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Quality Control of Cement Bags Using Pareto Diagrams and Analytical Hierarchy Process (AHP)

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A B S T R A C T

There are 13 cement manufacturing companies with different production capacities in Indonesia. One of them is a cement company in Bengkulu. A cement company in Bengkulu which has been operating and producing premium quality cement since April 2015 is experiencing quality product issues, particularly regarding its cement bags. Raw material was the largest defect contributor, accounting for 65% of the total defective bags with the causing criteria were raw materials that did not meet specifications, no hole at the end of the valve, bags with poor adhesive strength, oversized bags, oversized pores of the bags, and the valve holes were too tight. Another defect contributor was related to machinery factor that contributed to 30% of the total defective bags with the causing criteria were conveyor belt sway, spout accuracy issue, poor guide plate accuracy, and loading machine with brake issues. Another defect contributor was related to human factor, that contributed to 5% of the total number of defects caused by human error such as lack of focus and fatigue. Pareto diagram was one of the seven tools in quality control. Pareto chart was a special type of bar chart where, each bar represented a different category or part of a problem. The sample used in this study was the number of defective cement bags (40 kg and 50 kg of cement bags) for the period of January-December 2019.

1. INTRODUCTION

As an integral part of the infrastructure ecosystem, cement industries play a vital role in Indonesia's development (Amrina & Lubis, 2017). This function is becoming more crucial as the Indonesian government has enacted Government Regulation No. 14 of 2014 concerning the National Industry Development Master Plan (RIPIN) 2015-2035, which states the cement sector as one of the ten national industry priorities. Similarly, the National Medium Development Plan (RPJMN) 2020-2024, as stated in Presidential Regulation No 18 of 2020, also highlights the vision of strengthening infrastructure in enhancing connectivity and economic growth in which the cement industries play significant parts. Despite their significant contributions to infrastructure development, cement industries have recently faced several challenges, especially concerning sustainability issues (Amrina & Lubis, 2017).

In Indonesia, there are several cement manufacturing companies with different production capacities such as PT. Sinar Tambang Astha Lestari, PT. Semen Tonasa, PT. Semen Padang, PT. Semen Kupang, PT. Java Cement, PT. Semen Gresik, PT. Semen Bosawa Maros, PT. Semen Baturaja, PT. Lafarge Holcim Indonesia, PT. Jui Shin Indonesia, PT. Indocement Tunggal Prakasa, PT. Conch Cement Indonesia and PT. Cemindo Gemilang.

(Amrina & Lubis, 2017) highlighted that as the producers of strategic commodities, all those companies are forced to enhance their production system to make the production process as effective and efficient as possible. It is important to note that a company's capacity to establish an effective and efficient process in its production system not only reduces production costs, leading to a higher level of competitiveness, but also increases the sustainability index of the cement industry. One of the crucial elements in ensuring the efficiency and effectiveness of the process is through reducing the number of defective products, so that waste or inefficiency can be avoided (Fithri et al., 2022).

One of the cement companies that carries out the continuous improvement in quality improvement is a cement company in Bengkulu. The cement factory in Bengkulu produces Portland Composite Cement (PCC), bulk cement products, and concrete cement products. Total production of Portland Composite Cement (PCC) can be seen in Table 1.

This company has established the characteristics of product quality standards that meet consumer expectation. However, defective products or products that do not align with the intended specifications do commonly take place in the shop floor.

Table 1. Total Production of Portland Composite Cement (PCC) of cement company in Bengkulu

Month	Quantity
January	5.909,25
February	3.358,30
March	3.158,70
April	3.293,30
May	4.212,76
June	7.369,14
July	9.513,11
August	7.095,85
September	14.119,90
October	16.047,15
November	14.879,51
December	13.328,00
Total	**102.284,97**
Average	8.523,75

Source: Cement company in Bengkulu (2019)

The cement company in Bengkulu experienced defective products in its Portland Composite Cement (PCC) bag. The PCC bags consist of two sizes, namely 40 kg and 50 kg of cement. The defects found are bags that are easily broken, bags with no hole at the end of the valve, bags with poor adhesive strength and the size of the bags that does not meet the specification. Factors causing defective cement bags are raw material, machine, and human factors. The data of defective cement bags are as shown in Figure 1.

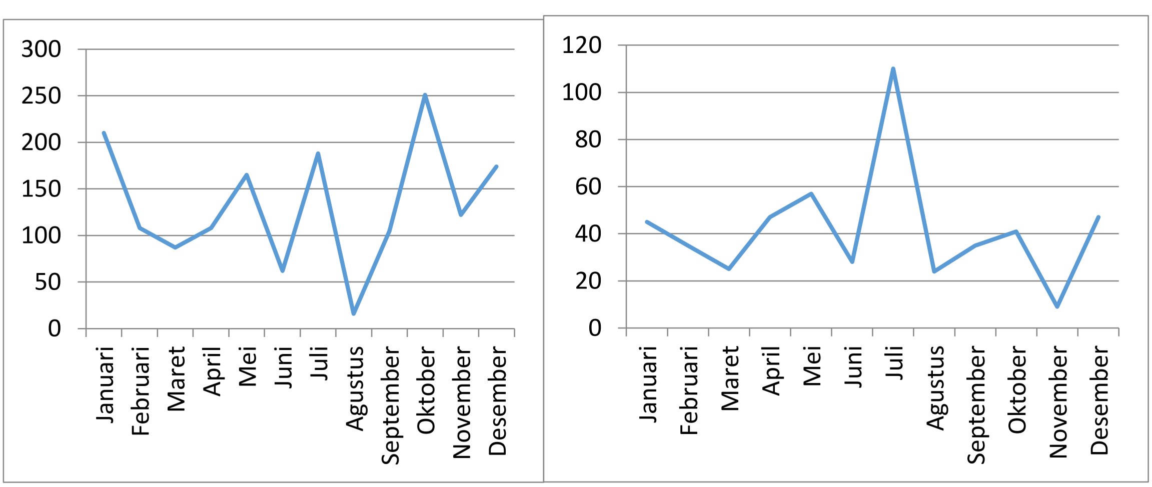

Figure 1. Defective products of 40 and 50 kg of cement bags

Source: Cement company in Bengkulu, 2019

(Ernita, 2016)'s research on Quality Control of Cement Bag Products at Line IV of PT Semen Padang's Packing Plant also found dominant defects in cement bags, 34% due to defects in cement products, 30.5% due to improper valve installation. The reason was because the engine factor caused by the improper engine settings that make the position of the valve was incorrect.

The competitors did also experience this defect of cement bags as it was recorded in a study conducted by (Helia & Suyoto, 2018). At PT. XYZ, there were 8 problems with cement bags defects, there are issues with the end bottom, tube width deviation, pasting tube issues, deviation of overlap distance of two consecutive papers, deviation of the tube length, incomplete cap. Based on the Pareto diagram analysis, among those 8 problems faced by PT. XYZ, it was obtained that the bottom failure on the pasted bag was the biggest contributor of the defects, accounting for 60%.

This study aims to determine the causing factors of bag defects and to design strategies in controlling the causes of cement bag defects. It is expected that the findings of this study will contribute to shed light on quality thinking within the company in implementing quality control.

Quality Control

Quality control is a very useful tool in ensuring products to meet its specifications from the beginning to the end of the processes. The main purpose of quality control is to attain quality assurance of the product or service produced in accordance with the quality standards that have been set at the lowest possible cost. Quality control can be done using the seven tools method (Kamal & Sugiyono, 2019).

According to (Marlina, 2022) there are seven quality control tools, they are check sheets, scatter diagrams, cause and effect diagrams, pareto diagrams, flow diagrams, histograms and control charts.

Pareto Diagram

The Pareto diagram according to (Heizer, Jay and Render, 2015) is as shown in Figure 2.

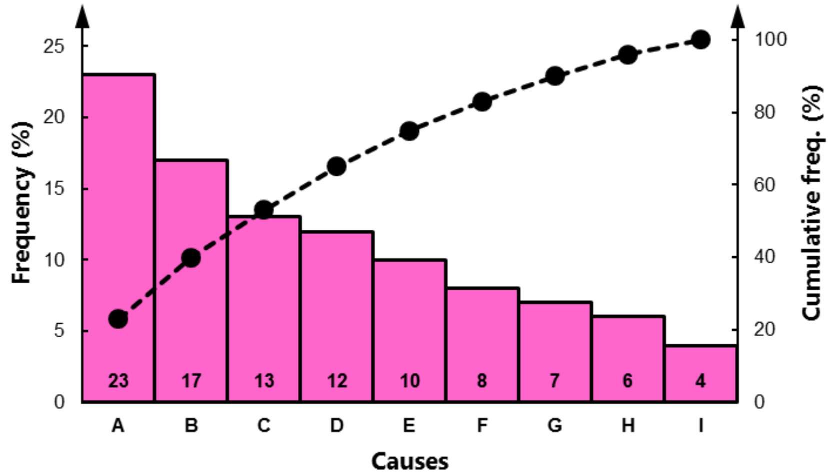

Figure 2. Pareto diagram
Source: Heizer, Jay and Render, 2015

According to (Realyvásquez-Vargas et al., 2018) a Pareto diagram is a special type of bar chart where, each bar represents a different category or part of a problem.

Pareto diagram is one of the seven tools in product quality control. The Pareto diagram according to is one of the seven quality control tools in the form of a diagram that is used to identify quality characteristics that need to be prioritized for improvement.

Pareto distribution and pareto analysis may be considered as an efficient tool that is used to help in analyzing defects and diagnose all causes and the cause roots of the biggest defects to determine and take necessary corrective actions which will minimize product defects (Al-Baldawi & Ali Hussein, 2020).

A Pareto chart is a chart that shows data classifications and values, while line charts represent cumulative data totals. Data classification is sorted according to ranking order. The highest ranking is the most crucial problem to be resolved immediately. The principle of the Pareto chart follows Pareto's law which states that a group always has the smallest percentage (20%) that is worth or had the most significant impact (80%). The Pareto chart identifies 20% of the main problem causes to realize 80% overall improvement (Marlina et al., 2020).

Analytic Hierarchy Process (AHP)

Analytic hierarchy process (AHP) is a model developed by Thomas l. Saaty as a decision support model regarding multi-factor or multi-criteria complex problems into a hierarchy. The AHP has an ability to solve a multi-criteria problem by facilitating a comparison procedure on preferences of an element in the hierarchy. The comparison score given by the respondent must be constructed as a set of pairwise comparison matrices. The comparison matrix of both criteria and sub-criteria was then analyzed to determine the priority weight of each element (Nurani et al., 2017).

(Setiawan & Setiawan, 2020) stated that AHP is commonly used to find the ranking or priority order of various solutions to a problem. In this study, AHP was employed to find out the strategies used to control cement bag defects.

2. RESEARCH METHODS

This research uses qualitative and quantitative methods using Pareto Diagrams and Analytical Hierarchy Process (AHP). Quantitative method is a research based on the philosophy of positivism, are used to examine certain populations or samples, data collection uses research instruments, data analysis is quantitative or statistical (Sugiyono, 2014). Descriptive quantitative method modeled a comprehensive decision making using analytical hierarchy process (AHP).

According to (Marlina et al., 2020) qualitative analysis was carried out descriptively. Descriptive qualitative method is using triangulation by checking the information obtained from direct interviews to Manager and employees as in Table 2.

Table 2. Research Triangulation

Manager	Employees
The raw material factor is the most significant contributor to defects in the total defective cement bags.	The causes of damaged cement bags are caused bags breaking when they fall. There is no hole at the end of the valve, the adhesive on the bag is not strong, and the bag size is not according to what is specified.

Source: Researcher (2019)

Descriptive research is a type of research that involves the studied use of a collection of multiple empirical materials and sources or interprets phenomena such as case studies, individual and group interviews and so on. The object of this research was defective products of 40kg and 50 kg of PCC cement bags. According to (Sekaran, Uma and Bougie, 2003), the population refers to the entire group of things of interest that the researcher wishes to investigate. The population of this study was the total number of defective 40kg and 50kg cement bags in 2019. The sample of this research was 2,099 defective bags derived from 1,596 of 50 kg cement bags and 503 of 40 kg cement bags.

This research consisted of primary and secondary data which can be seen in Table 3

Table 3. Types of data

Primary data	Secondary data
Interview on the root cause of defective cements	Total number of defective 40 kg and 50 kg of PCC cement bags

Source: Researcher (2019)

Pareto diagram is a diagram that classifies data from left to right according to the highest to lowest ranking so that important problems are found to be resolved immediately. The formula of diagram Pareto can be seen in the following (Sunarto, 2020).

$$\text{Percentage of defect} = \frac{\text{The number defects of each contributor}}{\text{Total number of defects}} \times 100\% \quad \text{................(1)}$$

The data collection based on interview of the Production Manager of Bengkulu cement factory to determine the cause root of defective cement bags using Pareto diagram instrument (Wisnubroto et al., 2019). In this study, several procedures were used to completely conduct the research as is drawn in flow diagram below.

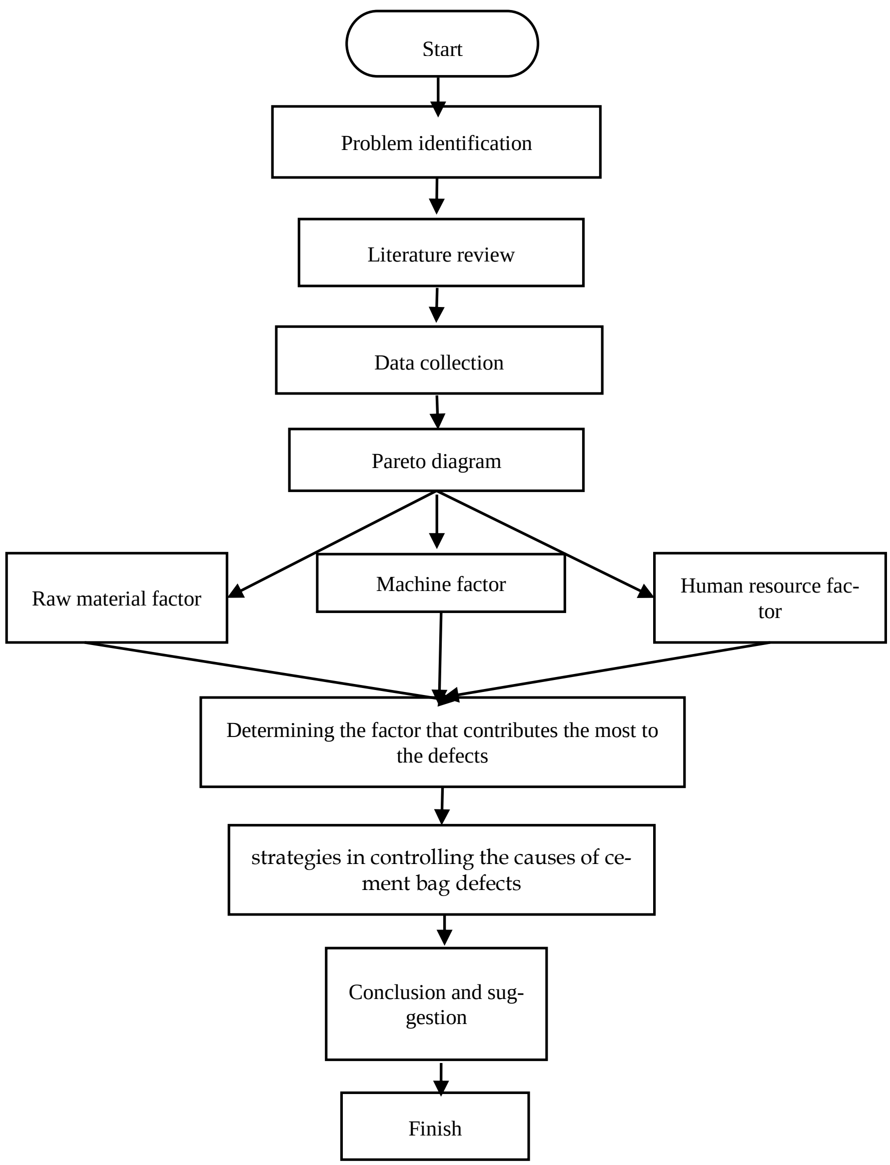

Figure 3. Flow diagram of the study

Source: Processed data, 2019

Figure 3. shows that after knowing the cause-effect of the defective cement bag using Pareto Diagram, the company will make a strategy to avoid the defects by using AHP.

There are six main steps in the application of the AHP method (Nedjar, Nizar Hassoun, Yassine Djebbar, 2022):

(1) Step 1: Identification of the objective

(2) Step 2: Selection of evaluation items

(3) Step 3: Building the hierarchical structure

(4) Step 4: Establishing the decision matrices

(5) Step 5: Calculating the priority vector for each element

6) Step 6: Check the consistency ratio (CR) for each element

In solving problems using AHP, there are several principles that must be fulfilled, one of which is a comparative judgment which is the process of assessing the relative importance or preference of pairwise elements in a level related to the level above it. This principle provides an assessment of the relative importance of two elements at a given level that relates to the level above it. The results of this assessment are presented in the form of a pairwise comparison matrix. The importance scale of the AHP can be seen in Table 4.

Table 4. Basis of comparison criteria

Intensity of importance	Definition
1	Equal importance
3	Weak importance of one over another
5	Essential or strong importance
7	Very strong importance
9	Absolute importance
2,4,6,8	Intermediate values between two adjacent judgments

Source: Nedjar, Nizar Hassoun, Yassine Djebbar (2022)

3. RESULTS & DISCUSSION

The problem that occurs in the 50 kg of cement bag product at the cement company in Bengkulu was related to the raw material factor, with a total defect of 1036 items, equivalent to 64.9% as it is shown in table 5

Table 5. Percentage of defects and percentage of cumulative defects of 50 kg cement bags

Category	Total defects	Percentage of defects	Cumulative percentage
Raw material	1036	64,9%	64,9%
Machine	481	30,1%	95%
Human resources	79	4,9%	100%
Total	1596	100%	

Source: Cement company in Bengkulu (2019)

Based on the calculation, it can be depicted in a Pareto diagram which shows the comparison of problem categories as shown in Figure 4.

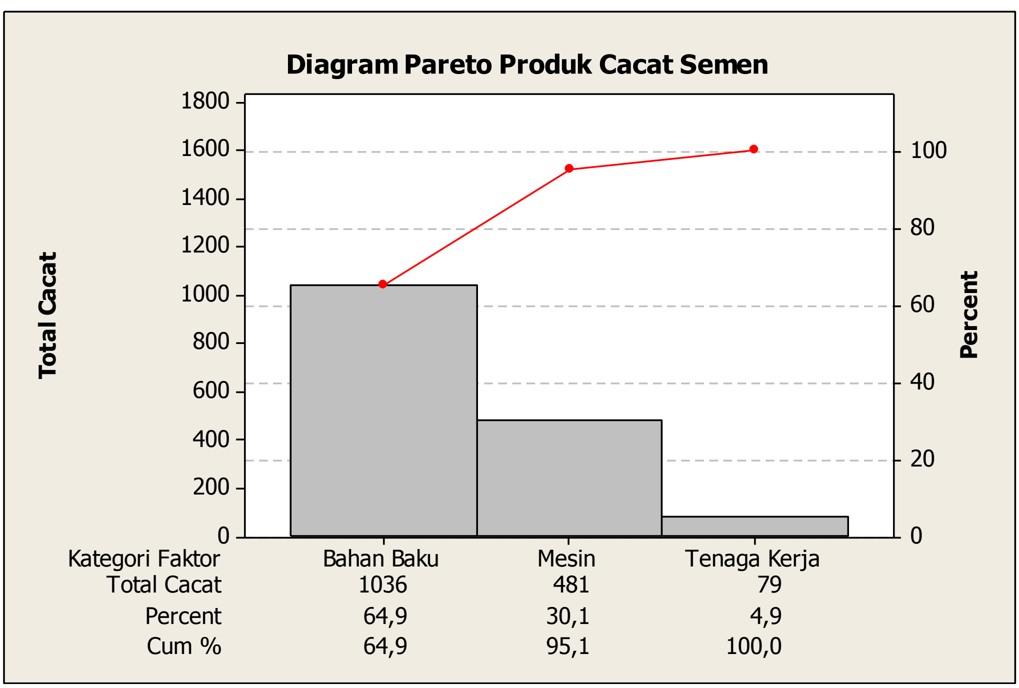

Figure 4. Pareto diagram of 50 kg of cement bags

Source: Processed data, 2019

The problem that occurred in the 40 kg of cement bag product at cement manufactures in Bengkulu was related to the raw material factor, with a total damage of 329 units, equivalent to 65.4% as it is shown in table 6.

Table 6. Percentage of defects and percentage of cumulative defects of 40 kg cement bags

Category	Total defects	Percentage of defects	Cumulative percentage
Raw material	329	65,4%	65,4%
Machine	151	30%	95,4%
Human resources	23	4,6%	100%
Total	503	100%	

Source: Cement company in Bengkulu (2019)

Based on the calculation, it can be depicted in a Pareto diagram which shows the comparison of problem categories as shown in Figure 5.

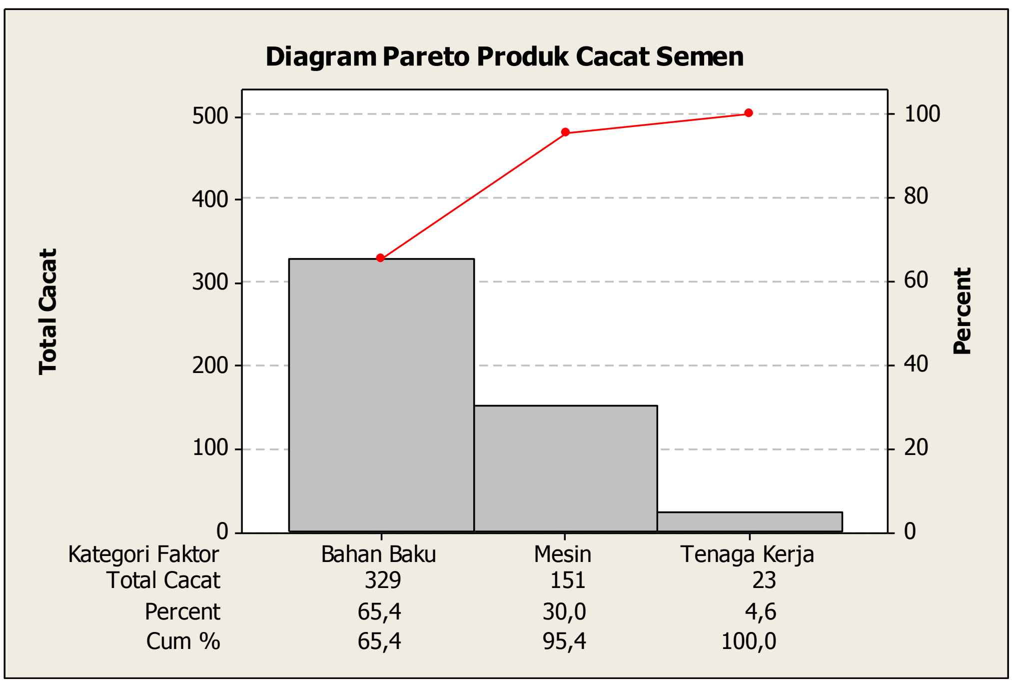

Figure 5. Pareto diagram of 40 kg of cement bags

Source: Processed data, 2019

Using Pareto diagram for both 40 and 50 kg of cement bags above, it can be concluded that the biggest contributor of the defects was the raw material factor. This finding is in line with previous research by (Salawu et al., 2018) which used Pareto Diagrams to identify product defects. Pareto diagram has provided a clear understanding of the various quality issues associated with process and packaging solution.

Analytical Hierarchy Process (AHP)

According to (Andalia, 2017), the Analytical Hierarchy Process (AHP) is a comprehensive decision-making model by considering qualitative and quantitative aspects. In the strategy for dealing with cement defects, several decision criteria are made as shown in Table 7.

Table 7. Pair-wise comparison level I

Element	Cement testing	Cement bags	Inspection
Cement testing	1,000	4,219	3,876
Cement bags	0,237	1,000	2,434
Inspection	0,258	0,411	1,000
	1,495	5,630	7,310

Source: processed data (2019)

The presented table illustrates the three primary components contributing to cement bag faults, namely cement tests, cement bags, and inspection. The elements mentioned are further categorized as illustrated in Table 8. The calculation of pair-wise comparison level II can be seen in Table 8.

Table 8. Pair-wise comparison level II

Element	**Cement color**	**Float Test**	**Setting Test**	**cement strength testing**	**Packing date**	**Cement slump**
Cement color	1,0000	3,5713	3,8730	3,9140	3,1355	3,4364
Float Test	0,2800	1,0000	2,4052	3,0000	4,7510	3,0000
Setting Test	0,2582	0,4158	1,0000	3,0000	3,3227	3,0000
cement strength testing	0,2555	0,3333	0,3333	1,0000	2,5210	3,0000
Packing date	0,3189	0,2105	0,3010	0,3967	1,0000	3,1572
Cement slump	0,2910	0,3333	0,3333	0,3333	0,3167	1,0000
Total	2,4036	5,8642	8,2458	11,6440	15,0469	16,5936

Source: processed data (2019)

According to the Pair-wise comparison level II table for cement testing elements, the factors included are Cement color, Float Test, Setting Test, cement strength testing, Packing date, and Cement slump. It is observed that Cement slump has the largest overall weight among these factors. The calculation of pair-wise comparison level II can be seen in Table 9

Table 9. Pair-wise comparison level II

Element	**Motif shape**	**Additional material**	**Photo size**
Motif shape	1,000	0,220	2,636
Additional material	4,547	1,000	4,870
Photo size	0,379	0,205	1,000
Total	5,926	1,425	8,506

Source: processed data (2019)

According to the data shown in Table 9, pair-wise comparison level II is a component of the cement bag elements, encompassing the bag's shape theme, additional material, and photo size. Based on the weight measurement of the photograph contained within each bag, identify the bag that exhibits the greatest weight value. The calculation of partial weight of each level can be seen from Table 10 to Table 12.

Table 10. Weighted Level I

Element	Changing of manufac-turing bag	Batch number	Cement layer	Partial weights
Changing of manufactur-ing bag	0,669	0,749	0,530	0,649
Batch number	0,159	0,178	0,333	0,223
Cement layer	0,173	0,073	0,137	0,128
Total	1,000	1,000	1,000	1,000

Source: processed data (2019)

Table 10 displays the components involved in the inspection of cement bags. This category encompasses the examination of the manufacturing bag, batch number, and cement layer. The maximum weight achieved was associated with the alteration of the manufacturing process for cement bags.

Table 11. Weighted Level II

Element	Cement color	Float testing	Setting testing	Strength testing	Packaging date	Cement slump	Partial weights
Cement color	0,416	0,609	0,470	0,336	0,208	0,207	0,374
Float testing	0,116	0,171	0,292	0,258	0,316	0,181	0,222
Setting testing	0,107	0,071	0,121	0,258	0,221	0,181	0,160
Strength testing	0,106	0,057	0,040	0,086	0,168	0,181	0,106
Packaging date	0,133	0,036	0,036	0,034	0,066	0,190	0,083
Cement slump	0,121	0,057	0,040	0,029	0,021	0,060	0,055
Total	1,000	1,000	1,000	1,000	1,000	1,000	1,000

Source: processed data (2019)

According to the data presented in Table 11, it is evident that color cement exhibits the largest weight value compared to float testing in the context of cement testing. Consequently, it is imperative for the organization to focus on enhancing these two aspects.

Table 12. Weighted Level II

Element	Changing of manufac-turing bag	Batch number	Cement layer	Partial weights
Changing of manufac-turing bag	0,169	0,154	0,310	0,211
Batch number	0,767	0,702	0,573	0,681
Cement layer	0,064	0,144	0,118	0,109
Total	1,000	1,000	1,000	1,000

Source: processed data (2019)

According to the data shown in Table 12, it can be observed that the batch number with the highest weight has a significant impact on the occurrence of damage to cement bags. The weight ranking for the Analytic Hierarchy Process (AHP) of the damaged cement bag is derived. According to (Nedjar, Nizar Hassoun, Yassine Djebbar, 2022), the values of the urgency level obtained ranged from 0.1261 to 0.4816. Subsequently, the bags were grouped into four classes of urgency levels:

(1) 1st level: urgency level > 0.3000

(2) 2nd level: 0.2300 < urgency level ≤ 0.3000

(3) 3rd level: 0.1500 < urgency level ≤ 0.2300

(4) 4th level: urgency level ≤ 0.1500

From the calculation above, it provides recommendations as shown in Table 13.

Table 13. Strategy recommendations

Rank	Alternative	Total value
1	Batch number	0,681
	Cement color	0,374
2	Changing of manufacturing bag	0,211
3	Float testing	0,222
4	Cement layer	0,109

Source: processed data (2019)

Based on the recommendation strategy above, it is required for the management of the company in order to ascertain the cause of damages in each batch of cement, whether resulting from mechanical or human factors, it is necessary to conduct a thorough inspection. The implementation of AHP can be conducted in manufacturing and non-manufacture industry as it aligns with the previous study conducted by (Sarjono et al., 2020).

4. CONCLUSION & SUGGESTION

Based on research, the conclusion of research as followings: The average production bags of Portland Composite Cement (PCC) of cement company in Bengkulu is 8523.75 tons/month; meanwhile, the number of defects in bag production cement was estimated cumulatively occur every month on average 1596 bags for 50 kg and 503 bags for 40 kg. Without quality control, the company lost a massive amount of money every month. Of those 3 factors causing cement defects in the cement company in Bengkulu, the most dominant factor causing the 50 kg of cement bag defects was the raw material factor, accounting for 64.9% of the total defects. It was then followed by the machine factor and human resource factor, accounting for 30.1%. and 4.9% respectively. Similarly, in a 40 kg of cement bag, the most dominant factor causing the defects was also the raw material factor, accounting for 65.4% of the total defects. It was then followed by machine factor and labor factor, accounting for 30% and 4.6% respectively. It means the company has to control the raw materials of cement before processing them to avoid the bag cement defects. From AHP calculation, it was found that cement layer is the decision criteria with the highest weights, scoring for 0.681. It was then followed by batch numbering with score of 0,211 and changing of manufacturing bags with score of 0.109. According to the results of this model, the cement layer is considered with high risk to damage of cement bags. Management of the company should produce cement bag with more than one layer.

The implication of this research is it contributes to formulation strategy of decision making at a cement company in Bengkulu in dealing with product quality control. The strategy that can be applied in controlling defects lies in the raw material treatment, where it requires the company to reduce the water content of the clinker before proceeding to next processes as well as cement bag inspection for ensuring quality of the bags. For example, raw materials such as clay and limestone should dry before going through to cement process. For the defects that are related to the machine factor, the solution strategy that is required for company to implement is to carry out preventive maintenances such as establishing regular maintenance schedule, replacing any broken or unreliable parts, and so on. The operator should check the machines manually to avoid damage to cement bags. For the defects that are related to the human factor, some initiatives that management needs to establish within the company is conducting direct supervision to the operator, establishing shift work and rotation, as well as providing an appropriate work schedule the operators. Management must also include standard operating procedures for the packaging division

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