storage |
| Make | Production process | E13 | Errors in recording outgoing raw materials |
| | | E14 | Stockouts of raw materials in the warehouse |
| | | E15 | Machine breakdowns |
| | | E16 | Insufficient machine capacity |
| | | E17 | Production processes not adhering to schedule |
| | | E18 | Production targets not met |
| | Finished product inspection | E19 | Finished product composition does not meet standards |
| | | E20 | Variance in production output by product type |
| | Packaging process | E21 | Shortages of packaging materials |
| | Storage of finished goods | E22 | Errors in recording finished goods |
| Delivery | Delivery of finished goods | E23 | Errors in recording outgoing finished goods |
| | | E24 | Delays in delivering finished products to customers |
| | | E25 | Delivered products not matching orders |
| | | E26 | Product damage during delivery |
| | | E27 | Technology disruptions during the delivery process |
| Return | Aftersales process | E28 | Returned goods from customers |

*Table 2. Identified Risk Events in the MAKO Supply Chain*

| Code (Ej) | Risk Agent | Code (Aj) |
|---|---|---|
| E1 | Changes in consumer demand | A1 |
| E2<br>E7 | Seasonal availability of raw materials | A2 |
| E3 | Errors in raw material procurement scheduling or planning | A3 |
| E4 | Lack of staff understanding regarding supplier selection standards | A4 |
| E5 | Poor communication and data integration with suppliers | A5 |
| E6 | Absence of technology in ordering processes, such as e-procurement | A6 |
| E8 | Delivery delays by suppliers | A7 |
| | Imported raw materials delayed in transit due to ongoing conflicts | A8 |
| E9 | Supplier negligence in delivering raw materials not meeting the promised quality standards | A9 |
| E10 | Lack of staff understanding regarding raw material quality standards | A10 |
| E11<br>E13<br>E22<br>E23 | Absence of technology in warehouse processes, such as barcode systems | A11 |
| E12 | Warehouse systems not meeting standards, lacking temperature sensors and airtight facilities | A12 |
| | Staff negligence in storing raw materials (failure to apply the first-in, first-out principle) | A13 |
| | Lack of quality control during raw material storage | A14 |
| E14<br>E18 | No confirmation of delivery delays from suppliers | A15 |
| E15 | Lack of regular inspections and maintenance of production equipment | A16 |
| E16 | Aging mixing machines | A17 |
| E17 | Production processes delayed due to waiting for raw materials | A18 |
| E19 | Insufficient staff knowledge about product compositions | A19 |
| | Quality control only conducted after production completion | A20 |
| E20<br>E21<br>E25 | Poor communication and data integration among internal teams | A21 |
| E24 | Delivery disruptions caused by weather conditions and accidents | A22 |
| E26 | Negligence by logistics staff during the delivery process | A23 |
| E27 | Lack of tracking technology for finished goods deliveries | A24 |
| E28 | Poor communication and data integration with customers | A25 |

*Table 3. Identified Risk Agents in the MAKO Supply Chain*

### 3.3. House of Risk Phase 1

The severity scores of risk events, the occurrence scores of risk agents, and the correlation values between risk events and their causes were processed to calculate the Aggregate Risk Potential (ARP). Based on the ARP calculations, the risk agents with the highest ARP scores were prioritized for mitigation. The values for ARP, severity, occurrence, risk agents, risk events, and the correlations between them were organized using the House of Risk Phase 1 framework. The framework is illustrated in Figure 3.

| Risk Event (Ej) | Risk Agent (Aj) | | | | | | | | | | | | | | | | | | | | | | | | | Severity |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 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 | |
| E1 | 9 | | | | | | | | | | | | | | | | | | | | 3 | | | | 3 | 3 |
| E2 | | 9 | | | | | | | | | | 3 | 1 | 1 | | | | | | | | | | | | 6 |
| E3 | | | 9 | | | | | | | | | | | | | | | | | | 3 | | | | 3 | 3 |
| E4 | | | | 9 | | | | | | | | | | | | | | | | | | | | | | 2 |
| E5 | | | 9 | | 3 | | | | | | | | | | | | | | | | 9 | | | | | 3 |
| E6 | | | | | 9 | 9 | | | | | | | | | | | | | | | | | | | | 6 |
| E7 | | 9 | | | | | | 3 | | | | | | | | | | | | | | | | | | 5 |
| E8 | | | | | 3 | 1 | 9 | 9 | | | | | | | 3 | | | | | | | | | | | 6 |
| E9 | | | | | 3 | | | | 9 | 9 | | | | | | | | | | | | | | | | 8 |
| E10 | | | | | 3 | | | | 9 | 9 | | | | | | | | | | | | | | | | 6 |
| E11 | | | | | | | | | | | 9 | | 3 | | | | | 1 | | | 1 | | | | | 8 |
| E12 | | | 1 | | | | | | 1 | | | 9 | 9 | 9 | | | | | | | 1 | | | | | 7 |
| E13 | | | | | | | | | | | 9 | | 3 | | | | | 1 | | | 1 | | | | | 8 |
| E14 | | | | 9 | | 9 | 9 | | | | 1 | | | | 3 | | | 9 | | | | | | | | 6 |
| E15 | | | | | | | | | | | | | | | | 9 | 9 | | | | 1 | | | | | 4 |
| E16 | | | | | | | | | | | | | | | | 3 | 9 | | | | | | | | | 3 |
| E17 | | 1 | 1 | | | | 3 | 3 | | | | | | | 3 | | | 9 | | | 3 | | | | | 5 |
| E18 | | | 1 | | | | 3 | 9 | | | | | | | 9 | | | 9 | | | 1 | | | | | 7 |
| E19 | | | | | | | | | | | | | | | | | | | 9 | 9 | 1 | | | | | 5 |
| E20 | | | | | | | | | | | | | | | | | | | | 1 | 9 | | | | 9 | 3 |
| E21 | | | | | | | | | | | | | | | | | | | | | 9 | | | | | 3 |
| E22 | | | | | | | | | | | 9 | | | | | | | | | | 1 | | | | | 8 |
| E23 | | | | | | | | | | | 9 | | | | | | | | | | 1 | | 1 | | | 8 |
| E24 | | | | | | | 3 | 3 | | | | | 9 | | 3 | | | | | | | 9 | | | | 5 |
| E25 | | | | | | | | | | | | | | | | | | | | | 9 | | 9 | | 9 | 4 |
| E26 | | | | | | | | | | | | | | | | | | | | | | 9 | 9 | | | 2 |
| E27 | | | | | | | | | | | | | | | | | | | | | | | | 9 | 3 | 8 |
| E28 | | | | | | | | | | | | | | | | | | | | | 3 | | 1 | | 9 | 2 |
| Occurence | 3 | 2 | 3 | 2 | 8 | 9 | 3 | 3 | 2 | 3 | 7 | 8 | 3 | 4 | 8 | 4 | 5 | 3 | 2 | 4 | 8 | 4 | 2 | 8 | 7 | |
| ARP | 81 | 208 | 219 | 144 | 984 | 1026 | 477 | 486 | 266 | 378 | 2058 | 648 | 486 | 276 | 1032 | 180 | 315 | 534 | 90 | 192 | 1688 | 252 | 128 | 576 | 861 | |
| Rank | 25 | 19 | 18 | 22 | 5 | 4 | 12 | 10 | 16 | 13 | 1 | 7 | 11 | 15 | 3 | 21 | 14 | 9 | 24 | 20 | 2 | 17 | 23 | 8 | 3 | |

*Figure 3. House of Risk Phase 1 Framework*

Following the ARP calculations in the House of Risk Phase 1, cumulative ARP values, percentage of ARP, and cumulative percentage of ARP were determined. Based on the ARP calculation results in the HOR phase 1 framework, the next step will be to calculate the cumulative ARP value, ARP percentage, and cumulative ARP percentage. The results of the calculation are shown in Table 4.

| Rank | (Aj) | ARP Value | Cumulative ARP | % ARP | Cumulative % ARP |
|---|---|---|---|---|---|
| 1 | A11 | 2058 | 2058 | 15.15% | 15.15% |
| 2 | A21 | 1688 | 3746 | 12.43% | 27.57% |
| 3 | A15 | 1032 | 4778 | 7.60% | 35.17% |
| 4 | A6 | 1026 | 5804 | 7.55% | 42.72% |
| 5 | A5 | 984 | 6788 | 7.24% | 49.97% |
| 6 | A25 | 861 | 7649 | 6.34% | 56.30% |
| 7 | A12 | 648 | 8297 | 4.77% | 61.07% |
| 8 | A24 | 576 | 8873 | 4.24% | 65.31% |
| 9 | A18 | 534 | 9407 | 3.93% | 69.25% |
| 10 | A8 | 486 | 9893 | 3.58% | 72.82% |
| 11 | A13 | 486 | 10379 | 3.58% | 76.40% |
| 12 | A7 | 477 | 10856 | 3.51% | 79.91% |
| 13 | A10 | 378 | 11234 | 2.78% | 82.69% |
| 14 | A17 | 315 | 11549 | 2.32% | 85.01% |
| 15 | A14 | 276 | 11825 | 2.03% | 87.04% |
| 16 | A9 | 266 | 12091 | 1.96% | 89.00% |
| 17 | A22 | 252 | 12343 | 1.85% | 90.86% |
| 18 | A3 | 2019 | 12562 | 1.61% | 92.47% |
| 19 | A2 | 208 | 12770 | 1.53% | 94,00% |
| 20 | A20 | 192 | 12962 | 1.41% | 95.41% |

| Rank | (Aj) | ARP Value | Cumulative ARP | % ARP | Cumulative % ARP |
|---|---|---|---|---|---|
| 21 | A16 | 180 | 13142 | 1.32% | 96.74% |
| 22 | A4 | 144 | 13286 | 1.06% | 97.80% |
| 23 | A23 | 128 | 13414 | 0.94% | 98.74% |
| 24 | A19 | 90 | 13504 | 0.66% | 99.40% |
| 25 | A1 | 81 | 13585 | 0.60% | 100.00% |

*Table 4. Cumulative ARP %*

After obtaining the cumulative ARP values, ARP percentages, and cumulative ARP percentages as shown in Table 4, the next step is to evaluate the risks within the supply chain. The analysis is carried out using a Pareto diagram, following the 80/20 principle, where 20% of the risk causes (risk agents) are responsible for 80% of the risk events. By prioritizing the mitigation of these top 20% of risk causes, it is expected that the overall impact of the remaining 80% of less critical risks can be significantly reduced. The results of this analysis are presented in Figure 4.

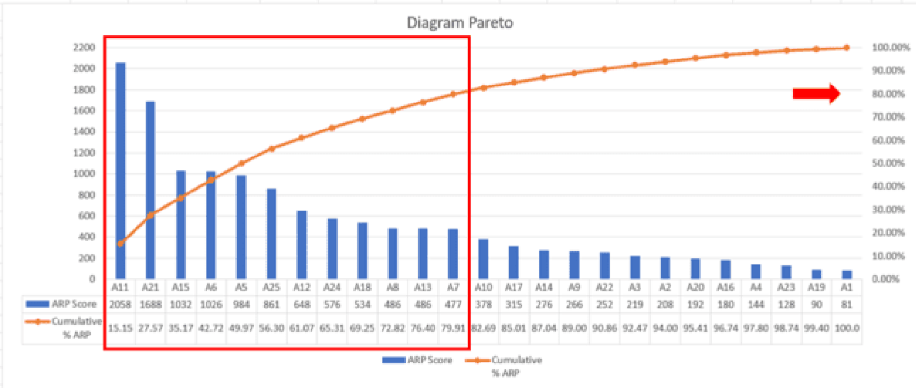


*Figure 4. Pareto Diagram*

Based on Figure 4, there were 12 risk agents with cumulative ARP percentages falling between 0% and 80%. Following the Pareto principle, these 12 risk agents were prioritized for designing proactive mitigation strategies. The prioritized risk agents are presented in Table 5.

| Code (Aj) | Risk Agent | ARP Value |
|---|---|---|
| A11 | Absence of technology in warehouse processes, such as barcode systems | 2058 |
| A21 | Poor communication and data integration among internal teams | 1688 |
| A15 | No confirmation of delivery delays from suppliers | 1032 |
| A6 | Absence of technology in ordering processes, such as e-procurement | 1026 |
| A5 | Poor communication and data integration with suppliers | 984 |
| A25 | Poor communication and data integration with customers | 861 |
| A12 | Warehouse systems not meeting standards, lacking temperature sensors and airtight facilities | 648 |
| A24 | Lack of tracking technology for finished goods deliveries | 576 |
| A18 | Production processes delayed due to waiting for raw materials | 534 |
| A8 | Imported raw materials delayed in transit due to ongoing conflicts | 486 |
| A13 | Staff negligence in storing raw materials (failure to apply the first-in, first-out principle) | 486 |
| A7 | Delivery delays by suppliers | 477 |

*Table 5. Prioritized Risk Agents*

### 3.4. House of Risk Phase 2

Each risk mitigation strategy is assigned a code (PA) for proactive action to facilitate easier identification. The correlation assessment between the prioritized risk causes (risk agents) and the proposed risk mitigation strategies (proactive actions) was conducted through the distribution of a questionnaire to five experts at XYZ Dairy Cooperative. In this questionnaire, a correlation scale was used, where a score of 0 indicates no correlation, 1 indicates a weak correlation, 3 indicates a moderate correlation, and 9 indicates a strong correlation. The subsequent step involved calculating the Total Effectiveness (TEk), the Effectiveness to Difficulty Ratio (ETDk), and the ranking of the mitigation strategies. The results of these calculations were used to determine the most effective and efficient mitigation strategies for reducing risks within the supply chain. The correlation values between the prioritized risk causes (risk agents) and the mitigation strategies (proactive actions), along with the average difficulty rating, the Total Effectiveness (TEk), the Effectiveness to Difficulty Ratio (ETDk), and the resulting ranks, are presented according to the House of Risk Phase 2 framework in Figure 5.

| | PA1 | PA2 | PA3 | PA4 | PA5 | PA6 | PA7 | PA8 | PA9 | PA10 | PA11 | PA12 | PA13 | ARP Value |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| A11 | | 1 | 9 | | | | | 9 | | | | | 9 | 2058 |
| A21 | | | | | | 9 | | | | | | | | 1688 |
| A15 | | | | 9 | 3 | | | | | | 9 | | | 1032 |
| A6 | | | | | | 1 | 9 | | | | | | 9 | 1026 |
| A5 | | | | 1 | | 9 | 3 | | | | | | | 984 |
| A25 | | | | | | 9 | | | | | | | | 861 |
| A12 | | 1 | 1 | | | | | | 9 | 9 | | | 9 | 648 |
| A24 | | | | | | | | | | | | 9 | 9 | 576 |
| A18 | 1 | | | 3 | 1 | | | | | | 1 | | | 534 |
| A8 | 9 | | | | | | | | | | | | | 486 |
| A13 | | | 3 | | | | | | | | | | | 486 |
| A7 | 1 | | | | 9 | | | | | | | | | 477 |
| TEk | 5385 | 2706 | 20628 | 11874 | 7923 | 32823 | 12186 | 18522 | 5832 | 5832 | 9822 | 5184 | 38772 | |
| Dk | 4 | 3 | 3 | 3 | 3 | 4 | 4 | 4 | 5 | 5 | 3 | 4 | 3 | |
| ETDk | 1346,25 | 902 | 6876 | 3958 | 2641 | 8205,75 | 3046,5 | 4630,5 | 1166,4 | 1166,4 | 3274 | 1296 | 12924 | |
| Rank | 10 | 9 | 3 | 5 | 8 | 2 | 7 | 4 | 13 | 12 | 6 | 11 | 1 | |

*Figure 5. House of Risk Phase 2 Framework*

Based on the evaluation results from House of Risk Phase 2, a priority order for the implementation of proactive actions has been established. This order is arranged from the actions that are easiest to implement to those that are more difficult, based on the assessments provided by experts at XYZ Dairy Cooperative. The purpose of this prioritization is to ensure the effectiveness of risk mitigation strategies while also considering the level of difficulty associated with their implementation. The prioritized order of proactive actions is presented in Table 6.

| Ranking | Code (PAj) | Proactive Action |
|---|---|---|
| 1 | PA13 | Conduct training on the use of technology in supply chain processes |
| 2 | PA6 | Implement a website-based database technology to integrate internal and external data |
| 3 | PA3 | Implement an integrated warehouse system |
| 4 | PA8 | Apply barcode technology in warehouse processes |
| 5 | PA4 | Conduct regular confirmations of raw material shipments with suppliers |
| 6 | PA11 | Implement website technology to manage all communications and confirmations with suppliers |
| 7 | PA7 | Implement e-procurement technology in the raw material ordering process |
| 8 | PA5 | Evaluate criteria and requirements for supplier selection |
| 9 | PA2 | Conduct strict monitoring during the raw material storage process |
| 10 | PA1 | Seek backup suppliers to fulfill raw material needs |
| 11 | PA12 | Implement tracking technology using GPS in the delivery process of finished products |
| 12 | PA9 | Construct a warehouse that meets standards, including airtightness and temperature sensors |
| 13 | PA10 | Rent a warehouse that meets standards, including airtightness and temperature sensors |

*Table 6. Proposed Proactive Actions*

Based on previous studies summarized in Table 7, research on supply chain risk management and risk assessment has been extensively conducted. These studies commonly establish relationships between risk agents and risk events to formulate mitigation strategies that can be effectively implemented. However, the proposed mitigation actions in these studies primarily focus on conventional or non-technological approaches.

| Title, Authors, Year | Variables & Research Method | Mitigation Strategies |
|---|---|---|
| House of Risk Approach for Assessing Supply Chain Risk Management Strategies: A Case Study in Crumb Rubber Company Ltd. (Immawan & Putri, 2018) | *Variables:* Process Plan, Source, Make, Delivery, and Return in supply chain *Methods:* SCOR, House of Risk and FMEA | This study focuses on the crumb rubber industry, which faces significant challenges related to supplier dependency. The proposed risk mitigation strategies, however, remain limited to conventional, non-technological approaches, such as enhancing distribution processes through transportation management and improving coordination with distribution personnel. |
| Supply Chain Risk Management in Newspaper Company: House of Risk Approach (Ratnasari et al., 2018) | *Variables:* process Plan, Source, Make, Delivery, and Return in supply chain *Methods:* SCOR and House of Risk | This study focuses on the newspaper printing industry, which encounters significant challenges within the production process. The proposed risk mitigation strategies remain conventional and non-technological, emphasizing operational efficiency through the establishment of standardized lead times, regular maintenance, and manual material monitoring. |
| Pengelolaan Risiko Supply Chain dengan Metode House of Risk (Tampubolon et al., 2013) | *Variables:* The processes of supplier selection, purchasing, payment, shipping, receiving, and storage *Method:* House of Risk | This study focuses on the furniture industry, which encounters significant challenges within the procurement process. The implemented risk mitigation strategies remain conventional and non-technological, consisting of supplier and employee evaluations to enhance reliability and minimize human error, as well as strengthening communication with suppliers through structured scheduling. |

*Table 7. Previous Studies on Supply Chain Risk Management and Mitigation*

### 3.5. Smart Supply Chain System Design

The Smart Supply Chain design comes from the proactive actions that were studied using the House of Risk (HOR) method. To make the supply chain work better and be stronger, several steps were taken to lower risks and help people work together more easily. By using the Smart Supply Chain strategy, the company hopes to make operations faster, reduce problems in the supply chain, and become more competitive by using technology at every step. After looking closely at how things work at XYZ Dairy Cooperative and talking to some of the workers, it was found that most of the supply chain activities are still done manually. Therefore, the Smart Supply Chain system was designed to incorporate technologies such as e-procurement, barcode systems, a website-based database, and the Internet of Things (IoT) to monitor supply chain flows in real time.

#### 3.5.1. E-Procurement

The entire raw material ordering process is currently managed by the procurement staff through WhatsApp. Orders are placed every 15 days with international suppliers under permanent contracts and local suppliers under temporary contracts. However, delivery delays without prior confirmation from suppliers have the potential to disrupt production schedules and result in unmet production targets. Moreover, the Division Head does not have direct access to monitor the raw material ordering process, which limits the ability to respond quickly and implement alternative solutions to ensure raw material availability.

Based on previous studies, e-procurement technology has been implemented to address inefficiencies in the procurement process; however, these analyses were not conducted within a structured risk prioritization framework. The relevant previous studies are summarized in Table 8.

| Title, Authors, Year | Variables & Research Method | Mitigation Strategies |
|---|---|---|
| Perancangan Sistem E-Procurement CV W3 Indonesia (Prasetya et al., 2020) | *Variable:* Procurement process performance<br>*Method:* Rapid Application Development (RAD) approach with prototyping | This study focuses on optimizing the procurement process through the implementation of an e-procurement system and an internal website. The problem analysis was conducted via interviews with the IT manager and an evaluation of procurement documents at CV W3 Indonesia. However, this study lacks a structured risk prioritization framework to determine the most critical areas for intervention. |
| E-Procurement System Pengadaan Barang dan Jasa pada PT Trakindo Utama Surabaya (Utama & Prabiyanto, 2019) | *Variables:* The Efficiency and effectiveness<br>*Methods:* Qualitative and case studies | This study focuses on optimizing the procurement process within the heavy equipment supply chain through the implementation of an e-procurement system and a web-based platform. The problem analysis was conducted via interviews with personnel and an evaluation of procurement documents at PT Trakindo Utama. However, this study lacks a structured risk prioritization framework to identify and address the most critical supply chain vulnerabilities. |

*Table 8. Previous Studies on E-Procurement Technology*

To make raw material ordering more clear and faster, e-procurement technology (PA7) was used. This system lets the ordering process be done online, so it makes transactions quicker, helps avoid delivery delays, and makes the raw material ordering more accurate. Additionally, to strengthen communication with suppliers, website-based technologies (PA11 and PA4) have been adopted as the primary platforms for communication and confirmation. These systems allow the entire raw material ordering process to be handled digitally, ensuring faster transactions, minimizing delays, and enhancing procurement accuracy. The following presents an analysis of the e-procurement technology design, integrated with a website-based database, along with the system features that have been developed, as summarized in Table 9.

| Activity | Problem | Proposed Improvement | Smart Supply Chain Technology | System Feature | Stakeholder |
|---|---|---|---|---|---|
| Raw material ordering | Absence of a system to document all raw material orders | System upgrade | Document the entire raw material ordering process using website-based e-procurement technology | 1. Raw material ordering feature<br>2. Raw material order form feature | • Procurement staff<br>• Suppliers<br>• Head of MAKO division |
| Raw material payment | Absence of a system to document all proof of raw material payments | System upgrade | Document all proof of raw material payments using website-based e-procurement technology | 3. Raw material delivery feature | • Procurement staff<br>• Suppliers |
| Raw material delivery | Absence of delivery delay confirmations, leading to production plan changes and unmet production targets | System upgrade | Develop a platform to confirm order statuses and delivery delays using website-based database technology | 4. Raw material delivery feature | • Suppliers<br>• Procurement staff<br>• Head of MAKO division |

*Table 9. E-Procurement System Design Features*

The following is the mockup design based on the results of the e-procurement technology design analysis, which is integrated into a website-based database. The mockups listed in Table 9 are presented in Figures 6 through 9.

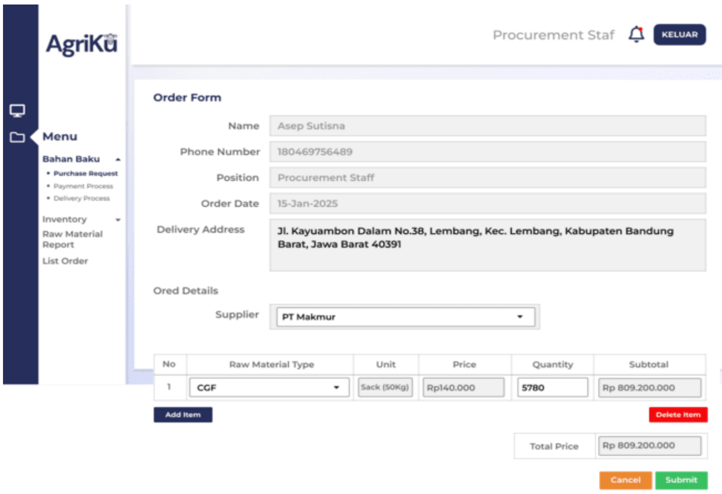


*Figure 6. Raw Material Order Form Page*

Figure 6 shows the mockup of the raw material order form page. Users can reach this page by clicking the "+ Order" button on the raw material ordering page. Then users can enter the required raw material order information, including the delivery address, supplier, type of raw material, and quantity of items on this page. The data will then be saved into the database when the procurement staff clicks "Submit."

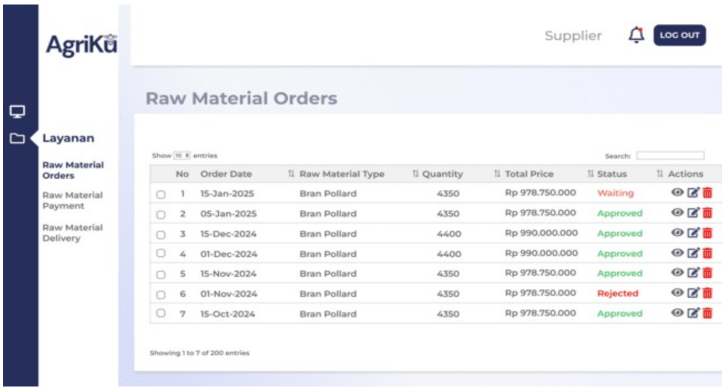


*Figure 7. Raw Material Orders Overview Page*

Figure 7 shows the mockup of the raw material orders page. The overview shows the list of orders, including the order date, type of raw material, quantity of items, total price, and order status. Users can also view, edit, and delete raw material order data. When users select the edit option, they can approve or reject raw material orders.

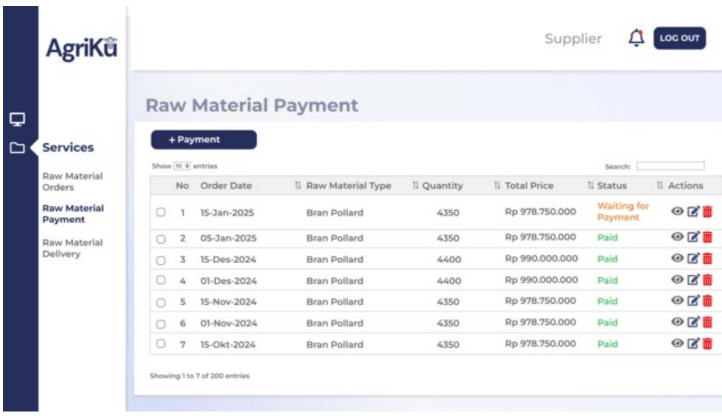


*Figure 8. Raw Material Payment Overview Page*

Figure 8 shows the mockup of the raw material payment page. The overview shows the list of payments, including the order date, supplier, type of raw material, quantity of items, total price, and payment status. Users can also view, edit, and delete raw material payment data. When users select the edit option, they can approve raw material payments.

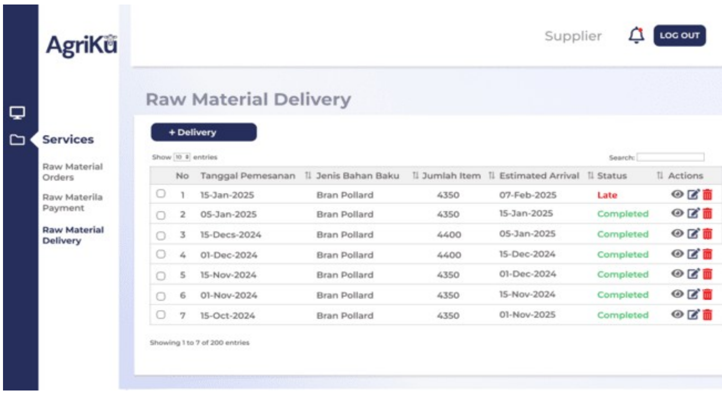


*Figure 9. Raw Material Delivery Overview Page*

Figure 9 shows the mockup of the raw material delivery page. Here users can access the list of deliveries, including the order date, supplier, type of raw material, quantity of items, estimated arrival date, and delivery status. Next to that, users can see more detailed information about raw material deliveries from this page.

### 3.5.2. Barcode

The warehouse keeps track the entering and leaving of raw materials and finished. This process is still performed manually using stock books. Given that both raw materials and finished goods are susceptible to shrinkage if stored for more than two weeks, recording errors can lead to material spoilage, thereby disrupting the raw material procurement planning process. In addition, recording errors involving supporting materials can hinder the packaging process. To address these issues, an integrated warehouse management system (PA3) has been designed to ensure more accurate stock management. Furthermore, barcode technology has been designed to improve operational efficiency in the warehouse (PA8). This technology assists in recording incoming and outgoing goods, thereby accelerating the inventory process and reducing recording errors. The warehouse management system is integrated into a website-based database, allowing users to record, monitor, and manage inventory digitally. A study on barcode technology conducted by Panjaitan and Utami (2024) demonstrated that barcode scanning can be effectively implemented in snack food manufacturing to optimize warehouse and storage operations within the supply chain. The underlying issues were analyzed through direct observation, interviews, and internal data evaluation; however, the study lacks a structured risk prioritization framework to determine the most critical areas for mitigation. The features developed for warehouse management are summarized in Table 10.

The following is the mockup design based on the results of the barcode technology design analysis, which is integrated into a website-based database. The mockups listed in Table 10 are presented in Figure 10 until Figure 12.

Figure 10 shows the mockup of the barcode page. This page shows the list of barcodes, including product codes, product names, categories, units, warehouse locations, and barcode previews. Users can also add, view, edit, and delete barcodes from this page.

Figure 11 shows the mockup of the inventory entry and exit page. Only the procurement staff, production staff, and logistics staff are allowed to access this page. This page can be accessed by clicking the "+Entry" or "–Exit" buttons on the inventory list page. This page gives an overview on detailed product information, including the product name, unit, category, and warehouse location. Users can also search a certain product by scanning a barcode or by manually entering the product code and input the quantity of products entering or exiting the warehouse on this page. After clicking "Submit," the system will automatically update and adjust the inventory data.

| Activity | Problem | Proposed Improvement | Smart Supply Chain Technology | System Feature | Stakeholder |
|---|---|---|---|---|---|
| Inventory | Absence of a system to identify raw materials, supporting materials, and MAKO products, causing difficulties in stock tracking and management | System upgrade | Use barcode technology to identify raw materials and MAKO products, where barcodes are scanned and the data is automatically stored and integrated with the database system | 1. Barcode feature | • Head of MAKO division<br>• Procurement staff<br>• Production staff<br>• Logistics staff |
| | Absence of a system to document all raw materials and MAKO products entering and leaving the warehouse | System upgrade | Document all raw material and MAKO product inventory using a website-based database technology | 2. Inventory feature | • Head of MAKO division<br>• Procurement staff<br>• Production staff<br>• Logistics staff |

*Table 10. Barcode-Based Inventory Management System Features*

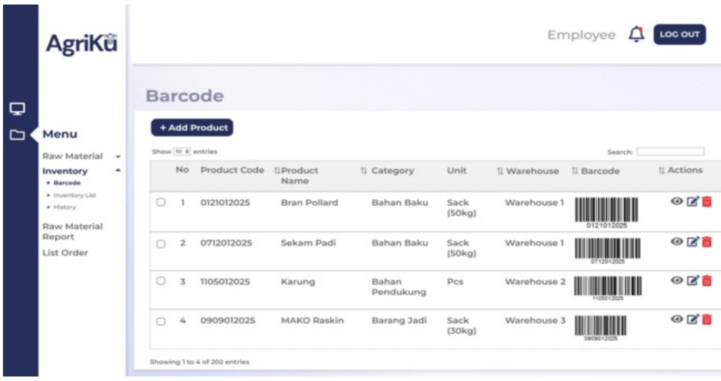


*Figure 10. Barcode Page*

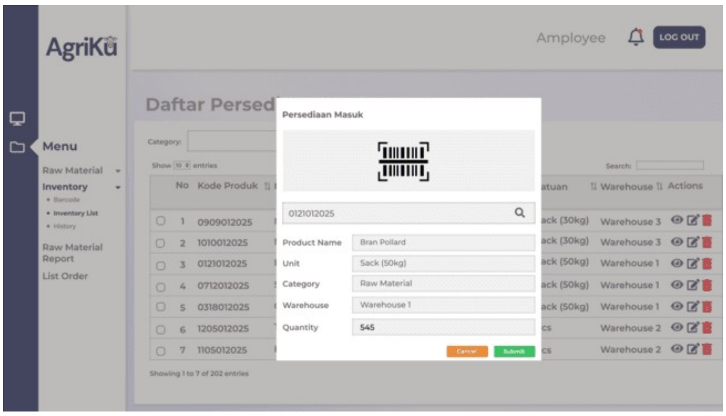


*Figure 11. Inventory Entry/Exit Page*

Figure 12 shows the mockup of the inventory history page, which can be accessed by the Division Head, procurement staff, production staff, and logistics staff. On this page, users can view information including the type of inventory movement (entry or exit), product code, product name, category, initial quantity, user, date, and final quantity. Users can categorize the data based on material type, such as raw materials, supporting materials, and finished goods. Through this page, users can also identify the employees responsible for each inventory movement.

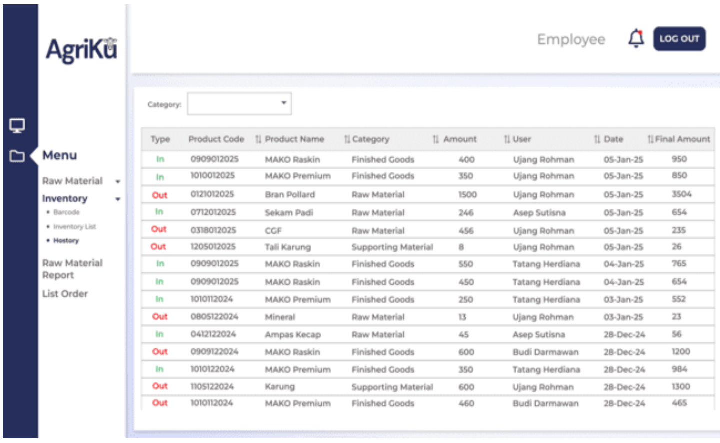


*Figure 12. Inventory History Page*

### 3.5.3. Website-Based Database

The use of manual record-keeping through books is still applied for recording consumer and supplier data, as well as order data. The confirmation process between consumers and the Division Head, and between logistics staff and consumers, is still conducted through WhatsApp, where communication is only visible to the parties directly involved. This often results in miscommunication between internal and external parties. The Division Head is unable to directly monitor the entire process and production status, making it difficult to respond quickly to address production and delivery delays, which ultimately impacts the quality of service. To address these issues, a website-based database system is implemented to integrate internal and external data (PA6). This system enables XYZ Dairy Cooperative to monitor orders, production status, and delivery information through a single platform accessible in real time. A study on website-based database technology conducted by Burhani et al. (2023) demonstrated that a web-based information system can be effectively implemented in an imported fruit distribution company to integrate distribution processes including purchasing, delivery, inspection, and tracking via barcode scanning with all data stored in a centralized database. While the issues were analyzed using the PIECES framework, the study lacks a structured risk prioritization framework to determine the most critical risk factors for mitigation. The following presents the analysis of the website-based database technology design and the features developed within the system, as summarized in the Table 11.

<table>
<tr><th>Activity</th><th>Problem</th><th>Proposed Improvement</th><th>Smart Supply Chain Technology</th><th>System Feature</th><th>Stakeholder</th></tr>
<tr><td rowspan="2">MAKO Ordering</td><td>Absence of a system to document all consumer orders</td><td>System upgrade</td><td rowspan="2">Document all consumer orders accessible by all staff using website-based database technology</td><td rowspan="2">1. Order feature<br>2. Order list feature<br>3. Order form feature</td><td rowspan="2">• Consumers<br>• Head of MAKO division<br>• Procurement staff<br>• Production staff<br>• Logistics staff</td></tr>
<tr><td>Orders can only be received and accessed by the head of MAKO division, causing issues in MAKO production and delivery processes</td><td>System upgrade</td></tr>
<tr><td rowspan="2">MAKO Payment</td><td>Absence of a system to document all payment proofs for MAKO orders</td><td>System upgrade</td><td rowspan="2">Document all payment proofs for MAKO orders that are automatically integrated into the sales report using website-based database technology</td><td rowspan="2">4. Payment feature<br>5. Sales report feature</td><td rowspan="2">• Consumers<br>• Head of MAKO division</td></tr>
<tr><td>Difficulty in creating sales reports</td><td>System upgrade</td></tr>
</table>

| Activity | Problem | Proposed Improvement | Smart Supply Chain Technology | System Feature | Stakeholder |
|---|---|---|---|---|---|
| MAKO Delivery | Absence of order confirmation and estimated arrival time for MAKO, causing unsynchronized schedules between logistics staff and consumers, resulting in MAKO products not being received directly by consumers | System upgrade | Create a platform to provide order status confirmation and estimated arrival times to consumers using website-based database technology | 6. MAKO delivery feature | • Consumers<br>• Logistics staff |
| Raw Material Payment | Difficulty in creating raw material payment reports | System upgrade | Automatically integrate all raw material payment proofs into raw material reports using website-based database technology | 7. Raw material report feature | • Head of MAKO division |
| Internal Management | Absence of a system to document all employee, supplier, and consumer data | System upgrade | Document all employee, supplier, and consumer data | 8. Employee data feature<br>9. Supplier data feature<br>10. Consumer data feature | • Admin |

*Table 11. Database Feature Designed*

This is the mockup design based on the analysis of the barcode technology design that is integrated into the website-based database. The mockups listed in Table 9 are shown from Figure 13 to Figure 20.

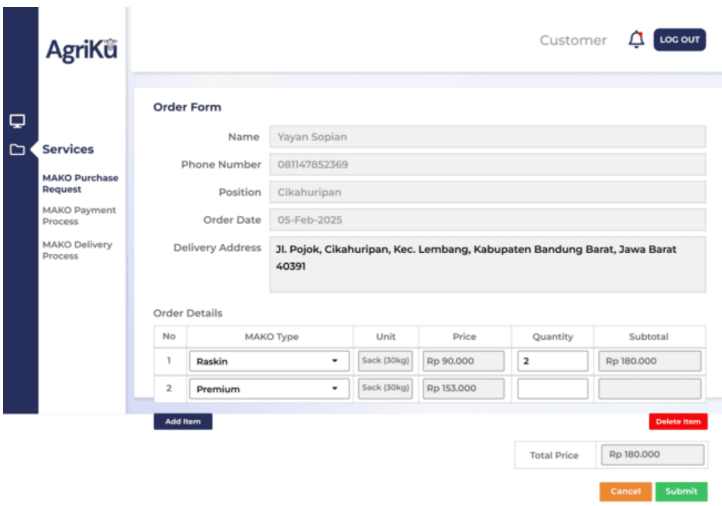


*Figure 13. MAKO Orders Form*

Figure 13 shows the mockup of the MAKO order form page Users can reach this page by clicking the "+ MAKO Order" on the MAKO ordering page. Users can fill in the order information needed, like the delivery address, type of MAKO, and the number of items here. After filling in the form, the data will be saved into the database when the customer clicks "Submit."

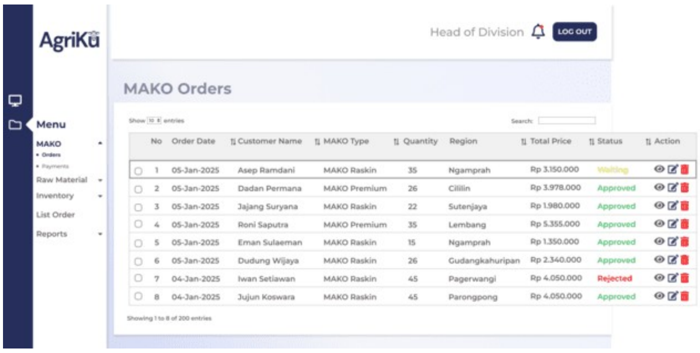


*Figure 14. MAKO Orders Page*

Figure 14 shows the mockup of the MAKO orders page. This page shows the list of orders, including the order date, customer name, type of MAKO, number of items, total price, and order status. From this page, users can view, edit, and delete MAKO orders. When users choose to edit, they can approve or reject a MAKO order.

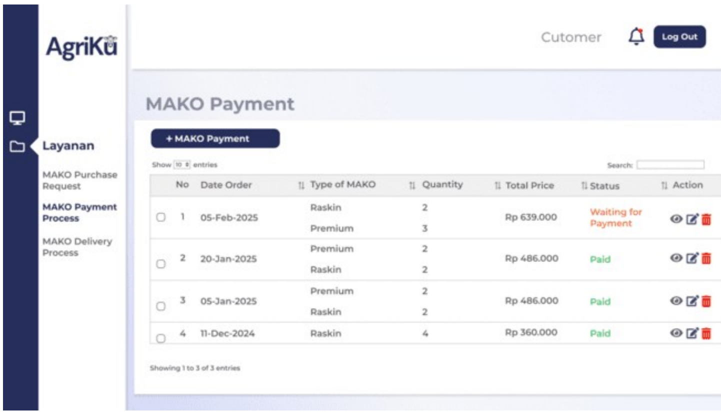


*Figure 15. MAKO Payment Page*

Figure 15 shows the mockup of the MAKO payment page. This page shows the list of payments, including the order date, type of MAKO, number of items, total price, and payment status. From this page, users can add, view, edit, and delete MAKO payment data. When users choose to edit, they can approve the MAKO payment.

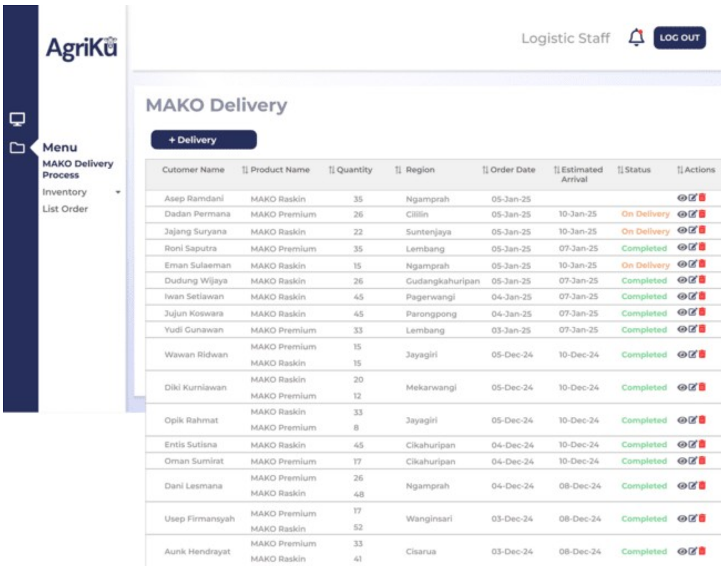


*Figure 16. MAKO Delivery Page*

Figure 16 shows the mockup of the MAKO delivery page. This page shows the list of deliveries, including the customer name, type of MAKO, number of items, area, order date, estimated arrival, and delivery status. From this page, users can add, view, edit, and delete delivery data.

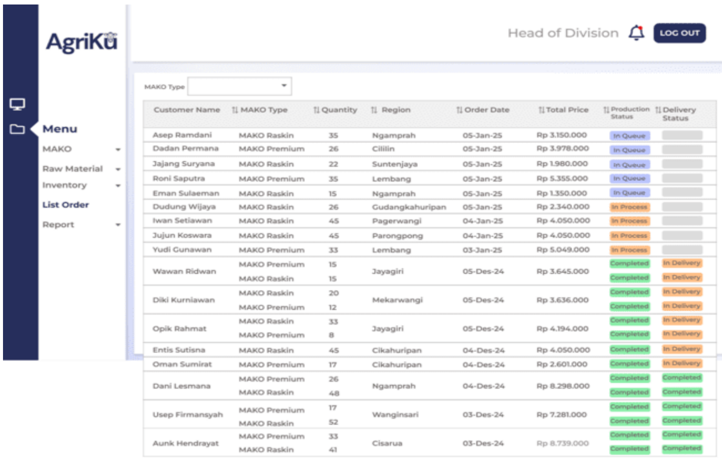


*Figure 17. List Order Page*

Figure 17 shows the mockup of the MAKO list order page. This page shows the list of orders, including customer name, type of MAKO, number of items, area, order date, total price, production status, and delivery status. From this page, users can also group the data based on the type of MAKO, either MAKO Raskin or MAKO Premium.

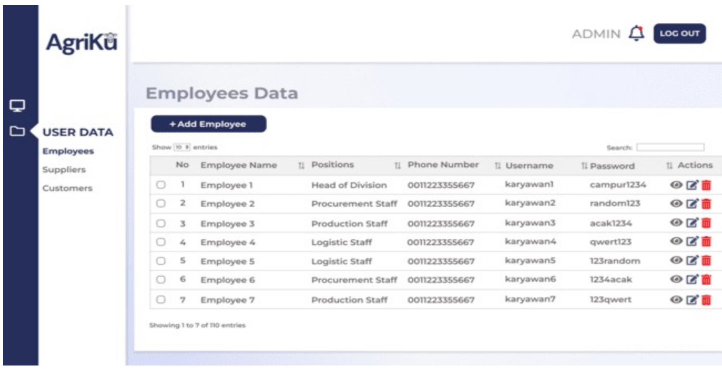


*Figure 18. Employee Data Page*

Figure 18 shows the mockup of the employee data page. The administrator can access the list of employee names, job positions, phone numbers, usernames, and passwords on this page. The administrator can also add, view, edit, and delete employee data.

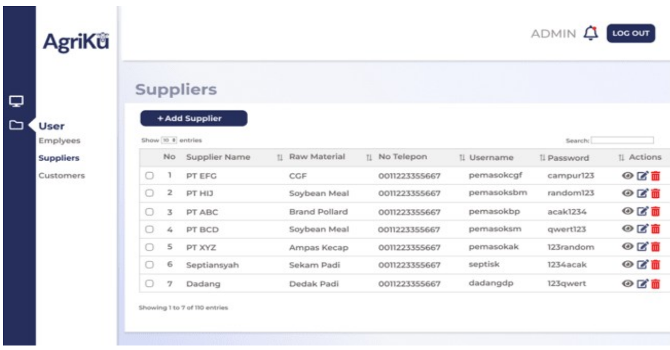


*Figure 19. Supplier Data Page*

Figure 19 shows the mockup of the supplier data page. This overview is only accessible for the administrator. The administrator will be able to see the list of company names, raw materials, phone numbers, usernames, and passwords on this page. The admin can also add, view, edit, and delete supplier data.

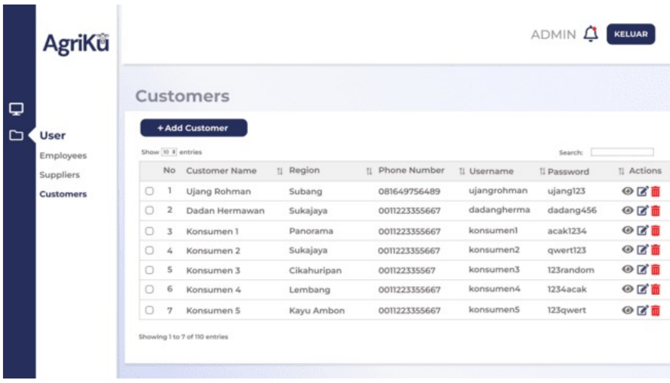


*Figure 20. Customer Data Page*

Figure 20 shows the mockup of the customer data page. On this page, the administrator can see the list of customer names, areas, phone numbers, usernames, and passwords. From this page, the administrator can also do other activities like adding, viewing, editing, and deleting customer data.

### 3.5.4. Internet of Things

The Internet of Things (IoT) is used as a technology to connect and integrate all the data used in the MAKO supply chain process in real time. This data includes MAKO order data, raw material orders, records of goods entering and leaving the warehouse, and deliveries of products to customers. The recording of goods in and out is done automatically using a barcode scanner device. The data collected is directly saved into the database and can be accessed by all stakeholders. Using IoT technology allows all data to be sent and saved accurately into the database through an internet connection, creating real-time data integration.

Based on previous studies, Internet of Things (IoT) technology has been implemented to facilitate real-time data integration and enhance supply chain visibility; however, these analyses were not conducted within a structured risk prioritization framework. The relevant previous studies are summarized in Table 12.

| Title, Authors, Year | Variables and Research Method | Mitigation Strategies |
|---|---|---|
| Implementasi IoT dalam Manajemen Rantai Pasok Distribusi Elpiji pada Agen Gas3 Kg di Kota Palembang (Wirawan & Ita, 2023) | *Variables:* Upstream, Downstream, and Internal Supply Chain<br>*Methods:* Qualitative deskriptive | This study focuses on managing the LPG supply chain through the implementation of Internet of Things (IoT) technology to automate distribution processes; however, it does not specifically identify critical vulnerabilities within the supply chain. The problem analysis was conducted through interviews and direct observation without employing a structured risk prioritization framework. |
| Integrasi IoT dan Big Data untuk Optimasi Logistik dan Rantai Pasok (Usanto et al., 2024) | *Variables:* Consumer satisfaction and operational processes<br>*Methods:* Qualitative and quantitative methods | This study focuses on optimizing logistics processes in a general context by utilizing Internet of Things (IoT) and Big Data technologies, consequently, the findings remain generic. The problem analysis was conducted through interviews with the logistics manager and direct observation of the manufacturing warehouse, without employing a structured risk prioritization framework to address industry-specific challenges. |

*Table 12. Previous Studies on Internet of Thing (IoT)*

Based on the analysis in Table 9 to Table 11 and the designs shown in Figure 6 to Figure 20, an activity diagram was made to model the workflow or processes in the system, both automatic and manual. This diagram shows the sequence of activities and the interactions between different people or entities to complete certain tasks. There are six actors involved in the system: customers, suppliers, division head, procurement staff, production staff, and logistics staff. The activity diagrams are shown in Figure 21 and Figure 22.

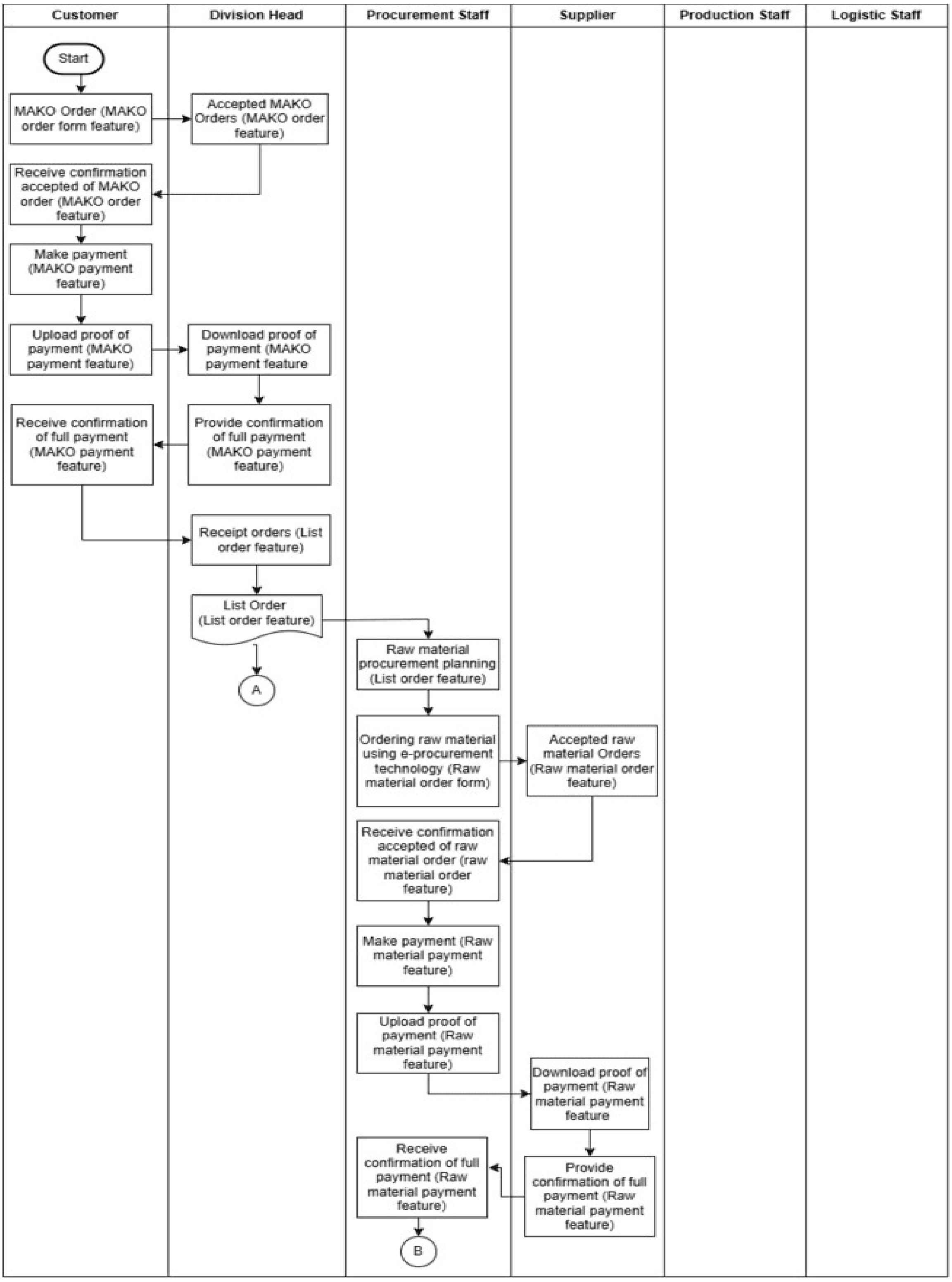


*Figure 21. Activity Diagram Part 1*

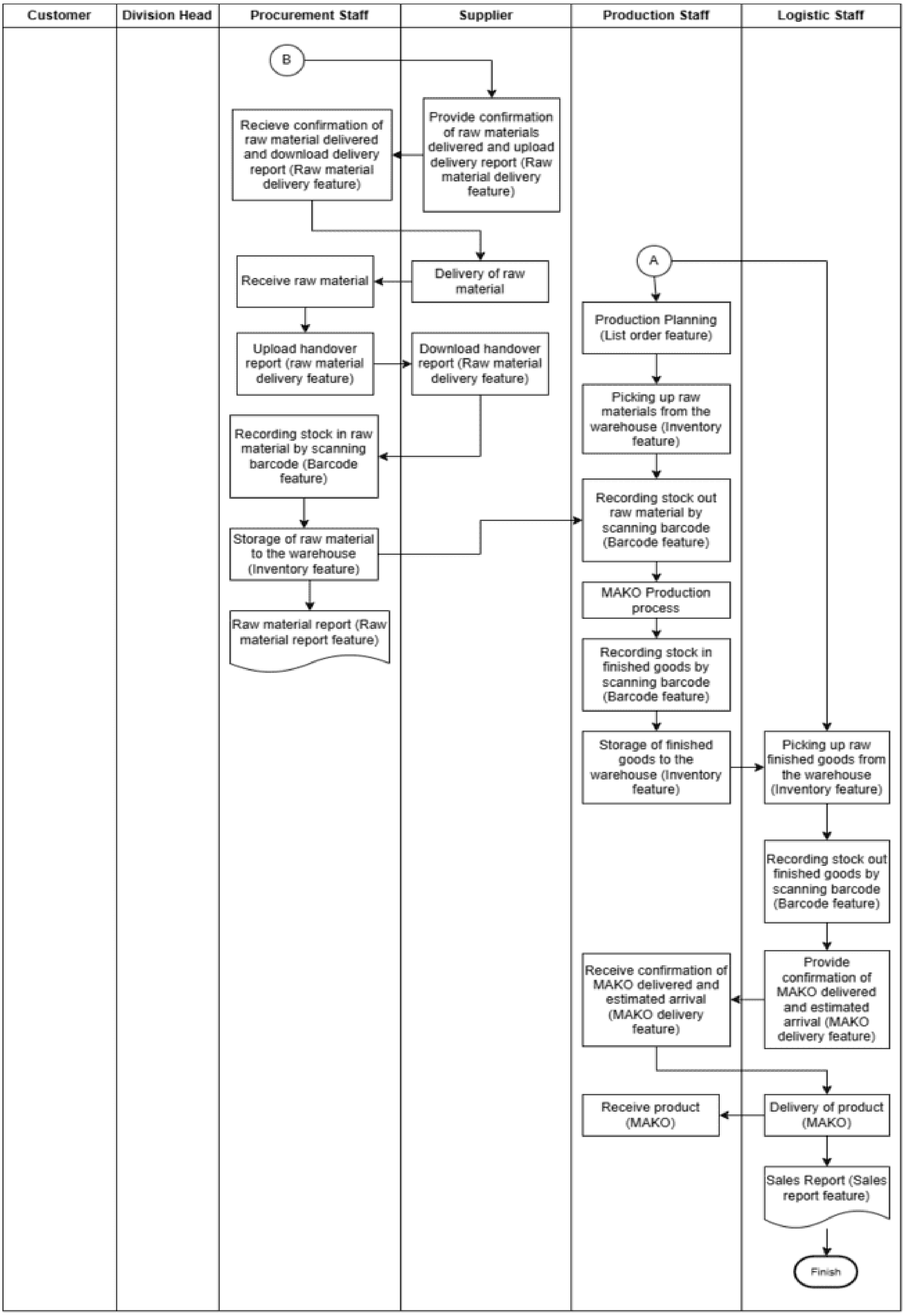


*Figure 22. Activity Diagram Part 2*

Based on the activity diagrams in Figure 21 and Figure 22, an Entity Relationship Diagram (ERD) was made to show the relationships between different data elements in the supply chain management system at the MAKO Division, XYZ Dairy Cooperative. The purpose of designing the ERD is to make sure that the data is organized in a structured and accurate way. The ERD helps organize the data more effectively and efficiently, so the system can work better in managing business processes. The Entity Relationship Diagram (ERD) for the information system design in this research is shown in Figure 23.

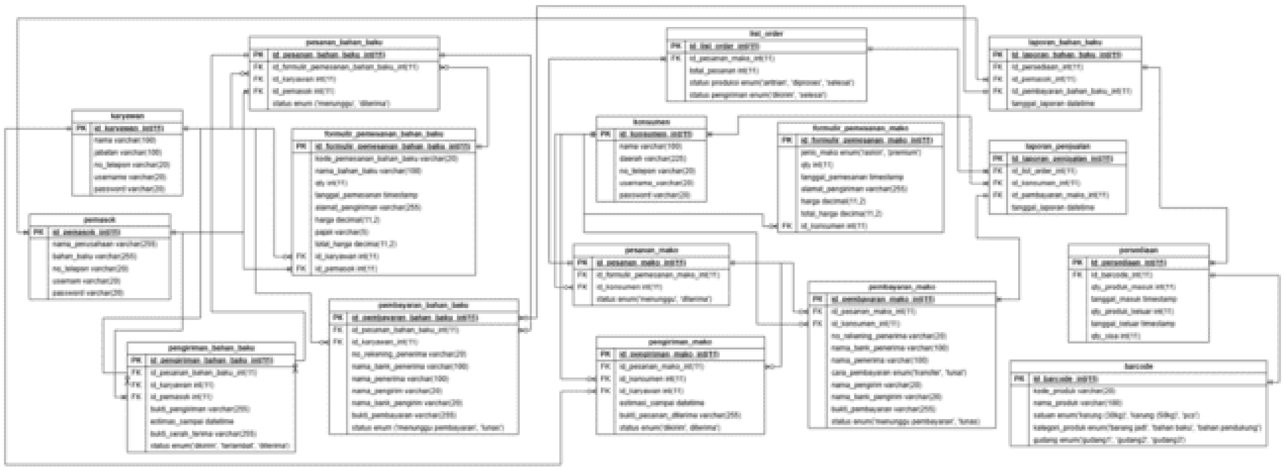

*Figure 23. Entity Relationship Diagram (ERD)*

### 3.6. Verification and Validation

The prototype mockup of the website was verified using the System Usability Scale (SUS) method, which is widely recognized as a standardized statistical validation method for evaluating system usability. The System Usability Scale (SUS) is a simple yet robust instrument used to quantitatively assess the perceived ease of use of a system or interface based on users' subjective evaluations. The SUS method was selected because it provides a reliable and valid measurement of usability with a relatively small sample size, making it suitable for early-stage system evaluation. In addition, its standardized scoring system enables the usability level of the system to be interpreted objectively and compared across different studies and systems. SUS has 10 statements with a scoring scale that helps find out how easy the system is to use, understand, and accept by users. The purpose of using this method is to get a general idea about how comfortable, easy, and satisfying the system is for users. This method was chosen because it is fast, efficient, and has been proven to be valid and reliable in testing different types of systems, including prototype mockup. The scale values for each statement and the SUS scores are shown in Table 13.

Based on the summary results in Table 13, the average SUS score was 78.9. Using this score, the next step is to interpret the data by using the interpretation scale from Bangor et al. (2009). The interpretation of the data is shown in Figure 24.

Based on Figure 24, it can be seen that from the usability aspect, the website prototype mockup is in Grade A- with a SUS score of 78.9. From the adjective rating, it falls into the "Good" category. From the acceptable rating, it is in the "Acceptable" category, and from the NPS aspect, it is in the "Promoter" category (Bangor et al., 2009). Grade A- means that the prototype mockup website is considered easy to use, efficient, and gives users a good experience. Being in the "Good" category means that users are satisfied with the system, although there are still some things that could be improved. The "Acceptable" category means that the prototype mockup meets the users' needs and is good enough to be used in real operations. The "Promoter" category means that most users are happy and willing to recommend the website prototype to others. Based on these results, it can be concluded that the prototype mockup website has a high level of readiness, is well accepted, and has the potential to be used widely by different stakeholders.

Validation of the website mockup design was done by checking it against the problems found in the current business process and the needs (requirements) from the stakeholders involved in the system. The goal of the validation process was to make sure that every feature and display designed in the mockup fits the real needs in the field and can solve the current business problems. From the validation results, it was found that all the designed features match the stakeholder requirements and meet their expectations.

| Respondent | Statement Items | | | | | | | | | | SUS Score |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Q1 | Q2 | Q3 | Q4 | Q5 | Q6 | Q7 | Q8 | Q9 | Q10 | |
| R1 | 5 | 2 | 4 | 2 | 5 | 1 | 4 | 1 | 4 | 3 | 82.5 |
| R2 | 5 | 1 | 4 | 3 | 4 | 2 | 4 | 1 | 5 | 3 | 80 |
| R3 | 5 | 1 | 5 | 2 | 4 | 2 | 5 | 2 | 4 | 2 | 85 |
| R4 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 75 |
| R5 | 4 | 3 | 5 | 2 | 5 | 2 | 4 | 2 | 3 | 3 | 72.5 |
| R6 | 5 | 2 | 5 | 3 | 5 | 2 | 5 | 2 | 5 | 2 | 85 |
| R7 | 5 | 2 | 5 | 3 | 5 | 1 | 4 | 2 | 4 | 3 | 80 |
| R8 | 4 | 1 | 4 | 3 | 5 | 2 | 4 | 2 | 3 | 3 | 72.5 |
| R9 | 4 | 2 | 4 | 1 | 4 | 2 | 4 | 2 | 4 | 2 | 77.5 |
| R10 | 4 | 2 | 3 | 3 | 4 | 1 | 5 | 1 | 3 | 2 | 75 |
| R11 | 5 | 3 | 4 | 2 | 5 | 3 | 5 | 3 | 4 | 2 | 75 |
| R12 | 5 | 2 | 5 | 1 | 4 | 3 | 5 | 2 | 4 | 1 | 85 |
| R13 | 4 | 2 | 4 | 2 | 3 | 2 | 3 | 2 | 4 | 2 | 70 |
| R14 | 5 | 2 | 4 | 3 | 5 | 2 | 4 | 2 | 4 | 2 | 77.5 |
| R15 | 5 | 1 | 4 | 3 | 5 | 2 | 4 | 1 | 5 | 3 | 82.5 |
| R16 | 4 | 1 | 2 | 1 | 4 | 2 | 3 | 2 | 4 | 3 | 70 |
| R17 | 4 | 2 | 4 | 2 | 4 | 1 | 4 | 2 | 5 | 2 | 80 |
| R18 | 4 | 1 | 4 | 2 | 5 | 2 | 5 | 1 | 5 | 2 | 87.5 |
| R19 | 4 | 1 | 4 | 1 | 5 | 2 | 4 | 3 | 5 | 2 | 82.5 |
| R20 | 5 | 2 | 5 | 2 | 4 | 2 | 4 | 2 | 4 | 2 | 80 |
| R21 | 3 | 2 | 4 | 1 | 4 | 2 | 4 | 2 | 4 | 2 | 75 |
| R22 | 4 | 2 | 5 | 1 | 4 | 2 | 4 | 2 | 4 | 1 | 82.5 |
| R23 | 5 | 3 | 4 | 2 | 3 | 2 | 4 | 3 | 4 | 2 | 70 |
| R24 | 5 | 1 | 5 | 2 | 5 | 1 | 3 | 2 | 4 | 2 | 85 |
| R25 | 5 | 2 | 5 | 1 | 5 | 2 | 5 | 3 | 5 | 3 | 85 |
| Average SUS Score | | | | | | | | | | | 78.9 |

*Table 13. SUS Score*

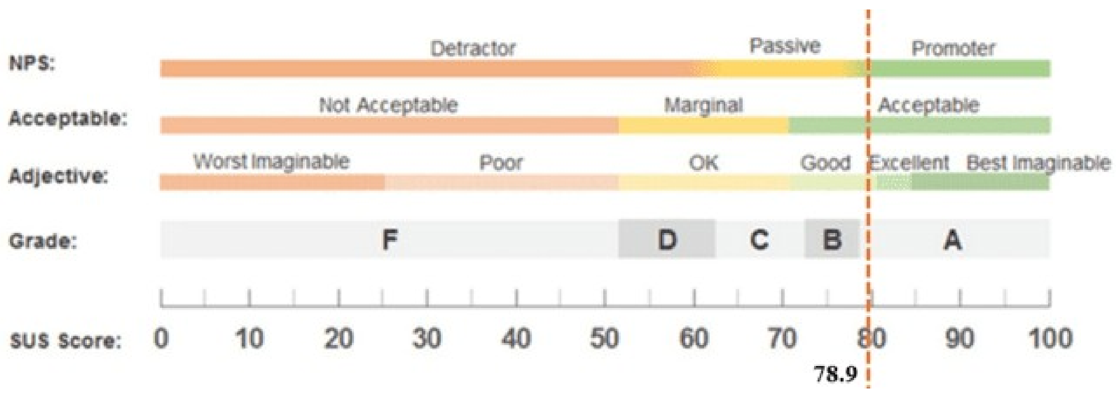


*Figure 24. SUS Score Interpretation (Bangor et al., 2009)*

### 3.7. Conclusion

From this research using the House of Risk method, 28 risk events and 25 risk agents were found in the supply chain. Out of these, 12 risk agents were chosen as priorities for risk mitigation actions. Based on the design of the proactive actions, 13 mitigation actions were created that can be used.

From the House of Risk Phase 2 results, the priority mitigation actions are: providing training on how to use technology, developing a website-based database to integrate internal and external data, using barcode technology in warehouse processes, and using e-procurement technology for procurement activities. The smart supply chain design was made in the form of a website mockup.

Verification was done using the System Usability Scale (SUS) method, and the system got a score of 78.9, which falls into the “Grade A–”, “Good,” “Acceptable,” and “Promoter” categories. From the validation results, all of the designed features matched the stakeholder requirements and met their expectations.

The novelty of this study lies in the integration of the House of Risk (HOR) framework with Internet of Things (IoT) technologies, specifically tailored to address the supply chain challenges of dairy concentrate feed at XYZ Cooperative. Unlike previous studies that focus on either technology implementation or risk assessment in isolation, this approach proactively identifies and mitigates risks by utilizing IoT devices for real-time monitoring. By storing collected data in a centralized database accessible via a web-based platform, the proposed system not only enhances visibility but also enables data-driven decision-making. This integration is crucial for XYZ Cooperative to ensure the continuous availability of raw materials and maintain the sustainability of milk yields.

Future research should focus on the full-scale development and implementation of the proposed system, moving beyond the current design and mock-up stages. Additionally, incorporating user feedback into subsequent iterations will be essential to refine system functionality. Further exploration of broader smart supply chain technologies is recommended to enhance system comprehensiveness, ensuring long-term alignment with the operational requirements of the MAKO division at XYZ Cooperative.

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The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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## Authors' contributions

Zahrayna Shebina Syabira: conceptualization, data processing, formal analysis, investigation, methodology, writing original draft, review & editing .

Iphov Kumala Sriwana: conceptualization, data processing, formal analysis, investigation, methodology, writing original draft, review & editing.

Muhammad Almaududi Pulungan: conceptualization, data processing, formal analysis, investigation, methodology, writing original draft, review & editing.

## Data availability

Data included in the article itself or supplementary material

## Use of Artificial Intelligence

The authors declare that this research was conducted honestly and transparently. All data, text, figure, and research results are original and accountable. The figures used in this manuscript were personally designed using Figma based on field observations and interviews with all relevant stakeholders. No Artificial Intelligence (AI) tools are used in the preparation of this manuscript.

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