# Productivity and Cost Analysis of Log Hauling Using Logging Trucks in Natural Forests in East Kalimantan, Indonesia

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**Abstract.** Log hauling is a critical and cost-intensive stage in timber harvesting operations. In Indonesia's natural forests, log hauling is mechanized by using logging trucks to enhance efficiency and productivity. This study aimed to calculate the productivity, cost, and efficiency of log hauling in natural forests in East Kalimantan using a Mercedes-Benz MB 3836 AK logging truck. This study was carried out at PT Inhutani I Sambarata, located in the Berau District, East Kalimantan Province, Indonesia. To determine productivity, measurements of distance and time for 30 sample trips of log-hauling were recorded. Data on timber volume were obtained from company records, while transportation costs were calculated by considering the fixed and operational costs incurred during the log-hauling process. The data were collected in 2023. The study found that the mean productivity of timber transportation was 248.86 $m^3.km.h^{-1}$, while the total costs for thirty trips amounted to Rp. 86,152 per $m^3.km$, resulting in a cost per trip of Rp2,872 per $m^3.km$. Additionally, the level of efficiency in transportation process exhibited an efficiency level of 87%. Future efforts should prioritize operator training in fuel efficiency, safety, and digital tools while linking performance evaluations to hauling efficiency for improved productivity and management.

**Keywords:** log yard, log transportation, timber harvesting, work efficiency, working hours

## 1 Introduction

Timber transportation is an important but frequently unprofitable component of timber supply chain [1]. Log transport is a significant stage in the raw timber supply process [2, 3] and consumes significant quantities of energy [3]. Timber transportation is one of the most difficult issues for logging companies and the forestry industry [4].

Log trucks owned by logging companies or contract carriers move timber to mills [1]. The employment of a variety of machines in timber harvesting operations lowered the total operational costs while increasing production. However, the specific time consumption and cost fraction of whole timber harvesting processes have not been

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analyzed [4]. Furthermore, according to [5], log hauling productivity and cost efficiency have become vital in forest harvesting operations.

PT Inhutani I Sambarata is a timber company that manages natural forests in East Kalimantan, where timber is mechanically transported using a Mercedes-Benz MB 3836 AK logging truck. Trucks have become popular for log transport in dryland forests because of their ability to carry large volumes and heavy timber, and because they can travel on forest roads that are not as ideal as public roads in terms of surfacing and topography. In addition, truck trailers can be quickly modified to accommodate delivered commodities, and workshops for truck maintenance are conveniently accessible and available [6]. Although trucks such as the Mercedes-Benz MB 3836 AK have been commonly used in timber transportation because of their capacity and flexibility, to date, there has been no quantitative study at PT Inhutani I Sambarata that specifically measures the productivity, costs, and efficiency of their use. This information gap can hamper strategic decision-making regarding the operational management of timber transportation. Therefore, this study aimed to calculate the productivity, cost, and efficiency of transporting timber in natural forests using a Mercedes-Benz MB 3836 AK logging truck.

## 2 Materials and Methods

### 2.1. Materials

The log transportation activities observed in this study were conducted by a natural forest company, PT Inhutani I Sambarata, located in Berau Regency, East Kalimantan Province, Indonesia. The data collection was conducted in 2023. Log hauling is a truck activity that transports logs from a loading area to a delivery location [4]. Hauling trucks move logs from temporary log yards to larger log yards or directly to timber company [2].

At PT Inhutani I Sambarata, log transportation is the process of moving logs from landings to temporary log yards or ponds. Timber transportation at PT Inhutani I Sambarata was performed mechanically using a Mercedes-Benz MB 3836 AK logging truck (Fig 1).

**Fig 1**. Log hauling using Mercedes-Benz MB 3836 AK logging truck at PT Inhutani I Sambarata.

## 2.2. Methods

The primary data in this study consisted of the time and distance data for timber transport. Timber transport time was measured using a stopwatch with a nonstop method for 30 timber transport trips. The transport time is divided into effective and ineffective working times. Effective working time is the working time that includes activities directly related to timber transport, with the following work elements: loading logs, loaded running trucks, unloading logs, and empty running trucks.

Ineffective working time, on the other hand, is working time that includes activities that are not directly related to the main activities but are necessary for the smooth transport of timber. The working elements were as follows: preparation, breaks/rest, loading queues, repairs, refueling, refilling lubrications/oil, and others. In addition, the distance of timber transport was measured by measuring the distance from the landing to the log yard based on the information posts of the distance travelled to the left and right of the transport road. Secondary data were obtained from company records, which consisted of data on the cost components of timber transport activities, both fixed and operating costs, as well as data on the volume of timber transported per trip.

## 2.3. Data Analysis

**Log-hauling productivity.** The transport productivity is calculated using the following formula [7, 8]: $P = \frac{V \times D}{T}$

Whereas:

P = Truck productivity ($m^3$ km $h^{-1}$)
V = Wood volume ($m^3$)
D = Transportation distance (km)
T = Total transportation time (h)

**Log Hauling Cost.** The total timber transport cost was estimated using three types of costs: fixed, variable, and labor costs [9]. Fixed costs consist of depreciation costs, taxes, and insurance; variable costs consist of fuel and lubricants, tires, repair, and maintenance [4, 10].

**Log Hauling Efficiency.** Transportation efficiency was calculated using the following formula: $E = \frac{ET}{T} \times 100\%$

Whereas:

E = Log hauling efficiency (%)
ET = Effective time (h)
T = Total transportation time (h)

# 3 Result and Discussion

## 3.1. Log Hauling Time

The process of timber transportation at PT Inhutani I Sambarata is as follows: timber is transported from the landing to Log Yard 69, then to Log Yard 51 through Camp 62, then to the log pond via Camp 32, and finally back to the landing. The total sample consisted of 30 sample log transportation trips, using three Mercedes Benz 3836 AK logging trucks and three different operators. The distance travelled also varied according to the prescribed route of the day. Table 1 lists the results of the time measurements.

**Table 1**. Effective time, ineffective time, and total time of log transportation.

| No | Effective Time (min.) | | | | Total Effective Time (min.) | Ineffective Time (min.) | | | | | | | Total Ineffective Time (min.) | Total Time (min.) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | LL | LRT | UL | ERT | | P | B | LQ | R | Rf | RL | O | | |
| 1 | 17.58 | 14.59 | 5.09 | 22.08 | 59.34 | 43.10 | 0 | 27.58 | 0 | 0 | 0 | 30.58 | 101.26 | 160.60 |
| 2 | 14.53 | 31.17 | 6.26 | 19.38 | 71.34 | 0 | 0 | 5.05 | 0 | 0 | 0 | 0 | 5.05 | 76.39 |
| 3 | 16.13 | 36.23 | 7.24 | 29.20 | 89.20 | 0 | 0 | 0 | 10.09 | 0 | 0 | 0 | 10.09 | 99.29 |
| 4 | 13.37 | 47.40 | 6.43 | 28.48 | 96.08 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 96.08 |
| 5 | 11.26 | 42.35 | 6.23 | 26.14 | 86.38 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 86.38 |
| 6 | 13.21 | 39.44 | 5.27 | 25.32 | 83.24 | 0 | 2.40 | 0 | 0 | 0 | 0 | 0 | 2.40 | 85.64 |
| 7 | 14.19 | 38.12 | 6.18 | 24.38 | 83.27 | 0 | 18.26 | 0 | 0 | 0 | 0 | 0 | 18.26 | 101.53 |
| 8 | 14.58 | 43.20 | 7.24 | 24.17 | 89.19 | 0 | 0 | 0 | 2.18 | 0 | 0 | 0 | 2.18 | 91.37 |
| 9 | 9.40 | 46.42 | 5.23 | 27.16 | 88.21 | 0 | 3.35 | 0 | 0 | 0 | 0 | 0 | 3.35 | 91.56 |
| 10 | 9.40 | 37.51 | 6.26 | 39.55 | 93.12 | 0 | 0 | 0 | 8.17 | 0 | 0 | 0 | 8.17 | 101.29 |
| 11 | 14.55 | 37.42 | 8.52 | 27.31 | 88.80 | 6.23 | 0 | 45.40 | 0 | 0 | 0 | 0 | 52.03 | 141.23 |
| 12 | 14.57 | 40.17 | 6.52 | 30.06 | 61.26 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 61.26 |
| 13 | 14.01 | 42.02 | 4.19 | 32.21 | 92.43 | 0 | 5.17 | 0 | 0 | 0 | 0 | 0 | 5.17 | 98.00 |
| 14 | 15.09 | 227.57 | 5.34 | 153.06 | 401.06 | 3.43 | 0 | 10.48 | 0 | 11.43 | 18.04 | 17.23 | 60.61 | 461.67 |
| 15 | 14.43 | 241.15 | 6.42 | 161.32 | 423.32 | 0 | 3.57 | 0 | 0 | 0 | 0 | 0 | 3.57 | 427.29 |
| 16 | 21.11 | 230.28 | 5.30 | 146.17 | 382.15 | 17.26 | 25.38 | 29.32 | 0 | 8.01 | 0 | 0 | 80.37 | 462.52 |
| 17 | 18.37 | 241.13 | 6.50 | 143.09 | 409.09 | 0 | 19.13 | 0 | 0 | 0 | 0 | 0 | 19.13 | 428.22 |
| 18 | 13.19 | 203.31 | 5.49 | 125.58 | 347.57 | 12.54 | 43.49 | 37.13 | 0 | 0 | 0 | 0 | 93.16 | 441.13 |
| 19 | 12.42 | 196.45 | 5.32 | 165.48 | 380.07 | 0 | 0 | 0 | 0 | 8.32 | 0 | 0 | 8.32 | 388.39 |
| 20 | 12.02 | 32.41 | 4.31 | 29.21 | 78.35 | 58.35 | 0 | 0 | 0 | 0 | 0 | 23.42 | 82.17 | 160.52 |
| 21 | 14.09 | 37.42 | 6.33 | 26.52 | 84.36 | 12.25 | 0 | 0 | 0 | 0 | 0 | 28.21 | 40.46 | 125.22 |
| 22 | 10.47 | 35.22 | 6.26 | 27.03 | 79.38 | 0 | 0 | 0 | 5.12 | 0 | 0 | 0 | 5.12 | 84.50 |
| 23 | 12.21 | 37.12 | 5.45 | 29.03 | 84.21 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 84.21 |
| 24 | 16.21 | 35.41 | 5.14 | 28.01 | 85.17 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 85.17 |
| 25 | 18.10 | 36.21 | 6.42 | 26.52 | 87.25 | 0 | 0 | 18.31 | 0 | 0 | 0 | 0 | 18.31 | 105.56 |
| 26 | 15.02 | 37.20 | 6.04 | 28.01 | 86.27 | 0 | 13.15 | 0 | 0 | 0 | 0 | 0 | 13.15 | 99.42 |
| 27 | 15.21 | 38.40 | 7.14 | 28.20 | 89.35 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 89.35 |
| 28 | 17.02 | 38.09 | 7.26 | 29.11 | 91.48 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 91.48 |
| 29 | 11.44 | 34.38 | 3.51 | 28.42 | 78.15 | 49.32 | 0 | 10.10 | 0 | 0 | 0 | 24.45 | 84.27 | 162.42 |
| 30 | 15.12 | 37.31 | 3.42 | 28.41 | 84.26 | 0 | 9.01 | 0 | 0 | 0 | 0 | 0 | 9.01 | 93.27 |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Total | 407.19 | 2235.10 | 176.31 | 1528.55 | 4353.35 | 202.48 | 142.91 | 183.37 | 25.56 | 27.76 | 18.04 | 48.27 | 727.30 | 5080.96 |
| Mean | 14.04 | 74.50 | 6.28 | 53.11 | 145.11 | 6.75 | 5.05 | 6.11 | 1.25 | 1.33 | 0.60 | 4.13 | 24.19 | 169.37 |

Note: LL= log loading, LRT = loaded running truck, LU= log unloading, ERT = empty running truck, P = preparation, B= breaks, LQ = loading queue, R = repairs, Rf= refueling, RL = refilling lubricants, O = others.

Effective activities/work elements are activities or work elements related to the main activities in log transportation. The effective time for the average duration of each work element was as follows: 53.11 min. min for the empty running truck, 14.04 min. for loading, 74.50 min. For the loaded running truck, and 6.28 min. for unloading. Therefore, the average effective time per transport trip was 145.11 min. (2.42 h). The average ineffective time of the work elements was 6.75 min. for preparation, 5.05 min. for rest, 6.11 min. for queue loading, 1.25 min. for repair, 1.33 min. for refueling, 0.60 min. for refilling lubricants/oil, and 4.13 min. For other factors (such as stopping due to drizzling or waiting for the field foreman direction), the average total ineffective time amounts to 24.19 min. (0.40 h). Therefore, the average time for log transport per trip was 2.82 h. The percentage of the effective time for each work element is shown in Figure 2.

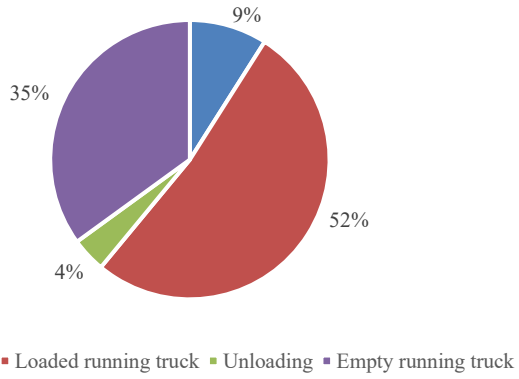


**Fig 2**. Percentage of effective time work elements.

Fig. 2 shows that the loaded running truck element has the largest percentage of time at 52% of the total effective working time. This is understandable because the load carried by the logging truck is very heavy when it is running; therefore, the working time is longer than when the truck is empty, which only accounts for 35% of the total effective time. Meanwhile, the percentage level for loading logs is 9%, while unloading logs have the smallest activity at only 4%.

Ineffective activities mean that these activities are not related to the main activities or core activities in wood transportation, but are still necessary or cannot be avoided. The percentage of ineffective work time elements is shown in Fig 3.

Fig 3 illustrates that preparation activities have the highest percentage of ineffective time at 31%, whereas refilling oil has the lowest percentage at 3%. Meanwhile, the condition in which logging truck operators have to queue to load wood is the second

largest at 28%. For preparation activities, it is advisable that logging truck operators and Foremen improve time efficiency. In addition, to minimize the loading queue time, the company should consider adding wheel loader units. This would create a more efficient workflow and ultimately increase transportation productivity. A comparison between the percentage of productive and unproductive log transportation times is illustrated in Fig 4.

It is evident from Fig. 4 that the timber transportation operations at PT Inhutani I Sambarata Berau have been running efficiently, with 87% of the time being effective and only 13% ineffective. The Mercedes Benz MB 3836 AK logging truck is also considered productive as it is utilized for 87% of the available working time.

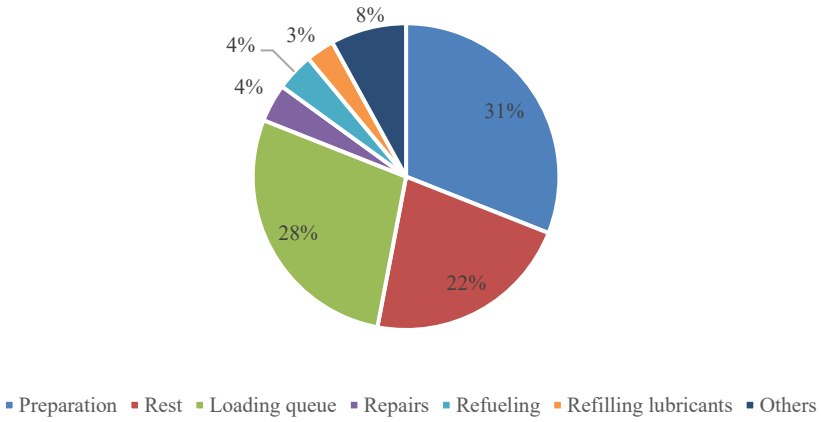


**Fig 3**. Percentage of ineffective time work elements.

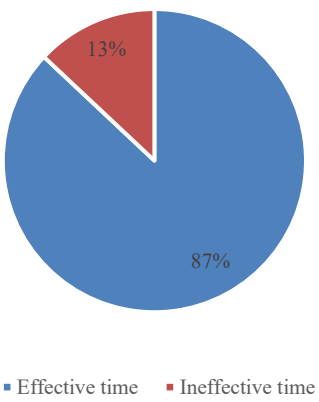


**Fig 4**. Percentage of effective and ineffective times.

Various factors influence the working time required for this logging activity, including the condition of the road. At PT Inhutani I Sambarata, road conditions are not ideal,

as both the main and branch roads are unpaved. Although the design allows the truck to travel on unpaved ground [11], drizzles or rain can cause road slippery. This poses a danger to trucks that transport timber, as they are prone to slipping, thus hampering work and potentially causing fatal accidents. Roads are a fundamental infrastructure that provides sustainable access to forest areas. To perform this critical purpose, road construction must adhere to sufficient technical standards [12].

Several timber trucks overturn multiple times because of slippage, endangering the safety of the operator. To mitigate this risk, PT Inhutani I Sambarata began using bull-dozers to assist logging trucks in traversing uphill roads. This method is employed on roads that are relatively dry but still soft enough for logging trucks to operate safely, even while carrying heavy loads. This solution substantially improves productivity while maintaining safety.

### 3.2. Log Hauling Productivity

Of these 30 trips, 200 pieces of wood were successfully transported. The smallest amount of wood transported was four pieces on trips 2 and 23, whereas the largest amount was nine pieces on trips 13, 16, and 17. On average, to 6-7 pieces of wood were transported per trip. The total volume of wood transported during the 30 trips was 1069.58 $m^3$, with an average volume of 35.65 $m^3$ per trip. In the transportation of timber within natural forests, the quantity of pieces does not affect the volume of the wood transported. This is because certain pieces have a sufficient volume, thereby requiring only a minimal quantity of wood for substantial volume transport. For instance, during trip 2, only four pieces of timber were transported, but with a higher volume of 37.05 $m^3$, compared with trip 13, where nine pieces of wood were transported, but with a lower volume of 34.6 $m^3$ (Table 2).

The mean productivity of the Mercedes Benz MB 3836 AK lorry at PT Inhutani 1 Sambarata was 248.86 $m^3.km.h^{-1}$. On average, it was capable of conveying seven logs in a single trip, with an average volume of 35.65 $m^3$ per day. The lowest transportation productivity was observed during the first trip (98.33 $m^3$ km $h^{-1}$. This was due to the below-average volume of logs carried and excessive time consumption, both of which significantly affected the productivity level. The highest productivity was recorded during the 19$^{th}$ trip at 449.72 $m^3.km.h^{-1}$, largely driven by the transportation of a substantial volume of 42.19 $m^3$ over a distance of 69 km in 6.47 h. In contrast, the study by [4] reported productivity as $8.36 \pm 2.49$ $m^3$ per productive machine h (PMH), a unit that reflects the volume of logs hauled per h of active machine operation without considering haul distance. The duration and length of transport activities have a significant impact on transport productivity, with greater productivity achieved by reducing the transport time [7,13]. The productivity of log hauling was modified by the species of wood, stem diameter, weather, and harvesting method [4].

From Table 2 below, it is evident that the 14-19th trip covers a distance of 69 km (from landing to log pond) carrying an average volume of 41.91 $m^3$ per trip, which is higher than the average volume of 34.09 $m^3$ per trip transported over a distance of 10 km (from landing to log yard). Transport distance has a significant impact on transport time, as longer distances require more time. In general, wood transportation

productivity is determined by the volume of wood transported, hauling distance, and duration of transportation, and productivity increases with shorter transportation times [7]. The hauling distance, piece volume, total load volume, and slope travelled were found to be significant and were used to predict the output of a logging truck. Hauling distance and load size may have a significant impact on hauling productivity [4].

**Table 2**. Productivity of log hauling using Mercedes Benz 3836 AK logging truck

| Trip Number | Distance (km) | Time (h) | Log Quantity | Volume ($m^3$) | Productivity ($m^3.km.h^{-1}$) |
|---|---|---|---|---|---|
| 1 | 10 | 2.68 | 6 | 26.32 | 98.33 |
| 2 | 10 | 1.27 | 4 | 37.05 | 291.01 |
| 3 | 10 | 1.65 | 6 | 32.92 | 198.93 |
| 4 | 10 | 1.60 | 5 | 32.74 | 204.45 |
| 5 | 10 | 1.44 | 6 | 32.83 | 228.04 |
| 6 | 10 | 1.43 | 6 | 33.44 | 234.28 |
| 7 | 10 | 1.69 | 6 | 31.01 | 183.26 |
| 8 | 10 | 1.52 | 8 | 34.42 | 226.03 |
| 9 | 10 | 1.53 | 6 | 34.01 | 222.87 |
| 10 | 10 | 1.69 | 6 | 35.59 | 210.82 |
| 11 | 10 | 2.35 | 8 | 34.38 | 146.06 |
| 12 | 10 | 1.02 | 7 | 35.42 | 346.01 |
| 13 | 10 | 1.63 | 9 | 34.60 | 211.84 |
| 14 | 69 | 7.69 | 7 | 43.68 | 391.70 |
| 15 | 69 | 7.12 | 7 | 42.37 | 410.52 |
| 16 | 69 | 7.71 | 9 | 40.75 | 364.75 |
| 17 | 69 | 7.14 | 9 | 41.89 | 404.99 |
| 18 | 69 | 7.35 | 7 | 40.55 | 380.56 |
| 19 | 69 | 6.47 | 7 | 42.19 | 449.72 |
| 20 | 10 | 2.68 | 7 | 37.38 | 139.72 |
| 21 | 10 | 2.09 | 5 | 37.30 | 178.73 |
| 22 | 10 | 1.41 | 7 | 35.08 | 249.09 |
| 23 | 10 | 1.40 | 4 | 33.93 | 241.75 |
| 24 | 10 | 1.42 | 7 | 34.53 | 243.25 |
| 25 | 10 | 1.76 | 7 | 30.66 | 174.27 |
| 26 | 10 | 1.66 | 7 | 37.09 | 223.84 |
| 27 | 10 | 1.49 | 7 | 36.55 | 245.44 |
| 28 | 10 | 1.52 | 7 | 37.12 | 243.46 |
| 29 | 10 | 2.71 | 6 | 32.55 | 120.24 |
| 30 | 10 | 1.55 | 7 | 31.23 | 200.90 |
| Total | 654 | 84.68 | 200 | 1069.58 | 7465.77 |
| Mean | 22 | 2.82 | 7 | 35.65 | 248.86 |

### 3.3. Cost of log hauling

It was found that the total cost of transporting timber using a Mercedes Benz MB 3836 AK logging truck for 30 trips is IDR 86,152, which includes fixed and variable costs,

whereas the average cost of timber transport is IDR 2,872 per trip. In particular, on the 14th-19th trip, operating costs are significantly higher owing to the transport of timber from the log yard to the log pond, resulting in higher operator wages based on the volume and distance transported, as well as additional wages per trip. For other trips, specifically from landing to the log yard, the operator receives a per-trip wage. The maximum cost of timber transport was Rp4,945 per trip, and the lowest cost was Rp1,714 per trip.

Various factors impact the expenses involved in timber transportation, such as operator payouts, the amount of timber transported, maintenance and repair costs, and other costs included in the variable costs, particularly fuel consumption. As the average hauling distance increased, the mean amount of fuel used per unit of production as well as poor road quality increased [14]. Queuing to load logs also increases the time spent, reduces productive time, and increases fuel consumption [3]. Fuel efficiency reduces operating costs. Furthermore, according to [15], fuel savings may mitigate the environmental damage caused by log hauling such as carbon or greenhouse gas emissions [16, 17, 18].

### 3.4. Efficiency of log hauling

The Mercedes Benz 3836 AK logging truck used by PT Inhutani I Sambarata had a very high level of efficiency, with an average efficiency of 86.70%. The maximum efficiency level of 100% was reached for seven trips, and the lowest was 36.77% on the first trip. The efficiency level of timber transportation time is affected by the effective time used [7, 19]. It has been stated that, through fleet management techniques, efficiency can be improved by optimizing routes, shortening travel time, and optimizing load capacity.

The study observed three operators with work experience of 7, 10, and 24 years, aged between 36 and 48 years. It can be concluded that logging truck operators at PT Inhutani I Sambarata are experienced in operating logging trucks, which is one of the factors influencing the productivity of transporting timber [4, 7, 19, 20].

## 4 Conclusions

The timber transportation productivity within natural forests using Mercedes Benz MB 3836 AK Logging Truck was 248.86 $m^3.km.h^{-1}$. The average cost of transportation is Rp2,872 per $m^3$.km. Moreover, the efficiency level of timber transportation was calculated to be 86.70%, indicating its effectiveness. Human factors continue to play a pivotal role in the effectiveness of mechanized log-hauling operations. It is therefore recommended that future initiatives incorporate regular training programs for truck operators, with a focus on fuel-efficient driving techniques, adherence to safety standards, and effective utilization of digital monitoring tools. Moreover, assessing operator performance and analyzing its relationship with hauling efficiency could offer valuable insights for improving human resource management and designing performance-based incentive systems aimed at enhancing overall operational productivity.

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**Disclosure of interest**. The authors have no competing interests to declare relevant to the content of this article

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