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Improving the Productivity of Basalt Rock Crusher through Workflow Process Redesign and Additional Crushing Components: A Case Study of the Terex TC1000 Crusher at PT Putra Perkasa Abadi Jobsite MAC

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ABSTRACT

Background: The crusher is the core of the basalt quarrying business at the PT Putra Perkasa Abadi (PPA) MAC jobsite. From April to June 2025, the productivity of the Terex TC1000 crusher averaged only 34.83 Lcm/h (87% of the 40 Lcm/h target), causing production shortfalls and a revenue gap against plan of –IDR 95.52 million. **Methods:** This applied study used an eight-step Plan-Do-Check-Act (PDCA) cycle and Quality Control Project (QCP) methodology to identify the root causes of low productivity and evaluate the effectiveness of a crushing-circuit modification, through Pareto analysis of downtime from January to June 2025 and a cause-and-effect (fishbone) diagram across the Man, Material, Machine, and Method categories. **Results:** Pareto analysis identified the MC Cone as the largest downtime contributor (124 hours; 36.6%), while the fishbone diagram revealed that most primary jaw product measured 20–30 cm, exceeding the ideal cone feed size of 10–15 cm, with an inadequate workflow design and component composition as the dominant root cause. The selected solution—a workflow redesign combined with a secondary jaw crusher, two vibrating screens, a second surge bin, a PLFC sand maker, and 11 additional conveyors (14 in total), with an investment of IDR 7.46 billion—raised average productivity in October–December 2025 to 57.44 Lcm/h (144%; +64.9%), turned the revenue gap positive at IDR 457.05 million, and increased the crusher rental rate from USD 190 to USD 283, so that the Plant Department's average rental revenue rose 136.6% to IDR 1,645.46 million per month. **Conclusion:** Staged size reduction with closed-circuit screening effectively improved productivity, product quality (five fractions for LPA/LPB/LPC blending), and the financial performance of the basalt crusher, with an indicative revenue-based payback of about 7.9 months.

Keywords: *crusher productivity; cone crusher; workflow redesign; staged size reduction; screening; PDCA*

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1. INTRODUCTION

1.1 Background

In basalt quarrying operations, the crusher functions to convert blasted and excavated rock (getting) into aggregate of specific sizes used for hauling-road pavement and mine construction needs. At PT Putra Perkasa Abadi (PPA) Jobsite MAC, the Terex TC1000 crusher is a centre-critical unit that supports two other activities, namely getting and hauling. Prolonged crusher stoppages directly halt material flow from the pit and reduce project revenue.

Performance data for April–June 2025 show crusher Pdty at 31.63, 33.89 and 38.95 Lcm/h, all below the 40 Lcm/h target. Actual production reached only 87.6% of plan, and actual revenue was IDR 95.52 million lower than planned. In addition, the existing configuration produced only a single product fraction, so the owner could not yet blend Aggregate Base Course Class A (LPA), Aggregate Base Course Class B (LPB) and Aggregate Base Course Class C (LPC) in accordance with the Indonesian National Standard (SNI) and the Bina Marga General Specification for hauling-road pavement.

1.2 Literature Review

Comminution is the process of reducing rock particle size that, in industrial practice, is carried out in stages because each type of crusher has a limited reduction ratio (Wills & Finch, 2016; Gupta & Yan, 2016). Primary crushers such as jaw crushers handle large-sized feed with a moderate reduction ratio, after which secondary and tertiary stages further reduce the size to product specification. Size separation with a vibrating screen between stages allows material that already meets the size specification to exit as product, while oversize material is returned to the crusher (closed circuit) so that the load on each crusher is more balanced (Gupta & Yan, 2016; Napier-Munn et al., 1996).

Cone crushers are generally used in the secondary or tertiary stage. Their performance is strongly influenced by how well the feed size and distribution match the geometry of the crushing chamber (Evertsson, 2000). Feed that is too large causes uneven loading, rapid and non-uniform liner wear (mantle and concave), and reduced throughput. A comparative study of cone-crusher circuits against theoretically optimal crushing sequences shows that dividing size reduction across several stages affects energy efficiency and product quality (Lee & Evertsson, 2011).

The Plan-Do-Check-Act (PDCA) cycle is a continuous-improvement framework popularized by Deming (1986). In Quality Control Project (QCP) practice, this cycle is elaborated into eight steps and supported by quality tools such as the Pareto diagram and the Ishikawa cause-and-effect (fishbone) diagram (Ishikawa, 1985). Improvement targets are set using the SMART criteria (Specific, Measurable, Achievable, Relevant, Time-bound) (Doran, 1981).

Crusher performance in this study is measured by productivity (Pdty) in loose cubic meters per hour (Lcm/h), i.e., production volume divided by operating hours. Supporting indicators are monthly production volume (Lcm), revenue LR (the gap between actual and planned revenue), and the rental-rate revenue received by the Plant Department as the owner of the crusher unit. Component reliability is assessed through downtime and part lifetime, in line with the productive-maintenance approach

(Nakajima, 1988) and good mining practice (Ministry of Energy and Mineral Resources of the Republic of Indonesia [MEMR], 2018).

1.3 Research Gap

Prior studies on cone-crusher performance and crushing circuits are generally theoretical or based on laboratory simulation, focusing on crushing-chamber geometry and optimal size-reduction sequences (Evertsson, 2000; Lee & Evertsson, 2011). Applied research that documents the full implementation of the PDCA cycle and QCP methodology for workflow redesign and physical modification of a crushing circuit in an actual contractor mining operation—while also evaluating its impact on productivity, product quality, and financial performance (both project revenue and unit rental revenue)—remains relatively scarce, particularly in the context of basalt quarrying in Indonesia.

1.4 Novelty and Rationale

This study contributes an empirical case study that links three evaluation dimensions at once—productivity (Pdty), component reliability (downtime and part lifetime), and financial performance (project revenue LR and the Plant Department's rental revenue)—within a single eight-step PDCA cycle applied to a basalt crusher circuit modification. This approach rationalizes that improving workflow design and component composition is a fundamental prerequisite for achieving the staged size reduction consistent with comminution principles (Wills & Finch, 2016), before improvements in product quality and financial performance can be sustainably achieved.

1.5 Research Objectives

Based on the conditions above, this study aims to: (1) identify the root causes of the crusher's failure to meet its Pdty target; (2) determine and implement the most effective improvement solution; and (3) evaluate the impact of the solution on the crusher's Pdty, production, and financial performance during the June–December 2025 period.

2. METHODS

2.1 Research Design

This study uses a case-study design with an applied action-research approach, following the Plan-Do-Check-Act (PDCA) cycle integrated with the eight-step Quality Control Project (QCP) methodology: (1) determining the activity through problem stratification with a Pareto diagram and setting a SMART theme and target; (2) identifying causes through field review and a fishbone diagram (Man, Material, Machine, Method); (3) determining the solution through evaluation of alternatives; (4) preparing a 5W1H improvement plan and budget; (5) implementing the plan and measuring data; (6) evaluating the solution by comparing before–progress–after KPIs; (7) standardizing through drafting and approving an SOP; and (8) determining the next improvement theme.

2.2 Research Location and Period

The study was conducted in the crusher area of PT PPA Site Maruwai (AMI–MAC), Lampunut, Central Kalimantan, over the period from April to December 2025.

2.3 Research Object and Scope

The object of the study is the Terex TC1000 crusher, with an initial configuration of Hopper & Vibrating Grizzly Feeder (VGF) – Jaw Primary JW42 – Surge Bin & Pan Feeder – MC Cone MTC1000 – conveyor, producing a single product fraction. The scope of the study covers the entire crushing process chain from the hopper feed to the final product, excluding the getting process (blasting and excavation) and hauling beyond the crusher point.

2.4 Data Collection Procedures and Instruments

Data were collected through: (1) review of breakdown and downtime data for January–June 2025 and the MC Cone inner-part replacement history from June 2024–May 2025, from Engineering reports; (2) monthly Pdty, production and revenue data for April–December 2025, from Engineering reports (daily, weekly, monthly); and (3) Plant Department crusher rental-rate revenue data for the same period. The analysis period was divided into three phases: before (April–June), progress/implementation (July–September), and after (October–December 2025).

2.5 Data Analysis

Breakdown and downtime data were analyzed using a Pareto diagram to identify the largest contributors, followed by a cause-and-effect (fishbone) diagram across the Man, Material, Machine and Method categories to formulate the dominant root cause. Alternative solutions were evaluated based on advantages, disadvantages and risk analysis, after which the selected solution was set out in a 5W1H plan before implementation. The impact of implementation was analyzed descriptively and comparatively between the before, progress and after phases for the Pdty, production, revenue LR, rental rate, and Plant Department rental-revenue indicators. The investment payback indication was calculated using a simple payback method based on the difference in average rental revenue before and after implementation.

2.6 Scope and Methodological Limitations

The study is limited to a single crusher unit (Terex TC1000) at a single operating site (PPA Site MAC), with a nine-month observation period (April–December 2025) that includes a relatively short post-implementation evaluation window (three months); generalizing the results to other crusher units or sites with different material characteristics and configurations should therefore take each operational context into account.

3. RESULTS AND DISCUSSION

3.1 Results

The results of the study are presented in the following six subsections, covering the initial condition, root-cause analysis, solution selection, modification implementation, evaluation of results, and the Plant Department's financial performance.

3.1.1 Initial Condition

Downtime stratification for January–June 2025 shows that the MC Cone had a relatively low failure frequency (14 occurrences) but the highest downtime, at 124 hours or 36.6% of the total 339 hours (Figure 1). This occurred because every Cone failure required replacing the mantle and concave, waiting for genuine parts from a distant vendor's supply, and required technician supervision. By type of work, mechanical work contributed the highest downtime (197 hours).

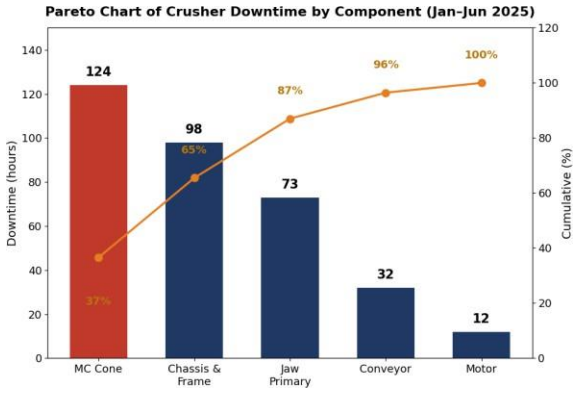


Figure 1. Pareto chart of crusher downtime by component, January–June 2025

The MC Cone inner-part replacement history shows lifetimes of 661, 293, 426, 588 and 501 hours, averaging ±494 hours, so that most replacements occurred at or below the lower bound of the planned 500–1,000-hour lifetime (Figure 2). These unscheduled replacements were the main source of unscheduled breakdowns.

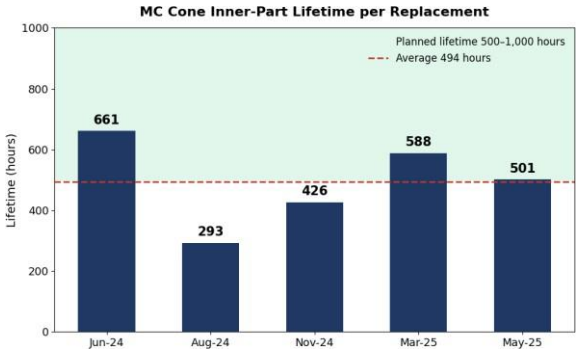


Figure 2. MC Cone inner-part lifetime at each replacement

3.1.2 Root Cause Analysis

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Field observations found that Jaw Primary product varied from 10–30 cm, with a majority of 20–30 cm, while the ideal Cone feed size is 10–15 cm. In the initial configuration, material from the Jaw Primary was fed directly to the Cone without any secondary reduction or screening stage. The fishbone diagram (Figure 3) summarizes the contributing factors: Machine (low Cone durability due to oversize feed), Material (genuine parts are expensive and frequently delayed in delivery), Man (long repair times requiring supervision), and Method (inadequate workflow design and component composition).

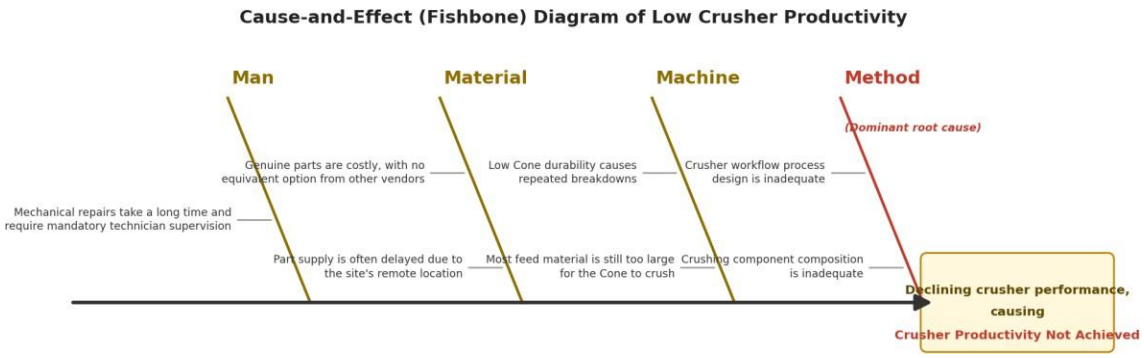


Figure 3. Cause-and-effect diagram of low crusher productivity

Verification of the four factors showed that the oversize-material problem, the excessive load on the Cone, and the absence of additional crushing components all originate from a single cause: inadequate crusher workflow design and component composition. This factor was established as the dominant root cause (Table 1).

Table 1. Determination of the Dominant Root Cause

Factor	Fact	Conclusion
Material	Majority of Jaw Primary product is 20–30 cm, above the Cone feed specification	Priority
Machine	Cone receives oversize rock above the 10–15 cm standard	Priority
Machine	No crushing component besides the Jaw Primary & Cone	Priority
Method	**Inadequate workflow design & component composition**	**Dominant**

3.1.3 Solution Selection

Four alternative solutions were evaluated (Table 2). Scheduling part replacement according to the APL (part-life schedule) is easy to implement but does not eliminate the cause and creates repeat work. The run-to-failure approach risks increasing costs and disrupting mining activity. The combination of workflow redesign and adding components was selected because it addresses the dominant root cause, the components are available from vendor BMS, its implementation is measurable and schedulable, and it is supported by stakeholders, even though it requires a larger budget and a more complex implementation.

Table 2. Evaluation of Alternative Solutions

Alternative	Key Consideration	Decision
Scheduled part replacement per APL	Easy, familiar; but repetitive and high effort	Not selected
Redesign workflow process	**Best-assessed option, well-planned; requires time & approval**	**Selected**
Additional component crushing	**Reduces Cone load, reliable unit; high cost**	**Selected**
Run to failure	High cost, mining disrupted	Not selected

3.1.4 Modification Implementation

Technical assessment and design were carried out together with vendor BMS in June 2025, followed by procurement, foundation civil works, chassis and frame fabrication, erection using a 10-ton crane truck and a Tadano crane, wiring and panel installation, and ground testing in July–August 2025. Risk was controlled through JSA, P5M (pre-shift safety talks), direct supervision, and logistics coordination. The added components are presented in Table 3.

Table 3. Added Components

Component	Specification	Vendor
Jaw Secondary	PE 250 × 1200	BMS
Surge Bin 2nd	30 m^3	BMS
PLFC (sand maker)	1250	BMS
Screen 1st	VS150400	BMS
Screen 2nd	VS180500	BMS
Line conveyor	+11 lines (14 total)	Cominco

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Total modification investment reached IDR 7,461,894,903, consisting of design (IDR 194.81 million), major components (IDR 3,863.67 million), instrument wiring and panels (IDR 322.09 million), chassis and frame (IDR 738.30 million), tools (IDR 55.49 million), manpower (IDR 849.46 million) and mobilization (IDR 1,438.07 million). The installed conveyors were inspected and tested by a Technical Inspection Service Company (PJIT) on 24 July 2025, with an acceptable result.

The post-modification configuration (Figure 4) divides the process into three areas. Area 1 comprises the Hopper & VGF, Jaw 1st and Surge Bin 1st. Area 2 is the secondary reduction stage with the Jaw 2nd, with the MC Cone now receiving only Screen 1st reject material, plus Surge Bin 2nd and the PLFC. Area 3 is a two-stage screening circuit producing five product fractions: 0–5 mm (dust/sand), 5–10 mm, 10–20 mm, 20–30 mm and 30–50 mm.

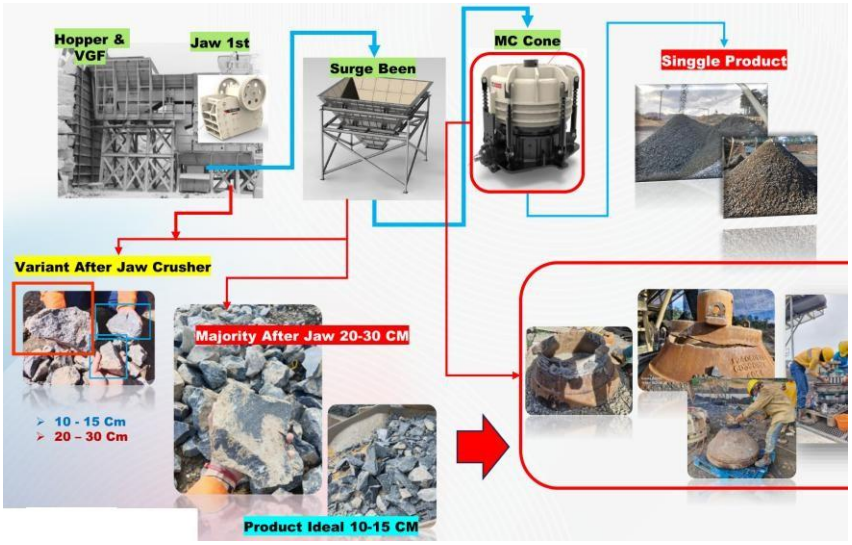


Figure 4a. Crusher workflow before modification (single product)

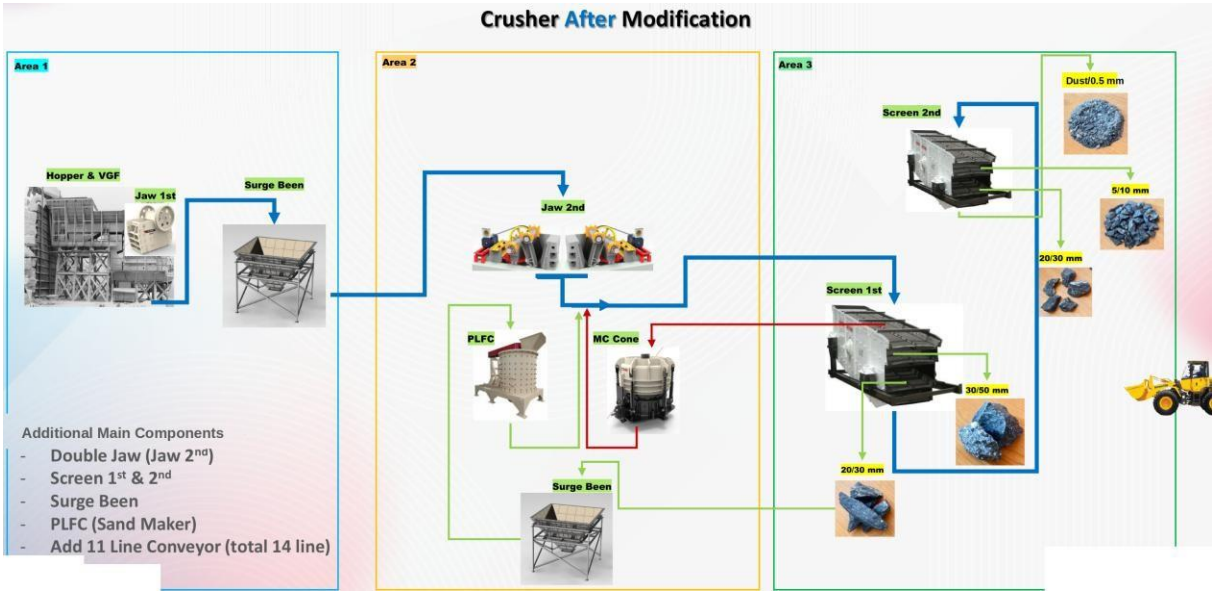


Figure 4b. Crusher workflow after modification: double jaw, two screens, PLFC and 14 conveyor lines

3.1.5 Evaluation of Results

The inter-phase KPI comparison is presented in Table 4 and Figure 5. Average Pdty rose from 34.83 Lcm/h (87%) in the before phase to 44.91 Lcm/h (112%) in the progress phase and 57.44 Lcm/h (144%) in the after phase, an increase of 64.9%. In July, achievement was still 93% as it coincided with the installation period, then jumped to 123% in August once the new components were operating, reaching a peak of 65.38 Lcm/h (163%) in December 2025.

Table 4. Crusher KPI Comparison by Phase

Indicator	Before	Progress	After
Average Pdty (Lcm/h)	34.83	44.91	57.44
Pdty achievement	87%	112%	144%
Average production (Lcm/month)	8,752.88	9,637.90	19,886.23
Production achievement	87.6%	117.1%	142.4%
Total actual revenue (IDR million)	675.50	743.81	1,534.72
Revenue LR (IDR million)	–95.52	+108.48	+457.05
Crusher rental rate	USD 190	transition	USD 283
Average Plant rental revenue (IDR million/month)	695.51	888.00	1,645.46
Product fractions	1	–	5

Average monthly production in the after phase reached 19,886.23 Lcm, or 2.27 times the initial condition. Financially, the revenue LR turned from –IDR 95.52 million to +IDR 108.48 million in the progress phase and +IDR 457.05 million in the after phase, with average actual revenue per month increasing from IDR 225.17 million to IDR 511.57 million (+127%).

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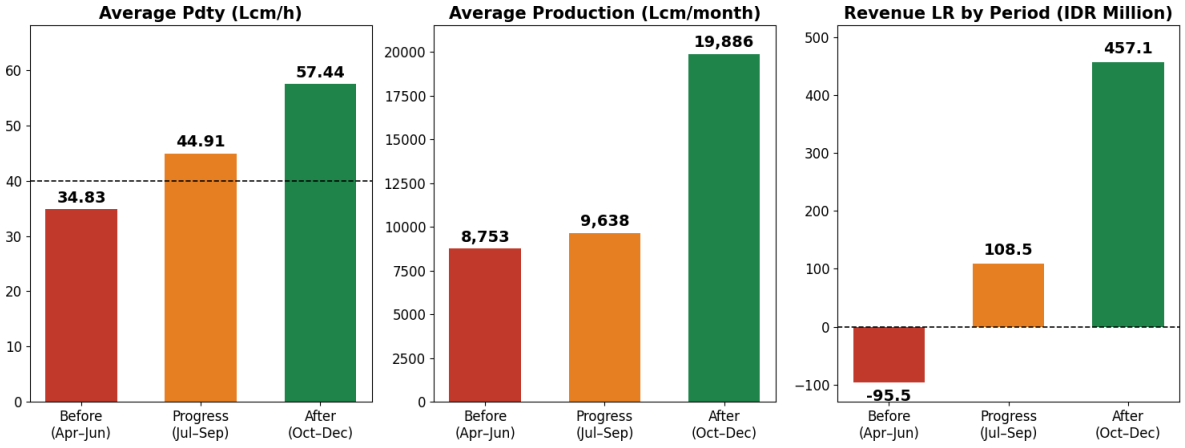


Figure 5. Comparison of Pdty, production and revenue LR across the before, progress and after phases

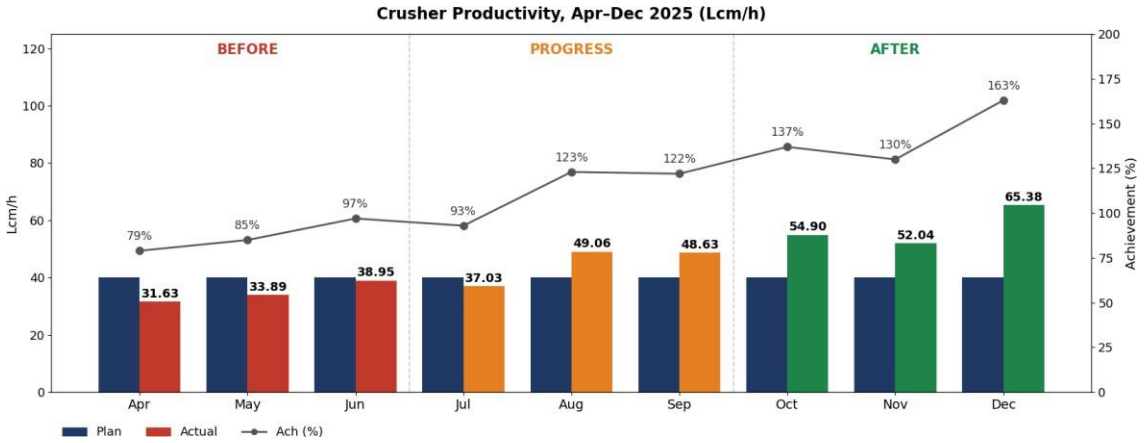


Figure 6. Monthly trend of crusher Pdty against plan, April–December 2025

3.1.6 Plant Department Financial Performance

As the unit owner, the Plant Department earns revenue from the crusher rental rate. After the modification, the rental rate rose from USD 190 to USD 283 (+48.9%) in line with the added major components, capacity and product fractions. Average rental revenue increased from IDR 695.51 million per month in the before phase to IDR 888.00 million in the progress phase and IDR 1,645.46 million in the after phase (+136.6%), peaking at IDR 1.77 billion in October 2025 (Figure 7). The dip in July (IDR 284.47 million) coincided with the installation period. Total rental revenue for April–December 2025 reached IDR 9.69 billion.

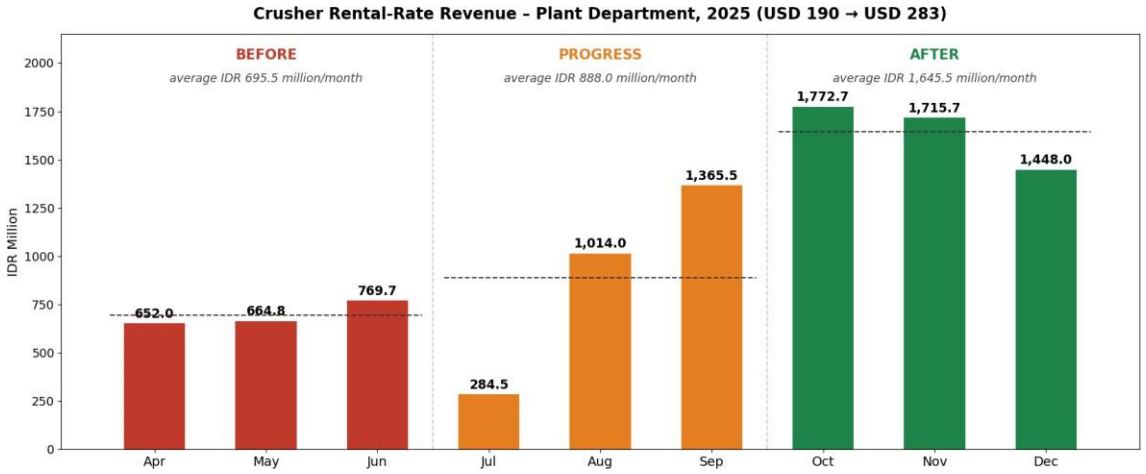


Figure 7. Plant Department crusher rental-rate revenue, April–December 2025

Table 5. Indicative Investment Payback (Based on Plant Rental Revenue)

Description	Value
Modification investment	IDR 7,461,894,903
Additional revenue per month (after – before)	IDR 949,954,125
Cumulative additional revenue, Jul–Dec 2025	IDR 3,427,327,785
Investment portion recovered as of Dec 2025	±45.9%
Indicative simple payback	**±7.9 months**

With additional revenue of about IDR 950 million per month over the baseline, the IDR 7.46 billion investment is indicatively recovered within ±7.9 months after full implementation. This figure is based on gross revenue and does not yet account for operating, maintenance and fuel costs.

3.2 Discussion

The performance improvement can be explained by three mechanisms. First, adding the Jaw Secondary divides the size-reduction load so that material entering the next stage falls within a more suitable size range, consistent with the principle of staged reduction (Wills & Finch, 2016; Gupta & Yan, 2016). Second, the closed-circuit screening removes material that already meets size specification as product, so the Cone only processes the reject fraction; this reduces the Cone's load and improves crushing-chamber operating conditions (Evertsson, 2000). Third, the second Surge Bin and the PLFC improve material-flow stability and add production capacity for the fine fractions.

Financially, the increase in the Plant Department's revenue is driven by two mutually reinforcing factors: a 48.9% increase in the rental rate as a consequence of the unit's increased value and capacity,

and an increase in effective operating hours because the crusher is no longer held back by repeated Cone breakdowns and can operate more than one shift. The combination of these two factors produced a rental-revenue increase (+136.6%) far exceeding the increase in the rental rate alone.

Beyond quantity, the modification also improved product quality. Voice-of-customer feedback from the CRSO & Engineer AlamTri team stated that before the improvement, only one product fraction was produced and the crusher operated only on the day shift, whereas after the improvement five fractions became available, enabling blending of LPA and LPB in accordance with hauling-road pavement standards, and increasing the supply of basalt product.

Post-implementation evaluation still found breakdowns, with the dominant causes being clogging (32 occurrences), cracking (21), rain (20), and operator pauses (13). Clogging occurred due to wet and oversize material from the stockpile and rock overload during feeding. As a preventive measure, the team installed CCTV at critical points on the crusher so operators can monitor material circulation in real time; the main risks of this measure are WiFi network stability, wiring condition, and camera positioning.

3.3 Implications

The results of this study have practical implications for basalt crusher operators and other mining contractors facing similar constraints, namely excessive load on secondary/tertiary units due to the absence of adequate reduction and screening stages. The principle of staged size reduction with a closed-circuit screening system applied in this study can serve as a design reference for crusher modification in similar configurations, while also confirming that investment in additional crushing components should be evaluated not only in terms of productivity, but also the financial performance of the unit as an asset rented out (rental) between departments.

3.4 Research Contribution

This study contributes to the cone-crusher literature, which has so far been dominated by theoretical studies and laboratory simulations (Evertsson, 2000; Lee & Evertsson, 2011), by providing an applied case study that simultaneously measures the impact of a crushing-circuit modification on productivity, component reliability, product quality, and financial performance in an actual contractor mining operation.

3.5 Limitations

This study has several limitations. The post-implementation evaluation period was relatively short (three months), and the monthly production plan varied, so the achievement percentages should be read together with their absolute values. Both the revenue LR and rental revenue are revenue figures, not net profit, so the indicative ±7.9-month payback still needs to be confirmed through an operating-cost analysis. In addition, the contribution of each additional component has not been separated quantitatively.

3.6 Recommendations

Future research is recommended to: (1) continue monitoring Pdty and Cone inner-part lifetime for at least 12 months to confirm the sustainability of the results; (2) confirm the indicative ±7.9-month payback through a margin-based feasibility analysis (net present value and actual payback period) using the Plant Department's LR reports; (3) control the moisture content and size of stockpile material to reduce clogging incidents; and (4) carry out the next improvement theme, namely optimizing reject material to increase the proportion of LPA product to above 40%.

4. CONCLUSION

This study concludes that the low Pdty of the Terex TC1000 crusher in April–June 2025 (average 34.83 Lcm/h; 87%) originated from an inadequate workflow design and component composition, which caused the Cone to receive oversize feed of 20–30 cm with an inner-part lifetime of only ±494 hours. The workflow redesign, combined with the addition of a Jaw Secondary, two vibrating screens, a second Surge Bin, a PLFC, and 11 conveyor lines, proved effective in addressing this dominant root cause: after implementation, average Pdty rose to 57.44 Lcm/h (144%), average production rose to 19,886.23 Lcm/month, revenue LR turned to +IDR 457.05 million in October–December 2025, and the crusher produced five product fractions. For the Plant Department as the unit owner, the crusher rental rate rose from USD 190 to USD 283 and average rental revenue increased 136.6% to IDR 1,645.46 million per month, with an indicative investment payback of ±7.9 months based on revenue.

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