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Identification of risk mitigation due to noise in the G2R production area at PT OMI

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Production activities are the core of a manufacturing company. To produce goods, production activities are necessary. Concentration or focus is one of the factors determining the success of the production process. Through interviews with one of the G2R relay production supervisors, it was found that there is an issue related to the decreased concentration of operators working in the G2R relay production area. This indirectly affects the operators' work performance, which in turn impacts the quality of the products produced. The root cause of the decreased concentration was found to be the production machines generating very loud noise. The objective of this final project is to minimize the risks caused by this noise. Therefore, the House of Risk (HOR) method will be used as the solution method. The House of Risk (HOR) can identify risk events, risk agents, and propose mitigation strategies. The HOR calculation for this project suggests a mitigation strategy of applying proper or thicker machine covers to reduce noise from the production machines.

Keywords: House of Risk, Mitigation, Noise

INTRODUCTION

Production activities are the core of a manufacturing company. To produce products, production is necessary. The quality of a product is partly determined by how the product is treated during the production process. There are many opportunities for problems that can occur and cause losses for the company during the production process. One of the direct factors that affects this is focus or concentration.

The most influential factor in employee comfort is the work environment, which can be divided into two parts: physical and non-physical work environments (Sari et al., 2019). The physical work environment in an organization is the condition of the workplace aimed at creating a comfortable atmosphere for employees to achieve organizational goals (Podungge, 2020). Poor working conditions can cause employees to easily feel stressed, have difficulty concentrating, and decrease work motivation (Podungge, 2020). The physical work environment is the physical situation that includes various elements in the workplace such as lighting, temperature, humidity, color, cleanliness, noise, and vibration (Saefullah & Basrowi, 2022).

From interviews with one of the G2R relay production supervisors, it was found that there were problems related to the decreasing concentration of operators when working in the G2R relay production area. The decrease in operator concentration indirectly affects the performance of the operators themselves. If this problem is left unaddressed, the resulting impact will be greater, such as not achieving production targets or a decrease in the quality of the products produced. After conducting a breakdown analysis, the root cause of the decrease in operator concentration was found to be the noise generated by the production machine. This is supported by noise measurements on production machines in one of the G2R relay production lines.

Table 1. Machine Noise Data

No	Item	Bowl Feeder (dB)	Linear Feeder (dB)	Sucking Blowing (dB)	With Cover (dB)
1	Base Blowing	92.2	80.4	112.9	99.9
2	Auto Core Rivet DC	-	-	92.7	84.5
3	Card Insert	92.5	83.2	-	81.3
4	Coil to Base Insert	-	-	101.2	88.6
5	Core Insert	102.6	95.3	-	87.6
6	Coil to Base Pressing	-	-	103.1	89.8
7	Arm Transfer	-	82.8	-	72.9
8	Arm Insert	91.3	86	-	80,4
9	Contact S/B	-	-	110.2	95.2
10	RSB	-	-	103	101.5
11	Case Insert	-	-	104.9	90.1
12	Case Marking	99.4	83.6	-	81.3
13	Hinge Spring m/c	-	-	-	93.7

Source: Preventive Maintenance Team at PT OMI

The permissible exposure limit according to the Indonesian Ministry of Manpower Regulation No. 13 of 2011 and the Indonesian Ministry of Health Regulation No. 70 of 2016 states that the permissible exposure limit (PEL) that can still be tolerated is 85 dB for eight hours of work in a day. In Table 1, it can be seen that many machines exceed the PEL value. Therefore, risk mitigation identification is needed as an effort to prevent larger risks from occurring.

METHODS

Plan, Do, Study, Act (PDSA) Cycle

PDSA cycle is a framework developed to implement continuous improvement and foster better teamwork in the process of making changes for the better (Iryawati et al., 2023). It is believed that the PDSA cycle can address complex problems conceptually and provide a structured framework for conducting sustainable quality improvement projects (Cook et al., 2023). The PDSA cycle is highly suitable as a tool when planning continuous change.

Within the PDSA cycle, tests are conducted to assess improvements, starting from planning the change, implementing the change, evaluating or studying the outcomes of the implemented change, and finally, making adjustments to the change plan if deemed necessary (Kezirian et al., 2019). Improvement activities within the PDSA cycle are easily measurable and analyzable as guidance for further improvements because these activities are structured into several improvement stages (Akhter et al., 2017). The use of the PDSA cycle can facilitate the execution of the current noise risk mitigation project due to its structured framework and clear stages.

1. Plan

Plan is the first phase in the PDSA cycle, encompassing the planning of an improvement. Planning includes what, where, how, and the steps involved in executing the plan. In the plan phase, the team is tasked with identifying which changes will be implemented and measurable (Iryawati et al., 2023).

2. Do

Do is the second phase in the PDSA cycle. In the do phase, the planned changes are implemented (Zahroti & Chalidyanto, 2018). The change plan for improvement is tested during implementation (Morris et al., 2019). In the do phase, data regarding the outcomes of the change plan begins to be collected (Sinapuelas et al., 2018).

3. Study

Study is the third phase in the PDSA cycle. In the study phase, the success rate of the improvement implementation is tested or studied (Katowa-Mukwato et al., 2021). The study phase assesses the effectiveness of the implementation data of the change plan in addressing issues (Sinapuelas et al., 2018).

4. Act

Act is the final phase in the PDSA cycle, where adjustments are made to the change plan based on the results of the previous study phase. In the last phase of the PDSA cycle, future changes or improvements are planned based on the data learned (Lanter et al., 2015). Based on the data learned, change plans that are not optimal will be modified or replaced with new change plans (Sinapuelas et al., 2018).

House of Risk

The House of Risk is an innovative method for analyzing risks sustainably, combining the Failure Mode and Effect Analysis (FMEA) and House of Quality (HOQ) methods in its implementation (Magdalena & Vannie, 2019). The primary focus of the House of Risk method is to prevent risks in its risk management (Purnomo et al., 2021). The House of Risk method is used to identify the opportunities for risk occurrence and the causes of these risks (Wahyuni et al., 2023). The House of Risk method facilitates the mapping of risks and finding the most optimal alternative solutions to reduce the likelihood of these risks occurring.

HOR is a modification of the FMEA and HOQ methods aimed at prioritizing which risk sources should be addressed first with the most effective actions to reduce the potential risks from those sources (Ulfah et al., 2016). The HOR method consists of two stages; the first stage is to determine the priority risk agents or causes, and the second stage is to determine the priority of solutions for the most optimal risk mitigation (Lestari et al., 2021). The first stage of HOR is related to determining the severity and occurrence values and also identifying the correlation between the risk event and the risk agent, information obtained from direct observation data as well as interviews with relevant parties (Hadi et al., 2020).

The House of Risk originates from the merging of two types of research: Failure Mode and Effect Analysis (FMEA) used to determine the risk level, and the House of Quality (HOQ) method used to design risk management strategies (Rozudin & Mahbubah, 2021). In the House of Risk (HOR), the severity level is linked with the risk events, while the occurrence is linked with the risk agents (Rozudin & Mahbubah, 2021). One risk agent can potentially result in several risk events (Rozudin & Mahbubah, 2021).

Here is an explanation of the two stages of the House of Risk process (Emmanual & Basuki 2019):

1. HOR 1 (Risk Identification)
   a. Identify the risk events (E_i) that are likely to occur and assess the severity of these risk events (S_j) on a scale of 1 to 10.
   b. Identify the risk agents (A_j) and assign a value for the likelihood of occurrence of the risk agents (O_j) based on a scale of 1 to 10.
   c. Establish the correlation value (R_{ij}) between the risk events and the risk agents with weights of 0.1, 3, and 9

Table 2. Correlation Value Scale

Weight	Explanation
0	No correlation
1	Low correlation
3	Moderate correlation
9	High correlation

Source: Priyambada (2020)

d. Calculate the Aggregate Risk Potential (ARP_j) for the risk agents to prioritize them in the risk management process.
Formula:

$$ARP_j = O_j \sum S_i R i_j \quad (1)$$

2. HOR 2 (Risk Treatment)
1. Select several risk sources with the highest priority using Pareto analysis of ARP_j.
2. Identify relevant mitigation actions to prevent the risk sources.
3. Determine the relationship between each mitigation action and the risk source (E_{jk}) referring to weights (0, 1, 3, 9).

Table 3. Correlation Value Scale

Weight	Explanation
0	No correlation
1	Low correlation
3	Moderate correlation
9	High correlation

Source: Priyambada (2020)

4. Calculate the effectiveness of each proposed mitigation action.
Formula:

$$TE_k = \sum ARP_j \, . \, E_{jk} \quad (2)$$

5. Estimate the degree of difficulty (D_K) for each mitigation action with reference to weights (3, 4, 5).

Table 4. Difficulty Degree Scale

Weight	Explanation
3	Mitigation actions can be easily implemented
4	Mitigation actions are somewhat difficult to implement
5	Mitigation actions are challenging to implement

Source: Hadi et al. (2020)

6. Calculate the total effectiveness to obtain the ratio value.
Formula:

$$ETD_k = TE_k / D_k \quad (3)$$

7. Determine the priority ranking of each mitigation action based on the highest ETD_k.

Failure Mode and Effecr Analysis (FMEA)

Failure Mode and Effect Analysis (FMEA) is one useful method in quality control efforts (Syahrullah & Izza, 2021). FMEA is an analysis method that combines technology and practical knowledge to identify potential failures in the production process and design preventive measures to prevent their recurrence (Prasetiyo et al., 2017). The FMEA method can be used to research the possibility of failure modes (Rimantho & Mariani, 2017).

FMEA is a structured method that emphasizes identifying, evaluating, and mitigating potential failure risks in a process or product (Ardyansyah & Purnomo, 2024). FMEA is explained according to the rationality of risk assessment levels, which are determined by considering factors such as severity, occurrence, and detection (Wahyuni & Handayani). In HOR phase 1, a modified version of the FMEA method is adapted.

1. Severity

Table 5. Severity Value Scale

Score	Rating	Explanation
1	No	No impact
2	Very slight	No impact means
3	Slight	Causes very slight impact on system performance
4	Minor	Causes minor impact on system performance
5	Moderate	Causes moderate impact on system performance
6	Significant	Causes degradation in system performance but still operational and safe
7	Major	Causes significant degradation in system performance but can still function and be safe
8	Extreme	Causes system to be inoperable but still safe
9	Serious	Potentially causes hazardous impact
10	Hazardous	Very dangerous impact

Source: Prasetyo et al. (2022)

2. Occurrence

Table 6. Occurrence Value Scale

Score	Rating
1	Almost never
2	Remote
3	Very slight
4	Slight
5	Low
6	Medium
7	Moderately high
8	High
9	Very high
10	Almost certain

Source: Prasetyo et al. (2022)

House Of Quality (HOQ)

HOQ is a graphical method that depicts the relationship between consumer needs and product characteristics (Hairiyah et al., 2021). The House of Quality (HOQ) method can be applied to systematically evaluate product quality as an effort to enhance it (Zulkarnain et al., 2023). The HOQ method is used as a tool in Quality Function Deployment (QFD) to improve product quality, among other objectives (Jakaria et al., 2023).

The House of Quality method, or HOQ, will be utilized as an adaptation method in HOR phase 2. The aim is to obtain the most optimal alternative solutions based on priority risk requirements. There will be calculations ranging from the correlation value between alternative solutions and risks, as well as assessments regarding the difficulty of implementing alternative solutions.

RESULTS AND DISCUSSION

Plan, Do, Study, Act (PDSA) Cycle

1. Plan

In the effort to reduce noise in the G2R relay production area, risk mitigation will be identified. The first stage will involve identifying risks that may arise due to the impact of noise. Then, alternative solutions will be sought to mitigate these risks.

2. Do

In this "do" phase, the previously prepared improvement plan will be implemented. The following data is needed for the "do" phase in the risk mitigation plan:

   a. Complaints related to noise, obtained through interviews with leaders in the G2R relay production area such as supervisors, line leaders, and team leaders. Additionally, literature studies related to complaints due to noise will be conducted. Data related to these complaints can be categorized as risks of noise itself.
   b. Risk occurrence probability, obtained from estimates adjusted based on interviews with supervisors and the project management team, as well as direct observations or actual conditions in the production area.
   c. Risk severity level, related to the extent of loss or impact from a single risk. Assessment of the severity level is obtained through interviews and direct observations.

3. Study

Based on the PDSA study phase method, the author will identify risk mitigation related to noise in the G2R relay production area. The risk mitigation identification process will be based on the House of Risk (HOR) method concept. The House of Risk method focuses on identifying priority risks so that alternative solutions for these priority risks can be identified later.

4. Act

From the previous three phases, in the "act" phase, the author expects an optimal alternative solution to address the causes of priority risks. With the successful implementation of alternative solutions, the risks caused by noise can be reduced, or even more than that.

House of Risk 1 (HOR 1)

The implementation of HOR 1 is almost similar to the implementation of the Failure Mode Effects Analysis (FMEA) method. Later, two variables will be used: risk impact (severity) and likelihood of risk occurrence (occurrence). The first step involves the identification of risk events or risk occurrences that in this case may be caused by noise in the production area. After identifying the risks, each identified risk must be assigned a severity value. Risk event assessment is conducted by direct observation, in-depth interviews with experts in the field, and brainstorming. In this project, there are two experts whom the author interviewed: the G2R relay production area supervisor and one of the G2R relay production area productive maintenance (PM) team members. The severity values assigned to the risk events can be seen in Table 7.

Table 7. Severity List

Code	Risk Event (E_j)	Severity (S_i)
E_1	Reduced concentration	7
E_2	Headache	6
E_3	Ringing in the ears	5
E_4	Deafness	10
E_5	Difficulty hearing	9

Five risk events have been identified and assigned severity values. Severity assessment for risk events is based on brainstorming results from observations and in-depth interviews with both experts. The severity value indicates the level of severity or impact caused by a risk event, with a severity scale ranging from 1 to 10. A scale of 1 indicates the lowest impact, while a scale of 10 indicates the highest impact. In this case, the risk event with code E_2, which is dizziness, has the lowest severity value of 6. Meanwhile, the risk event with code E_4, which is deafness, has the highest severity value of 10.

The second step in HOR 1 is the identification of risk agents or causes of risk. One risk agent may potentially cause several risk events. After identification, each risk agent needs to be assessed for occurrence, which relates to how often the risk agent appears. Similar to risk events, the process of identifying and assessing risk agents is derived from brainstorming, direct observation, and in-depth interviews with both experts. The identified risk agents and their occurrence values can be seen in Table 8.

Table 8. Occurrence List

Code	Risk Agent (A_j)	Occurrennce (O_j)
A_1	Machine production noise	10
A_2	Small room area	9
A_3	Not using Personal Protective Equipment (PPE)	6
A_4	Operators chatting frequently	5
A_5	Thin machine covers	8
A_6	Sounds from activities in the production area	5

Six risk agents have been identified as causes of the previously identified risk events. Each identified risk agent has been assigned an occurrence value on a scale from 1 to 10, where a scale of 1 means almost never occurs, and a value of 10 means almost always occurs. It is noted that there are two risk agents with codes A_4 and A_6 that have the smallest occurrence value of 5. Meanwhile, the risk agent with code A*1* has the highest occurrence value of 10.

After identifying and assessing risk events and risk agents, the next step is to identify the correlation between risk events and risk agents. Assigning values on a scale (0, 1, 3, 9), the meaning of values in this scale can be seen in Table 2. The correlation values between risk events and risk agents can be seen in Table 9.

The next step is to calculate the ARP (Aggregate Risk Potential) value. The ARP value is used as a reference in determining the priority of risk causes. ARP calculation can use a formula as in equation 1. The results of the ARP calculation can be seen in Table 9.

Table 9. HOR 1

Risk Event (E_j)	**Risk Agent (A_j)**						**Severity (S_i)**
	A_1	**A_2**	**A_3**	**A_4**	**A_5**	**A_6**	
E_1	9			3	3	3	7
E_2	1		1		1	1	6
E_3	9	3	9		9		5
E_4	9	1	9		9		10
E_5	9	1			3	1	9
Occurrence (O_j)	10	9	6	5	8	5	
Aggregate Risk Potential (ARP_j)	2850	306	846	105	1512	180	

In Table 9, there are six ARP calculations, with the highest ARP value being 2850 (ARP_1), and the smallest ARP value being 105 (ARP_4). For a clearer understanding, ARP calculation can be observed as follows.

ARP1 = 10 . (9(7) + 1(6) + 9(5) + 9(10) + 9(9)) = 2850
ARP2 = 9 . (3(5) + 1(10) + 1(9)) = 306
ARP3 = 6 . (1(6) + 9(5) + 9(10)) = 846
ARP4 = 5 . (3.7) = 105
ARP5 = 8 . (3(7) + 1(6) + 9(5) + 9(10) + 3(9)) = 1512
ARP6 = 5 . (3(7) + 1(6) + 1(9)) = 180

The final step in HOR 1 is to rank the results of the aggregate risk potential (ARP) values from largest to smallest. This is to facilitate the determination of priority risk agents for mitigation. The ranking of the ARP values can be seen in Table 10.

Table 10. ARP Ranking

Rank	**Code**	**Risk Agent**	**ARP**
1	A_1	Production machine noise	2850
2	A_5	Thin machine covers	1512
3	A_3	Not using Personal Protective Equipment (PPE)	846
4	A_2	Small room area	306
5	A_6	Sounds from activities in the production area	180
6	A_4	Operators chatting frequently	105

House of Risk 2 (HOR2)

In HOR 2, the working concept adapts the House of Quality (HOQ) method to determine actions or mitigation measures to minimize the impact of risk agents. The first stage in HOR 2 involves identifying priority risk agents with high ARP values for action. This determination is made using the Pareto principle. Referring to the Pareto principle 75/25, where the identification of risk agents to be mitigated constitutes about 75% of the total ARP values (Prasetyo et al., 2022).

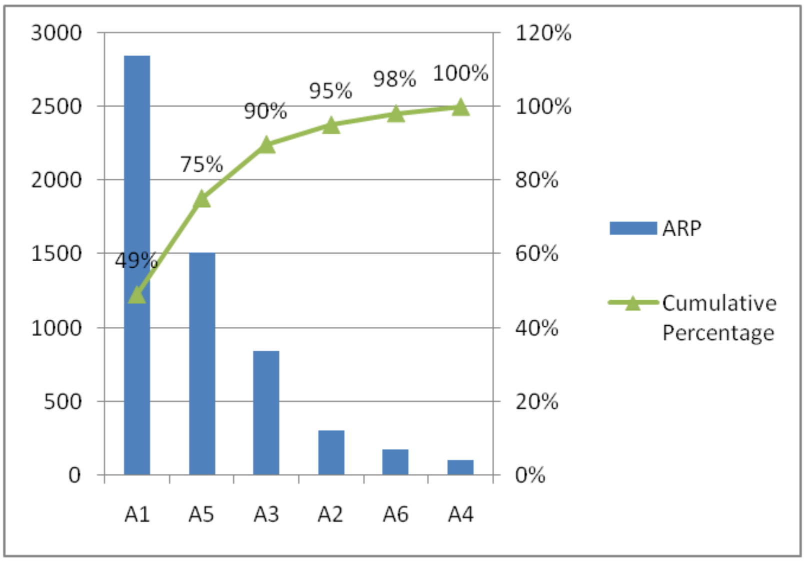

Figure 1. Pareto Chart of Risk Agents

As seen in Figure 2, the Pareto diagram above shows that risk agents A_1 and A_5, namely production machine noise and insufficiently thick machine covers, respectively, account for 49% and 29% of the total. When the percentages of A_1 and A_5 are cumulated, they result in a total percentage of 75%. This makes risk agents A_1 and A_5 the top priority for risk mitigation. The next stage in HOR 2 involves identifying preventive actions or mitigations for priority risk agents. Input for the mitigation identification process includes direct observation results and interviews with both experts in the field. Proposed mitigations must be assigned correlation values to each risk agent; the meaning of the correlation assessment scale can be found in Table 3.

Table 11. Mitigation Strategy & Correlation Value

Code	**Mitigation Strategy**	**Correlation A_1**	**Correlation A_5**
PA_1	Applying a more suitable machine cover	9	9
PA_2	Redesigning the production machine	3	0
PA_3	Replacing product drive components on the production machine	9	0

In Table 11, there are three proposed mitigation strategies that have been correlated with risk agents A_1 and A_5. These proposals stem from brainstorming sessions, direct observations, and in-depth interviews with both experts. The next step is to calculate the total effectiveness (TE_k) of each mitigation strategy against the risk agents. The calculation uses the same formula as in Equation 2. The results of the total effectiveness calculation can be seen in Table 12.

Table 12. Total Effectiveness Value Result

Code	Mitigation Strategy	**Total Effectiveness (TE_k)**
PA_1	Applying a more suitable machine cover	39258
PA_2	Redesigning the production machine	8550
PA_3	Replacing product drive components on the production machine	25650

Here is the calculation of the total effectiveness (TE_K):

TE_1 = (2850(9) + 1512(9)) = 39258
TE_2 = (2850(3) + 1512(0)) = 8550
TE_3 = (2850(9) + 1512(0)) = 25650

After obtaining the total effectiveness results, the next step is to determine the level of difficulty (Dk). The determination of the difficulty level is based on financial aspects and other aspects needed and related to the actual situation of the company. The meaning of the difficulty level assessment scale can be seen in Table 4. The results of determining the difficulty level can be seen in Table 13.

Table 13. Difficulty Degree Assessment

Code	Mitigation Strategy	**Degree of Difficulity (D_k)**
PA_1	Applying a more suitable machine cover	3
PA_2	Redesigning the production machine	5
PA_3	Replacing product drive components on the production machine	4

The determination of the difficulty level values as stated in Table 13 is based on direct observations and interviews with both experts. Mitigation action PA_1 has the lowest difficulty level of 3. This is because, from a financial perspective, PA_1 does not incur significant costs compared to other mitigation actions.

The next step in HOR 2 is to calculate the total effectiveness against the difficulty ratio to determine the ratio value. The formula for calculating the total effectiveness against the difficulty ratio can be seen in Equation 3. Here are the results of the calculation of the total effectiveness against the difficulty ratio in Table 14.

Table 14. HOR 2

Risk Agent	Mitigation Strategy			ARP
	PA_1	**PA_2**	**PA_3**	
A_1	9	3	9	2850
A_5	9			1512
TE_k	39258	8550	25650	
D_k	3	5	3	
ETD_k	13086	1710	8550	

Here is the calculation of the total effectiveness against the difficulty ratio:
$ETD_1 = 39258/3 = 13086$
$ETD_2 = 8550/5 = 1710$
$ETD_3 = 25650/3 = 8550$

As seen in Table 14, mitigation action PA_1 has the highest ETD_k value of 13086. This suggests that mitigation action PA_1 is recommended to reduce the risk due to noise. Meanwhile, mitigation action PA_2 has the lowest ETD_k value of 1710. This indicates that mitigation action PA_2 is the last option in efforts to reduce the risk due to noise.

The final step in HOR 2 is to determine the ranking of mitigation strategies based on the ETD_K calculation results. The ranking based on mitigation strategies can be seen in Table 15.

Table 15. Mitigation Strategy Ranking

Rank	Code	Mitigation Strategy	ETD_K
1	PA_1	Applying a more suitable machine cover	13086
2	PA_3	Replacing product drive components on the production machine	8550
3	PA_2	Redesigning the production machine	1710

Risk Mitigation Proposal

It can be noted from the previous House of Risk (HOR) method implementation that three mitigation strategies were identified. These mitigation strategies have been evaluated based on their effectiveness to difficulty ratio (ETD_k). Among these, PA_1 emerged with the highest ETD_k value of 13086. Therefore, PA_1 is recommended as the mitigation strategy to reduce noise risks in the production area of G2R relays at PT Omron Manufacturing of Indonesia.

The PA_1 mitigation strategy involves the implementation of a more proper machine cover. Here, "proper" implies an improved or optimal version compared to the previous machine cover. The base material for the machine cover is acrylic plastic with a thickness of 5 mm. Plastic was chosen as the base material due to its noise-reducing capabilities.

The difference between the old and new machine covers lies in the number of layers of acrylic plastic used. The old machine cover consists of only one layer of acrylic plastic covering the machine, whereas the new one uses two layers of acrylic plastic. In the new machine cover, there is a small gap between each layer of acrylic plastic, so the two layers do not adhere tightly. This is useful in reducing the noise generated by the machine.

Another component of the machine cover that contributes to sound insulation is the acrylic seal to the aluminum profile slot. The acrylic seal used is made of rubber raw material. Rubber raw material is known for its noise-reducing properties. It takes one week to complete the machine cover installation, and the installation is carried out over the weekend when there is no production activity.

CONCLUSION

Three mitigation strategy recommendations were found from the results of this research using the House of Risk method. The first recommendation is to apply a more proper machine cover. The second recommendation is to redesign the production machine. The third recommendation is to replace the product drive components on the production machine. Of these three recommendations, the first recommendation has the highest ETDK value, indicating that the first recommendation is highly recommended to be implemented. The material used for the machine cover aligns with the first mitigation strategy recommendation, made from 5 mm thick acrylic plastic material constructed in two layers.

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