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Optimizing Operational Efficiency through Improved Crushing & Loading Strategies at PT Girimulya Resource

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ABSTRACT

In 2023, PT Girimulya Resource's production reached 42.1 million tons of coal, with 34.2 million tons processed using the company's crushing and loading facilities, while the remaining 7.9 million tons were processed by third parties due to capacity constraints. During the 2018-2023 period, PT Girimulya Resource's crushing and loading facility utilization rate remained below the 85% target. This research aims to identify the main causes of the sub-optimal performance using the DMAIC (Define, Measure, Analyze, Improve, Control) method, which focuses on customer needs as the main driver of profitability in the production process. This research method involves various tools and techniques, such as Pareto Chart, Fishbone Diagram, 5 Whys method, focus group discussion (FGD), and observation to identify significant factors and root causes. Based on the analysis results, two quick win solutions and three long-term solutions were proposed to improve facility utilization. Two quick wins involving the application of blasting methods and the dismantling of the weighbridge at KM 0.3 were successfully implemented, which reduced large coal sizes and queues at KM 0.3. The three long-term solutions began to be implemented in phases from mid-2023, with further trials starting in January 2024. Initial results show a positive impact, with facility utilization rates now exceeding 85%. The implications of this study show that the application of data-driven methods, such as DMAIC, can provide strategic guidance in overcoming operational limitations and improving efficiency, and can therefore be adopted by other companies in similar industries to face production capacity challenges.

Keywords: DMAIC, Focus Group Discussion, Pareto Chart, Fishbone Diagram, 5whys.

INTRODUCTION

The coal mining sector is one of the main pillars in supporting global energy needs, with significant contributions to electricity production in various countries (Pahlevi et al., 2024). In the last five years, coal demand has remained high despite efforts to transition global energy towards more environmentally friendly energy sources (Apriliyanti & Rizki, 2023). The price trend of Newcastle coal, as shown in Figure 1, shows sharp fluctuations, with the price peaking in 2022 before gradually falling again in 2023. Predictions show price declines of up to 28% in 2024 and 12% in 2025. This puts mining companies in a situation that demands increased operational efficiency to remain competitive amid market pressures (Firoozi et al., 2024).

Figure 1. Newcastle Coal Price in the last 5 years

In the global context, mining companies face various challenges such as commodity price fluctuations, intensified competition, and pressure to improve operational sustainability (Muchamad Taufiq, 2024). One of the key strategies adopted by mining companies is the optimization of internal facilities, including crushing and loading processes. According to (Nwaila et al., 2022), companies that are able to maximize the utilization of internal facilities have a greater chance of significantly reducing production costs, while increasing profit margins.

PT Girimulya Resource, one of the leading coal producers in Indonesia, recorded a production of 42.1 million tons in 2023. Of this, 34.2 million tons are processed using the company's own crushing and loading facilities, while the remaining 7.9 million tons are processed using third-party facilities. The use of third-party facilities, while providing operational flexibility, incurs additional costs of $2.6 per ton of coal, or equivalent to $2.6 million for every 1 million tons processed. With the production target increasing to 54 million tons by 2025, PT Girimulya Resource faces a major challenge to increase the proportion of coal processed through in-house facilities, from 81% in 2023 to 85% in 2025.

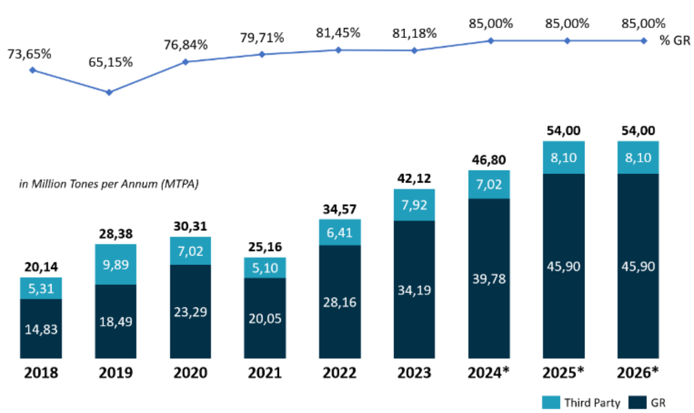

Figure 2. PT Girimulya Resource crushing and loading record, with PT Girimulya Resource and third party

Figure 2 shows the historical trend of the proportion of PT Girimulya Resource's crushing and loading facility utilization compared to third-party facilities from 2018 to 2023. Despite the increase, the proportion of internal facility utilization has not yet reached the optimal target of 85%. This confirms the urgent need to increase the capacity and efficiency of the company's in-house facilities to be able to handle larger production volumes in the future.

Previous studies, such as those conducted by (Wang et al., 2024) suggest that the decline in coal prices can be anticipated with aggressive efficiency strategies, including investment in internal facility capacity enhancement. In addition, research by (Fahmi, 2020) also highlighted the importance of optimizing crushing and loading operations as a step to reduce dependence on third parties and reduce production costs. However, there is still a gap in the literature regarding specific approaches that can be applied by mining companies in Indonesia, especially in facing capacity and operational efficiency challenges.

Specifically, this research focuses on analyzing the capacity of internal facilities, identifying factors that hinder efficiency, and formulating strategic solutions to achieve a production target of 54 million tons in 2025 with a proportion of 85% internal facility utilization. The urgency of this research lies in the need to respond to the pressure of an increasingly competitive global coal market, where profit margins are increasingly eroded due to price fluctuations and rising operational costs. By minimizing reliance on third-party facilities, PT Girimulya Resource can reduce additional costs by $2.6 million per 1 million tonnes, thus contributing directly to the company's profitability. The novelty of this research lies in the systematic approach to integrate capacity analysis, operational efficiency, and strategies to increase the proportion of internal facility utilization in coal mining companies. This research not only provides a practical solution for PT Girimulya Resource, but can also serve as a reference for other mining companies facing similar challenges.

Based on the above background, the purpose of this study is to formulate an effective crushing and loading system improvement strategy at PT Girimulya Resource, so as to support the company's long-term production targets efficiently and sustainably. This research is expected to provide significant benefits, both in increasing company profitability, reducing operational costs, and as a contribution to academic literature related to operations management in the mining industry.

RESEARCH METHOD

The method employed in this study is the DMAIC methodology (Define, Measure, Analyze, Improve, Control), widely recognized as a crucial approach for improving operational efficiency and profitability (Jacobs & Chase, 2018). This methodology aligns with customer-centric principles, emphasizing the role of data-driven decision-making in achieving production goals. The study incorporates a variety of tools and techniques, such as Pareto Charts, Fishbone

Diagrams, the 5 Whys method, Focus Group Discussions (FGDs), and field observations, to systematically identify and address inefficiencies.

Detailed Explanation of the DMAIC Stages

Define

a. This stage involves evaluating the current coal flow and identifying constraints in the crushing and loading facility. Data is gathered on throughput and operational patterns to define the problem clearly. The scope of the analysis includes the operational conditions and the gap between current and desired performance (target of 85% capacity).

b. Tools used: Process mapping and stakeholder analysis to understand the workflow and key constraints.

Measure

a. Operational data is collected using advanced measurement tools, including Weigh-In-Motion systems and belt weigher systems, to quantify throughput and identify delays or inefficiencies in the process.

b. Techniques:
   a) Statistical analysis of throughput data to evaluate patterns and variability.
   b) Pareto analysis to prioritize the most impactful factors causing inefficiencies.
   c) Operation delay data is categorized and visualized to provide actionable insights.

Analyze

a. The root cause analysis is conducted using:
   a) Fishbone Diagram: This visual tool identifies potential causes of inefficiency across categories such as manpower, materials, methods, and machinery.
   b) 5 Whys Technique: Applied to dig deeper into the underlying causes of significant problems identified in the Fishbone Diagram.

b. FGDs with operators and supervisors provide practical insights and validate analytical findings.

Improve

a. Solutions are developed to eliminate inefficiencies, focusing on both operational and systemic improvements. A cost-benefit analysis supports decision-making to ensure practical feasibility.

b. The improvement phase includes trial implementations to validate the proposed changes and ensure alignment with operational goals.

Control

a. A monitoring framework is established to sustain improvements. Key metrics (e.g., throughput rate, operational delays) are tracked using real-time monitoring systems.

b. Tools such as control charts and dashboards are used to visualize performance trends and detect any deviations early.

Technical Justifications for Selected Techniques

a. The Fishbone Diagram and 5 Whys were chosen for their simplicity and effectiveness in identifying root causes in a structured manner. These tools provide actionable insights by breaking down complex problems into manageable components.
b. The measurement systems (Weigh-In-Motion and belt weigher systems) were selected for their precision and reliability in tracking material flow rates, which are critical for analyzing throughput.

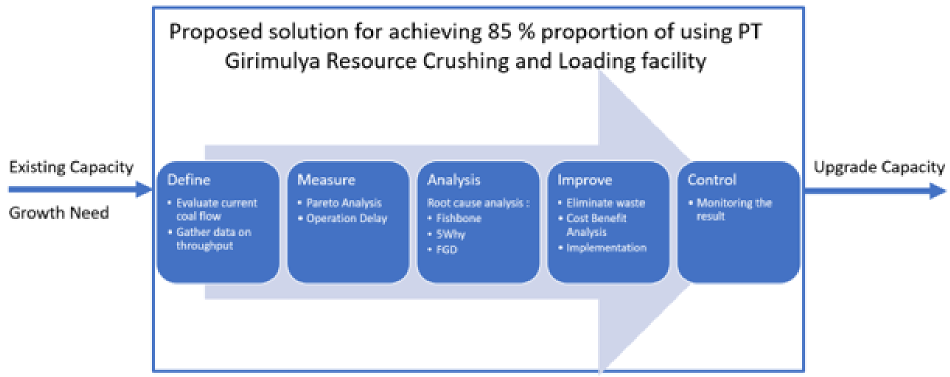

Figure 3. Conceptual framework

Figure 3 illustrates the conceptual framework guiding this study, highlighting the application of DMAIC stages to diagnose inefficiencies and implement targeted improvements.

RESULT AND DISCUSSION

Define Stage

PT Girimulya Resource is committed to managing contracts and overseeing operations, with mining, hauling, crushing, barging, and transshipment processes being carried out and managed by contractors. The company has invested in the construction and upgrading of coal handling infrastructure to support its coal supply chain operations at various capacities.

Crushing involves the reduction of raw coal to a size suitable for various industrial applications (Sarkar & Lassi, 2024). The crushed coal should not exceed 70 cm in size, with a fine coal content of no more than 17%. Loading refers to the process of transferring the crushed coal onto barges, using a Barge Loading Conveyor (BLC), with barge sizes ranging from 300 to 330 feet.

The increase in crusher capacity from 6,510 to 8,010 TPH was achieved through the revitalization of the existing CP1 and CP2 crusher and the addition of crushers CP2A, CP2B, CP6, CP7, and CP8. Crushers CP6, CP7, and CP8 are equipped with Draw Down Hoppers (DDH), which are conically shaped to allow coal to flow by gravity from the stockpile to the conveyors.

Enhancing crusher capacity is a practical approach to improving operational efficiency (Muharam & Faturohman, 2024). The study indicates that upgrading the crusher is feasible, provided the equipment's usage life exceeds two years. Furthermore, the company's Life of Mine (LoM) is projected to end in 2036, with a potential 10-year extension

The term "CP" refers to Crushing Plant. At PT Girimulya Resource, the Crushing Plant is designed either as a one-stage process using a feeder breaker for plants with capacities below 700 TPH, or as a two-stage process employing both a feeder breaker and a double-roll crusher for capacities exceeding 700 TPH.

The Barge Loading Conveyor (BLC) was upgraded in 2019 by increasing its speed and widening the belt, resulting in a throughput capacity of 44 million tons per annum. This principle was similar to other coal mining company in upgrading conveyor capacity.

Stockpile capacity was expanded with the development of a new ROM stockpile area in the north, which can hold up to 1.4 million tons. Additionally, the hauling road was upgraded by increasing the thickness of aggregate layers (Class A and B) and applying double chipseal on the top layers for enhanced durability.

	2020	2021	2022	2023 - 2024	2025 onwards
Crushing Plant Capacity (MTPA)	20 -32	24 – 32	30 - 36	Up to 42	Up to 48
	6510 TPH Throughput	6510 TPH Throughput	7510 TPH Throughput	8010 TPH Throughput	9700 TPH Throughput, with back up 700 TPH
BLC Capacity (MTPA)	44	44	44	44	Optimize up to 48
Port Stockpile Capacity (MT)	• **370,000** Product • **70,000** Raw	• **155,000** Product • **30,000** Raw	• **275,000** Product • **70,000** Raw	• **275,000** Product • **70,000** Raw • **765,618** Raw [North]	• **275,000** Product • **70,000** Raw • **1.400.000** Raw [North]
Hauling Road Capacity (MTPA)	➢ Phase 1*: **36** ➢ Phase 2: **36** ➢ Phase 4: **20** ➢ Bunati Loop: **20**	➢ Phase 1*: **36** ➢ Phase 2: **36** ➢ Phase 4: **20** ➢ Bunati Loop: **20**	➢ Phase 1*: **54** ➢ Phase 2: **40** ➢ Phase 4: **28** ➢ Bunati Loop : **20**	➢ Phase 1*: **54** ➢ Phase 2: **54** ➢ Phase 4: **28** ➢ Phase 7 : **22** ➢ Bunati Loop: **20**	➢ Phase 1*: **54** ➢ Phase 2: **54** ➢ Phase 4: **28** ➢ Phase 7 : **22** ➢ Bunati Loop : **20**
Production Achievement & Plan (MTPA)	Bunati Port 23.29 [76.9%]	Bunati Port 20.05 [79.8%]	Bunati Port 28.16 [81.4%]	Bunati Port 34.19 [81.3%] 2024 Plan – 86 %	Bunati Plan – 86 %
	Total BIB 30.31	TOTAL 25.16	Total BIB 34.57	Total BIB 42,11 Plan 2024 46,8	Total BIB 54

Figure 4. Capacity of Crushing Plant, BLC, Port Stockpile & Hauling Road

Electricity efficiency in PT Girimulya Resource's crushing and loading operations was enhanced in mid-2019 through integration with PLN's medium-voltage transmission system, while the generator set remained as a backup. Comparative studies from various industries (Saputri, 2023); (Al Firdausi et al., n.d.) have shown that utilizing PLN's power supply is more cost-effective. However, transmission reliability, particularly voltage drops, continues to be a concern in South Kalimantan.

PT Girimulya Resource's current crushing capacity stands at 8,010 TPH, equivalent to 42 million tons per annum. However, based on the performance record for the first half of 2024 (HY1), the average utilization rate was only 48%. This underutilization is attributed to operational delays, including suboptimal hauling hours, Dump Truck (DT) queuing at the port, barge waiting times, and limited Run of Mine (ROM) capacity at the port. Consequently, the proportion of coal processed through PT Girimulya Resource's crushing facilities remains below the target of 85%, necessitating the use of third-party ports.

As shown in Table 1, the record for the full year 2023 (FY2023) reflects similar challenges. The 85% utilization target has been difficult to achieve due to the company's inability to secure necessary land acquisitions, which has led to reliance on third-party ports. This, in turn, has resulted in lower-than-expected utilization of PT Girimulya Resource's crushing and loading facilities.

Table 1. Record of PT Girimulya Resource crushing FY 2023

Crusher	EU	Actual Capacity (TPH)	Coal Crusher (MTPA)
CP1	46,4%	878,2	3,6
CP2	21,9%	715,9	1,4
CP2A	38,9%	526,5	1,8
CP2B	42,7%	523,4	0,5
CP3	57,9%	821,1	4,1
CP4	57,3%	830,6	4,2
CP5	59,2%	522,4	2,7
CP6	48,6%	1.320,6	5,6
CP7	54,1%	1.235,4	5,9
CP8	56,8%	898,6	4,5
Total / Average	48,4%	8.272,6	34,2

EU refers to Effective Utilization that regulated in Decree of Minister of Energy and Mineral Resources No 1827 of Republic of Indonesia (Khairunisa et al., 2023). EU represents Percentage of effectiveness of tool use calculated based on the comparison between working time divided by working time plus non-operational/waiting time and repair time. For 46.4 % EU, means in 365 days available time, the Crushing Plant used for crushing activities is 169.4 days. PT Girimulya Resource crushing and loading facilities is located at 4 km to south from National Road. Figure 4 shows the PT Girimulya Resource crushing facilities.

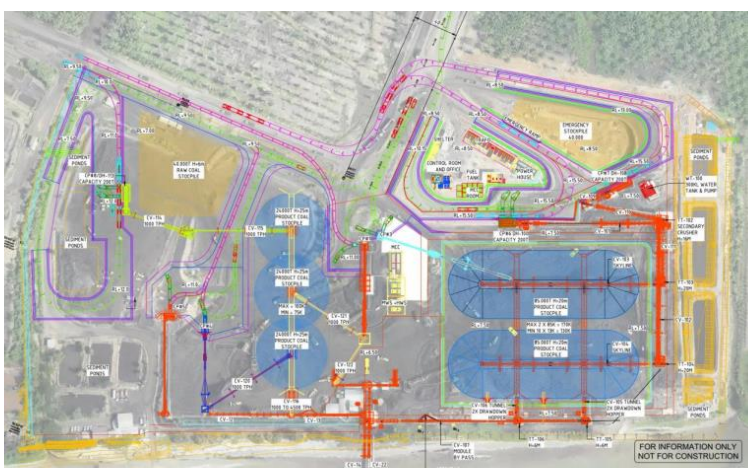

Figure 4. PT Girimulya Resource crushing facilities at port

The SIPOC (Suppliers, Inputs, Process, Outputs, and Customers) diagram provides a structural overview of the crushing plant process at PT Girimulya Resource, outlining the roles of various stakeholders and the flow of materials through its crushing and loading facilities (Mustaniroh et al., 2021). This research focuses on the process component to identify root causes of inefficiencies and areas for improvement, specifically aiming to achieve a target operational rate of 85%.

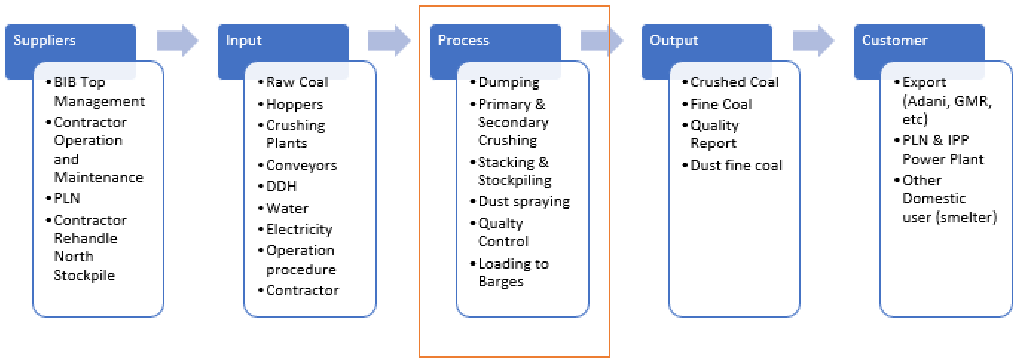

Figure 5. SIPOC of PT Girimulya Resource crushing and loading facilities

Measure Stage

The daily performance of the PT Girimulya Resource crushing and loading operations is monitored by tracking dump trucks hauling raw coal to the crusher's dump hopper. The volume of hauled material is measured using a Weigh-In-Motion (WIM) system installed at Road Phase I, located at km 13. Additionally, conveyor volumes are measured with a belt weigher system, providing data for draft surveys when barge loading is completed.

Operational parameters, maintenance activities, and delays. The duration of crushing and conveying activities is recorded on a daily time sheet, categorized as either With Cargo or Without Cargo. Any disruptions during crushing and loading operations that result in stoppages are logged as delay contributors, including their duration. Maintenance activities, whether scheduled or unscheduled due to equipment failures related to predictive or preventive maintenance, are also recorded daily.

A key aspect of this research is analyzing delay contributors to identify root causes and potential areas for improvement. These findings will be evaluated and discussed to develop actionable solutions for operational optimization.

For FY 2023, the available working time was 365 days, with operations running in both day and night shifts, resulting in a total of 8,760 operational hours. According to the data, the primary delay contributor was Crusher Standby, which accounted for an average of 666.8 hours. This refers to instances when the crusher, though mechanically and electrically operational, is forced to stop due to the unavailability of raw coal from either hauling or rehandling activities.

										Delay Contributor											
Crusher	TPH	Coal Crusher (MTPA)	PA	MA	UA	EU	Working Hours (With Cargo)	Scheduled Maintenance	Unscheduled Maintenance	Cargo Unavailable	Bolder (COS)	Rain (Bad Wether)	HE/Equipment Support Problem	Dust Suppression Problem	System Fault	Safety Talk	Rest/Pray/Mill	Crusher Standby	Coal Spillage / Blocking / Cleaning	Operation's Incident	Available Time
CP1	878	3,6	97%	94%	48%	46%	4.061	129	133	886	511	45	8	25	217	6	68	1.810	847	16	8.760
CP2	716	1,4	98%	90%	22%	22%	1.921	128	85	1.938	127	17	16	15	48	5	80	4.305	66	8	8.760
CP2A	526	1,8	98%	95%	40%	39%	3.406	81	87	1.699	617	19	0	22	152	6	100	2.480	84	6	8.760
CP2B	523	0,5	97%	92%	44%	43%	944	29	48	472	114	3	1	11	20	5	19	405	17	122	2.208
CP3	821	4,1	93%	89%	62%	58%	5.073	238	358	603	580	5	1	38	317	4	101	1.260	175	7	8.760
CP4	831	4,2	95%	92%	60%	57%	5.022	188	258	504	506	16	2	25	219	3	96	1.743	172	7	8.760
CP5	522	2,7	96%	94%	62%	59%	5.186	120	213	321	445	21	-	29	75	5	94	2.139	112	3	8.760
CP6	1.321	5,6	92%	86%	53%	49%	4.260	225	458	1.523	559	4	8	7	451	3	93	846	297	28	8.760
CP7	1.235	5,9	94%	90%	58%	54%	4.741	268	279	929	606	4	19	5	576	4	92	1.027	186	25	8.760
CP8	899	4,5	92%	88%	62%	57%	4.973	242	450	1.079	192	-	1	36	435	5	93	1.169	68	18	8.760
Average			95,2%	91,1%	51,0%	48,4%	3.959	165	237	995	426	13	6	21	251	4	84	1.718	202	24	8.105

Figure 6. Record of PT Girimulya Resource crushing performance FY2023

The delay contributors have been categorized into seven groups, with minor delays consolidated into the Others category. The total duration of delays amounts to 14,801.9 hours. Both the percentage and cumulative percentage of each delay category are calculated and presented in Table 2. Using this data, a Pareto chart can be generated to visually highlight the most significant delay contributors, specifically Crusher Standby, Cargo Unavailable, and Boulder or Coal Oversize, as shown in Figure 6.

Table 2. List of delay contributor and cumulative percentage for crushing

Crusher Standby	1.718,4	42,2%	42,2%
Cargo Unavailable	995,4	24,5%	66,7%
Bolder (COS)	425,7	10,5%	77,2%
System Fault	250,9	6,2%	83,4%
Rest/Pray/Mill	202,4	5,0%	88,3%
Coal Spillage / Blocking / Cleaning	151,9	3,7%	92,1%
Others	323,0	7,9%	100,0%
Total	4.067,6	100%	

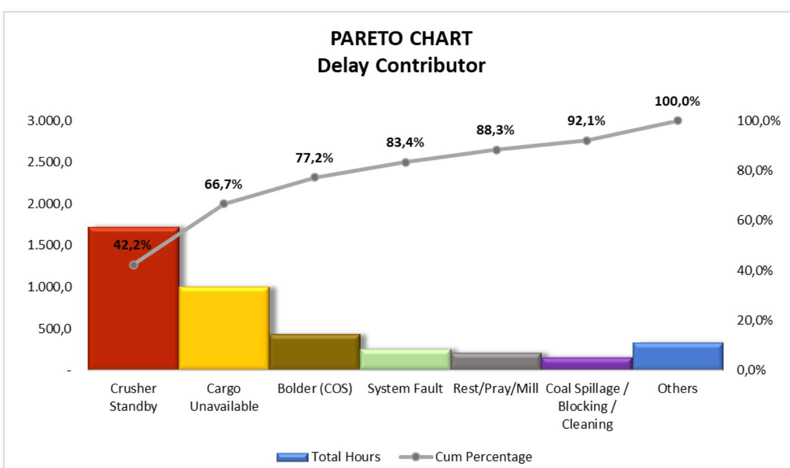

Figure 7. Pareto chart of delay contributor of Crushing 2023

For barge loading activities in 2023, the available working hours total was 8,760. Based on the data, the primary delay contributor was Waiting Barge, accounting for a total of 485 hours. This delay is largely due to unfavorable weather conditions at the transshipment area, which hinder the transfer of unloaded barges from transshipment to the BLC.

											Delay Contributor													
CP	TPH	Coal Convey (MTPA)	PA	MA	UA	EU	Working Hours [With Cargo]	Working Hours [Without Cargo]	Schedule	Non Schedule maintenance	Heavy Rain	Dusty	No Job	Safety Talk	Waiting Cargo	Shifting	Heavy Swell	Rest Time	Re Fuel	Waiting Information BIB	Cleaning Area	Waiting Barge	Overflow	Available Time
BLC22(L1)			96%	95%	79%	76%	6.619	133	152	101	26	24	25	4	666	1	75	90	-	206	7	491	141	8.760
BLC14(L2)			96%	95%	85%	81%	7.134	150	145	119	25	12	25	7	155	1	79	95	2	183	13	482	134	8.760
BLC All Line	4.520	34	99%	99%	86%	85%	7.489	135	23	62	24	28	25	7	124	1	73	95	-	158	-	484	32	8.760
Average			97%	96%	83%	81%	7.081	139	107	94	25	22	25	6	315	1	76	93	1	182	7	485	103	8.760

Figure 8. Record of PT Girimulya Resource loading performance FY 2023

Similarly, a Pareto chart can be created from the data, as shown in Figure 8, to represent the major delay contributors for barge loading: Waiting Barge, Overflow, Waiting Cargo, Rest Time, and No Job.

Table 3. List of delay contributor and cumulative percentage for loading FY 2023

Delay Contributor	Total Hours	Percentage	Cumulative Percentage
Waiting Barge	485.5	36.2%	36.2%
Waiting Cargo	314.8	23.5%	59.7%
Overflow	102.5	7.7%	67.4%
Rest Time	92.9	6.9%	74.3%
No Job	75.8	5.7%	80.0%
Heavy Swell	25.0	1.9%	81.9%
Others	242.9	18.1%	100.0%
Total	1,339.5	100%	100.0%

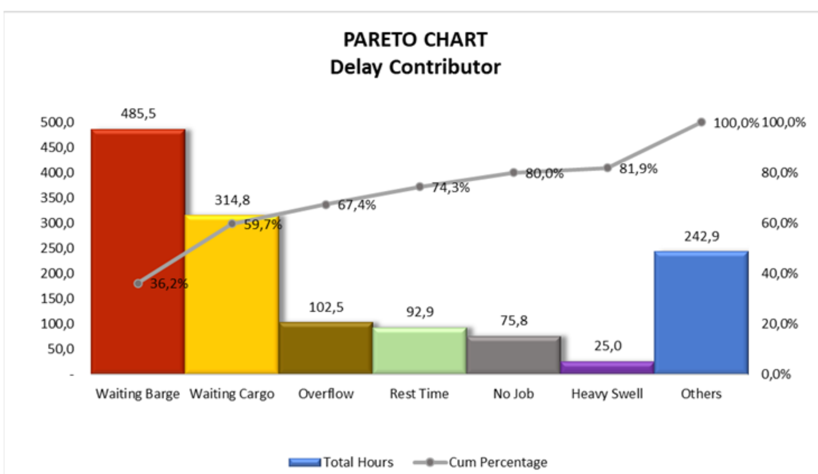

Figure 9. Pareto Chart of PT Girimulya Resource Loading performance FY 2023

Analysis Stage

Following the development of the Pareto chart based on PT Girimulya Resource's crushing and loading performance records, this analysis stage applies the Fishbone/Ishikawa diagram and the 5 Whys technique to explore the root causes of the company's inability to consistently achieve an 85% operational rate. A focus group discussion was conducted involving Top Management, Operations, Maintenance, Planning, and Project Departments to complete these tools.

In the Fishbone diagram discussion, six major categories were identified: Manpower, Material, Machine, Method, Measurement, and Environment (Tsou & Hsu, 2022). Delay contributors, compiled using the Pareto analysis, were grouped into these relevant categories and placed as branches in the diagram. For example, delays due to waiting for barges were classified under the Environment category.

The discussion with the Operations and Maintenance Departments identified potential root causes within the Manpower category, including insufficient training or skills, lack of attention, inadequate supervision, and lack of motivation. The Material and Machine categories were linked to data from delay contributors. In the Method category, root causes were derived from technical discussions and observations on the execution of preventive and predictive maintenance practices.

Given that PT Girimulya Resource's crushing and loading operations are supported by control systems such as SCADA and PLC, a technical discussion was held involving electrical control and mechanical engineers to identify potential root causes under the Measurement category.

The Environment category included external factors like weather, PLN power outages, and long queuing at the port. From the performance records, potential root causes were identified as waiting for barges and dust conditions. A complete Fishbone diagram, illustrating the potential root causes of crushing and loading performance falling below 85%, is shown in Figure 2. PLN refers to State Electricity Company that supply electricity to PT Girimulya Resource's crushing and loading since mid of 2019. The supply is using medium voltage transmission, transmitted around 21.5 km from PLN's substation.

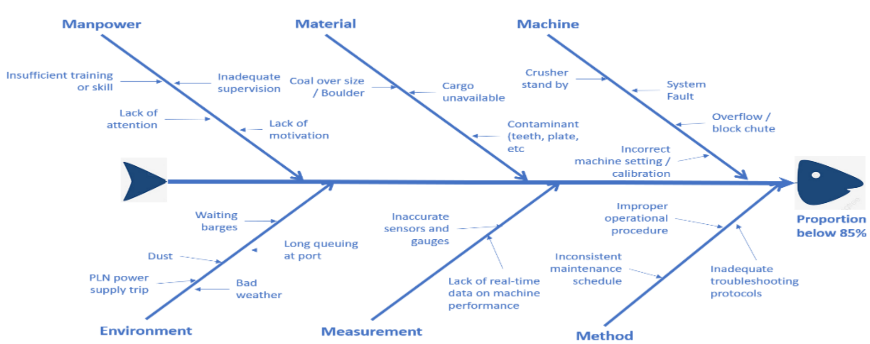

Figure 10. Fishbone diagram of analysis

Cargo Unavailable refers to the situation that raw coal at ROM is limited due bad weather at mine area. This situation will stop hauling operation. Building on the Fishbone diagram, the next step was a focus group discussion using the 5 Whys technique, focusing on three key issues: Crusher Standby, Long Queuing at the Port, and Overflow. These problems were selected by Top Management due to their significant contribution to delays, as indicated by the Pareto chart, and their impact on achieving the target 85% operational rate.

In the Crusher Standby discussion, two root causes were identified: insufficient feeding from hauling operations and rehandling activities. The lack of hauling feeds was attributed to prolonged shift changes. From benchmarking at other mining sites, it was determined that this could be mitigated through a staged shift change approach. The results of this discussion are summarized in Table 5.

Feeding from rehandling activities was identified as dependent on the availability of raw coal stockpiles. A fundamental root cause of Crusher Standby is insufficient stockpiling. Ensuring adequate stockpile levels would enable continuous feeding and minimize standby time. The root causes of Long Queuing at the port were explored through the 5 Whys technique, focusing on issues such as crusher breakdowns, mechanical damage, oversized coal or boulders and coal getting PC2000 due productivity reason. The source of boulders was found to be from thick coal seams and the size of the PC2000 bucket. The proposed solution is to implement a blasting process to reduce boulder size.

With the increase in production volume, traffic congestion at the port has worsened, especially during critical periods like shift changes (7–9 a.m. and 7–9 p.m.). Benchmarking and observations revealed that the fundamental cause of high traffic density was the lack of facilities to manage shift changes effectively.

The focus group discussion also identified that the weighbridge installed at KM 0.3 was contributing to port queuing issues. The weighbridge requires trucks to stop for weight measurements, which slows operations. The group recommended relocating the weighing process to KM 13 to alleviate congestion.

Current queuing control practices involve radio communication and the use of a three-lane system, with queues directed to the dump pad of the crusher via CCTV and human controllers. The discussion recommended traffic modifications, including a six-lane queuing system with separators, electronic signboards, and the application of artificial intelligence for traffic management.

A technical group discussion with conveyor design experts was also held to identify the root cause of poor chute design at transfer points. The analysis was conducted using actual coal streamlines and simulations with Discrete Element Modeling (DEM) software.

An outdated sensor at the Draw Down Hopper (DDH) was identified during a calibration process. The existing proximity switch sensor, which detects objects based on contact, was deemed ineffective. According to (Pawlak, 2017) in Sensors and Actuators in Mechatronics:

Design and Applications, proximity sensors detect the presence or absence of objects within a range without contact. This outdated technology was a fundamental root cause affecting performance.

Table 5 provides an analysis of the fundamental root causes, indicating whether they are controllable or not, along with proposed solutions. For example, long queuing at the port due to PLN power outages during bad weather is an uncontrollable issue. However, the recommendation from Top Management is to establish regular discussions with PLN to mitigate the impact of such events. The proposed solutions will be further elaborated in the Improvement Stage.

Table 4. 5 Whys for Crusher Standby, Long Queuing and Overflow

Problem	Why 1	Why 2	Why 3	Why 4	Why 5	Controllable / Uncontrollable	Proposed Solution
Crusher Standby	Lack of feeding from hauling	Prolong over shift	Improper managing for staging over shift	Lack of facility to control over shift		Controllable	Solution 1
	Lack of rehandle for raw coal	Lack of stock for raw coal	Lack of feeding for stock (stacking)	Insufficient stockpile and rehandle equipment		Controllable	Solution 1
Long queuing at port	Crusher breakdown	Mechanical component damaged	Coal over size / Boulder	Coal getting with PC2000	Productivity	Controllable as quick win	Blasting
		Relay activated	Electricity supply stop	PLN Trip	Bad weather	Uncontrollable	NA
	High density of traffic at critical time	Start hauling at the same time	Prolong over shift operator hauling	Improper managing over shift of hauling	Lack of facility to control over shift	Controllable	Solution 1
		DT Hauling should stop at KM 0.3	Weighing process	Unproper location		Controllable as quick win	Demolish existing weighbridge
	Improper managing queuing	Lack of facility to reduce queuing	Insufficient of queuing lane & Crushing facility			Controllable	Solution 2
Overflow	Sensor block	Hit by coal trajectory	Increasing speed of	Coal trajectory	Poor design of chute at	Controllable	Solution 3

Problem	Why 1	Why 2	Why 3	Why 4	Why 5	Controllable / Uncontrollable	Proposed Solution
	chute activated		coal trajectory	chocked at transfer point	transfer point		
		Fluctuation feeding from DDH	Improper operation of DDH	DDH sensor position is not accurate	Outdated sensor	Controllable	Solution 3

The proposed solution of blasting and demolish existing weighbridge KM 0.3 were classified as controllable and quick wins. The blasting has been implemented by Mine Contractors and still continue the implementation. Existing weighbridge KM 0.3 has been demolished as elimination approach (Weiss & Tucker, 2018) and now is using WIM KM 13 for weighing process.

Improvement Stage

Analyse Stage has defined three (3) problems and nine (9) fundamental root causes. From 9 fundamental root causes, two (2) fundamental root cause can be solved with quick wins for blasting and demolishing existing weighbridge. Other seven (7) fundamental root cause were discussed with Top Management and has generated proposed solutions as below:

Solution 1 – North Stockpile Expansion

Solution 1 - North Stockpile Expansion will have the scope of work for the development of North Stockpile with capacity minimum 1 million ton and Overshift facilities. North stockpile will be dedicated as buffer stock or ROM Stockpile for 6 days duration recovery (Assimi et al., 2022) and dedicated for rehandle stock to minimize Crusher Standby. Overshift facilities are intended to manage overshift properly therefore staging overshift can be realized. Estimate budget for North Stockpile Expansion is USD 5 million.

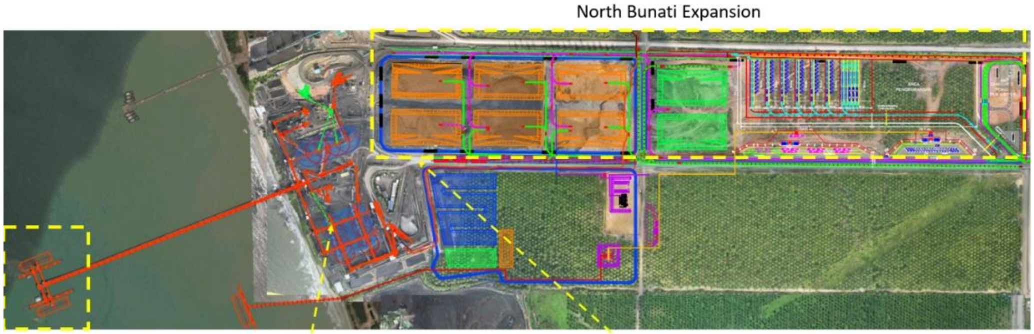

Figure 11. North Stockpile and Hauling Over shift Facilities

The application of ROM Stockpile before crushing and loading facilities has been implemented by PT TIA. PT TIA is situated east side of PT Girimulya Resource crushing and loading facilities. PT TIA crushing and loading capacity is lower than PT Girimulya Resource crushing and loading capacity, hence during high density of traffic at port will direct to ROM Stockpile. Capacity comparison of North Stockpile at PT Girimulya Resource and ROM Stockpile at PT TIA.

Table 5. Comparison Capacity of North Stockpile and ROM Stockpile PT TIA

	PT Girimulya Resource	PT TIA
Crusher Capacity	8,010 TPH	1,700 TPH
Barge Loading Capacity	8,400 TPH	2,000 TPH
ROM Stockpile at port	1.6 miilion ton	400,000 ton

Overshift facilities has been implemented at other mining company. This facility is proven to properly control overshift and improve productivity. North Stockpile was commenced by mid of 2023 with 600,000 ton of capacity. This facility has been used and trial from January 2024.

Solution 2 – Traffic Modification and New Crusher 9

Solution 2 – Traffic Modification and New Crusher 9 will have the scope of work for traffic modification for 6 lanes of queuing, completed with digital sign board and construction of New Crusher 9. Digital sign board will direct the queuing to specific crusher or North Stockpile. New Crusher 9 will have additional capacity of 1000 TPH and reduce the queuing for 25 DT hauling in one hour duration. Estimate budget for this solution is USD 6 million.

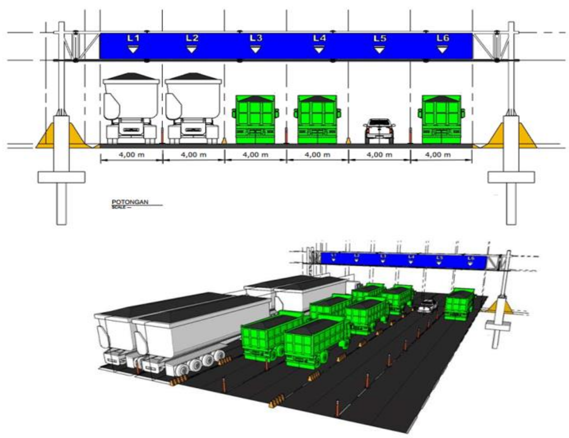

Figure 12. Traffic modification

Figure 13. New Crusher CP9

Solution 3 – Improvement for BLC Chute and Upgrade DDH Sensor

The scope of work will require engagement of expert to optimize chute design, fabrication of new chute and upgrade DDH sensor. Estimate budget for Modification of Chute and Upgrade DDH sensor is USD 0.5 million.

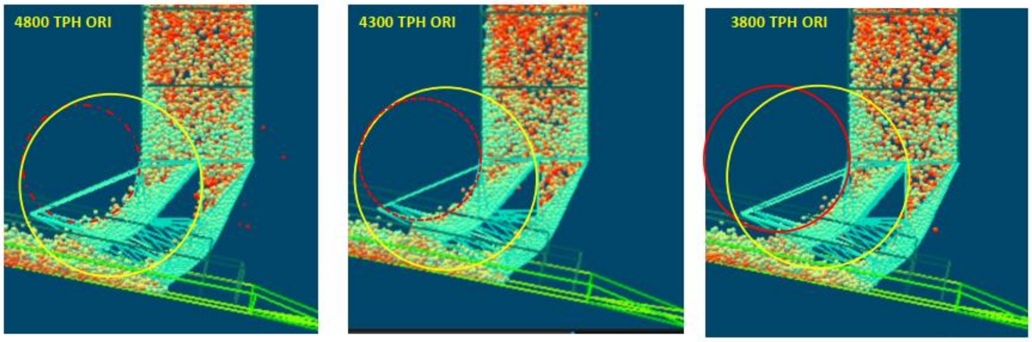

Figure 14. Chute simulation for design optimization

From the chute simulation, it was recommended to have modification for lower chute and the curve of spoon to have higher flow rate of materials. The liner material was also recommended for replacement with Teflon instead of alloy steel of 3CR12. The implementation of proposed solution could increase the capacity coal loading from 3900 tph become 4100 tph.

Technical group discussion was conducted on August 4th, 2024 related with the finding of discrepancy between actual gate opening and status on SCADA. The inspection has identified that the sensor is outdated for gate opening system. Proposed solution for the fundamental root cause of DDH outdated sensor was to upgrade DDH sensor with photoelectric sensor using a light beam to the detect the presence, absence, or distance of an object.

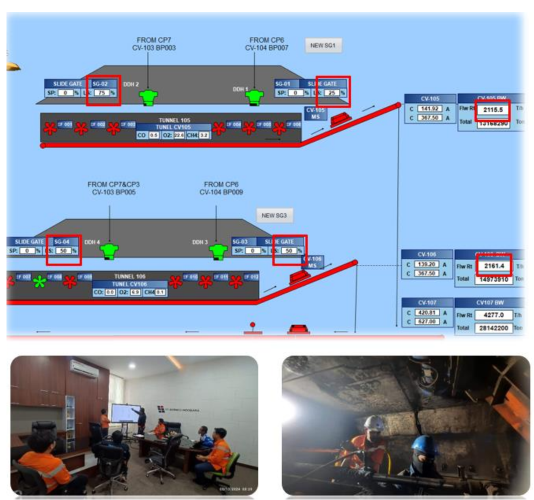

Figure15. Technical Discussion of DDH sensor, inspection and status at SCADA

Control Stage

Three (3) proposed solution have been agreed by Top Management. The schedule of all solution implementation as below.

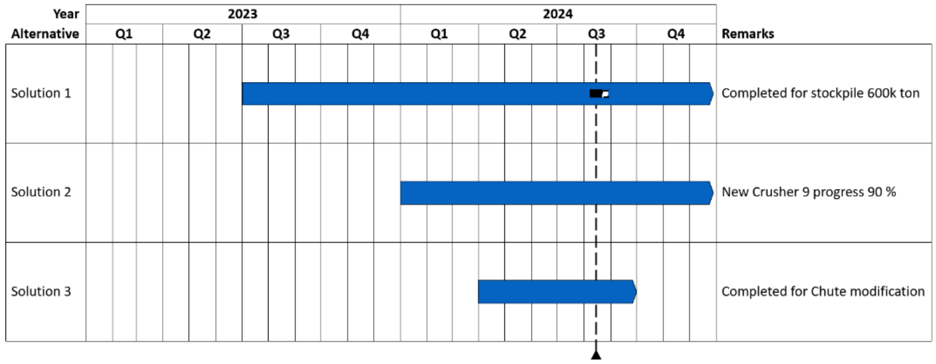

Figure 16. Progressive schedule of all solution

A feasibility study for all proposed solutions was conducted by the internal team, external consultants, and representatives from Top Management. The study evaluated various aspects, including safety, operational and functional feasibility, geotechnical considerations, execution plans, costs, and economic impact, with the aim of addressing the fundamental root causes of Crusher Standby, Long Queuing, and Overflow.

The implementation plan for the proposed solutions, as depicted in Figure 14, was reviewed and approved by Top Management. It was decided to execute the solutions as a multi-year project, with Solution 1 prioritized. Solution 1, derived from the 5 Whys analysis, is specifically designed to resolve the issues of Crusher Standby and Long Queuing.

As PT Girimulya Resource is responsible for managing contracts, the execution plan from the feasibility study also included a strategy for contractor selection. This was based on external factors, long-term contract, technology, and the tender process. The study recommended direct appointments for land preparation and earthwork related to Solution 1 and the installation of New Crusher 9 under Solution 2. Contractor selection for the BLC chute modification was carried out through a tender process.

The land preparation and earthwork for Solution 1 commenced in mid-2023 by the appointed contractor. Of the planned 1.6 million tons stockpile, 600,000 tons were completed and handed over by Q1 2024. Trials on the North Stockpile were then initiated to reduce Long Queuing and to begin rehandling raw coal, with the aim of minimizing Crusher Standby.

Solution 3 was initiated with the direct appointment of a conveyor design expert, selected based on previous experience. A tender process was subsequently conducted to execute the fabrication, design, and installation according to the expert's recommendations. The progressive schedule of all solutions is shown in Figure 14, indicating that implementation is ongoing. Both Solution 1 and Solution 3 have been partially completed and are currently in operational use. Since January 2024, the crushing and loading performance at PT Girimulya Resource has improved significantly, surpassing the 85% target. Figure 15 shows the company's crushing and loading performance over the past three years.

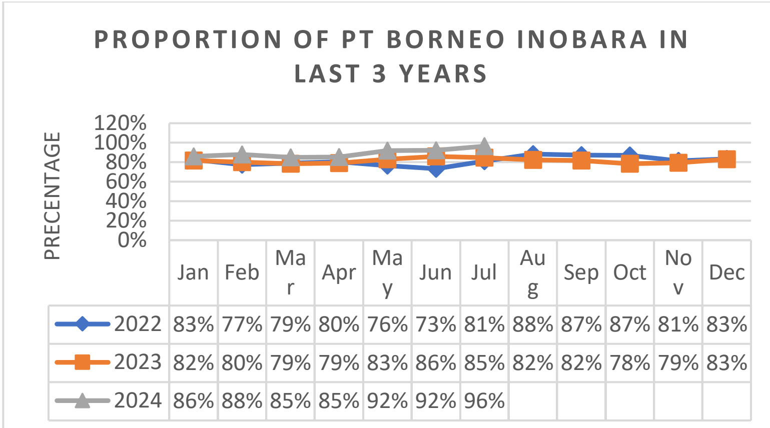

Figure 17. Proportion of PT Girimulya Resource Crushing and Loading in last 3 years

CONCLUSION

The conclusion of this study applies the DMAIC methodology along with tools such as Pareto diagrams, Fishbone diagrams, 5 Why, and focus group discussions to address the underperformance of PT Girimulya Resource's crushing and loading facility, which was below the 85% utilization target. Through detailed analysis, nine root causes were identified, along with two quick-win opportunities and three strategic solutions to improve operational efficiency. PT Girimulya Resource's top management has committed to implementing these solutions through multi-year projects. Initial results are promising, with facility utilization now exceeding 85%, highlighting the practical impact of the strategies implemented. Unlike theoretical models often emphasized in previous research, this study demonstrates tangible improvements in operational performance backed by real-world data and actionable steps.

For industries seeking similar improvements, this study offers a replicable framework. Companies should consider implementing the DMAIC methodology and prioritize solutions that can deliver quick results, such as resource reallocation and optimized equipment schedules, to get quick results. Future research can further enhance these findings by incorporating multi-year analysis to reflect market dynamics more comprehensively and exploring the role of emerging technologies, such as IoT, automation, and AI, in improving efficiency. In addition, research can be extended to cross-industry benchmarking to identify transferable innovations and expand the applicability of these methods. These advancements will not only strengthen the operational framework, but also position the industry to better adapt to evolving challenges and opportunities.

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