Equivalent: Jurnal Ilmiah Sosial Teknik
Volume 8, Issue 3, 1362-1374
e_ISSN: 2775-0833
https://jurnalequivalent.id/index.php/jequi/index
DOI: doi.org/10.59261/jequi.v8i3.346

Lean Six Sigma Approach to Reduce Miss Shooting Bag Waste in Cement Packaging

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Article Info:
Article history:
Received: May 15, 2026
Revised: June 29, 2026
Accepted: July 11, 2026
Available Online: September 05, 2026

Keywords:
Lean Six Sigma; Miss Shooting Bag; Waste; DMAIC; Cement Industry.

Abstract

Background: Competition in the cement industry in Indonesia encourages companies to maintain production quality and efficiency. One cement company in Tuban Regency frequently faces the problem of *miss-shooting bag* in the cement packaging process, namely the failure of the rotary packer machine to shoot cement bags onto the filling spout, causing the bags to fall and resulting in waste.
Objective: This study aims to identify the types of waste that occur, analyze the factors causing *miss-shooting bag*, and formulate improvement recommendations using the *Lean Six Sigma* approach.
Methods: This study uses a quantitative descriptive research design with the *DMAIC* approach (*Define, Measure, Analyze, Improve, Control*), focusing on the *Define, Measure, Analyze,* and *Improve* stages. Data were collected through direct observation, interviews with packer operators, and secondary production records from June 2024 to May 2025 at PT X in Tuban, East Java.
Results: The results show that *miss-shooting bag* causes defect waste and overprocessing waste. The sigma values for defects on packer machines 1 and 2 are 4.63 and 4.62, respectively, indicating that process quality is already good but still requires improvement. The fishbone diagram analysis identifies factors causing *miss-shooting bag*, including human, machine, material, method, and environmental factors.
Conclusion: The proposed improvement recommendations include establishing bag quality standards, conducting routine machine maintenance, improving workplace cleanliness, and providing a dedicated rest area for workers to reduce *miss-shooting bag* incidents and improve the efficiency of the cement packaging process.

To cite this article: Kalista, A. (2026). Lean Six Sigma Approach to Reduce Miss Shooting Bag Waste in Cement Packaging. *Equivalent: Jurnal Ilmiah Sosial Teknik*, *8*(3), 1362-1374. https://doi.org/10.59261/jequi.v8i3.346

INTRODUCTION

The cement industry is one of the strategic sectors supporting national infrastructure development in Indonesia. Rapid development in housing, roads, bridges, and commercial buildings has driven cement demand to increase from year to year (Amelia & Prianjani, 2026; Astuti & Lathifurahman, 2020; Devani & Amalia, 2021; Sirine & Kurniawati, 2017). According to the Indonesian Cement Association (ASI), national cement production capacity continues to expand to meet growing domestic needs. However, increased production capacity alone is insufficient if it is not accompanied by process efficiency and strict quality control. In a competitive market, cement companies are required not only to produce in large volumes but also to ensure that each product unit meets established quality standards at efficient production costs (Herlina et al., 2021; Ummah, 2024).

According to Ratnadi and Suprianto (2016), product quality is one of the determining factors of corporate competitiveness amid increasingly intense competition in the cement industry (Fitri, 2026). Customers, both from the retail segment and large-scale projects, are becoming more selective in choosing products based on quality consistency and supply reliability. Therefore, the production process must be designed and managed in such a way that it produces uniform products with the lowest possible defect rate. Failure to maintain quality not only affects customer satisfaction but also creates resource waste, leading to increased production costs and reduced company profitability.

To address these challenges, various quality management approaches have been developed and implemented in the manufacturing industry. One proven effective method is Six Sigma, a data-based approach aimed at reducing product defects to only 3.4 defects per million opportunities (DPMO) (Irwanto et al., 2020; Kusuma & Guritno, 2020; Ummah, 2024). Six Sigma uses a structured framework known as the DMAIC cycle, namely Define, Measure, Analyze, Improve, and Control, as a systematic guide for identifying and solving quality problems (Ihsan & Irpansah, 2026; Kurniawan et al., 2021; Najib et al., 2014; Pradana et al., 2018). Meanwhile, Lean Manufacturing focuses on eliminating all forms of waste in the production process that do not add value for customers. From the lean perspective, there are eight types of waste: defects, overproduction, waiting, non-utilized talent, transportation, inventory, motion, and extra processing. The integration of these two approaches, known as Lean Six Sigma, enables companies to improve product quality while simultaneously eliminating non-value-added activities in the production flow (Khusuma & Utomo, 2021; Rif'an, 2019; Soetiyono & Alexander, 2025). This approach has been widely applied in various global manufacturing industries, including the cement industry, and has shown significant results in improving efficiency and reducing operational costs.

Although numerous studies have applied Lean Six Sigma in manufacturing industries, most previous research has focused on the production or assembly stages rather than the packaging process. Specifically, no prior study has systematically examined the miss-shooting bag phenomenon in cement packaging using the Lean Six Sigma framework. This gap is significant because the packaging stage represents the final quality checkpoint before distribution, and failures at this stage directly affect product integrity and operational costs. Furthermore, existing studies on cement industry quality control have predominantly addressed kiln operations and grinding processes (Condé et al., 2023; Sharma & Yadav, 2023; Sharma et al., 2026), leaving the packaging process largely underexplored. This study addresses this gap by providing a focused analysis of miss-shooting bag waste using the DMAIC framework.

Table 1

Comparison of Previous Research with Current Study

Author (Year)	Method	Research Focus
Astuti and Lathifurahman (2020)	Lean Six Sigma	Waste reduction in cement packaging section
Kusuma and Guritno (2020)	Six Sigma (DMAIC)	Quality control of cement bagging process
Ummah (2024)	Six Sigma (DMAIC)	Quality control of cement bagging at PT X Central Java
Condé et al. (2023)	Lean Six Sigma (DMAIC)	Defect reduction in car parts manufacturing
Current Study 2026	Lean Six Sigma (DMAIC) + Fishbone	Miss shooting bag waste analysis in cement packaging with rotary packer machine

Source: Research Synthesize

The novelty of this research lies in its specific focus on the miss shooting bag phenomenon, a packaging-stage defect that has not been previously investigated using an integrated Lean Six Sigma approach. Unlike earlier studies that applied generic DMAIC frameworks to broad production issues, this study combines waste identification, specifically defects and overprocessing, sigma-level measurement, and fishbone root cause analysis tailored to rotary packer machine operations. This targeted approach enables more precise and actionable improvement recommendations for the cement packaging industry.

PT X is one of the leading cement producers in Indonesia and is in Tuban Regency, East Java. As a large-scale company, PT X manages the entire cement production chain, from raw material mining to the packaging of finished products. The packaging process is the final stage in the production chain before products are distributed to the market. At this stage, bulk cement is packed into 40 kg and 50 kg bags using a high-capacity automatic rotary packer machine. The rotary packer machine is designed to fill cement bags precisely and quickly to support the company's daily production targets.

However, in its operational practice, PT X often faces problems in the packaging process, particularly the phenomenon known as miss shooting bag. Miss shooting bag refers to a condition in which the rotary packer machine fails to launch or shoot the cement bag accurately onto the filling spout, causing the bag to fall before the filling process begins. The fallen bag sustains physical damage, cannot be reused in the filling process, and must be handled manually by the operator. As a result, production flow is disrupted, operators' workloads increase, and material waste occurs in the form of damaged bags and spilled cement. Operational data for 2024 show that the percentage of miss shooting bag incidents on the two rotary packer units operated by PT X ranged from 3% to 18% per month, with fairly significant fluctuations. This condition indicates that the miss shooting bag problem is recurring and has not been systematically addressed, thereby potentially causing accumulated long-term losses.

Based on these conditions, this study was designed to analyze the miss shooting bag problem using the Lean Six Sigma approach with the DMAIC framework. The study focuses on the first four stages of DMAIC, namely Define, Measure, Analyze, and Improve, with the aim of comprehensively identifying the types of waste caused by miss shooting bag, quantitatively measuring process performance through sigma-value calculation, analyzing the root causes of the problem using a fishbone diagram, and formulating applicable improvement recommendations.

The scope of this study is limited to the packaging process using the rotary packer machine at PT X, from the bag input stage to the shooting process, excluding manual handling after shooting. Assuming that the machine was in normal operating condition at the time of the study, this research is fully directed toward identifying causal factors and formulating effective and measurable improvement solutions.

The practical benefits of this research include providing PT X with data-driven recommendations for reducing miss shooting bag incidents, thereby decreasing material waste and overtime costs. The theoretical implications contribute to the body of knowledge on the application of Lean Six Sigma in cement packaging operations, an area that has received limited academic attention. Furthermore, the findings may serve as a reference model for other cement manufacturers facing similar packaging challenges, particularly those operating rotary packer machines.

The results of this study are expected to make a practical contribution to PT X by identifying the dominant factors causing miss shooting bag and providing a scientific basis for process improvement decisions. At a broader level, this research is expected to serve as a reference for other cement industries in applying the Lean Six Sigma approach to solve similar problems. By improving packaging process efficiency, PT X can not only reduce waste and production costs but also strengthen its competitive position in the increasingly dynamic national cement market.

METHOD

This study employed a quantitative descriptive research design using a case study approach at PT X, a cement manufacturing company located in Tuban Regency, East Java, Indonesia. The research object was the cement bag packaging process using two rotary packer machine units, namely Packer 1 and Packer 2. Data were collected over a 12-month period from June 2024 to May 2025.

The data collection techniques included: (1) direct observation of the packaging process to identify non-value-added activities and miss shooting bag occurrences; (2) structured interviews with packer operators and production supervisors to validate causal factors; and (3) secondary data analysis of production records, including production quantity, miss shooting bag frequency, bag defect counts, and overtime hours. The research instruments consisted of observation checklists, interview guides, and data recording sheets. The data analysis techniques applied in this study included value stream mapping for activity classification, DPMO and sigma-level calculation for process capability measurement, and fishbone diagram analysis for root cause identification (Condé et al., 2023; Kumah, 2026).

The Lean Six Sigma methodology was implemented through the DMAIC framework, focusing on four stages: Define, which identified waste through value stream mapping and activity classification; Measure, which calculated sigma values from defect data; Analyze, which identified root causes using fishbone diagrams based on brainstorming sessions with production staff; and Improve, which formulated improvement recommendations. The Control stage was excluded because it required long-term implementation beyond the scope of this study.

Cause-and-Effect Diagram

The Cause-and-Effect Diagram, better known as the Ishikawa Diagram or Fishbone Diagram, was developed by Kaoru Ishikawa in 1976 (Ishikawa, 1976; Sharmaa & Taliba, 2026). This diagram is used to identify the causes of a problem by grouping factors that influence quality (Dwiyanti & Valentin, 2025; Soemohadiwidjojo, 2017; Tannady & Chandra, 2017).

The principle of this diagram is to identify root causes through brainstorming and then classify them into main categories. In general, the causes of problems are divided into five main factors known as the 5M, namely man, machine, material, method, and mother nature or environment (Sulianta & Widyatama, 2024; Wicaksono et al., 2017).

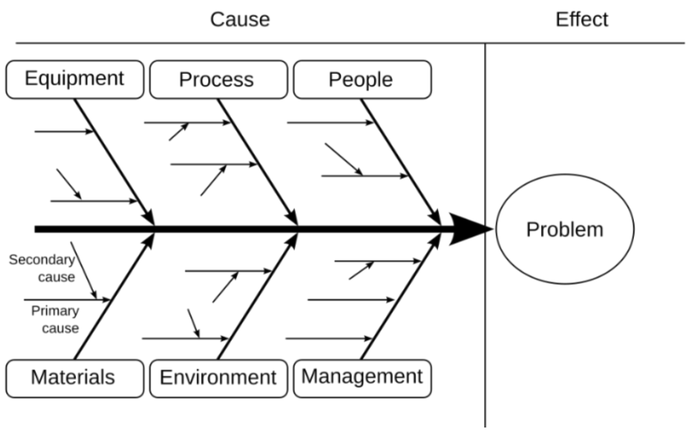

Figure 1. Cause-and-Effect Diagram

To improve the effectiveness of Lean Six Sigma implementation in the cement packaging process, artificial intelligence (AI) technology can serve as a significant supporting solution. AI can process data quickly and accurately, thereby strengthening the Define, Measure, Analyze, and Improve stages of the DMAIC methodology.

RESULTS AND DISCUSSION

Results

Cement Packaging Process and Miss Shooting Bag

In the cement packaging process at PT X, cement bags are placed in the bag holder and then directed to the rotary packer machine to be filled through the filling spout according to the required dosage. After filling, the cement bags pass through the bag cleaner and belt weigher to ensure that their weight remains within the standard range of 39.6–40.4 kg. Bags that do not meet the standard are rejected through the reject belt, destroyed, and the cement is returned to the filling process. Meanwhile, bags that pass inspection are forwarded to the palletizer before entering the warehouse or distribution stage.

In the cement packaging process, one problem that arises is miss shooting bag, namely a condition in which the bag is not positioned correctly during the filling process, causing it to fall and become damaged. This results in material waste and time loss, thereby reducing production efficiency. Therefore, an in-depth analysis is required, one of which can be conducted using the Six Sigma approach, to identify the root causes, reduce process variation, and continuously improve packaging performance.

Define

At the Define stage, the company's value stream mapping, activity classification, and waste identification in the cement packaging process are presented.

Activity Classification

Table 2 presents a recapitulation of activities across all packaging processes. The activity classification was determined through direct observation and brainstorming sessions involving packer operators, production supervisors, and the quality control team. Each activity was categorized as Value Added (VA) if it directly contributed to the final product, Necessary but Non-Value Added (NNVA) if it was required for the process but did not add customer value, or Non-Value Added (NVA) if it could be eliminated without affecting product quality. The classification was validated through consensus among the production team members and cross-checked against the value stream mapping results (Gaspersz, 2020; Hartono & Destian, 2026).

Table 2
Activity Recapitulation

No	Process	VA	NNVA	NVA
1	Bag preparation	0,0%	100,0%	0,0%
2	Bag input process into machine	37,5%	12,5%	50,0%
3	Bag filling process	50,0%	50,0%	0,0%
4	Palletizing process	66,7%	33,3%	0,0%
5	Storage to warehouse	0,0%	100,0%	0,0%
	Total	154,2%	295,8%	50,0%
	Percentage (%)	30,8%	59,2%	10,0%

Source: Research Data

Based on the table 2, a bar chart was created to identify the activities with the highest percentage values that become the focus of the study, as shown in Figure 2.

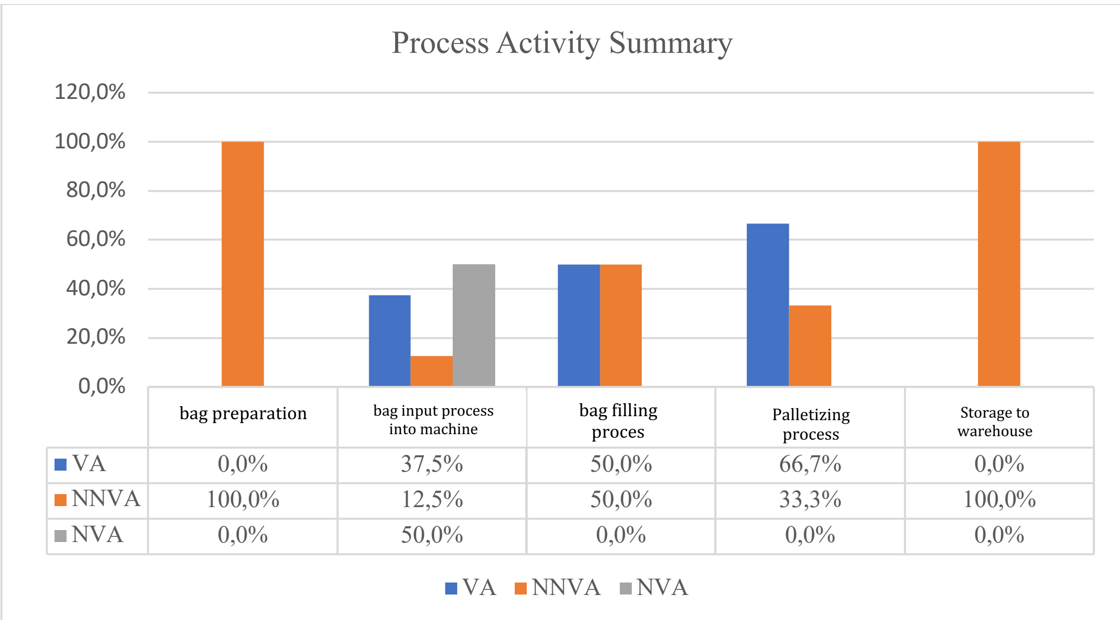

Figure 2. Activity Recapitulation
Source: Research Data

Based on the diagram in Figure 2, 50% of the activities carried out in the bag input process into the machine are classified as Non-Value Added (NVA) activities. These activities include picking up bags that fall during miss shooting bag failures, sorting bags that are still usable, arranging and stacking usable bags, and manually installing bags onto the filling spout one by one.

NVA activities have a considerable influence on the packaging process and should be minimized or eliminated. These activities occur due to failures in the cement bag input process into the machine, resulting in several unnecessary activities that cause waste. Therefore, the following discussion analyzes the waste occurring in the cement bag input process to the packer machine based on these NVA activities.

It should be noted that this study identified only defect waste and overprocessing waste as the primary types of waste caused by miss shooting bag. The remaining six types of waste in the Lean framework (overproduction, waiting, non-utilized talent, transportation, inventory, and motion) were not found to be directly caused by miss shooting bag. Overproduction does not occur because the packer machine operates based on demand targets. Waiting waste is minimal because operators immediately retrieve fallen bags. Transportation and inventory waste are not affected because miss shooting bag occurs at a fixed station. Motion waste, although present during bag retrieval, is subsumed under overprocessing. Non-utilized talent is not applicable in this operational context.

Waste Identification

The following section identifies the waste in the activity of retrieving bags that fall during miss shooting bag failures in the cement bag input process to the packer machine at PT Solusi Bangun Indonesia Tbk, Tuban Plant.

Defect Waste

The defects that occur in the cement bag input process to the packer machine are caused by miss shooting bag. Miss shooting bag occurs when the machine fails to shoot the bag onto the filling spout for cement filling, causing the bag to fall. Table 3 presents miss shooting bag data for the period from April 2024 to May 2025.

Table 3

Production Quantity and Miss Shooting Bag

Period	*Packer* 1		*Packer* 2	
	Production Quantity (Bag)	MSB (*Bag*)	Production Quantity (Bag)	MSB (*Bag*)
Jun	639.869	10.961	827.208	24.558
Jul	936.970	26.648	860.000	36.363
Aug	1.016.975	33.537	869.105	25.676
Sep	672.636	14.177	811.305	33.177
Oct	824.921	14.137	982.973	28.030
Nov	868.683	15.108	786.416	18.423
Dec	421.028	22.602	897.184	17.790
Jan	289.976	8.305	743.952	7.970
Feb	176.472	15.541	699.994	1.603
Mar	113.800	2.702	574.552	9.408
April	233.184	6.691	286.832	8.348
May	642.048	16.000	930.786	22.623
Total	6.836.562	186.409	9.270.307	233.969

Source: Research Data

The occurrence of miss shooting bag requires packer operators to manually retrieve and reinstall the fallen cement bags. However, not all fallen cement bags can be reinstalled and filled with cement because imperfect bag conditions cause them to be classified as defective, making them unusable and potentially resulting in losses.

Overprocessing Waste

In the cement packaging process, overprocessing waste occurs during the activities of sorting usable bags, arranging and stacking usable bags, and manually installing bags onto the filling spout one by one. This overprocessing waste occurs due to miss shooting bag or machine failure when shooting the bag onto the filling spout, whereas the bag-shooting process should be carried out automatically by the machine. Table 4 shows the overprocessing waste that occurred during the June period, which caused the packaging process time to become longer.

Table 4

Overprocessing Waste

Period	*Packer* 1		*Packer* 2	
	MSB (Bag)	*Overtime* (Jam)	MSB (Bag)	*Overtime* (Jam)
Jun	10.961	62,07	24.558	139,06
Jul	26.648	150,90	36.363	205,91
Aug	33.537	189,91	25.676	145,39
Sep	14.177	80,28	33.177	187,87
Oct	14.137	80,05	28.030	158,72
Nov	15.108	85,55	18.423	104,32
Dec	22.602	127,99	17.790	100,74
Jan	8.305	47,03	7.970	45,13
Feb	15.541	88,00	1.603	9,08
Mar	2.702	15,30	9.408	53,27
April	6.691	37,89	8.348	47,27
May	16.000	90,60	22.623	128,11

Source: Research Data

This waste causes the time required for the packaging process to become longer and results in daily overtime. Installing bags manually one by one indicates the existence of process steps that are more complicated than actually needed to achieve the same result.

Measure

The Measure stage is conducted to quantify and process the collected data.

Sigma Value Calculation Due to Defect Waste

The defect data used in the sigma calculation are bag defects caused by improper adhesive application, which represent the most frequent defect type associated with miss shooting bag. When bags fall due to miss shooting bag, the impact can damage the adhesive seal, making it a primary measurable defect directly linked to miss shooting bag occurrences. Therefore, adhesive defect data are used as a proxy indicator to assess the process quality impact of miss shooting bag events.

Table 5

Bag Defects Over a One-Year Period

Period	*Packer* 1		*Packer* 2	
	Production	*Defect (Adhesive)*	Production	*Defect (Adhesive)*
Jun	639.869	346	827.208	1.290
Jul	936.970	705	860.000	1.099
Aug	1.016.975	1.109	869.105	846
Sep	672.636	470	811.305	1.090
Oct	824.921	466	982.973	895
Nov	868.683	469	786.416	582
Dec	421.028	729	897.184	573
Jan	289.976	270	743.952	230

	Packer 1		*Packer* 2	
Period	Production	*Defect (Adhesive)*	Production	*Defect (Adhesive)*
Feb	176.472	525	699.994	40
Mar	113.800	50	574.552	313
April	233.184	223	286.832	274
May	642.048	531	930.786	981
Total	6.836.562	5.892	9.270.307	8.213

Source: Research Data

Calculation of Defects Per Million Opportunities (DPMO) and Sigma Level for Packer Machine

a. Defect Per Unit (DPU)

$\mathrm{DPU} = \frac{\mathrm{D}}{\mathrm{U}}$

$= 0.000862 \mathrm{DPU} = \frac{5892}{6.836.562}$

b. Total Opportunities (TOP)

TOP = Total Production x CTQ

TOP = 6,836,562 x 1 = 6,836,562

c. Defect Per Opportunity (DPO)

$\mathrm{DPO} = \frac{\text{Defect total}}{\mathrm{TOP}}$

$= 0.000862 \mathrm{DPO} = \frac{5.892}{6.836.562}$

The DPO value is the same as the DPU value because there is only one type of defect opportunity, namely inappropriate adhesive.

d. Defects Per Million Opportunities (DPMO)

DPMO = DPO x 1,000,000

DPMO = 0.000862 x 1,000,000 = 861.7879 = 862

e. Sigma Level

Microsoft Excel software was used to determine the sigma value with the formula = $\frac{\text{Norm.S.INV }((1000000-\mathrm{DPMO})}{1000000} + 1{,}5$

Sigma Value (σ) = 4.6341

Based on calculations using the same method, the Sigma Value (σ) for packer machine 2 is 4.6260.

Based on the sigma value calculation, it can be seen that the shooting process in the bag input stage on packer machine 2 is at the fourth sigma level. This can be categorized as very good quality because the defect rate is relatively low, indicating that the process has run consistently and efficiently. Nevertheless, this result is still below the world-class quality standard achieved at the Six Sigma level, with only 3.4 defects per million opportunities; therefore, continuous improvement efforts are still required.

Discussion

Analysis of Sigma Value and Losses Due to Waste

The sigma value can be interpreted as how frequently defects may occur. The higher the sigma level, the smaller the tolerance for defects (Ristyantono et al., 2025). If the number of defects increases, the sigma value will decrease. In other words, a higher sigma value indicates better product quality.

At the Measure stage, the sigma value was calculated for waste occurring in the cement input process. The sigma value for defect waste on packer machine 1 was 4.6341, while that on packer machine 2 was 4.6260.

Compared with the Six Sigma standard, a sigma value in the range of 4.6 indicates that the production process on both machines is still at a fairly good level. This means that both packer machine 1 and packer machine 2 are capable of producing output with a high success rate, although they have not yet reached the optimal Six Sigma level.

When compared with previous studies, the sigma level of 4.6 achieved in this study is higher than that reported by Condé et al. (2023), who found sigma levels of 3.0–3.5 in automotive parts manufacturing before DMAIC implementation. Similarly, Sharma and Yadav (2023) reported sigma levels of approximately 3.8 in a comparable packaging process study. This indicates that PT X's packaging process demonstrates relatively better baseline performance; however, the miss shooting bag problem remains a significant source of waste that prevents reaching the Six Sigma benchmark. In terms of impact magnitude, miss shooting bag incidents on Packer 2 show consistently higher MSB rates (averaging 2.5% of production) compared to Packer 1 (averaging 2.7%), with machine-related factors, particularly weak suction, identified as the most influential root cause based on observation frequency.

Overall, the sigma performance of both machines indicates that the cement bag input process is already at a good level of control with relatively low defects. However, to approach a higher sigma level, the company still needs to identify existing sources of defect waste, whether originating from machine, human, or material factors. Through continuous improvement, the sigma level can be further enhanced so that product quality becomes more optimal and defect risk becomes increasingly minimal.

In addition, overprocessing waste also results in significant losses. This condition occurs due to rework caused by bags falling after they have previously been processed by the packer machine. As a result, workers must perform additional activities outside normal working hours to meet production targets, which affects work efficiency. Therefore, to minimize losses, the company needs to conduct an in-depth analysis in the next stage to identify the root causes of waste.

The total overtime caused by overprocessing waste across both packer machines reached approximately 2,300 hours over the 12-month period, representing a substantial operational cost burden. This finding aligns with Gaspersz (2020), who emphasized that overprocessing waste in manufacturing is often hidden because it is perceived as a normal part of operations (Hartono & Destian, 2026). Furthermore, the recurring nature of miss shooting bag suggests a systemic rather than incidental problem, reinforcing the need for structural improvements as recommended in the Improve stage (Alsadi et al., 2026; Pyzdek & Keller, 2018).

Analysis of Causal Factors Using the Fishbone Diagram

The analysis of causal factors was conducted using a fishbone diagram, as this method can identify and analyze potential causes of a particular problem or effect. The diagram is called a fishbone because its shape resembles a fish skeleton, with the main line representing the backbone and smaller branches representing potential causes (Afriandi & Saifuddin, 2023; Fhadillah et al., 2020).

Figure 3 illustrates the causes of miss shooting bag in the cement bag input process, which results in defect waste and overprocessing waste, based on observations and brainstorming sessions with relevant stakeholders conducted by the author.

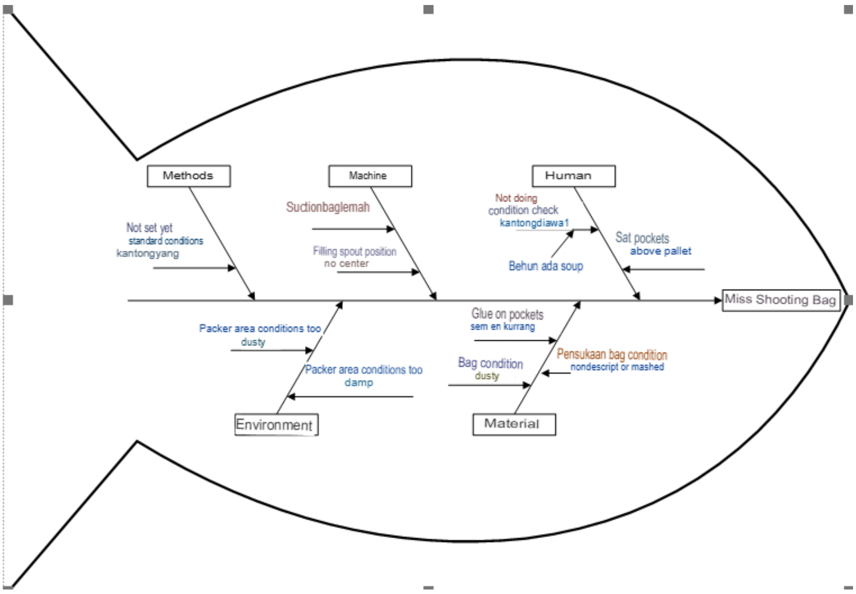

Figure 3. Fishbone Diagram
Source: Research Data

Based on the analysis of the causes of miss shooting bag in the bag input process using the fishbone diagram, it can be identified that the factors causing miss shooting bag are as follows:

1. Human Factor (Man)
   a. Not checking the condition of the bags at the beginning of the process
   b. Packer operators often rest by sitting on stacks of cement bags that will be used
2. Machine Factor (Machines)
   a. The suction bag is in weak condition
   b. The filling spout position is not centered
3. Material Factor
   a. The adhesive on the bags is inappropriate or not properly applied by the supplier
   b. The bags are too dusty
   c. The bag surface is uneven or wrinkled due to stacking or being sat on
4. Method Factor (Methods)
   a. No standard has been established for the condition of bags to be input into the machine
5. Environmental/External Factor (Nature)
   a. The packer area is too dusty due to cement
   b. The packer area is too humid

Improve

The Improve stage is carried out to obtain improvement solutions to address the occurrence of miss shooting bag. Based on the analysis of the causes of miss shooting bag using the fishbone diagram, the effects and improvement solutions that can be implemented to minimize miss shooting bag and eliminate defect waste and overprocessing waste are presented below. The improvement solutions that can be implemented are as follows:

a. Develop and implement an SOP for initial inspection of bag conditions before they are inserted into the machine
b. Provide chairs or a dedicated rest area for packer operators so they do not use stacks of bags as seats
c. Conduct routine maintenance and periodic checks of suction bag suction strength.
d. Perform periodic calibration and adjustment of the filling spout position.
e. Establish bag quality standards, such as proper adhesive, no wrinkles, and dust-free condition, and include them in the operational SOP. Create a bag inspection checklist before use.
f. Conduct quality control of raw materials from suppliers when the goods arrive
g. Store bags in a closed or covered area so they are not directly exposed to dust.

h. Use a vertical storage system or pallet racking so the bags are not compressed, and socialize the rule to workers not to sit on the bags
i. Improve routine housekeeping and cleaning in the packer area
j. Ensure good air circulation, use moisture-resistant pallets, and add silica gel in the storage warehouse.

By utilizing computer vision technology, production cameras can be combined with AI models to directly detect cement bag installation failures. This enables the system to provide early warnings, thereby reducing the number of defects and accelerating operator response.

CONCLUSION

This study demonstrates that miss shooting bag in the cement packaging process at PT X causes two types of waste: defect waste and overprocessing waste. The sigma value calculation reveals that packer machines 1 and 2 achieve sigma levels of 4.63 and 4.62, respectively, indicating good process quality that nonetheless falls short of the world-class 6-sigma standard. The fishbone diagram analysis identifies five categories of causal factors human, machine, material, method, and environment with weak suction bag condition and inappropriate bag adhesive emerging as the most critical root causes. These findings confirm that miss shooting bag is a systemic problem requiring multi-dimensional improvement strategies rather than isolated corrective actions.

Based on these findings, the recommended improvements include establishing bag quality standards and inspection SOPs, conducting periodic maintenance and calibration of suction bags and filling spouts, improving cleanliness and humidity control in the packer area, and providing dedicated rest areas for operators. These recommendations are designed to be immediately implementable and are expected to reduce the frequency of miss-shooting bags, minimize defect and overprocessing waste, and ultimately improve the overall efficiency and cost-effectiveness of the cement packaging process. Future research should consider implementing the Control phase of DMAIC to evaluate the long-term effectiveness of these improvement measures.

ACKNOWLEDGEMENT

The author would like to express sincere gratitude to Universitas PGRI Ronggolawe for providing academic support, research facilities, and encouragement throughout the completion of this study. Appreciation is also extended to industry practitioners and relevant parties who provided valuable information, insights, and support related to the implementation of the Lean Six Sigma approach in reducing miss shooting bag waste in cement packaging processes.

AUTHOR CONTRIBUTION STATEMENT

Anggia Kalista is the sole author responsible for the conceptualization, methodology, data collection, analysis, interpretation of results, and preparation of the original manuscript. The author conducted the research, developed the discussion, revised the manuscript, and approved the final version of the article.

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