West Science Interdisciplinary Studies
Vol. 02, No. 12, December and 2024: pp. 2318-2325

Evaluation of Production Capability of Transportation Equipment and Loading Equipment in Limestone Mining at PT X, South Sulawesi

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ABSTRACT

This study focuses on the evaluation of the production capacity of loading and hauling equipment in limestone mining operations at PT. X, South Sulawesi Province. The selection of this topic is based on the importance of operational efficiency in limestone mining which has a direct impact on the productivity and sustainability of the cement industry. The main objectives of this study are to determine the actual production of loading and hauling equipment, determine the number of equipment needed to meet production targets and identify compatibility factors between mechanical equipment at the mining site. The methods used include field data collection involving measurement of cycle time and production capacity of loading and hauling equipment. The data obtained are then processed using statistical methods to ensure the accuracy of the results. Data analysis is carried out by considering variables such as work efficiency, cycle time, and equipment capacity. The results show that Kobelco SK 480 LC has the highest production capacity (509.34 tons/hour), followed by Komatsu PC 400 (448.25 tons/hour) and PC 300 (417.05 tons/hour). To achieve the Crusher production target of 1450 tons/hour, a combination of loading equipment and dump trucks with a compatibility factor between 0.87 and 0.92 is required, indicating potential for increased efficiency. It is recommended to improve maintenance of equipment and mining roads to optimize productivity.

Keywords: *Production, Limestone, Efficiency, Mining Equipment*

1. INTRODUCTION

Limestone is an important commodity that is widely used in the cement industry, the existence of which is very crucial for infrastructure development [1]. PT. X, located in South Sulawesi Province, is one of the largest cement producers in the Indonesian region that manages this limestone resource [2]. In its operations, limestone mining requires the use of efficient loading and transport equipment to ensure smooth production and fulfillment of market targets [3].

However, in practice, there are often obstacles in terms of production efficiency caused by various factors, such as geographical conditions[4], availability of equipment, and operational management[5]. Therefore, an in-depth study is needed to evaluate the production capacity of loading and transport equipment in limestone mining[6]. This study aims to identify and analyze the factors that affect the productivity of heavy equipment and find solutions to increase production efficiency. This study aims to determine the actual production of loading and transport equipment in limestone mining at PT X. Determine the number of tools needed to meet production targets at PT X, and Identify the compatibility factors of mechanical tools at PT X and their impact on production efficiency.

Issues related to this research include operational efficiency of heavy equipment, sustainable management of natural resources, and environmental impacts of mining activities. Production efficiency is key to reducing operational costs and increasing company profits. On the other hand, mining that does not pay attention to environmental aspects can damage the ecosystem and reduce the quality of life of the surrounding community. The hypothesis in this study is that there are specific factors that affect the production efficiency of loading and transport equipment at PT X, which include the technical condition of the equipment, operator skills, mining methods, and field management. By identifying and optimizing these factors, it is expected to increase production efficiency.

2. LITERATURE REVIEW

2.1 Importance of Production Capability in Mining Operations

Evaluating production capability in mining operations is essential to optimize efficiency and ensure resource sustainability. According to Hustrulid and Bullock (2001)[7], production capability directly impacts operational productivity, which is essential to the economic viability of mining companies. In limestone mining, where operational costs can be significant, understanding the production capacity of loading and hauling equipment is essential to maximize output and minimize downtime [8].

2.2 Factors Affecting Equipment Performance

Several studies have highlighted the key factors that impact the performance of loading and hauling equipment in a mining environment. For example, Dikgale K. (2022) emphasized the role of cycle time, equipment maintenance, and compatibility between different types of machines[9]. These factors can significantly impact overall productivity and efficiency. The importance of routine maintenance and timely repairs is echoed by Pasco, E. A. (2020), who found that well-maintained equipment reduces operational disruptions and increases production capacity [10].

2.3 Evaluating Equipment Compatibility

Equipment compatibility is another important aspect that impacts production capability. Research by Thambas, A. H. (2024) shows that a suitable fleet of loading and unloading and transportation equipment can improve operational alignment and efficiency [11]. The study also shows that compatibility factor analysis, which measures how well different machines work together, can provide insight into potential bottlenecks in the production process. This is in line with the objective of evaluating equipment compatibility in the context of limestone mining at PT. X.

2.4 Statistical Methods for Data Analysis

The application of statistical methods in evaluating production capacity has been well documented in the literature. According to Montgomery (2017), statistical analysis is essential for processing field data to ensure the accuracy of production assessments[12]. Methods such as regression analysis and variance analysis can help identify significant variables that affect production capacity [13], allowing mining operators to make informed decisions regarding equipment usage and operational strategies [14].

2.5 *Implications for the Cement Industry*

Limestone mining is a fundamental component of the cement industry [15]. As highlighted by Zhang et al. (2019) The efficiency of mining operations not only affects production levels but also impacts the sustainability of cement production as a whole [16]. Given the increasing environmental concerns and the need for sustainable practices, improving the efficiency of loading and conveying equipment is critical to reducing the carbon footprint of the cement industry [17].

3. METHODS

This research was conducted through several systematic stages including preparation, data collection, data processing, and data analysis. Each stage is designed to ensure that the research can answer the problem formulation and achieve the objectives that have been set effectively and efficiently. Data collection was carried out in the field by observing and recording the performance of loading and transport equipment used in limestone mining operations. The data collected includes the type and specifications of loading and transport equipment, operational cycle time of loading and transport equipment, number of equipment operating, and operational conditions in the field. Data collected from the field will be processed using statistical methods to obtain reliable values. Data processing includes calculating the average cycle time, analyzing the production capacity of the equipment based on the data collected, and calculating operational efficiency using relevant formulas.

The processed data will be analyzed to determine the effectiveness of loading and transporting equipment in mining operations. This analysis will help in providing recommendations for increasing efficiency. The tools and materials used in this study include a stopwatch to measure cycle time. Camera for documenting field conditions. Laptop and statistical data processing software. Stationery for data recording. Data Collection and Processing Procedures, Direct observation conducting direct observation of the operation of loading and transport equipment in the field. Cycle time measurement Using a stopwatch, the cycle time of each tool is measured 30 times to obtain representative data. Interview Conducting interviews with operators to obtain information on the operation of the tool. The following is the formula used:

$$\bar{x} = \frac{\sum_{i=1}^{n} x_i}{n}$$

Where:
x^{-} = average cycle time,
xi = value of cycle time to-i,
n = number of observations.

Production capacity analysis uses cycle time data and work efficiency to calculate the production capacity of the tool.

$$P = \frac{Eff \times Kb \times Sf \times FF \times D \times 60}{CT}$$

where:
P = production (ton/hour)
Eff = work efficiency (%)
Kb = bucket capacity (m^3)

Sf = swell factor (%)
FF = fill factor
D = density (ton/m³)
CT = cycle time (minutes).

Data processing, namely data obtained from the field is processed using statistical methods and then calculations are carried out using equations related to the production capacity of mechanical equipment, the number of equipment needed to meet production targets and the suitability of the equipment.

4. RESULTS AND DISCUSSION

Based on the results of the analysis in the study, the Production Capacity of Loading Equipment and Transport Equipment was found to be shown in the following table.

Table 1. Production Capacity of Loading Equipment and Transport Equipment

Mechanical Equipment	Production Capacity (ton/hour)
Komatsu PC 400 Loader	448.25
Komatsu PC 300 Loader	417.05
Kobelco SK 480 LC Loader	509.34
Hino 500 Ranger FM Dump Truck	78.37
UD Truck Quon CW 33370 Dump Truck	52.90
Isuzu Giga FVC 285-PS Dump Truck	84.52

From Table 1, the results of the study show that the production capacity of loading and transport equipment in the Company has quite significant variations. The Kobelco SK 480 LC loading equipment has the highest production capacity among other loading equipment, which is 509.34 tons/hour, which shows better efficiency and capacity in handling limestone materials. Meanwhile, the Komatsu PC 300 loading equipment has the lowest production capacity among the tested loading equipment, which is 417.05 tons/hour.

On the transportation equipment side, the UD Truck Quon CW 33370 Dump Truck has the lowest production capacity, which is only 52.90 tons/hour. This can be caused by factors such as lower operational efficiency or technical condition of the vehicle. In contrast, the Isuzu Giga FVC 285-PS Dump Truck shows a higher production capacity among the tested transportation equipment, which is 84.52 tons/hour. This difference shows the importance of selecting the right equipment based on capacity and efficiency to increase overall productivity in mining operations. In addition, good maintenance and selecting an efficient operational strategy are also very important to maximize the output of each equipment. By understanding the production capacity of each equipment, PT X can plan and allocate resources better to achieve production targets effectively.

Table 2. Cycle Time of Loading Equipment and Transport Equipment

Mechanical Equipment	Cycle Time (minutes)
Komatsu PC 400 Loading Equipment	0.39
Komatsu PC 300 Loading Equipment	0.34
Kobelco SK 480 LC Loading Equipment	0.35
Hino 500 Ranger FM Dump Truck Transport Equipment	16.49
Isuzu Giga FVC 285-PS Dump Truck Transport Equipment	17.15
UD Truck Quon CW 33370 Dump Truck Transport Equipment	21.11

Table 2 of the research results shows that the cycle time for loading equipment is relatively uniform and very short compared to transport equipment. Komatsu PC 400, Komatsu PC 300, and

Kobelco SK 480 LC loading equipment have cycle times ranging from 0.34 to 0.39 minutes, indicating high efficiency in the material loading process. The minimal time difference between the three loading equipment demonstrates that all of these loading equipment operate with almost the same efficiency in terms of loading speed.

Meanwhile, the transport equipment shows a much longer cycle time, reflecting the higher complexity and duration of transporting materials to the processing location. The Hino 500 Ranger FM Dump Truck has the shortest cycle time among the transport equipment at 16.49 minutes, while the UD Truck Quon CW 33370 Dump Truck has the longest cycle time at 21.11 minutes. This difference can be influenced by several factors such as load capacity, engine efficiency, road conditions, and transport distance.

The significant difference in cycle time between loading and hauling equipment also shows the importance of effective coordination and scheduling between the two types of equipment to optimize workflow and reduce waiting time. High loading equipment efficiency must be balanced with good logistics management on the hauling equipment to ensure that loaded materials can be transported immediately without significant delay.

Table 3. Fill Factor of Loading Equipment

Mechanical Equipment	**Fill Factor (%)**
Komatsu PC 400 Loading Equipment	93,41
Komatsu PC 300 Loading Equipment	94,37
Kobelco SK 480 LC Loading Equipment	96,30

From the research results table above, it can be seen that the fill factor for each loading tool has a high value, indicating good efficiency in filling material into the loading tool bucket. The fill factor is an important indicator that shows how effectively the loading tool bucket is filled relative to its theoretical capacity. A higher value indicates more efficient filling, which contributes to higher productivity in mining operations.

The Komatsu PC 400 Loader has a Fill Factor of 93.41%, indicating that the bucket of this loading tool is filled almost full but there is still a small room for efficiency improvement. However, this value indicates that this loading tool is quite efficient in filling material. The Komatsu PC 300 Loader shows a slightly higher Fill Factor of 94.37%. This indicates that this tool has slightly better-filling efficiency compared to the Komatsu PC 400, possibly due to differences in bucket design or operating techniques used by the operator. The Kobelco SK 480 LC Loader recorded the highest Fill Factor among the three at 96.30%. This shows that these loaders are very efficient at filling their buckets to near maximum, which can contribute to higher production rates per operating cycle. This efficiency could be due to better bucket design, more effective operation, or a combination of both.

All loaders show high Fill Factors, indicating efficient operation. However, there is still room for improvement, especially for the Komatsu PC 400 and PC 300, to achieve efficiency comparable to the Kobelco SK 480 LC. This improvement could be achieved through better operator training, regular maintenance of the loader, or technical modifications to the bucket.

Table 4. Mechanical Equipment Work Efficiency

Mechanical Equipment	**Work Efficiency (%)**
Komatsu PC 400 Loading Equipment	78,57
Komatsu PC 300 Loading Equipment	76,19
Kobelco SK 480 LC Loading Equipment	72,61
Hino 500 Ranger FM Dump Truck Transport Equipment	72,61
Isuzu Giga FVC 285-PS Dump Truck Transport Equipment	73,80
UD Truck Quon CW 33370 Dump Truck Transport Equipment	75,00

From Table 4 of the research results, it can be seen that the work efficiency of mechanical equipment at PT X shows a relatively moderate variation between equipment. The work efficiency of the Komatsu PC 400 loading equipment reaches 78.57%, which is the highest value among all the equipment tested. This shows that this loading equipment has better operational performance compared to other loading equipment in terms of utilizing its operational time effectively. The Kobelco SK 480 LC loading equipment has the lowest work efficiency among the loading equipment, which is 72.61%. Although lower, this value still shows a fairly efficient use of operational time. The Komatsu PC 300 loading equipment has a slightly better work efficiency than the Kobelco SK 480 LC, which is 76.19%, indicating a fairly balanced performance in the use of its operational time.

For transport equipment, their work efficiency ranges from 72.61% to 75.00%. The Hino Ranger 500 FM 260 Dump Truck and the Isuzu GIGA PVC 285-PS Dump Truck have almost the same efficiency, which is 72.61% and 73.80% respectively. This shows that these two transport vehicles have similar performance in terms of utilizing their operational time. Meanwhile, the UD Truck Quon CW 33370 Dump Truck shows a slightly higher work efficiency, which is 75.00%, which indicates a more effective use of operational time compared to the other two transport vehicles.

Table 5. Mechanical Equipment Needs to Fulfill Production Targets

Loading Equipment	Number of Units	Transport Equipment	Number of Units
Komatsu PC 400	4	Dump Truck Hino 500 Ranger FM	20
Komatsu PC 300	4	Dump Truck UD Truck Quon CW 33370	28
Kobelco SK 480 LC	3	Dump Truck Isuzu Giga FVC 285-PS	18

Based on Table 5, it can be seen that the need for mechanical equipment to achieve the Crusher unit production target of 1450 tons/hour at PT X requires a different combination of loading and transport equipment. Komatsu PC 400 and Hino 500 Ranger FM Dump Truck: To achieve the production target, 4 Komatsu PC 400 loading units are needed which will work with 20 Hino 500 Ranger FM Dump Truck units. This combination shows that the loading equipment has sufficient capacity to meet the transportation needs carried out by 20 dump trucks, reflecting efficiency in the loading and transport process.

Komatsu PC 300 and UD Truck Quon CW 33370 Dump Truck: In this combination, 4 Komatsu PC 300 units are required to work with 28 UD Truck Quon CW 33370 Dump Trucks. The higher number of dump trucks compared to the first combination indicates that the Komatsu PC 300 may have lower loading efficiency or faster cycle time requiring more dump trucks to transport the loaded material. Kobelco SK 480 LC and Isuzu Giga FVC 285-PS Dump Truck: For this combination, only 3 Kobelco SK 480 LC units are required to work with 18 Isuzu Giga FVC 285-PS Dump Trucks. This indicates that the Kobelco SK 480 LC may have higher loading efficiency or capacity per unit compared to the other two loaders, thus requiring fewer dump trucks to achieve the same production target.

Table 6. Compatibility Factor of Mechanical Equipment

Loading Equipment	Transport Equipment	Compatibility Factor
Komatsu PC 400	Dump Truck Hino 500 Ranger FM	0,90
Komatsu PC 300	Dump Truck UD Truck Quon CW 33370	0,87
Kobelco SK 480 LC	Dump Truck Isuzu Giga FVC 285-PS	0,92

Based on Table 6 of the research results, the compatibility factor between loading equipment and transport equipment at PT X shows relatively small variations, with values ranging from 0.87 to 0.92. This compatibility factor indicates how efficiently loading and transporting equipment work together in the mining operational system.

Komatsu PC 400 and Hino 500 Ranger FM Dump Truck: A compatibility factor of 0.90 indicates that the loader and hauler are well-matched, but there is still room for improvement. A value below 1 indicates that the loader is running slightly faster than the hauler's capacity to transport the loaded material.

Komatsu PC 300 and UD Truck Quon CW 33370 Dump Truck: A compatibility factor of 0.87 is the lowest of the three combinations, indicating that the loader has a longer waiting time before the hauler is ready to receive a load. This could indicate that the hauler may not be fast enough or efficient enough to pick up the load, or that the loader is too fast for the hauler to return in time.

Kobelco SK 480 LC and Isuzu Giga FVC 285-PS Dump Truck: A compatibility factor of 0.92 is the highest, indicating that this combination is the most efficient of the others. The loading equipment and transport equipment have good coordination, with the transport equipment being able to follow the loading rhythm of the loading equipment well.

CONCLUSION

Based on the results of observations and data analysis that have been carried out on limestone mining at PT X, several important points can be concluded related to the production capacity of loading and transport equipment and the compatibility factor between the two. First, the production capacity of the Komatsu PC 400 loading equipment was recorded at 448.25 tons/hour, while for the Komatsu PC 300 loading equipment, it was 417.05 tons/hour, and the Kobelco SK 480 LC loading equipment had the highest production capacity of 509.34 tons/hour. In terms of the production capacity of transport equipment, the Hino 500 Ranger FM Dump Truck has a capacity of 78.37 tons/hour, the UD Truck Quon CW 33370 Dump Truck is 52.90 tons/hour, and the Isuzu Giga FVC 285-PS Dump Truck is 84.52 tons/hour. To achieve the Crusher unit production target of 1450 tons/hour, 4 Komatsu PC 400 loading equipment units are required to work together with 20 Hino 500 Ranger FM Dump Truck units, resulting in a tool compatibility factor of 0.90. This indicates that the loading equipment is working below its full capacity. Meanwhile, for the Komatsu PC 300 loading equipment, 4 units are required to work together with 28 UD Truck Quon CW 33370 Dump Truck units with a tool compatibility factor of 0.87. Finally, for the Kobelco SK 480 LC loading equipment, 3 units are required to work together with 18 Isuzu Giga FVC 285-PS Dump Truck units with a tool compatibility factor of 0.92. From these results, it can be seen that there is room for improving work efficiency, especially in terms of adjusting the number of loading equipment and transport equipment to achieve better compatibility and optimal operational efficiency. Therefore, it is recommended to improve the care and maintenance of mining equipment and roads so that damage to transportation equipment can be minimized, which in turn can increase company productivity.

ACKNOWLEDGEMENTS

Author would like to express our deepest gratitude to all parties who have assisted in completing the research entitled "Evaluation of Production Capacity of Transport Equipment and Loading Equipment in Limestone Mining at PT X, South Sulawesi". We would also like to thank our colleagues who have provided direction and input that have been very helpful in the process of this research. This research would not have been possible without the cooperation of all parties. Thank you.

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