Designing QCD jig Risk Mitigation Strategies in Electronics Manufacturing Companies by Combining House of Risk (HOR) and Ishikawa Diagram Methods

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Abstract

Industrial electronic manufacturers must survive to encounter the effect of Covid-19 and the 2023 global recession. Many companies initiate designing risk mitigation strategies for their production systems. Jig is one part of production systems and special tools which has a function to support production set up easier and ensure uniformity in the shape and size of products in large quantities and shorten production time. Risk mitigation is the risk identification process, arranging risk, and establishing strategies to manage risk prevention action. Risk mitigation must consider quality, cost, and delivery aspects. This paper establishes risk mitigation strategies using two combination methods, House of Risk and The Ishikawa Diagram. House of Risk is a modification method from FMEA and QFD that prioritizes risk sources for the most effective action to decrease risk sources and the impact of risk damage. Ishikawa Diagram is the method from Lean Manufacturing that solves problems intended to identify root cause problems. Both methods combined two-step analysis, using the data obtained through interviews, literature study, and questionnaires. The first step is identifying risk incidents and problems using the HOR, then ranking and analyzing them using Pareto and Ishikawa Diagram. After it's done and get conclusion, the data is used for the second step analysis to identify risk prevention strategies and the effectiveness ratio of the strategy using the HOR and ranked with a Pareto Diagram and set of mitigation actions or strategies based on quality, cost, and delivery aspects.

Keywords
Electronic Manufactures, Risk Mitigation, Lean Manufacturing, House of Risk, Ishikawa Diagram.

1. Introduction

Product quality is something that must be maintained and is the most basic factor for consumer satisfaction. Product quality in fulfilling satisfaction for customers can be represented or described with the Kano Model, a theory of product development and customer satisfaction developed by Professor Noriaki Kano in 1980 (Sauerwein et al., 1999). In the production system at the company, the quality or quality of the product becomes an absolute requirement that must be achieved and controlled before and during the production process until it's sent to the customer, so quality becomes an important item that should be focused on in various manufacturing companies. Supply Chain, Productivity Optimization, and Quality Control become topics that have been frequently discussed in recent years, plus there's an outbreak of Covid-19 which began in 2019 until now and issues the global recession in 2023 which is starting to feel its effect has caused various manufacturing companies to have to think hard about how to survive in the middle difficult economic conditions and still maintain the loyalty of customers. Manufacturing companies design Risk Management Strategies by reconstructing or rebuilding Production Systems or Production Supply Chains. The company sees and reviews how the production system works from upstream to downstream, whether are there any disturbances or obstacles.

Apart from that, manufacturing companies also have to do Productivity Optimization considering the decline in consumer purchasing power due to the global recession issue year 2023. One part of Productivity Optimization is the use of jigs and analysis of activities using Lean Manufacturing. Jig is special equipment that has functions to hold, and support, and is usually made specifically as a tool for the production process to facilitate the settings that ensure the uniformity of shape and product sizes in large quantities as well as to shorten production time (Prassetiyo et al., 2016), and Lean Manufacturing is also one aid in Productivity Optimization because it can eliminate some activities that aren't needed (waste) in production activities and also for adding value to the products produced by analyzing, measuring, identify, and provide better solutions in production activities (Salsabila and Rochmoeljati, 2021). The company also has to continue to carry out Quality Control to produce products that are quality and meet customer expectations. Quality Control must be implemented in the Supply Chain system and Productivity Optimization to maintain product quality stability, as well as Quality Control risk management also needs to be implemented so that the entire production system of the company can run well and under control to deal with various kinds of problems or risks that occur now and maybe even in the future. Jig is one of the instruments of Productivity Optimization and a small part of Supply Chain Production so the Quality Control of the jig needs to be improved with QCD standards (Quality, Cost, and Delivery) to help companies survive facing economic problems that are being faced today and even enable it to add value quality in customer satisfaction itself.

Many manufacturing companies only make risk mitigation using one or two of the three Supply Chain, Productivity Optimization, and Quality Control aspects in facing the economic crisis due to the Covid-19 outbreak and the issue of a global recession in 2023, and in particular, it doesn't exist yet looking at it from the jig's point of view. This phenomenon occurs, and as a result, there isn't research that discusses the relationship between these three aspects and becomes a guideline for the company in dealing with the problem at hand so that it can be raised to fill the gap in research. Several research journals focused on examining one or two aspects, such as research from Pujawan and Geraldin in 2009 about The House of Risk; a model for proactive Supply Chain Risk Management, Ramadhani and Baihaqi in 2018 concerning Designing Supply Chain Risk Mitigation Strategy in the Cable Support System Industry of PT.X, Alitosa and Kusumah in 2019 regarding The Main Critical Risk in the Supply Chain of Component Automotive Industry: A Case Study, Hazmi et al., in 2012 about Application of Lean Manufacturing to Reduce Waste at PT ARISU, Nuruddin et al., in 2013 concerning The Implementation of the Lean Manufacturing Concept for Minimizing Delays in Completion of "A" Products as Value Customers, Salsabila and Rochmoeljati in 2021 regarding Implementation Analysis Lean Manufacturing Concept in Stainless Steel Coil Production Process for reducing Waste at PT. XYZ, Rahayu and Supono in 2020 about Product Quality Control Analysis using Statistical Quality Control Methods (SQC) in the Curing Plant D Division of PT. Gajah Tunggal, Tbk, Jou et al., in 2022 concerning the Application of Six Sigma Methodology in an Automotive Manufacturing Company: A Case Study, Memon et al., in 2019 regarding Defect Reduction with the Use of Seven Quality Tools for Productivity Improvement at an Automobile Company, and Riyanto in 2015 concerning Implementation of the Quality Control Circle Method (QCC) to Reduce Defect Levels on Alloy Wheel Products.

1.1. Objectives

This study aims to propose a comprehensive methodology to set priorities for preventive action or risk mitigation based on the gap in research of the studies above, using The Supply Chain, Productivity Optimization, and Quality Control approaches especially jigs with standards control Quality, Cost, and Delivery. It has been intended to support the methodology with two combination methods, House of Risk and Ishikawa Diagram, both methods combined using two-step analysis. The proposed methodology aims to identify events and causes of risks and take countermeasures or prevention actions due to risks that occur with a predetermined priority scale. The result should bring guidelines or guide the company in dealing with problems and helping companies in their efforts to improve the quality of the goods produced to increase customer satisfaction.

2. Literature Review

Quality, Cost, and Delivery is an important element in a business as it relates to customer satisfaction and performance appraisal of a company (Mizutani, 2015). Quality is value, excellence, conformance with specifications, and meeting the needs or exceeding customer expectations and is an orientation or the main goal of all employees (Kazan et al., 2006). Cost is the amount of money that must be issued by the company to make or obtain an item or product (Olajide et al., 2016). Delivery is the process by which the product or service is provided by an organization or company to meet customer expectations (Rao et al., 2011). The Supply Chain is several activities carried out starting from upstream to downstream such as the supply of raw materials, production of goods, and delivery of products to customers (Rakadhitya et al., 2019), meanwhile, Supply Chain Management is a method, and tool, or management approach from the Supply Chain activity itself (Oliver and Weber, 1982). Three things must be managed in the Supply Chain, namely the flow of goods, the flow of money, and the flow of information. Supply Chain Management is a term used to organize and control the Supply Chain or flow of goods, consisting of four components, namely suppliers (raw material supplies), producers (produce products), warehouses or distribution centers (warehouses, distribution centers, and shops), and end users (receiving products or consumers).

Lean Manufacturing is a concept from the Toyota Production System to minimize waste everyone in the entire organization works together to eliminate waste and have other goals to increase the added value of work and reduce unnecessary work, costs lower price, higher quality, and shorter lead times (Nuruddin, 2013). Lean Manufacturing Tools are tools or methods from Lean Manufacturing used to analyze and reduce waste, including 5S, PDCA, Value Stream Mapping, Root Cause Analysis, Poka-Yoke, Kanban, Kaizen, Jidoka, Hoshin-Kanri, Muda, SMED, Standardized Work, Six Big Losses (Leksic, 2020). Root Cause Analysis is a method for problem-solving, identifying the causative factors of unexpected problems or events, and helping answer the 5W+1H question (Wibowo, 2018). Pareto Diagram is a bar-shaped graph that shows problems that occur are grouped based on the number of problems in successive events with the largest number of problems occurrences indicated by the first tallest bar graph placed on the left, and so on to the smallest problem occurrence indicated by the last bar graph placed on the right side (Wardhani, 2022). Ishikawa Diagram or diagram of cause and effect and some call it a fishbone diagram, is a diagram made to show factors that cause a failure or defect in the product or wastage of an activity (Salsabila, 2021).

House of Risk is a method based on the notion that proactive supply chain risk management should focus on preventive measures, namely by reducing the possibility of the occurrence of agent risk (Pujawan and Geraldin, 2009). Failure Mode and Effect Analysis Method (FMEA) and the House of Quality (HOQ) are integrated into one so that be the House of Risk method (HOR). In the House of Risk method, the FMEA is used to analyze the level of risk obtained through the calculation of the Risk Potential Number (RPN), and calculations are determined by three factors, namely occurrence, severity, and detection. While HOQ in the House of Risk method is used for designing strategies, and reducing or eliminating resources identified risks. The House of Risk method has two stages: HOR 1 and HOR 2. HOR 1 is used to sort risk agents based on ranking with consideration of the Aggregate Risk Potential (ARP) value. Meanwhile, HOR 2 is used to sort the priority scale or ranking in handling risks that have been identified and the risk level has been calculated through HOR 1 (Rizqiah, 2017). Risk management is the field of study of how organizations apply measures in mapping existing problems by placing various approaches to comprehensive and systematic management (Magdalena and Vannie, 2019).

3. Methods

The modification method by combining House of Risk and Ishikawa Diagram used in this research, and can be seen in the Figure.1

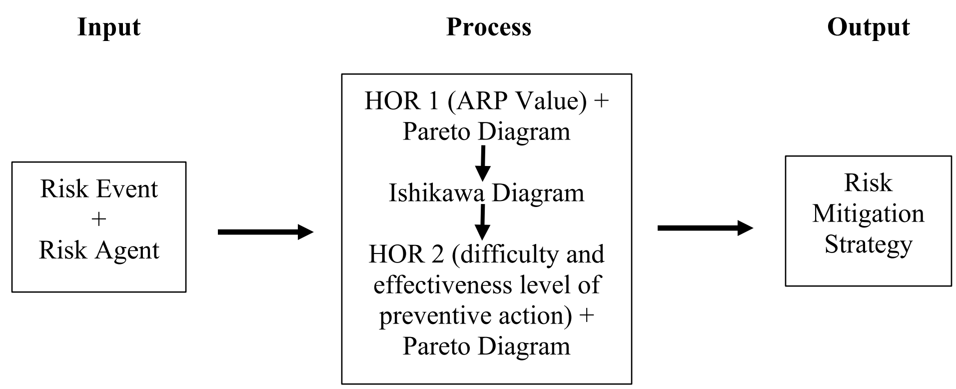

Figure 1**.** Research method modification diagram by combining House of Risk and Ishikawa Diagram

The first step in this research is the identification of perspectives based on Quality, Cost, and Delivery (QCD). The Quality, Cost, and Delivery (QCD) perspectives are identified by reviewing whether a jig used in the company already meets the expected criteria or still needs to be repaired. The stakeholders appointed in this research are Top Management, Engineering Manager, and Production Manager. The sub-perspective data that have been identified by interviews with stakeholders to validate their accuracy are by analyzing what are the risks, why these risks arise, where these risks can occur, and how these risks can arise in that place.

The risk event severity level, the risk event probability level, and the correlation value between the risk event and the risk agent are three factors that determine risk assessment. The stakeholders filled out the questionnaires, then interviews and discussion about this risk assessment The questionnaire measurement scale that will be filled out by stakeholders regarding the assessment of severity is 1-10. The measurement scale regarding the assessment of the level of probability is 1-10. And the measurement scale regarding the correlation value between the risk agent and the risk event is 0, 1, 3, and 9. The Aggregate Risk Potential (ARP) value is calculated by the three risk assessment factors, which is an important value for managing risk agents where the more dangerous risk, the higher the ARP value.

This ARP value is obtained by calculation using the following ARP formula.

$$ARPj = Oj \cdot \sum Si \cdot Rij \quad (1)$$

The ARP results are then ranked from the highest to the lowest value. After that, mapped using a Pareto Diagram, to screen the causes of risk that are included in the high category, then continue analysis using Ishikawa Diagram. Ishikawa Diagram is used to identify risk causes by using the 4M analysis, Man, Method, Machine, and Material in Quality, Cost, and Delivery perspective. Next, determine the mitigation strategy to reduce the risk. These preventive actions need to be identified first because they aim to reduce risk, therefore, these need to be matched with the cause of the risks that correlated with the result of obtaining the highest ARP value that has been ranked on a Pareto Diagram.

Real preventive actions that occur in the company can be determined by the results of the identification of preventive action. The two relationships are correlated by making a table of the relationship between the risk agent from the results of the highest ARP value, with the preventive measures that have been set and the scale unit is 0, 1, 3, and 9. The degree of difficulty states how difficult a preventive action is to take and also reflects the costs and other resources required to carry out the preventive action that is categorized into three values, 3 for low, 4 for medium, and 5 for high.

Determination of total effectiveness is obtained by using the following formula.

$$TEk = \sum_j^i (ARP\,j \,.\, E\,jk)\ \forall\, k \qquad (2)$$

The Ratio of Total Effectiveness to Difficulty Level can be obtained using the following formula.

$$ETDk = \frac{TEk}{Dk} \qquad (3)$$

The overall value of the total effectiveness ratio to the difficulty level has been calculated, then ranked from the highest to the lowest value. The ETDk value is mapped using a Pareto Diagram, filtering the potential ratio of the total effectiveness to the level of difficulty that falls into the high category. The highest ETDk value needs to be prioritized first for preventive action or risk mitigation strategies that have been determined.

4. Results and Discussion

In the process of identifying risks and assessing the severity of risk events, the data is collected through interviews with stakeholders. After the interviews finish, then filling out questionnaires from interviews result with stakeholders, Top Management, Engineering Manager, and Production Manager, the results of identifying risk events and severity levels with stakeholders are shown in Table 1.

Table 1. Severity score results

Perspective	Sub-Perspective	Code (Ej)	Risk Event (Ej)	Severity
Quality	Handling and Safety	E1	Jigs are difficult to use	5
		E2	Jigs cause injury	8
		E3	The jigs are too big and heavy	6
	Quality Improvement	E4	Low jig design innovation	4
		E5	Production stop time due to high jig problem	7
		E6	Miscommunication between departments	6
		E7	Value varies of UGS jig	7

		E8	Analysis and problem-solving are too long	6
		E9	Standard Quality index not achieved	7
		E10	High product rework	7
		E11	Low customer satisfaction	9
	Maintenance Control	E12	Low predictive maintenance	4
		E13	Low jig lifetime	5
		E14	5S and daily maintenance not working	4
		E15	Jig calibration is not done regularly	4
		E16	High preventive maintenance	6
		E17	No stock of jig standard part	8
		E18	Too much jig checkpoint control	3
		E19	Weekly and monthly maintenance not optimal	4
	Document Control	E20	ALO/SWP/SOP/WI documents not updated	6
		E21	Change the design part from the supplier	7
		E22	Jig was incorrectly used and an error in the assembly process	7
		E23	Illegal jigs are used in production	7
	Manpower Capability	E24	Low employee skill and capability	2
		E25	Low employee motivation	2
		E26	Low employee attitude and discipline	2
		E27	Low employee learning interest	1
		E28	KPI employees not achieved	1
		E29	Miscommunication between employee	3
		E30	High employee turnover	2
		E31	Low response to the problem	2
Cost	Budget Control	E32	The jig budget is not according to the estimates	8
		E33	Jig maintenance cost is too expensive	7
		E34	Jig fabrication cost is too expensive	7
	Jig Asset and Management Control	E35	Damage and lost of the jigs	9
		E36	Jig is not registered as an asset	9
		E37	Different quantity jig between actual with document	9
	Productivity and Efficiency	E38	Jig output not comparable with production cost	7
		E39	Additional jig quantity because of production activity	8
Delivery	Delivery Schedule Control	E40	Jig delivery not according to schedule	6
		E41	Delivery of product by plane	6
		E42	Lead time order standard jig part is high	3

In the process of identifying the risk agent and assessing the probability level for the risk agent, the data is collected through interviews, then filling out questionnaires with stakeholders, Top Management, Engineering Manager, and Production Manager, the results of the risk agent and occurrence are shown in Table 2.

Table 2. Occurrence score result

Code	Risk Agent (A)	Occurrence
A1	Jig design doesn't pay attention to considerations of production needs	4
A2	Lack of awareness socialization about the use of jigs	3
A3	The jig design doesn't pay attention to the body size of the production operator and the ergonomics of the jig user	5
A4	Employees don't want to learn to innovate and haven't applied "Learning by Doing" principles	5
A5	Jig design human resources don't understand the target quality that must be achieved and lacks maintenance manpower	4
A6	Differences in understanding and lack of collaboration between departments	6

A7	UGS hasn't been implemented optimally and hasn't been reviewed from a functional perspective	5
A8	The follow-up jig problem list isn't optimal and human resources understanding and skill are low	5
A9	Finish good time and assembly time KPI hasn't been achieved and jig quality KPI is low	4
A10	ALO/SWP/SOP/WI not executing properly as well as 4M changes in production	7
A11	Employees haven't implemented PDCA to the fullest	5
A12	Automation innovations with 4.0 technology-integrated deterrent sensors haven't been implemented	6
A13	There's no type classification, or jig material class and there is no simulation, evaluation, or jig durability, and doesn't consider the production output result	3
A14	The operator isn't aware of the jig used and the SOP for the use and maintenance of the jig is difficult to understand and lacks detail	5
A15	There isn't any jig maintenance calibration in the SOP document and there are no jig design innovations that make maintenance easier	4
A16	The operator doesn't report to the leader or supervisor about the broken jig and lacks a sense of responsibility	3
A17	Controlling the need for jig spare parts that aren't optimal and the timing of requests and orders that aren't quite right	4
A18	The engineering design process isn't carried out and doesn't take into account the actual tolerances of the part in designing the jig	2
A19	Internal audits are rarely carried out and jig designs are difficult to maintain because there are too many items to control	4
A20	Documents aren't updated regularly following the speed of production	7
A21	Miscommunication with suppliers or vendors as well as negligence in providing and updating information	7
A22	There isn't Poka-Yoke on the jig and the jig isn't kept in the correct place	8
A23	The jig doesn't have label identity information and misses review from the process engineer and jig designer	8
A24	Lack of training for employees	3
A25	Lack of guidance to employees	3
A26	Employees lack a sense of responsibility toward work	4
A27	Employees don't have a high sense of willingness to learn and are stuck in a comfort zone	5
A28	Human resources assessment evaluation is still not going well	8
A29	Understanding abilities and different skills among employees	8
A30	Superiors don't appreciate the work and needs of employees and too micromanagement	3
A31	Don't place employees according to skills and experience and some human resources aren't yet capable of handling work	4
A32	Discrepancies between budget arrangements and actual costs and inaccurate vendor selection	4
A33	Uncontrolled and unintegrated weekly and monthly maintenance check control	5
A34	The jig design is too difficult and too many standard parts are used	5
A35	Poor control of jig asset ownership	3
A36	Too many jigs are controlled and registered as assets	3
A37	Lack of awareness socialization about jig ownership as an asset	3
A38	The jig design doesn't look at the actual process and assembly layout as well as production needs	6
A39	The jig design isn't updated following changes in production planning	5
A40	Schedule that's less systematic and structured and not integrated	3
A41	Jig problems cause production activities to be disrupted and cause product delivery schedules to be late	3
A42	There's no review and evaluation regarding the use of local standard parts	3

After finishing filling out questioner about identifying risks and assessing the severity of risk events, identifying the risk agent, and assessing the probability level for the risk agent. Then continue assessment of the correlation between risk events and risk agents obtained results in Table 3, Table 4, and Table 5.

Table 3. Correlation results between risk event and risk agent in the Quality Perspective

		Risk Agent (A)																															
Perspective	Risk Event (E)	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	Severity
Quality	E1	9	3	3	1	3	3	0	3	1	1	3	1	3	1	0	0	0	1	1	3	1	1	0	0	1	1	0	0	1	0	1	5
	E2	3	3	3	1	3	3	0	3	1	1	3	1	3	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	8
	E3	9	1	9	3	1	3	0	3	1	0	3	1	3	1	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	6
	E4	3	1	3	3	3	3	0	3	0	0	1	9	1	1	1	1	1	1	1	0	0	0	0	3	3	0	0	0	0	0	0	4
	E5	3	1	3	3	3	3	1	3	1	3	0	1	1	3	3	3	3	3	1	0	0	0	0	0	0	0	0	0	0	0	0	7
	E6	1	3	1	3	3	9	0	3	1	1	3	0	0	0	0	0	0	0	0	0	1	0	0	0	3	1	1	0	0	0	0	6
	E7	3	1	3	3	3	3	9	3	3	3	3	1	0	0	0	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	7
	E8	1	1	1	3	3	3	1	9	1	1	9	0	1	1	0	1	0	1	0	0	1	0	0	3	1	1	0	0	0	0	0	6
	E9	3	3	3	3	9	3	3	3	3	3	9	1	3	3	3	1	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	7
	E10	3	3	3	3	3	3	3	3	9	9	3	1	3	3	3	1	0	0	0	0	1	3	3	0	1	1	0	0	0	0	0	7
	E11	3	3	1	3	3	3	3	3	3	9	3	1	3	1	1	3	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	9
	E12	3	1	1	3	3	3	1	3	3	3	3	1	1	3	9	1	9	1	3	0	1	0	0	0	1	1	0	0	1	0	1	4
	E13	3	1	1	3	1	1	0	3	3	3	3	0	0	3	9	3	3	3	1	0	3	0	0	0	1	1	0	0	1	0	1	5
	E14	1	3	1	1	3	3	0	3	1	3	3	0	1	9	9	0	9	1	1	0	0	0	0	0	0	0	0	0	0	0	0	4
	E15	1	3	1	3	1	3	0	3	3	1	3	0	1	9	9	0	9	1	1	0	0	0	0	0	1	1	0	0	0	0	0	4
	E16	3	1	3	3	3	1	0	3	1	3	3	0	1	9	9	0	9	1	1	0	0	0	0	0	1	1	0	0	0	0	0	6
	E17	1	1	1	3	1	3	0	3	1	1	1	0	9	0	1	0	9	1	1	0	1	0	0	1	1	0	1	0	1	0	1	8
	E18	3	1	1	3	9	3	0	3	1	1	3	3	1	0	1	0	9	1	0	0	0	0	0	1	1	0	1	0	1	0	1	3
	E19	1	3	1	1	3	3	0	3	1	3	3	1	1	9	9	3	9	1	3	0	0	0	0	0	1	1	0	0	0	0	0	4
	E20	1	3	0	3	0	9	0	3	3	9	3	0	0	0	0	0	0	0	3	9	0	0	0	0	1	1	1	0	0	0	0	6
	E21	1	0	0	1	1	9	0	3	0	0	1	0	0	0	0	0	3	3	3	0	9	0	0	0	0	1	0	0	1	0	0	7
	E22	3	9	3	3	1	9	0	1	1	9	3	0	0	0	0	3	0	0	3	0	0	9	3	0	1	1	0	0	1	0	1	7
	E23	3	1	1	1	1	3	0	3	1	9	3	0	0	0	0	3	0	0	0	3	0	0	9	0	1	3	1	0	1	0	1	7
	E24	1	1	1	9	3	3	0	9	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	9	9	9	9	1	3	1	3	2
	E25	1	1	1	3	3	3	0	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	3	9	9	9	3	3	9	3	2
	E26	1	1	1	3	3	3	0	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	3	3	9	9	9	9	1	2
	E27	1	1	1	9	3	3	0	3	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	9	9	9	9	1	3	1	3	1
	E28	1	1	1	9	9	3	0	3	3	3	3	0	0	0	0	0	0	0	0	0	0	0	0	1	3	3	3	1	3	1	3	1
	E29	1	3	1	3	3	9	0	3	1	3	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	9	0	1	3
	E30	0	0	0	3	3	3	0	1	1	3	3	0	0	0	0	0	0	0	0	0	1	0	0	9	3	9	0	0	0	9	9	2
	E31	1	1	0	1	9	3	0	3	3	3	3	0	0	0	0	0	0	0	3	0	0	0	0	0	0	9	3	1	3	0	1	2
Occurrence		4	3	5	5	4	6	5	5	4	7	5	6	3	5	4	3	4	2	4	7	7	8	8	3	3	4	5	8	8	3	4	
ARP		1600	975	1495	920	1000	3648	745	2430	1148	3528	2325	654	720	1450	1320	498	1580	266	712	630	840	712	840	279	477	712	510	240	920	172	328	
Ranking		5	12	7	13	11	1	17	3	10	2	4	22	18	8	9	25	6	29	19	23	15	20	16	28	26	21	24	30	14	31	27	

Table 4. Correlation results between risk event and risk agent in the Cost Perspective

		Risk Agent (A)								
Perspective	Risk Event (E)	A32	A33	A34	A35	A36	A37	A38	A39	Severity
Cost	E32	3	3	3	1	1	1	3	3	8
	E33	9	9	3	9	1	1	1	1	7
	E34	9	1	3	0	0	0	1	1	7
	E35	9	3	1	9	9	9	0	1	9
	E36	0	1	0	9	3	3	0	1	9
	E37	0	1	0	9	9	9	1	9	9
	E38	3	3	1	0	0	0	9	3	7
	E39	0	1	1	1	1	0	9	9	8
Occurrence		4	5	5	3	3	3	6	5	
ARP		756	840	450	966	636	612	1092	1150	
Ranking		5	4	8	3	6	7	2	1	

Table 5. Correlation results between risk event and risk agent in the Delivery Perspective

		Risk Agent (A)			
Perspective	Risk Event (E)	A40	A41	A42	Severity

Delivery	E40	9	6	3	6
	E41	9	9	3	6
	E42	9	6	3	3
Occurrence		3	3	3	
ARP		405	324	135	
Ranking		1	2	3	

The calculation of the Aggregate Risk Potential (ARP) value is obtained using Equation 1, where there are 3 risk assessment factors, there is the severity level of the risk event, the probability level of the risk agent, and the correlation score between the risk event and the risk agent. After obtaining the ARP value, ranking is done using a Pareto Diagram obtained in Figure 2, Figure 3, and Figure 4.

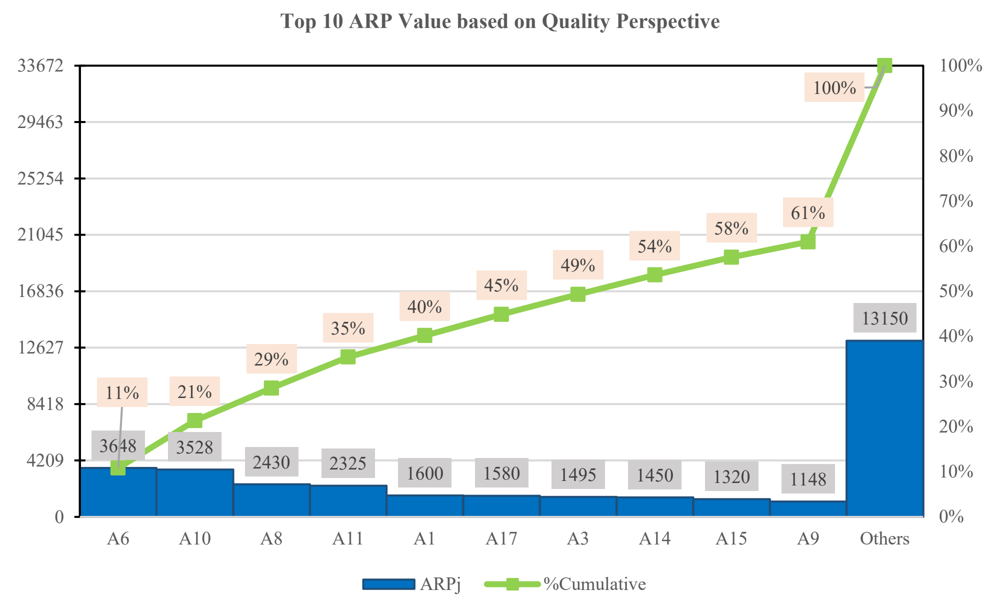

Figure 2. ARP Pareto Diagram in the Quality Perspective

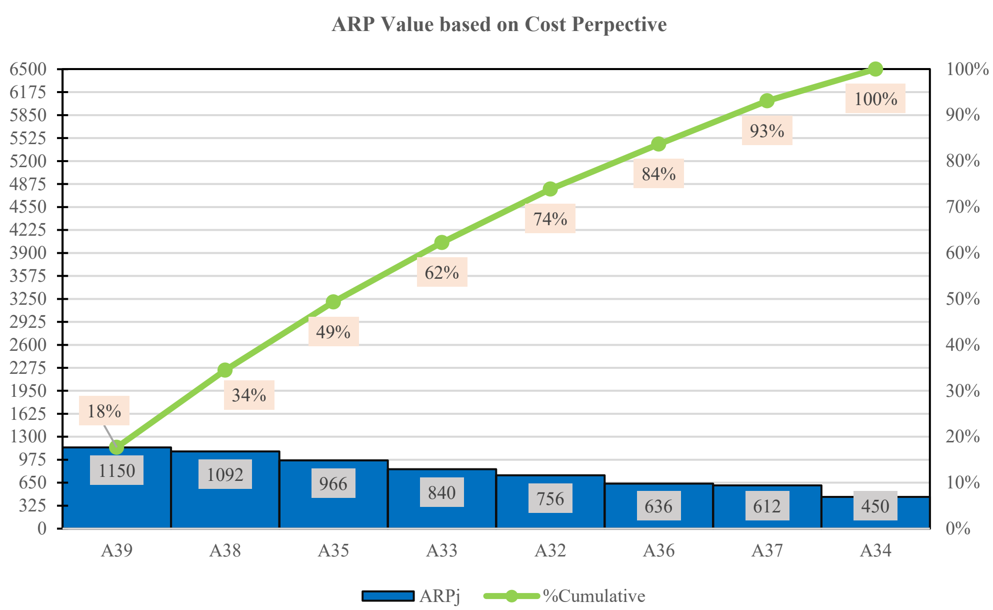

Figure 3. ARP Pareto Diagram in the Cost Perspective

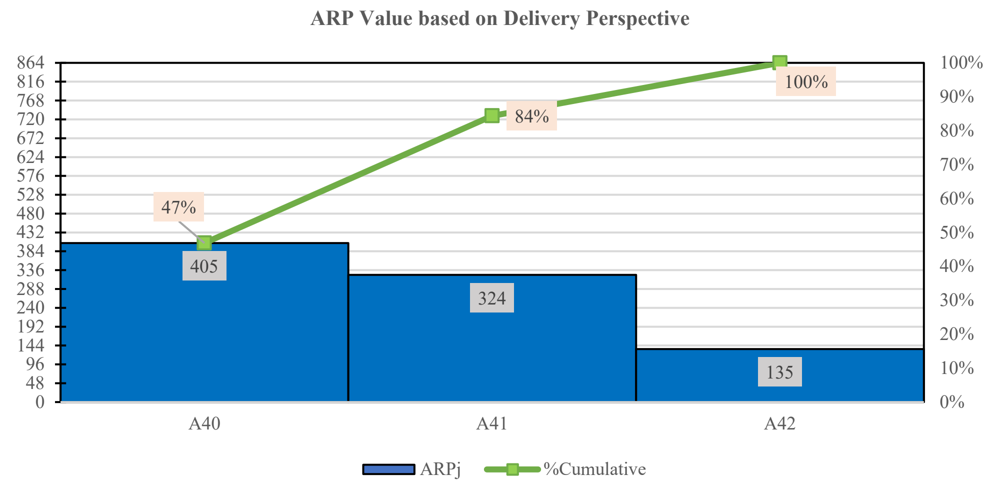

Figure 4. ARP Pareto Diagram in the Delivery Perspective

After identification and obtaining ranking from the ARP value is mapped using a Pareto Diagram, which is useful for screening the causes of risk that are included in the high category and mapping using a Pareto Diagram, then continue analysis using Ishikawa Diagram. Ishikawa Diagram is used to identify risk causes by using 4M analysis, Man, Method, Machine, and Material in Quality, Cost, and Delivery perspective obtained in Figure 5a, Figure 5b, Figure 6, and Figure 7.

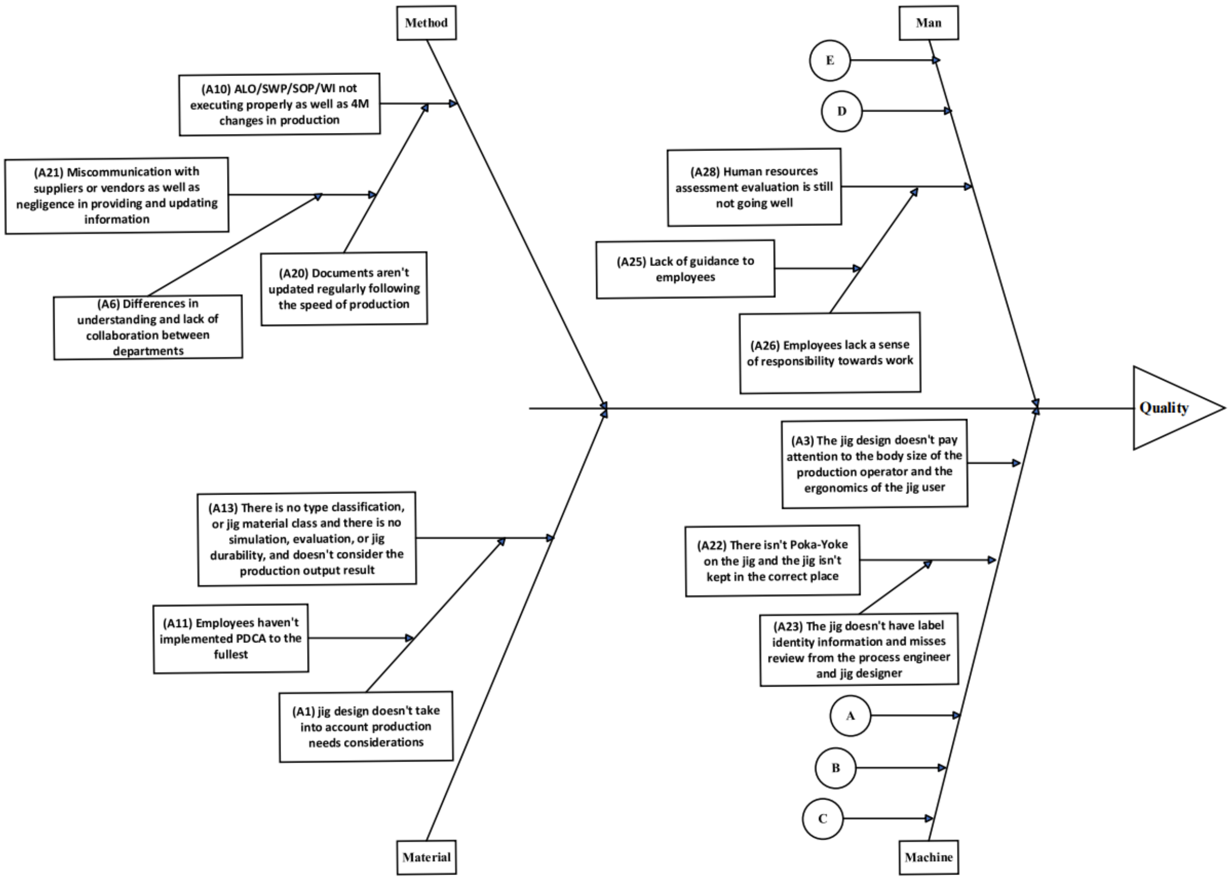

Figure 5a. Ishikawa Diagram Quality Perspective

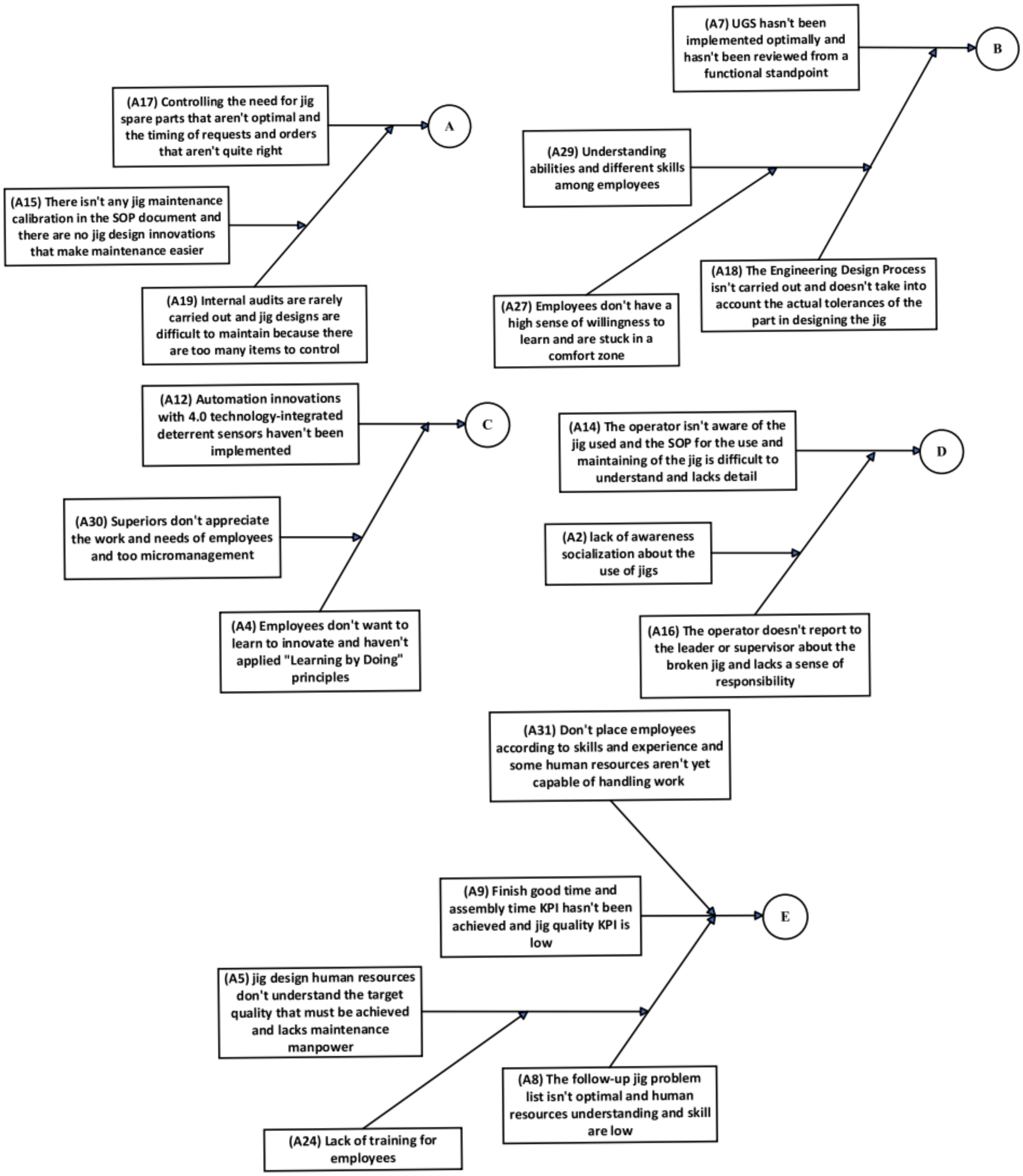

Figure 5b. Ishikawa Diagram Quality Perspective

The Ishikawa Diagram from Quality Perspective was very detailed so it needs to be broken down into several parts like Figure 5a. and Figure 5b. This solution is done to make it easier the process of analyzing the source of the problems that occur in the Quality Perspective where there is a very large possibility of the cause of the problems that occur in the factory in the assessment of Man, Machine, Method, and Material.

After analyzing using Ishikawa Diagram from Quality Perspective, next analyzing using the Cost Perspective using three assessments namely Man, Method, and Machine obtained in Figure 6.

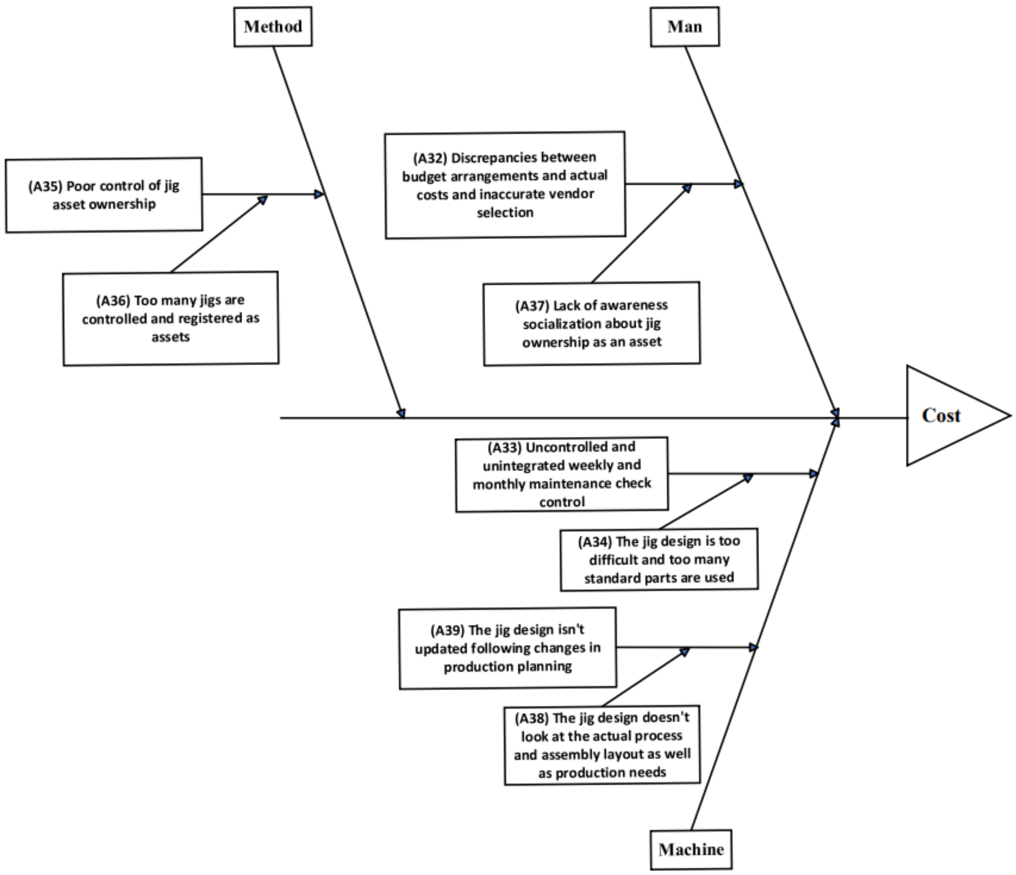

Figure 6. Ishikawa Diagram Cost Perspective

The Ishikawa Diagram from Cost Perspective isn't detailed like Quality Perspective because uses three assessments except for the material. Then analyzing Ishikawa Diagram from Delivery Perspective using two assessments namely Man and Machine obtained in Figure 7.

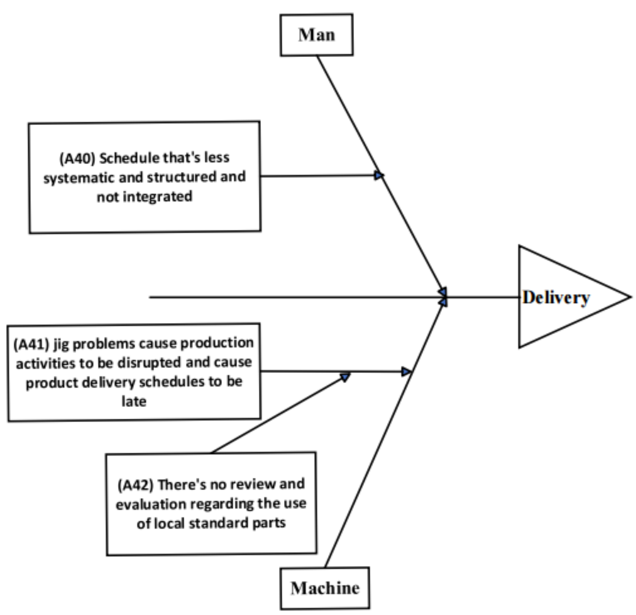

Figure 7. Ishikawa Diagram Cost Perspective

Furthermore, the identification of risk mitigation strategies based on the risk agent that analyzing using the Quality, Cost, and Delivery Perspective that has been ranked using the ARP Pareto Diagram and analyzed using the Ishikawa Diagram Quality, Cost, and Delivery Perspective. 10 risk agents with high ARP values from Quality Perspective, A6, A10, A8, A11, A1, A17, A3, A14, A15, A9. 3 risk agents with high ARP values from Cost Perspective, A39, A38, A35, and the last 1 risk agent with a high ARP value from Delivery Perspective, A40. Identification of preventive measures against the 14 main risks can be seen in Table 6 below.

Table 6. The results of the identification of risk mitigation strategies based on the difficulty scale

Code	Mitigation	Difficulty
PA1	Leveling understanding to equalize goals and meeting new model project jig follow-up structure for dividing and agreeing on each task at the beginning the project takes place and is reviewed every month as well as skill up leader skill of negotiation and target oriented	5
PA2	Production process audit by a third party (QA) for comparing documents with actual (review 4M change control system, training method, process audit methods)	4
PA3	Skill mapping of the problem list by including the 5W1H technique in the information and closing rate of 100% in the jig judgment assessment sheet as well as skill-up to members	5
PA4	PDCA cycle, QC, OJT, and KAIZEN training to all members related to jig job as well as develop guidelines and standards for follow-up problems (requires documentation of problem list in standards)	5
PA5	Genba and jig design concept discussion with production and make detailed specifications related to production plan (model and quantity)	3
PA6	Repair of jig spare-parts warehouse system with IT application that has a part classification (order time, delivery time)	5
PA7	Genba and jig design concept discussion based on needs production as well as entering ergonomics items (simulation jig usage) in jig important point and jig making operation guide by jig designer	3
PA8	Get feedback from retraining operators about subsequent use, maintenance, and checkpoint jigs added to the SWP document as well as the audit process production by third parties (QA) to improve awareness and revise the maintenance check sheet with item details and simple methods	4
PA9	Making guidelines on “how to create jig with additional calibration and maintenance items” and encouraging members to get to know new technology about jigs innovation	4
PA10	Reduce target max stop time gradually and carry out regular maintenance audits as well making KPI jig quality a regular monitoring item (weekly, monthly, quarter)	4
PA11	Communication with related departments and conducting review user escalation flow/procedure and include easy to modify and adjust features for new jig designs	4
PA12	Genba and jig concept discussion with production and added the actual production confirmation step after submitting jig specifications	3
PA13	Make a control jig list that is reviewed and audited every month and made a systematic asset control with IT application	3
PA14	Create a master schedule that is reviewed every month and daily report to see the progress of item implementation in the master schedule	4

After obtaining preventive action, then an assessment of the correlation of the mitigation strategy with the risk agent and the difficulty value of the mitigation strategy is carried out. After obtaining the correlation value and the difficulty value of the mitigation strategy, the total effectiveness value is calculated using Equation 2. Then the total effectiveness ratio value is calculated using Equation 3. The results of these calculations can be seen in Table 7.

Table **7.** The results of the assessment of risk management strategies

Risk agent (A)	Preventive Action (PA)														ARPj
	PA1	PA2	PA3	PA4	PA5	PA6	PA7	PA8	PA9	PA10	PA11	PA12	PA13	PA14	
A6	9	3	1	0	3	1	9	3	1	1	9	1	0	0	3648
A10	1	9	1	1	1	0	3	3	0	1	0	0	0	0	3528
A8	3	3	9	9	1	1	1	3	3	1	0	1	1	0	2430

A11	3	0	3	9	1	0	1	1	3	1	0	0	0	1	2325
A1	1	3	0	0	9	0	9	9	3	0	1	3	0	0	1600
A17	3	0	0	0	0	9	1	1	3	1	0	0	0	0	1580
A3	0	1	0	0	3	0	9	3	1	0	0	0	0	0	1495
A14	3	9	1	1	0	0	3	9	3	0	1	1	0	0	1450
A15	1	0	0	0	1	9	1	3	9	3	0	0	0	0	1320
A9	0	0	3	3	1	3	1	1	1	9	1	1	0	0	1148
A39	0	1	0	0	9	1	1	0	0	0	0	1	0	1	1150
A38	0	3	0	0	9	0	9	0	0	0	1	1	0	0	1092
A35	0	9	0	0	0	3	0	0	3	0	0	0	9	1	996
A40	9	0	0	0	0	3	0	0	1	1	1	0	0	9	405
Difficulty Level (Dk)	5	4	5	5	3	5	3	4	4	4	4	3	3	4	
Total Effectiveness (TEk)	66280	82721	40915	51217	60758	40975	95402	69766	49719	28208	38527	15718	11394	8116	
Total Effectiveness Ratio (ETDk)	13256	20680	8183	10243	20253	8195	31800	17441	12430	7052	9632	5239	3798	2029	
Ranking	5	2	10	7	3	9	1	4	6	11	8	12	13	14	

The overall value of the total effectiveness ratio to the difficulty level has been calculated, then ranked from the highest to the lowest value. The highest value is Preventive Action 7, and the lowest value is Preventive Action 14. The Pareto Diagram is obtained in Figure 8 below.

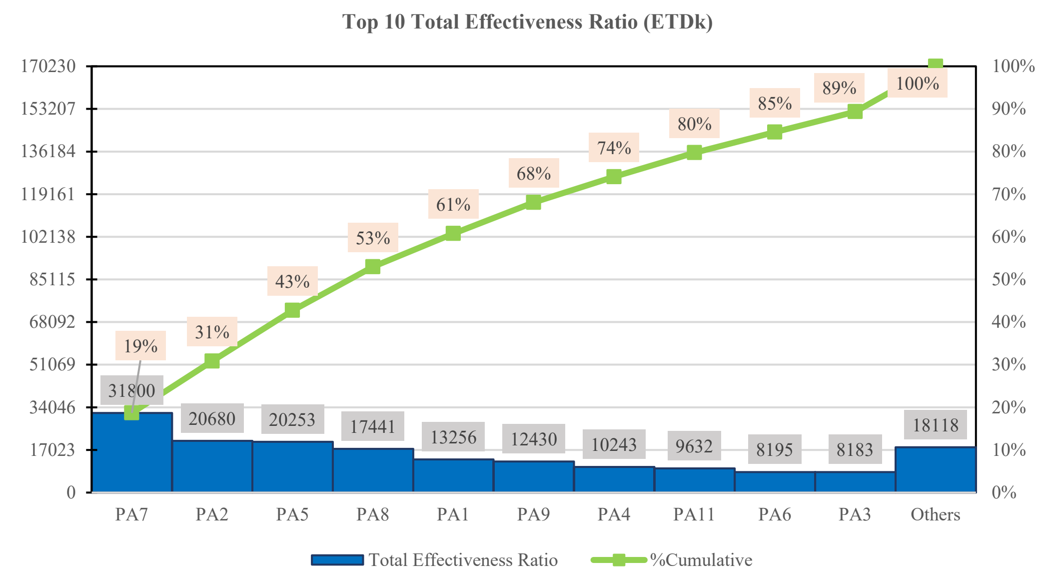

Figure 8. ETDk Pareto Diagram

5. Conclusions and Future Research

In this study, we have proposed a comprehensive methodology to set priorities for preventive action or risk mitigation based on the gap in research of the studies, using The Supply Chain, Productivity Optimization, and Quality Control approaches especially jigs with standards control Quality, Cost, and Delivery. It has been intended to support the methodology with two combination methods, House of Ishikawa Diagram, both methods combined using two-step analysis. The proposed methodology aims to identify events and causes of risks and take countermeasures or prevention actions due to risks that occur with a predetermined priority scale. For future studies, the risk research is expanded to cover all parts and systems of the company, because causative variables of risk, risk events, and preventive measures can be identified in more detail throughout the company's parts and systems, and improve the quality of the goods produced to increase customer satisfaction.

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