Original Research

Performance Analysis of Coal Unloading Equipment Using Quality Control Circle Method

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Abstract

This study aims to analyze the performance of coal unloading equipment apron feeder 1-4 which the unloading target wasn't achieved. One of the main aspects of mining activities is the transportation of coal and unloading of coal. Meanwhile, unloading is the activity of moving material or coal from the previous transportation to a place or tool on an ongoing basis. In the supply chain, the railway system has an important role in the distribution of goods because the train has a short travel time with a large capacity. The results of analysis of the existing situation showed that the unloading target was not achieved due to the high obstacles of apron feeder 1-4 and the slow unloading on the apron feeder. The results of root cause analysis obtained the roots of the problem were the modification of a new train carriage which caused the length of the train carriage wasn't suitable with apron feeder and there was no safety device in some parts, because of that we have modified the dimensions of apron feeders 1-4 which was adjusted to the length of the new train carriage with a target of decreasing slow unloading. With the decreasing of the unloading obstacles, the unloading achievement has increased.

Keywords - Apron Feeder; Coal Unloading; Equipment; Quality Control Circle

INTRODUCTION

Coal provides many advantages, including being a power source for electricity generators, the main fuel for the production of steel, cement, aluminum, and other industrial production [1]. Coal is one of the potential mining commodities in Indonesia. In Indonesia, coal transportation is commonly by land, train, and sea or river as a mode of transportation [2]. Coal is, therefore, both a source and reservoir rock for the gas [3]. One of the main aspects of mining activities is the transportation of coal and unloading of coal. Meanwhile, unloading is the activity of moving material or coal from the previous transportation to a place or tool on an ongoing basis. In the supply chain, the railway system has an important role in the distribution of goods because the train has a short travel time with a large capacity [4]. PT Bukit Asam Tbk Kertapati Port continues to make efforts to unload and deliver coal delivered on time as planned. The Kertapati Port has the main duties and functions to receive coal from the Tanjung Enim Coal Handling and Transport Unit sent by train and to unload and release or deliver coal to designated customers and coordinate with the Marketing Work Unit by barge boat or ship. Transportation is one of the problems faced by consumers in the coal supply chain [5].

In the case of receiving coal sent by train carriage, it will be unloaded using an apron feeder unloading equipment. Apron Feeder is one of the tools used to accommodate the results of unloading coal from train cars, then transferred to a belt conveyor and transported using a conveyor system. There are four apron feeders (AF), namely AF Number 1 (AF 1) until AF Number 4 (AF 4)

In the implementation of unloading or unloading, delays often occur which affect the achievement of unit targets and delays in coal delivery. The target has not been achieved for two months.

One of the dominant causes of delays in unloading time is the ability of the apron feeder to receive coal. This is of course inseparable from the suitability of the capacity of the train carriages with the capacity of the apron feeder. There are three types of carriages of train series that transport coal, namely Romanian carriages with a capacity of 30 tons, Inka (boats), and Flat Carriages with a capacity of 45 tons. The chute apron feeder 1-2 (AF 1-2) capacity is currently able to accommodate 60 tons of coal (with a length of 26 meters) or the equivalent of 2 Romanian carriages, while the apron feeder 3-4 (AF 3-4) is currently able to accommodate 30 tons (12 meters long) and that's the equivalent of 1 Romanian carriage. For boat carriages with a capacity of 45 tons with a length of 16 m, only 1.6 carriages can be unloaded in AF 1-2 and AF 3-4 as many as carriages, so that it takes a longer unloading time to adjust the position in the train line. The average length of delay in loading and unloading AF 1-4 is 926 minutes per month. In addition, the apron feeder obstruction is also one of the other factors that hinder demolition activities, where in the last three months, the average time of AF 1-4 obstruction is 920 minutes per month. The formulation of the problem in this study is the high resistance of the apron feeder and slow loading at AF 1-4. This study aims to analyze the performance of coal unloading equipment related to the speed of coal unloading or unloading time, apron feeder obstruction, and capacity. unloading equipment to achieve the company's target. The benefits of this research are expected to improve existing problems by using the Quality Control Circle method.

A coal power plant is a power plant whose main fuel is coal. the handling system is called a coal handling facility to meet the huge demand for coal fuel [6]. Coal Handling Facility (CHF) is a coal handling system at the Kertapati Port Unit that starts from the coal receiving system using an apron feeder unloading device which is then distributed through a belt conveyor to the crusher to get the size according to market demand. Coal loading and unloading port is the transportation of coal by land and then shipped by barge [7]. The coal handling operation also becomes increasingly stressful because extension of wharves or augmentation of handling equipment commonly has a long implementation time and is expensive [8]. The main focuses today are on safety, efficiency, quality, cost of design and transportation and, of course, higher capacities [9].

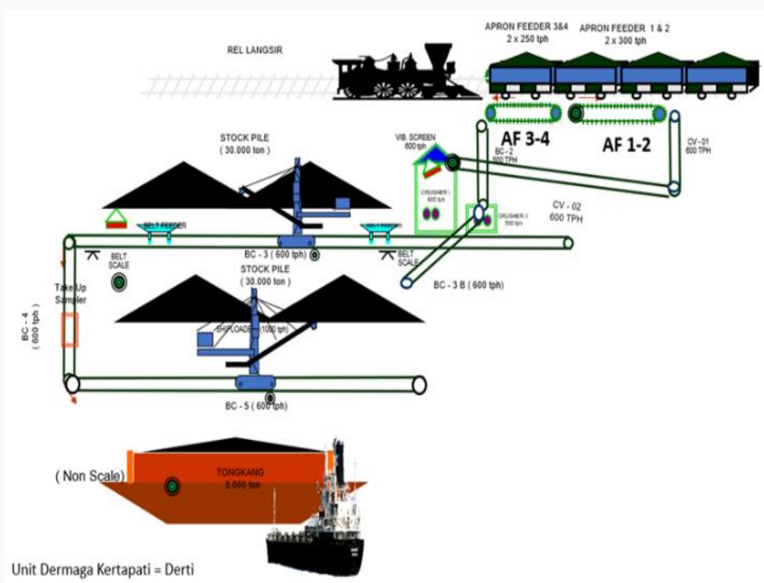

FIGURE 1
CHF KERTAPATI PORT UNIT

The next stage is the coal will be redistributed using a belt conveyor to the unloading equipment to the stock or distributed directly to shipments via the ship loader. Coal is transferred to the mill bunkers from the coal yard using a conveyor belt. in each mill bunker, there is one hopper that connects to the feeders [10]. For low capacity facilities, the rail car (or wagon) load-out area may be as simple as an apron feeder for front-end loaders to load directly into the cars [11]. For coal that is already in the stockpile, it can be redistributed to be loaded onto ships via a belt feeder and loading stock using a wheel loader. Apron Feeder is a means of transporting bulk material which is pulled by a belt or endless chain in horizontal and diagonal directions. AF capacity 1-2 with a capacity of 60 tons with a length of 26 meters (AF speed 25 m/min or 1,500 m/hour). AF capacity 3-4 with a capacity of 30 tons with a length of 12 meters.

A quality circle is defined as a minor cluster of workforces in an analogous field that is willing to repeat important work to group complications related to quality improvement, explain optimal articulation and provide consequences for administration along with recommendations for execution [12]. The quality control circle discusses problems that occur within the company and provides recommendations for problem-solving to management [13]. Quality improvement is important for every industry, and QCC is one of the popular TQM tools used in the industry. Much of QCC focuses on performance and leadership, but its application to organizational and group learning is still under-recognized [14]. Continuous improvement in maintenance activities, its methodologies and tools used, makei it complex to obtain the failure free production process/operation, and this objective try to fulfil by pointing out and substituting critical unit/components or through manufacturing surplus [15].

METHODS

The primary data used here are AF 1-4 unloading equipment performance data, dominant equipment obstruction data, coal transportation performance data, target data for the Company's Budget Work Plan, realization, and lack of achievement, AF material usage, and cost data 1- 4.

In carrying out this data processing, the authors use the QCC (Quality Control Circle) method with 8 steps as follows:

(1) Identify the problem by looking at the 4M+1E factor (Man, Method, Machine, Material, and Environment).
(2) Setting targets based on the identification of Specific, Measurable, Achievable, Realistic, and Time-Bound (SMART) aspects.
(3) Conduct a direct field inspection by taking into account the 4M+1E factor. This analysis will be carried out concerning the Fishbone Diagram and Flow Chart tools which will be processed to find out the root of the problem.
(4) From some of the existing root causes, analysis is needed to find solutions or improvement ideas to overcome existing problems so that they do not happen again. The analysis used using the 6W1H method to get a solution to the problem at each root of the problem.
(5) Collecting data on repair activities that have been carried out, and if there are countermeasures that are still not effective, then PDCA (Plan Do Check Action) planning must be carried out until it is successful. The QCC program followed the Plan-Do-Check-Act process [16].
(6) Evaluate the targets that have been set, then do a comparison between before and after repairs.
(7) After the evaluation results are considered effective and can provide the best solution to the root of the problem, the next step is to standardize with the approval of the relevant parties so that previous problems do not recur.
(8) Carry out further improvement plans for other problems that may arise after repairs or that have not been resolved.

RESULTS AND DISCUSSION

The performance data for the unloading apron feeder equipment that will be used has shown on Table I. The achievement of the coal unloading target in October 2020 was 96.47% of the target, in November 2020 there was an increase in the achievement of the target as much as 104.11%, and there was a decline in the achievement of the target as much as 90.97%.

TABLE I
PERFORMANCE UNLOADING IN OCTOBER - DECEMBER 2020

Period	Target (ton)	Actual (ton)	Percentage (%)	Time		*Unloading* Rate (tph)
				Unloading (min)	Obstacle (min)	
October	489.500	472.238,65	96%	50.276	16.124	830
November	473.500	492.983,21	104%	52.419	14.159	773
December	489.500	445.304,29	91%	43.105	9.410	793

For apron feeder 1, in October, 192 train series were received with a tonnage contribution of 276,120 tons. In November, apron feeder 1 received a series of 185 train series with a tonnage contribution of 261,975 tons, and in December, apron feeder 1 received a series of 155 train series with a tonnage contribution of 222,300 tons.

Of the six dominant obstacles that occurred in the last three months, we sort them based on the highest priority of completion from the Pareto that shown in Figure 2, then we get two main problems with the highest obstacle time are slow unloading AF 1 with an average hit time of 926 minutes and apron feeder (AF) obstruction 1 with an average hit time of 920 minutes. A Pareto diagram is usually constructed aiming at the determination and display of particularly high-risk processing steps and their corresponding corrective actions [17].

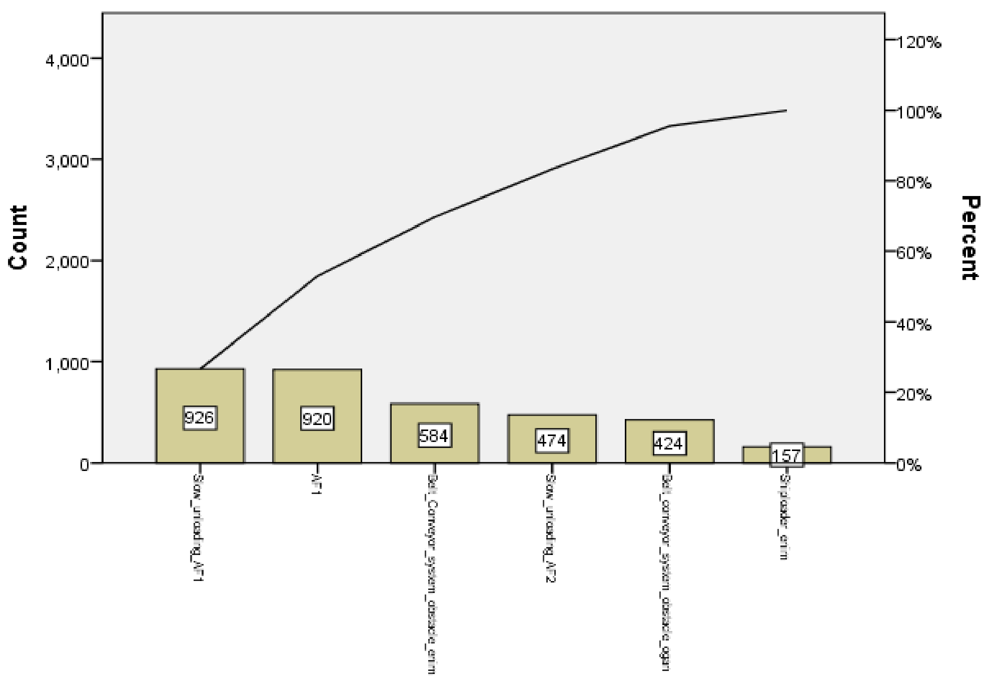

FIGURE 2
THE SIX DOMINANT OBSTACLES

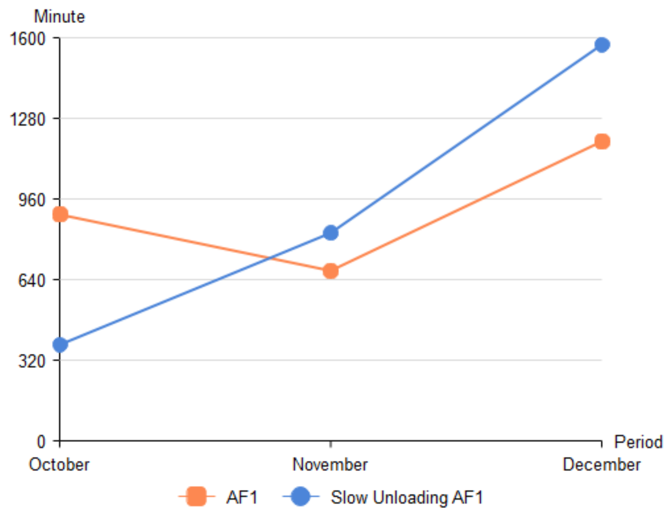

FIGURE 3
OBSTACLE TIME OF TWO HIGHEST DOMINANT OBSTACLE

From this data, it can be seen that the highest obstacle that occurred in the last three months was in December 2020 with a total time of AF 1 obstruction of 1,188 minutes with a frequency of 29 times. Besides that, there is also an obstacle in the form of the highest slow loading in December 2020 on AF 1 with a total time of 1,572 minutes with a frequency of 41 times. Slow unloading means the machine or tool for unloading the apron feeder operates but the unloading time exceeds the target is 120 minutes. If we look at the capability of AF 1 in December 2020 where the unloading target is 489,500 tons with the actual achievement of 445,304,287 tons, it can only be achieved 91% of the target. Therefore, it can be concluded that one of the reasons for not achieving the AF 1 coal unloading target was the high obstacles.

For several types of AF 1 obstacles that occur due to mechanical obstacles such as broken chains, raised buckets, broken bucket shafts, loose buckets, broken sprocket shafts, broken AF rails, as well as electrical obstacles such as electrical faults, MCB trips, and electrical systems in AF 1. As for the delay in unloading AF 1, it is caused by the slow setting of the unloading position of the train and the speed in unloading the train carriages. The realization of train transportation performance in the last three months is as shown in Figure 4.

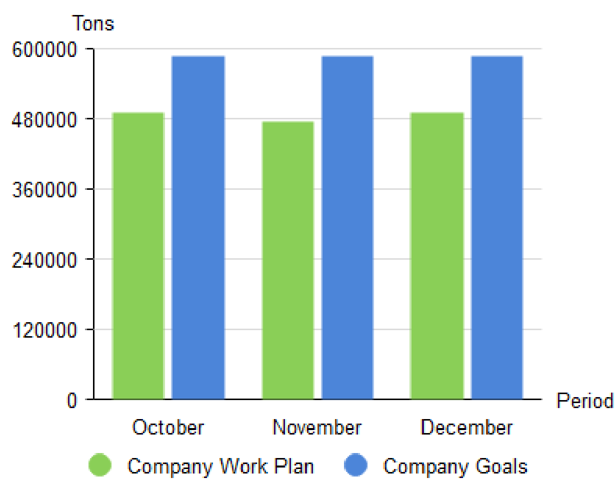

FIGURE 4
TRAIN TRANSPORTATION PERFORMANCE IN OCTOBER – DECEMBER 2021

Meanwhile, from the accumulated difference in coal unloading achievements from October-December 2020 by company work plan target, there is an amount of coal unloading loss of 61,457 tons that is shown in Table II. This is certainly very influential on the company's performance in achieving targets. Therefore, it is necessary to take steps to improve the deviation of the unloading loss.

TABLE II
LOSS UNLOADING OKTOBER – DESEMBER 2020

Period	Company work plan Target (ton)	Actual (ton)	Company work plan Loss (ton)
October	489.500	472.238,649	-1,7261.351
November	473.500	492.983,211	19,483.211
December	489.500	445.304,287	-44,195.713
		Total *Loss*	- 61,457

Types of AF 1 obstacles that occur due to mechanical obstacles such as broken chains, raised buckets, broken bucket shafts, loose buckets, broken sprocket shafts, broken AF rails, as well as electrical obstacles such as electrical faults, MCB trips, and electrical systems and amount of damages is shown in Table III.

TABLE III
MATERIAL COMPONENTS IN APRON FEEDER

Parts	Oct 2020 (pcs)	Nov 2020 (pcs)	Dec 2020 (pcs)	Total (pcs)
Bracket	95	53	131	279
Bucket	21	14	52	87
Bushing	135	64	67	266
Inside Link	81	70	74	225
Keyplate	39	19	14	72
Outside Link	5	3	3	11
Roller	96	23	18	137
Shaft	9	9	3	21
Total	481	255	362	

I. *Train Carriages Modification*

To produce a good quality final product, process control plays an important role of final product inspection [20] . The modelling of the train dynamics is challenging [21]. The old Romanian carriages (30 tons capacity) have a length dimension of 12 meters per carriage. As for the new Flat Carriages carriages and boats, each carriage has a length of 16 meters. With the length of AF 1 and AF 2 with a length of 26 meters, and AF 3 and AF 4 with a length of 12 meters, causing the train series have to do a lot of shifting time to adjust the unloading position of the carriages with AF 1- 4. This of course can be a factor in unloading time that exceeds the target of 120 minutes per train series. Therefore, it is necessary to modify the length dimensions of AF 1- 4 to be able to adjust to the length of the new carriage, to reduce the train slipping time to adjust the unloading position, and speed up the coal unloading time.

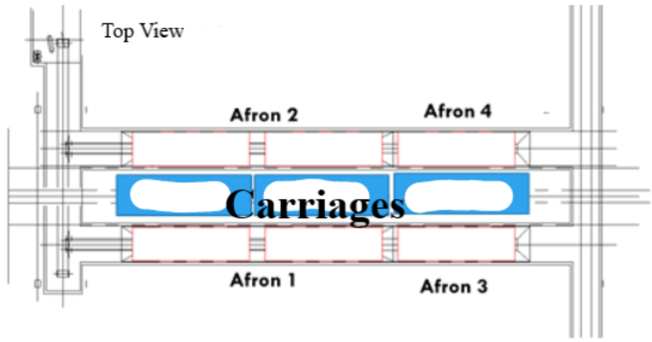

FIGURE 5
INCOMPATIBILITY NEW CARRIAGES LENGTH WITH AF 1 - 4

As for the problem statement, the problem that must be resolved is the non-achievement of the Company's Work Plan and Budget target for unloading coal in October and December 2021 with an unloading loss of 61,457 tons in the last three months. From the problem statement, we can plan the target or goal that we want to achieve in this final project, namely reducing the obstacles in Apron Feeder 1 and slow loading at Apron Feeder 1 to be able to increase coal unloading to achieve coal unloading targets. This target is based on the identification of the following SMART Analysis aspects as shown in Table IV.

TABLE IV
SMART ANALYSIS

	Reasons for Target Establishment
***S**pecific*	Reducing obstacles in Apron Feeder 1 to a maximum of 675 minutes per month and slow loading on Apron Feeder 1 to a maximum of 381 minutes per month, to obtain a company work plan target of 100%.
***M**easurable*	The target is measured based on the delay time of apron feeder 1, slow loading time on apron feeder 1, and company work plan target.
***A**chievable*	Achievement of the minimum obstacle time that has been achieved in the last three months (October-December 2020) and the achievement of the company work plan target that has been achieved.
***R**ealistic*	For low obstacle time of Apron Feeder 1 was achieved at 675 minutes in November 2020, and the slow loading of AF 1 was achieved at 381 minutes in October 2021 and the target achievement of more than 100% in November 2020.
***T**ime-Bound*	The improvement project will be carried out during January 2021.

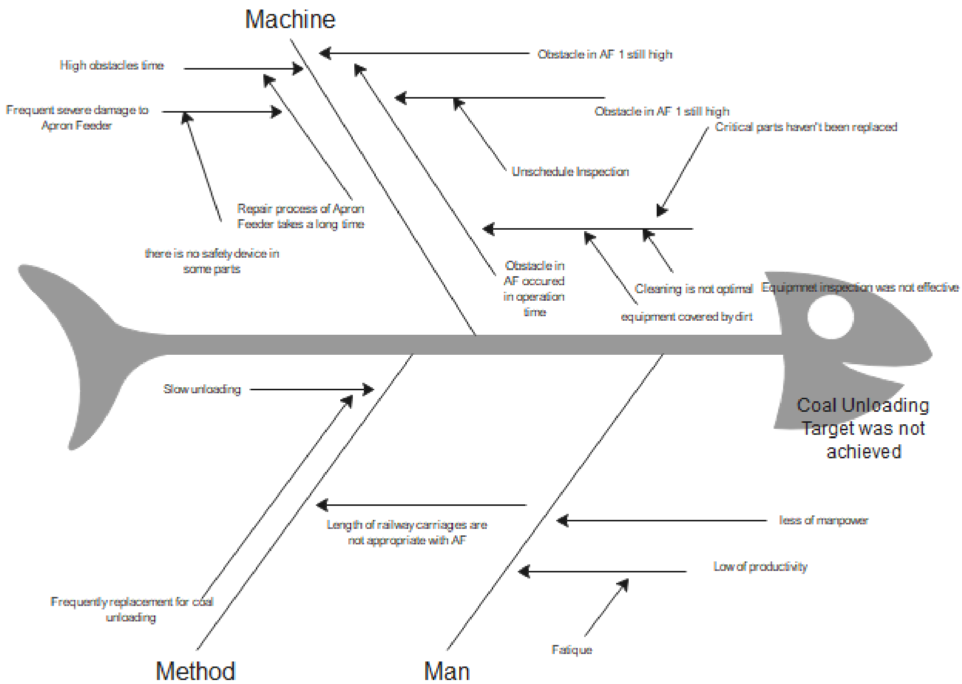

FIGURE 6
CAUSE AND EFFECT DIAGRAM FOR COAL UNLOADING TARGET

The cause of the unloading targets that are not achieved can be explained based on a cause-and-effect analysis of the methods, man, and machines used in the coal unloading process. To increase the value of process performance, the root cause of the problem can be determined with the help of a cause-and-effect diagram [22]. Cause and effect diagrams can help us to identify the main reason for the problem and are shown with a fishbone [23]. From the results of the cause-and-effect diagram shown in Figure 6. That was obtained several main problems are:

(1) The modification of the dimensions of the new train carriages causes the length of the train carriage to not be appropriate to the apron feeder.
(2) In some parts, there is no safety device.
(3) Cleaning the apron feeder has not been maximized
(4) Unscheduled inspection
(5) Operators and demolition workers do not know the target
(6) Less manpower
(7) Periodic Maintenance is not optimal

Of the seven root causes, an assessment was carried out by the team based on several criteria including whether it could be done individually or in groups, whether it had a direct impact on the target, whether it could be resolved on time, whether it was in contact with external partners, and what would happen if the problem could not be resolved. From this assessment, a Pareto root cause is made and a solution for the 2 root causes with the highest or dominant value that shown in Figure 7. The two dominant root causes are:

(1) The modification of the dimensions of the new train carriage causes the length of the train carriage to not appropriate the length of the apron feeder.
(2) In some parts, there is no safety device.

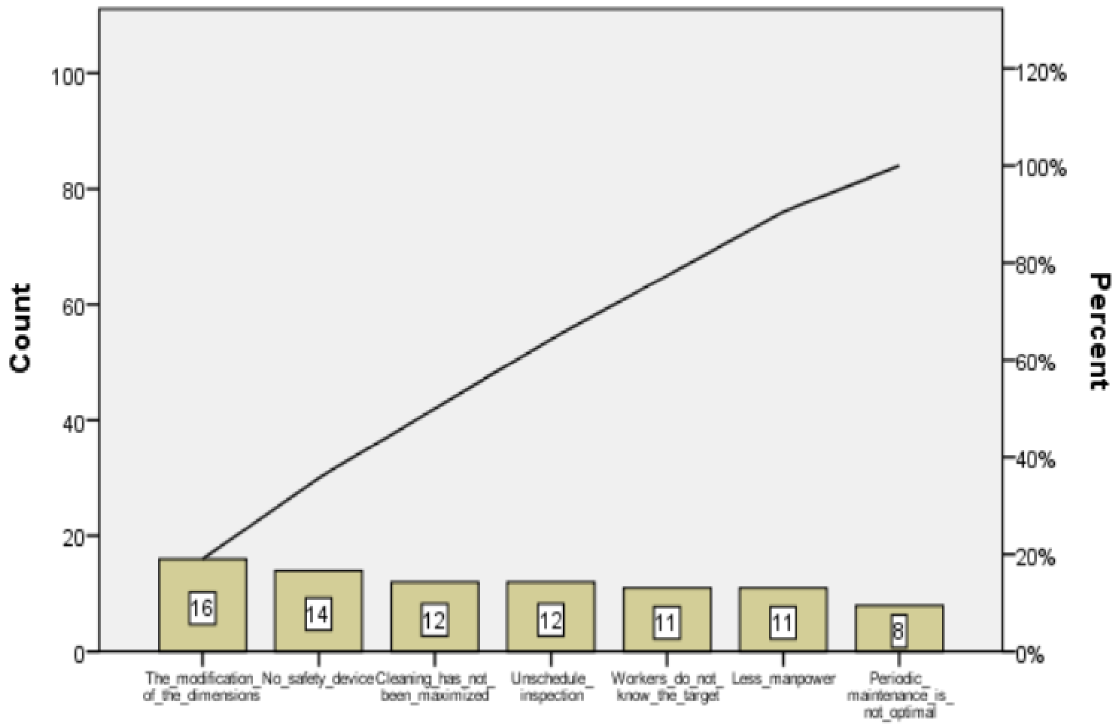

FIGURE 7
PARETO DIAGRAM FOR DOMINANT ROOT CAUSE

Analysis of the problem solutions used to use the 6W1H method to get a solution to the problem at each dominant root of the problem. The following 6W1H analysis has been made, including costs to be incurred by the company as shown in Table V.

TABLE V
THE 6W1H ANALYSIS METHOD

What	Why	How	Who	Where	When	Cost
The modification of the dimensions of the new train carriages causes the length of the train carriage to not be appropriate to the apron feeder	Speed up the unloading time by reducing the train shunt time due to the incompatibility of the length of the train carriage with the apron feeder	Modification of the dimensions of the apron feeder 1 (AF 1) that is adjusted to the length of the new train carriage	Team	Apron Feeder 1 – Apron Feeder 4	February 2022	Rp 380,582,460
In some parts, there is no safety device	Reduce the risk of severe damage to the apron feeder which requires a long repair time	Manufacture of safety devices at several vulnerable points to detect early if there is an abnormality of the equipment so that serious damage does not occur	Team	Apron Feeder 1 – Apron Feeder 4	February 2022	Rp 6,141,088

The modification of the apron feeder dimensions that will be carried out is adjusted to the dimensions of the new train carriages. The concept of this dimension is to extend the apron feeders 1-4 according to the length of the train carriage.

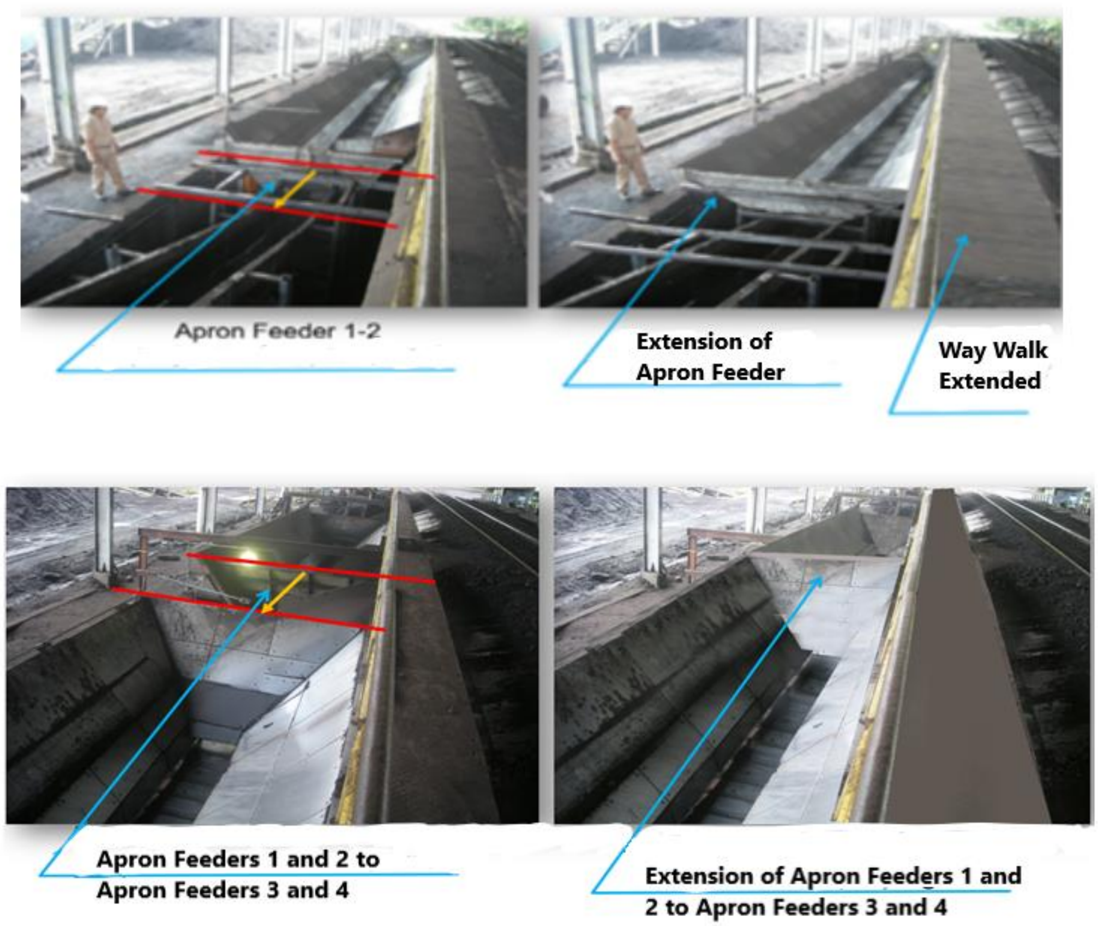

FIGURE 8
EXTENSION OF APRON FEEDER

Extension of the apron feeders 3 and 4 are extended 4 meters in the direction of the apron feeder drive. The initial length of apron feeders 3 and 4 is 12 meters with an additional 4 meters of length so that it becomes 16 meters. This is intended to be able to accommodate one new carriage (45 tons) with a length of 16 meters for each carriage. The walkway apron feeder is also widened by 50 cm to make it easier for unloading officers to open the carriage gate. The repair process for apron feeder damage such as damage to the apron feeder bucket, the average time required to install 1 set of buckets is about 60 minutes (1 set consists of a shaft, chain-link, bushing, roller, keyplate, bracket, and bucket). Moreover, after the extension of the apron feeder, the operator's supervision area will increase and the risk of equipment damage will increase if there is no safety device, especially for areas that have been extended. Therefore, innovation was made by making a bucket apron feeder sensor. This safety device was made by modifying the XCRA15 Sensor using an 8 mm stell handle with a length of 30 cm with a 12 cm long arm whose function is to detect the bucket when it is in a disposition. The installation of the bucket sensor is shown in Figure 9.

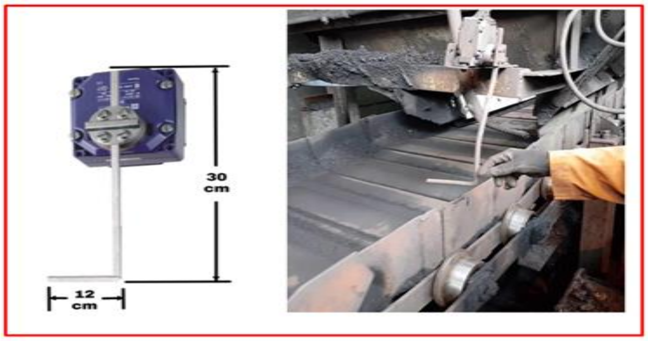

FIGURE 9
INSTALLATION OF BUCKET SENSOR

From the evaluation of the results of the apron feeder obstruction and slow loading where the target of the apron feeder obstruction is 675 minutes per month and the slow unloading is 381 minutes per month, the average for the last 5 months from February to June 2021 is 189 minutes per month and slow loading is 226 minutes per month. The average coal unloading realization in the last 5 months was 426,787.9 MT of coal with an average delivery of 426,765, 1 MT of coal, and an average company work plan target of 425,600 MT. Based on these data, this means that all coal shipped from the Tanjung Enim mine production can be unloaded through the Kertapati Port Unit and the average monthly company work plan target has been achieved above 100%. In terms of material usage, it also experienced a very significant decrease where the initial cost of material usage before the repair was Rp. 237,030,000 and after repair to Rp. 29,158,300 if we compare the material usage for 3 months (February – April 2021).

The standardization of the repair results still refers to the Working Procedures for the operation of the apron feeder which aims as a guideline for operating the apron feeder, so that the tool can operate correctly and safely and prevent damage to the tool by the function and environment, health and safety rules. From the data obtained, 3 dominant obstacles occurred in June 2021, namely, the Divergator or Sizer obstacle with an obstacle time of 1,728 minutes, operational settings is 668 minutes, and sticky material is 566 minutes. Then the team will focus on continuing the next improvement in overcoming the three problems or obstacles. Quality control circle is an important and effective tool used to solve problems in the organization and can improve performance company [24].

CONCLUSION

Based on the results of the analysis of the performance of coal unloading equipment using the Quality Control Circle (QCC) method, it is concluded that there was a failure to achieve the coal unloading target in November and December 2021 due to the high obstruction of the apron feeders 1-4 and slow loading on apron feeders 1-4. The results of the Quality Control Circle (QCC) root cause analysis obtained that the roots of the problem were that the modification of the new train carriage caused the length of the train carriage not to appropriate to the apron feeder and in some parts, there was no safety device, so modifications to the dimensions of the apron feeder 1-4 must be adjusted to the length new train carriages with a target of reducing slow loading from an average of 926 minutes per month to a maximum of 381 minutes per month and making safety devices at several vulnerable points to detect early if there is an abnormality of the equipment so that heavy damage does not occur with the target of reducing the apron feeder obstacle from 920 minutes per month to a maximum of 675 minutes per month. Results in February – June 2021 where the apron feeder obstacles n was an average of 189 minutes (28% of the target) and slow loading was an average of 226 minutes (59% of the target). With the decrease in these unloading obstacles, the unloading achievement in the last five months (February – June 2021) has increased, reaching an average of 100.26%.

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