Developing Strategies for Improving Overall Equipment Effectiveness Using FMEA and FAHP

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Abstract

Many companies in this competitive era are trying to increase productivity and effectiveness by reducing waste and losses in terms of production. So does PT DEX, a leading snack food company in Indonesia. This study aims to obtain the best improvement strategy to increase the effectiveness of the KWSM-3&4 machine in the Atom Nut Division of PT DEX. Efforts to improve were made by measuring machine effectiveness using Overall Equipment Effectiveness (OEE). By applying OEE, the machine effectiveness level parameters will be found. To find the cause of the level of effectiveness of the machine, it will measure the six big losses to determine the critical loss of the problem. Determination of critical losses aims to focus on essential areas of performance that cause the losses. An analysis of the cause of problems and the risk of failure was carried out through a cause-effect diagram and Failure Mode and Analysis (FMEA). These steps determine the causes and potential failures of the proposed corrective measures to minimize the failure. The company will take the best step of the several proposed improvements to require appropriate and effective decision-making. The decision-making used in this research is the Fuzzy Analytical Hierarchy Process (FAHP). The study found that optimization of production planning and control highly affects the performance of production machines.

Keywords
OEE, Critical losses, Six Big Losses, Critical Performance Area, FMEA, FAHP

1. Introduction

The rapid industrial development in Indonesia encourages companies to reduce waste and loss by increasing productivity and machine effectiveness. The effort was performed by using the principle of total productive maintenance (TPM) to resolve the six big losses (SBL) that caused machine effectiveness reduced. A measurement technique OF the machine effectiveness uses overall equipment effectiveness (OEE), which is beneficial in evaluating the effectiveness of the machine and minimizing SBL. OEE measurement technique is considered by pillars of availability, performance, and quality

PT DEX is an Indonesian leading snack food company that applies the TPM principle in its production, including the Atom Nut Division. The results of the TPM implementation in the division in 2020 using the OEE method on the Kawashima 3&4 Machine (KWSM-3&4) for 25 weeks had an average value of 51.2% with a record of 52.1% of performance effectiveness. This value is deficient in the TPM standard set by world-class companies, which is precisely 85% (JIPM, 2014; Ahmad et al., 2018; Cercós et al., 2019). This value indicates that the effectiveness of the machine is low. For that reason, it is necessary to analyze the problem of the machine as critical equipment of the division.

Several loss factors causing the OEE value was lower than others. Those factors were analyzed using the Pareto diagram to obtain critical loss so that the research focused on the critical area causing losses. The acquired critical loss was idling-minor-stop (IMS) with an average value of 46.72%, which is the cause of the low OEE value. Many factors are the causes of IMS, such as work-in-process (WIP) which is not punctual, so it is necessary to analyze the cause and the failure risk as an action to trace the root cause. A method frequently used to find the root cause is a cause-and-effect diagram. In addition, it is necessary to perform a failure risk analysis to anticipate all impacts and losses caused by the risk of an IMS in the future.

The risk analysis method applied in this study is failure mode and effect analysis (FMEA). FMEA is to identify potential failure by considering three factors; Severity, Occurrent, Detection (S, O, D) that are relatively important to determine corrective steps to avoid or minimize the failure mode (Chang et al., 2013; Hasbullah et al., 2017;Surya et al., 2017;Li & Chen, 2019). Failure risk identification using FMEA analysis will obtain the most dominant potential failure to be used as a critical point in determining corrective steps (Li & Chen, 2019). The company will take the best proposal from several improvement proposals as a reference to decide appropriate and effective decisions. The decision-making method used in this study is the fuzzy analytical hierarchy process (FAHP). FAHP is used in pairwise comparison decision-making because it has more criteria scales than the analytical hierarchy process (AHP). This method accommodates and understands the respondents' subjectivity (Lee & Yang, 2018; Hooda & Raich, 2019).

Based on the research gap identified, it is necessary to conduct further research on the KWSM-3&4 machine effectiveness using the FMEA and FAHP. The result is that the company can perform continuous improvement on target. This study aimed to obtain the best-proposed improvement in the strategy to increase the machine effectiveness in the Atom Nut Division.

2. Literature Review

TPM is proactive maintenance that includes all elements of the company to increase productivity related to reliability and industrial environment resources to achieve zero breakdown, zero defects and zero accidents (Dos Reis et al., 2019;Mishra et al., 2021; Rathi et al., 2021). This concept aims to minimize unscheduled maintenance (Wang, 2011; Roosefert et al., 2021). Proactive activities prioritize the improvement process by considering safety, cost, quality, creativity, and delivery involving the entire production line (Kurniawan, 2013). The implementation of TPM is intended for all company members (Kigsirisin et al., 2016; Rathi et al., 2021). The results of the implementation of the TPM are not only authoritarian monitoring but also the structuring of the character of each individual in an organization (Pascal et al., 2019). TPM seeks to create a "maintenance culture" followed by the formation of kaizen character, namely continuous improvement, so companies need to make a rule that can support production activities (Kurniawan, 2013; Mishra et al., 2021). The TPM principle consists of eight main pillars: autonomous maintenance, focused repair, planned maintenance, quality of care, education and training, occupational health and safety, administrative and office TPM, and 5S (Ahuja & Khamba, 2008; Pascal et al., 2019).

OEE is the parameter of TPM success (Ahmad et al., 2018) which is an activity to measure the scale of machine effectiveness by considering three pillars: availability of rate, performance efficiency, and rate of Quality (Nakajima, 1988; Naji & Mousrij, 2018; Roosefert et al., 2021). The ideal OEE value as a world-class company standard is 85%, with a minimum 90% of availability provisions, 95% of performance and 99% of quality (Stamatis, 2017; Chikwendu et al., 2020). Relation of the three pillars can be seen in the following equation formula:

$$\mathrm{OEE} = \mathrm{AR} \times \mathrm{PE} \times \mathrm{RQ} \tag{1}$$

There are three factors of OEE to calculation formula is used:

A. Availability of rate (AR)
   Availability of rate is a ratio that describes the utilization of available time for machine operation (Oliveira et al., 2019). In general, availability is strongly influenced by reliability, especially for products/goods that can repair (Kurniawan, 2013). Nakajima (1988) formulate the equation formula availability of rate as:

$$\mathrm{AR} = \frac{\text{Loading time} - \text{downtime}}{\text{loading time}} \times 100\% \tag{2}$$

B. Performance Efficiency (PE)
   Performance efficiency is a way to determine performance or machine speed that focus on reduce speed and idling-minor-stop (Stamatis, 2017). Pinna et al. (2018) revealed that performance describes the machine's ability to produce good products. Nakajima (1988) formulate the equation formula availability of rate as:

$$PE = \frac{Jumlah\ produksi\ x\ Waktu\ siklus\ ideal}{Operation\ time}\ x\ 100\% \tag{3}$$

C. Rate of Quality (RQ)
   Rate of Quality is a ratio that describes the machine's ability to produce good products and is free from product defects such as product scrap and rework (Xiang & Feng, 2021). Nakajima (1988) formulates the equation formula availability of rate as:

$$RQ = \frac{Jumlah\ produksi - Product\ defect}{Jumlah\ produksi}\ x\ 100\% \tag{4}$$

SBL is divided into three groups (Stamatis, 2017): availability losses, performance losses, and quality losses. Availability losses are related to the availability of rate, which is closely associated with the use of production time that is not maximal. There are two types of availability losses: equipment failure and setup-and-adjustment losses. While performance losses are related to performance efficiency, these losses consist of IMS and reduced speed. Quality losses are closely related to the quality rate. These losses consist of two types of losses, namely defects-in-process and reduced yield. The total sum of the OEE scores and the SBL scores must be 100% (Robert, 2001).

According to Ishikawa (1976), many aspects of production factors must be improved to solve a problem, such as time allocation, defective products, costs, percentages, Etc. Determination of the highest problem specifications can be known by identifying 80% damage using a Pareto diagram (Roosefert et al., 2021). While identifying the dominant root cause can use a causal diagram if a team tends to be oriented towards continuous improvement (McComb, 2008). A cause-effect diagram or fishbone diagram is a quality improvement tool capable of displaying specific causal factors regarding the character of quality or problems (Andersen & Fagerhaug, 2014).

Potential failures can be identified and prioritized in determining corrective steps to avoid or minimize failure (Hasbullah et al., 2017). Stamatis (2017) argues that FMEA is a method of evaluating failures that occur in a design, system, service or process. Identification of potential failure made by the method of scoring is based on the multiplication rate of S, O, D (Chang et al., 2013; Shafira & Mansur, 2018; Li & Chen, 2019). Data collection S, O, D are carried out as a follow-up to the analysis using a causal diagram so that the root cause of the fishbone will become a potential failure mode in FMEA (McComb, 2008).

Initially, the AHP method was developed by Saaty (2008) to choose alternatives in making decisions on an issue (Ayag, 2010). According to Liu et al. (2020), AHP has various advantages that describe the decision selection process, an illustrated chart to be understood. Conventional AHP uses pairwise comparison with a nine-level scale (Saaty, 2008). However, there are drawbacks to the AHP, including this method is used in the selection of decisions that have less sharp values, results in an unbalanced rating scale, and does not consider the uncertainty associated with one of the assessments of an amount (Hooda & Raich, 2019).

Conceptually, fuzzy logic is elementary to understand, flexible, tolerant of inaccurate data, model nonlinear functions, build on expert experience, and combine conventional control techniques (Kar, 2015). Ayag (2010) suggests that fuzzy rules can integrate pairwise comparisons as an extension of AHP to solve uncertainty models; this concept is often referred to as FAHP (Ayag, 2010; Kar, 2015; Li & Chen, 2019). The FAHP concept can cover the weaknesses of AHP, namely having more criteria so that it can accommodate and understand existing problems (Lee & Yang, 2018; Liu et al., 2020). There are five steps in the FAHP calculation: score comparison, making a fuzzy comparison matrix, solving fuzzy eigenvalues, and determining and summing up total priority weights (Naji & Mousrij, 2018). More than 100 articles were discussed by Liu et al. (2020) regarding the ins and outs of FAHP, which states that the Triangular Fuzzy Number (TFN) is more dominant used than other membership functions. The TFN concept proposed by Chang et al. (2009) and the concept of attributes and sub-attributes in improving overall equipment effectiveness using the AHP method proposed by Kodali & Chandra (2001) will be used in this study.

3. Methods

The research object was chosen based on the problems that occurred at PT DEX, namely the low value of production machines/equipment effectiveness. The low value of effectiveness is caused by high failures that cause bottlenecks in the production area, so that further investigations need to be carried out on the existing problems. Determination of the critical area for the KWSM-3&4 Division machine was selected based on the critical equipment of the Atom Nut Division as a pioneer and role model for the implementation of TPM at PT DEX. This study uses data on downtime, scheduled time, actual speed, rate of quality and setup and adjustment of the machine to determine the value of OEE and SBL for 25 weeks starting April 1 to October 10 2020. FMEA and FAHP respondents are selected based on sufficient knowledge and experience to find solutions to research problems.

3.1. Analysis model

The model of this research has three *points* important, namely:

- Measurement of OEE Value and Determination of *Critical to Losses*
  The Measurement of OEE value is carried out by considering the three pillars of OEE to determine the level of effectiveness of the machine/equipment. The calculation results will be used to evaluate the SBL value that occurs. The sum of the OEE scores and the SBL scores must be 100%. The results of the SBL calculation will determine the level of the problem using a Pareto diagram to obtain critical to losses.
- Determination of the Root of the Problem Using Cause and Effect Diagram Analysis and FMEA
  Determination of critical to losses will make it easier to determine the root of the problem using a causal diagram analysis. The results of problem identification using a causal diagram will be the potential failure mode of the FMEA analysis. Determination of criteria for the level of incidence S, O, D made by mutual agreement between the respondents with investigators.
- Priority Determination of Selected Alternatives Through FAHP

In making decisions using FAHP, the best alternative strategy will be selected based on several proposed dominant risk resolution strategies to increase the effectiveness of the KWSM-3&4 machine in the Atom Nut Division. The analysis model for determining the priority weighting of OEE improvement strategies using FAHP is presented in Figure 1.

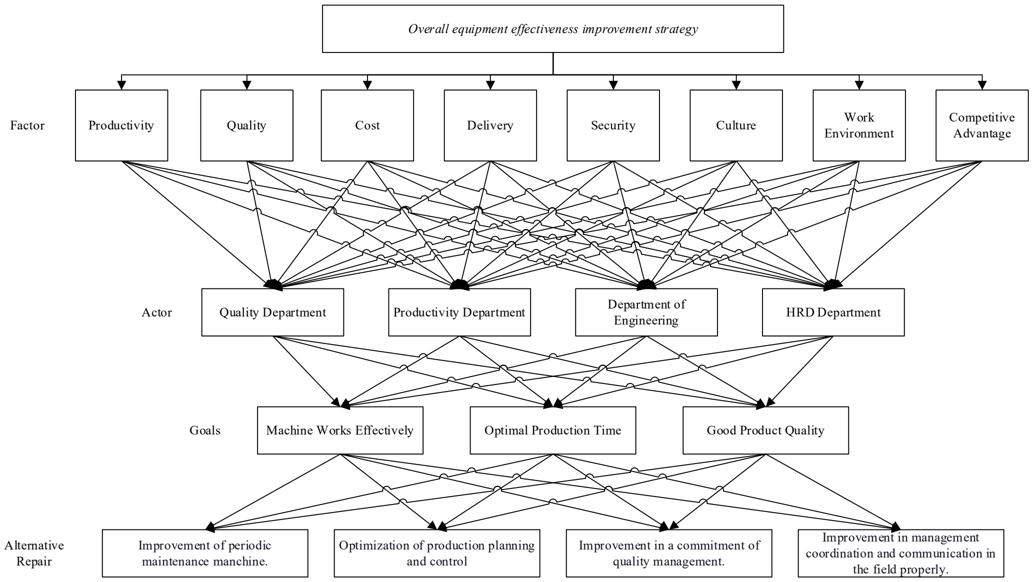

Figure 1. FAHP analyst model scheme in this study

3.2. Research Flowchart

This study uses a flow chart as a reference so that the work is orderly and structured. The research flow diagram can be illustrated in Figure 2.

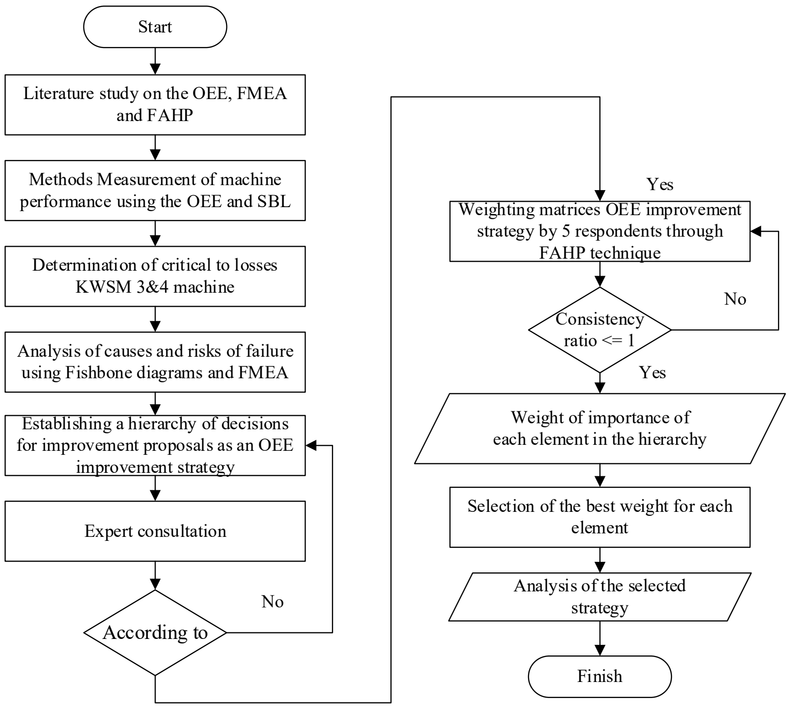

Figure 2. Research Flowchart

4. Data Collection

4.1. Data OEE

Data presentation of OEE at PT DEX is obtained by calculating the 3 supporting pillars, they are:

a. Availability of rate

In order to obtain the value of the Availability of rate, the ratio used in the utilization of available time for machine operations is required, both in the form of working time data and data downtime that shown in Table 1 and 2.

Table 1. Data of KWSM-3&4 machine working

Week	Start	Finish	Calendar Time (min)	Planned Downtime (min)	Unscheduled Downtime (min)	Scheduled Time (min)
1	01/04/2020	07/04/2020	10.080	474	517	9.089
2	08/04/2020	14/04/2020	10.080	226	444	9.410
….	….	….	….	….	….	….
25	30/09/2020	06/10/2020	10.080	533	100	9.447

Table 2. Data of KWSM-3&4 machine downtime

Week	Planned Downtime (min)	Failure Repair (min)	Setup and Adjustment (min)	Unscheduled Downtime (min)
1	474	0	60	517
2	226	0	0	444
….	….	….	….	….
25	533	6	0	100

b. Performance

In order to know machine performance or machine speed that focused on reduced operating speed and small stop, actual speed data and machine production data are required. The data is presented in Table 3 and 4.

Table 3. Actual Speed data of KWSM-3&4 Machine

Actual Speed			
Week	Minimum Speed (pack/minutes)	Maximum speed (pack/minutes)	Mode speed (pack/minutes)
1	30	32	31
2	27	32	31
….	….	….	….
25	32	32	32

Table 4. Production result of KWSM-3&4 Machine

Machine Capacity of KWSM-3&4 (Kg)										
Week	Gramatur									Total Amount
	42	70	130	140	90	225	450	150	60	
1	2.639,5	7.943,2	28.881	102,3	1.213,7	1.851,8	0	153,5	0	42.785,1
2	1.663,5	445,9	1.4301,7	127,4	294,9	2.866,8	172	696,2	0	20.568,5
….	….	….	….	….	….	….	….	….	….	….
25	1.782,5	0	38.152,4	0	2.673	36	0	180	0	42.823,9

c. Quality

In order to obtain a ratio that describes the ability of machine to produce products that are not caused by product defect such as product scrap and rework, product quality data is required and presented in Table 5.

Table 5. Product Quality Data of KWSM-3&4 Machine

Week	Total Production (Kg)	Reject and Rework (kg)
1	11.7069	0
2	45.200,5	0
….	….	….
25	42.823,9	8,56

4.2. Data FMEA

The collection of data on severity, occurrence, and detection was carried out as a follow-up to the analysis using a cause-effect diagram. The root cause the result of the cause-effect diagram result will be a potential failure mode in FMEA (McComb, 2008). This research was conducted on 6 research respondents, and described in Table 6.

Table 6. Data FMEA of KWSM-3&4 Machine

FMEA WORKSHEET		System : Operating system of KWSM-3&4 Machine																				
		Subsystem : Packaging peanut atom great packaging																				
No Operation	Process Description	Severity							Occurrence							Detection							Explanation
		1	2	3	4	5	6	SEV	1	2	3	4	5	6	OCC	1	2	3	4	5	6	DET	
1	Packaging	3	4	3	3	3	3	3	5	4	8	5	3	3	5	4	5	3	2	2	2	2	Minor Stop
2	Packaging	3	3	3	3	3	3	3	3	4	9	3	2	1	3	6	5	3	2	2	3	3	Minor Stop
….	….	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…	…		…	…
32	Packaging	6	5	6	6	3	6	6	1	3	1	2	1	1	1	3	1	4	1	2	1	1	Setup and adjustment

4.3. Data FAHP

FAHP modeling is accomplist by comparing the importance rate of factors, actors, objectives, alternatives that influence to increase in the OEE. The comparison of the rate of factors, actors, objectives, and alternatives is done through the steps as listed below:

1. The importance rate’s comparation of the OEE improvement strategy factors.
2. The importance rate’s comparation of the OEE improvement strategy actors.
3. The importance rate’s comparation of the OEE improvement strategy aims.
4. The importance rate’s comparation of the OEE improvement strategy alternatives

5. Result and Discussion

Based on the data collection of large packaging atom nut, which was taken from April 1 to October 6, 2020 on the KWSM 3&4 machine, the OEE level is generated and shown in Table 7. The OEE calculation for the machine can be shown in the following table.

Table 7. Calculation Results of OEE

Week	Availability rate	Performance rate	Quality rate	OEE
1	99,3%	63,55%	100,00%	63,13%
2	100,0%	24,81%	100,00%	24,81%
…	…	…	…	…
25	99,9%	57,15%	99,98%	57,11%
$\overline{x}$	98,5%	52,1%	100,0%	51,2%

Determination of the dominant loss can be performed using a Pareto diagram, which aims to identify the dominant loss in the SBL of the KWSM-3&4 machine, namely IMS, breakdown loss, setup and adjustment loss, reduce speed loss, defect in-process loss, yield loss. The percentage of SBL on the Pareto diagram is presented in Figure 3.

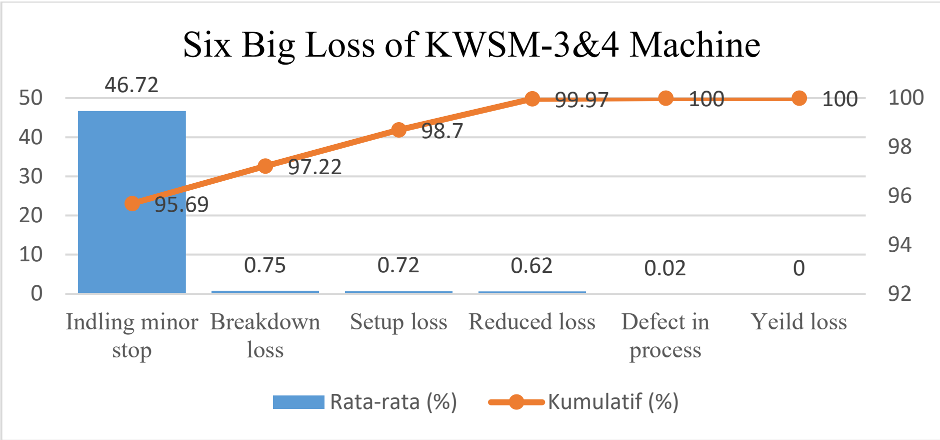

Figure 3. Pareto Six Big Losses Diagram for KWSM-3&4 Machine

Based on the Pareto diagram above, the dominant contributor to the occurrence of SBL during April 1 to October 6 2020 is IMS with an average value of 46.72%. It is necessary to further research on the problem. The high value of dominant loss caused by IMS as a contributor to SBL greatly affects the effectiveness of KWSM-3&4 machine. This statement is under the OEE value of the machine is 51.2%. The high value of IMS is critical in this study, so the most crucial problem as the cause of IMS is need to be identified. The cause-and-effect diagram analysis is further action to the critical loss that have been stated in the Pareto diagram. The cause-and-effect diagram explains the process of identifying the most critical problem by showing the specific causal factors in the character of the problem (Ishikawa, 1976). Five disadvantages cause IMS, namely broken packaging, leaking packaging, folding packaging, missed packaging, and not-punctual work-in-process (WIP). The cause-and-effect diagram of those are presented in Figure 4 - Figure 6.

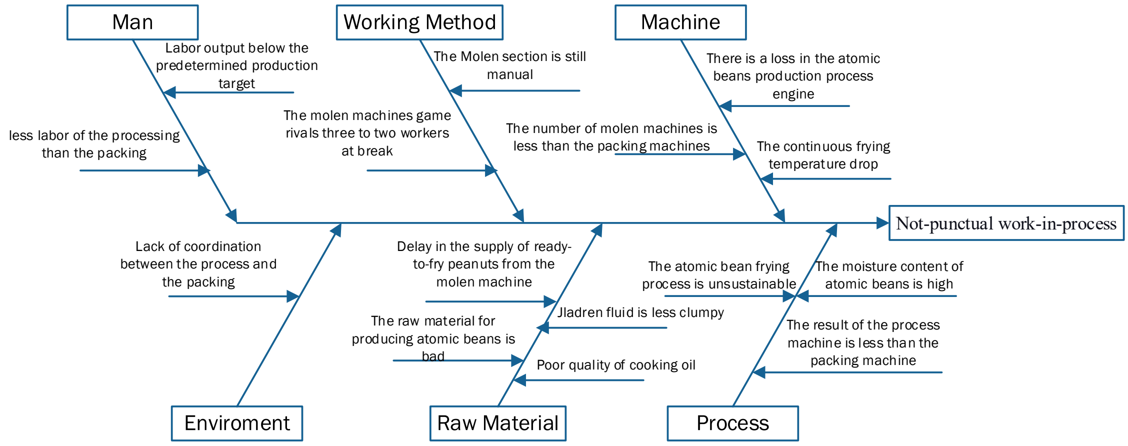

Figure 4. Cause-effect Diagram of not-punctual WIP

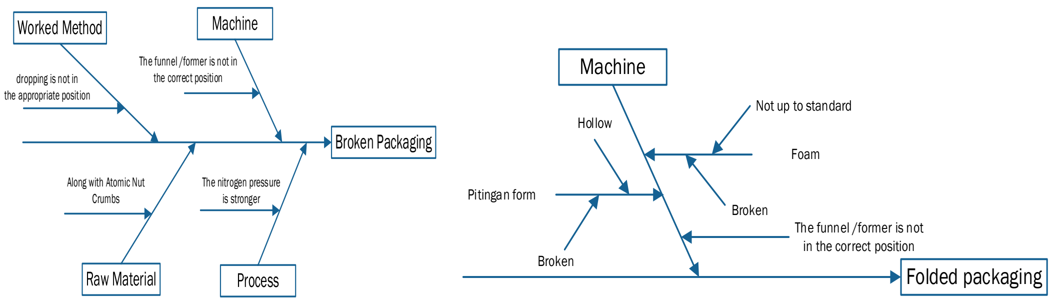

Figure 5. Cause-effect Diagram of Broken and Folded Packaging

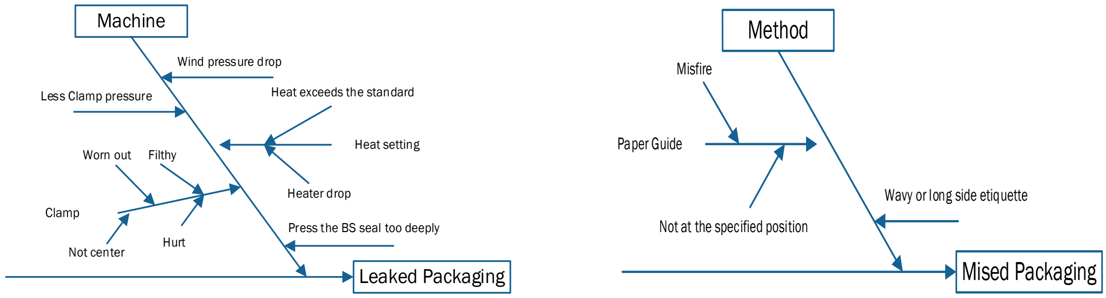

Figure 6. Cause-effect Diagram of Leaked and Missed Packaging

Identification of potential failure was made with a scoring method based on the multiplication rate of S, O, D. The S, O, D data collection is as further action to the analysis with a cause-and-effect diagram. The root cause from the cause-and-effect diagram is a potential failure mode in FMEA. The determination of the RPN value from the S, O, D multiplication, was obtained from the interview mode of the respondents. Determination of the priority risk value of the packaging that is determined at the RPN value ≥ 72. There are six dominant contributor losses are as follows:

1. Lack of labor while molen machine at rest.
2. Communication error during the execution of atom nut production planning between parts of the production process and the packaging department.
3. Over gramatur.
4. Unsuitable foam position.
5. Unclean clamp.
6. Less clamp pressure.

The effort to identify the failure risk using FMEA analysis obtains the most dominant potential failure to be used as a critical point in determining corrective steps. Based on the FMEA identification of the dominant losses, it obtained several steps for improvement proposals formulated to solve the low effectiveness value of the KWSM-3&4 machine. The steps are as follows:
1. Optimization of production planning and control.
2. Improvement in management coordination and communication in the field properly.
3. Increased commitment of management to quality.
4. Increased machine maintenance periodically.

Determination of the proposed improvement was obtained through FGD among researchers and experts. The proposed improvement is expected to respond and solve the low effectiveness value under the critical problem. It is for the purpose that decisive actions are to be created. After determining the critical loss with a Pareto diagram, identification of potential failure mode is performed using a cause-and-effect diagram. The most dominant identification of the potential cause and detection through FMEA can be a critical point in determining corrective steps. The company would take the best steps from several proposed improvements. Therefore, appropriate and practical decisions are needed. A method of decision-making to respond to the problem in this research is FAHP.

FAHP modelling compares the factor importance level, actors, goals, and alternatives that affect OEE's increase. The following attributes and sub-attributes that aim to be an OEE improvement strategy in this study are:
1. Productivity is idea power implication to drive improvements to be better, cheaper, more accessible and safer in the production process implementation considered with human factors, materials, energy, and machinery.
2. Quality is the degree of conformity of the product desired by consumers. Quality is greatly influenced by being no-defect in the process, manufacturing defects, consumer complaints, and consumer claims.
3. Cost is a profit-increasing attempt through actions to save production cost, energy consumption, labour, machine damage, heat, machine maintenance, and product repair. The efforts made are not only technical or commercial but also in order with the character of "culture of continuous improvement" to improve performance creating high productivity.
4. Delivery is a supplier's effort to fulfill the required quantity in accordance with the regulation in planning and scheduling production of raw materials and results.

5. Security is an attempt to identify and control work accident potency and pollution in relation to the safety and health for employees.
6. Culture is an attempt to arrange character based on participatory management to improve productivity by elevating improvement ideas, small discussion groups, and motivational programs.
7. The work environment is everything that affects the improvement of work quality, such as rise of information adeptness, ownership development, cooperation improvement and coordination, and great self-confidence.
8. Competitive advantage is a company's effort to be superior to competitors. It not only determined by the cost but also determined by the support of services and products, consumer trust, and a rise in value.

Essential actor in PT. DEX's OEE improvement are the Production Department, Engineering Department, Quality Department, and HRD Department. The Production Department contributes to all matters related to production actively. The HRD Department contributes to organizing the provision of human resources. The Engineering Department contributes directly to the operation of the production machine. Two divisions contribute directly to the Engineering Department, namely the Packing Engineering Division and the Maintenance Division. The Quality Department performs a direct role in all matters relating to quality management regarding products and machines.

The objectives of the OEE improvement strategy are based on the pillars of availability, performance, and quality. The expected goals are optimal production time, good product quality, and effective machines. Optimal production time as the purpose of the availability factor fulfillment is time availability in the production process. Meanwhile, effective machine operation as the purpose of the performance factor fulfillment, namely the effectiveness of the machine while working by the specified performance and not occurring off. Good product quality is a fulfillment of quality factors which are products according to quality standards set by management. The selection of alternative weights for repair is based on proposed improvements to solve the problem of the low effectiveness of the KWSM-3&4 machine. There are four alternative suggestions for improvement: enhancement of production planning and control improvement, Improvement in coordination and communication management properly, Improvement in commitment-to-quality management, Improvement in regular machine maintenance. Determination of the most important factors of the effectiveness improvement of the machine is shown in Table 8.

Based on the respondents' assessment calculation, the highest cumulative factor weight lied in the safety factor, with a weight of 0.224. The selected factors were the prioritized factors in increasing OEE. The determination of the most influential and directly related actors in further action to improve the effectiveness of KWSM-3&4 machines using the FAHP method can be described in Table 9.

Based on the respondents' assessment calculation, the highest cumulative actor weight selected was the Production Department weight of 0.321. The selected actors are influential actors and are directly related to further action to increase OEE. Determination of the actors' priority weight was highly influenced by the factor hierarchy. The factor hierarchy has the highest factor weight on safety. The company's regulation on security is closely related to the Production Department because all possible incidents occur in the production field. Determining the most expected goals and focusing on improvement of the effectiveness of the KWSM-3&4 machine using the FAHP method is described in Table 10.

Table 8. Calculation of Weights Cumulative Factors

Factor Element	**Result**		**Geometry Mean of the priority factor**	**Rank**
	R1	**R3**		
Productivity	0,104	0,139	0,120	5
…	…	…	…	…
Competitive advantage	0,120	0,082	0,099	6
Eigen value	8,310	8,217	8,264	
CI	0,044	0,031	0,037	
CR	0,031	0,022	0,026	

Table 9. Calculation of Weights Cumulative Actors

Actor Element	Result		Geometry Mean of the priority factor	Rank
	R1	R3		
Department Quality	0,253	0,330	0,289	2
…	…	…	…	…
Department Production	0,316	0,325	0,321	1
Eigen value	4,145	4,169	4,157	
CI	0,048	0,056	0,052	
CR	0,054	0,063	0,058	

Table 10. Calculation of Weights Cumulative Objectives

Objective Element	Result		Geometry Mean of the priority factor	Rank
	R1	R3		
Production Time Optimal	0,331	0,307	0,319	3
…	…	…	…	…
Good Quality	0,325	0,345	0,335	2
Eigen value	3,018	3,043	3,030	
CI	0,009	0,021	0,014	
CR	0,016	0,037	0,024	

Based on the experts' assessment calculation, the highest cumulative goal weight resulted in the machine working effectively with a weight of 0,346. The chosen objective is to focus on the improvement of the effectiveness of the KWSM-3&4 machine. The determination of priority weight was highly influenced by factor and actor hierarchy. The factor hierarchy has the highest factor weight on safety. In comparison, the actor hierarchy has the highest actor weight in the Production Department. The FMEA analysis shows that the Atom Nut Division often faces are loading losses and IMS. Loss caused by loading loss is work in process (ready-fried-peanuts that are not in time). Furthermore, it affects bottleneck on the next production. In comparison, the loss caused by IMS are brooked packaging, leaked packaging, slipped packaging, or folded packaging. The low value of productivity is due to the low value of the machine performance, with the result that the machine does not work effectively.

After selecting factors, actors, and focus of improvement objectives expected, the next step is selecting alternative weights for improvement. The selection of alternative weight for improvement is based on the best proposal to solve the problem. The determination of the cumulative alternative weight is shown in Table 11.

Table 11. Calculation of Weights Cumulative Alternative

Alternative Element	Result		Geometry Mean of the priority factor	Rank
	R1	R3		
Increased machine maintenance periodically	0,271	0,178	0,219	4
…	…	…	…	…
Increased commitment of management to quality	0,212	0,291	0,248	3
Eigen value	4,089	4,159	4,124	
CI	0,030	0,053	0,040	
CR	0,033	0,059	0,044	

Based on the experts' assessment calculation, the highest cumulative alternative weight was selected, which was an increase in the optimization of production planning with a weight of 0.268. The chosen alternative is a prioritized improvement proposal to improve machine effectiveness. Optimization of production planning and control is greatly influential to the production machine performance. The number of not-punctual WIPs and IMS cause the machine not to work effectively. It makes the production planning and control does not run optimally.

6. Conclusion

The OEE level of KWSM-3&4 machine in Atom Nut Division from April 1 to October 6, 2020 obtained an average score of 51.2%. The low level of machine effectiveness is based on calculating the availability, performance, and quality factors. To determine *Critical loss,* it is necessary to measure SBL to determine the cause of the reduced level of machine effectiveness. The average value of IMS the machine is 46.72%. From this percentage, an analysis of the problem causes and the failure risk was performed through a cause-and-effect diagram and *failure* FMEA. Attempts to identify the failure risk using FMEA analysis obtained the six most dominant potential failures (RPN≥ 72) so that they can be used as *critical points* in determining corrective steps. The six critical points obtained by the FMEA analysis will be used as a decision selection for the proposed improvement of OEE using FAHP. Based on the assessment results of proposed improvements in increasing OEE calculated with FAHP, the prioritized alternative is optimization on production planning and control, so the effective machine operation's goal can be achieved. Optimization of production planning has the most influential actor, namely the Production Department that prioritizes safety factors

The author realizes that this study's limitation to the weighting of the FMEA pillars (S, O, D) is still averaged. The following research opportunity is to give weight to the FMEA pillar with the purpose that the critical points that FAHP can be maximized.

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