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Efficiency of Timber Skidding Operation in Pasoh Forest Jelebu, Peninsular Malaysia

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ABSTRACT

Timber skidding is one of the most important elements of forest harvesting. The forest harvesting process includes all operations from tree cutting and logging to a mill, rail depot, or ship dock. Efficiency is the ability to avoid wasting materials, energy, efforts, money, and time in doing something or in producing a desired result. For skidding operation, widely using crawler tractors as a medium in transporting logs to the temporary log yard requires attention from many sides. This is because it may affect productivity and the time consumed to do the work. The objective of this study was to analyze the relationship between distance, time, and productivity of skidding operation by crawler tractor and take place at Compartment 65 and 66 Pasoh Forest Reserve, Jelebu, Peninsular Malaysia. Thus, in this study, the distribution of work elements on time consumption shows that skidding seems to consume more time compared to other processes, since crawler tractor workers manually do the work. As a result, the average volume per trip, productivity, and time for skidding using a crawler tractor at the initial skidding area close to the landing are 27.74 m3, 54.65 m3, and 13.5 minutes, respectively. The total distance travelled by the crawler tractor to handle the load also influenced the efficiency of time and consequently affected the rate of productivity. The harvesting operation in Pasoh Forest Jelebu, Negeri Sembilan, Peninsular Malaysia is still well managed to produce timber products, and the skidding operation in this site is efficient and productive. As the suggestion, more study need to be conducted in vary in term of distances, times, and volumes, and in various conditions representing the timber skidding operation in this area.

Keyword: timber skidding operation, efficiency, time consume, productivity, Jelebu, Peninsular Malaysia

1. Introduction

In Malaysia, a crawler tractor known as a "skidder" is mostly used in skidding operations to retrieve logs. Because of their greater mobility and productivity, skidders are one of the most popular ground-based logging tools in forests. As a result, numerous studies have been conducted on this kind of forest equipment [1]. Due to its suitability for ground base extraction systems, this technique is frequently seen in tropical hilly forests or mixed-hill dipterocarp forests. In addition, because they have a built-in arch and winch to hook and pull the logged timber, large-tracked skidding machines like bulldozers are also utilized in the forest harvesting operation. Thus, as time has gone on, technology has improved the process of moving wood from the forest to the deck. The primary tool used in skidding operations is a log extraction equipment, such as a crawler tractor, sometimes referred to as a skidder. Due to their increased mobility and productivity, skidders are among the most used forest ground-based logging tools. As a result, numerous efficiency studies have been conducted worldwide for this type of forest equipment thus far [1]-[4]. Because it is appropriate for ground-based extraction systems, this process always occurs in tropical hilly forests or mixed-hill dipterocarp forests.

An effective way to reduce off-road traffic in forests is to implement greater distances between skid trails. However, this implies that trees beyond the boom reach of the harvester need to be felled motor manually before being winched to the skid trail [5]. A productivity rate of 21.59 m^3/day for skidding uphill with a tractor with mean loads of 0.76 m^3 over a distance of 25 m in thinning beech stands [6]. In addition to winching, the authors also recorded driving the loaded tractor (C Holder 870 F) to the landing site and the driving of the unloaded tractor along the skid trails which could explain the differences. In Oregon and Washington, 80% of the total forest area is classified as timberlands with capability of producing an excess of 1.4 m^3 ha^{-1} $year^{-1}$ [7] and provides 27.7% of the nation's wood production (Oregon Forest Resources Institute, 2019). They consist of a machine, often a tracked feller-buncher, with a winch and cable attached to an anchor, typically a separate piece of equipment on the road or near the landing at the top of the slope.

A crucial step in the timber harvesting process, logging operations involve moving logs from stumps to a designated roadside or landing area using a variety of extraction techniques. This process can be more costly and time-consuming than tree felling and processing [8]. Consequently, examining every operation is carried out in the natural forest. In skidding operations, bulldozers are frequently utilized as a medium to move logs to temporary log landings. The labor component of logging operations may directly affect the environment, even if various techniques, such Reduced Impact Logging (RIL), are being implemented in some locations. In skidding operation, to reach every tree that needs to be felled, the skid trials are built using a bulldozer. After that, the logs are hauled out along the skid trials while being winched.

A crawler tractor is a construction vehicle that moves on tracks instead of wheels. The tracks spread the vehicle's weight over a larger surface area, enabling the tractor to exert a lower force per unit area on the ground. This allows the tractor to safely traverse over moisture ground like rich soil, snow, or mud. A variety of attachments can be added to the crawler tractor thereby maximizing its usability. When a dozer blade is attached to the front of the crawler tractor it is commonly known as a "bulldozer". Compared to conventional farm tractors, crawlers offer better maneuverability and superior traction capacity [9]. There are many tracked crawler tractor has been used for forestry purpose especially in bunching, and skidding a log timber and for constructing a forest road. Here are the main specifications for tracked crawler tractor which utilized in this study: machine power, handles for power on machine, stick for moving of drum, gear box marine, drum endless (Winch), and tracked tractor [10].

One of the most challenging and time-consuming aspects of forest operations is the removal of forest products from stumps to landing places. Because of its many benefits, including high productivity, labor efficiency, and worker safety, mechanized harvesting equipment has been used in timber extraction operations [11]. The ground-based logging operation in Malaysia is widely known to use a winch- equipped crawler tractor long ago in moving logs from felling site to the log yard as it is necessary for timber extraction [13]. The objective of this study is to determine the time, productivity and efficiency of skidding machine which is crawler tractor in hill dipterocarp forest. The study site take place in Pasoh Forest Reserve Jelebu, Negeri Sembilan, Peninsular Malaysia.

2. Materials and Methods

2.1 Study site

The skidding operations are carried out at the research site in the Pasoh Reserved Forest, located in Compartments 65 and 66 in Jelebu, Negeri Sembilan. From Serdang, Selangor, it took two hours to travel 118 km to the study site. Triang Reserved Forest, Kenaboi Reserved Forest, Berembun Reserved Forest, and Gapau Reserved Forest are additional reserved forests situated in the vicinity of the study sites, these logging sites with low and hill dipterocarp forests were examined, and all the data was collected. The coordinate of this study site is N 3°1'36" E 102°10'21" with elevation 220m. This study site was selected, it because the nearest and available study site for that period was (here, the operation is dependent on the dry seasons only).

2.2 Methods

Methods on work study and work measurement are included in the phrase "work study" as shown in Figure 1. While work measurement entails the use of techniques intended to determine the amount of time required for a qualified worker to complete a task at a specified rate of working, method study, the systematic recording and critical examination of ways of doing things to make improvements [14]. When skidding, every aspect of the operations is examined using the work study method.

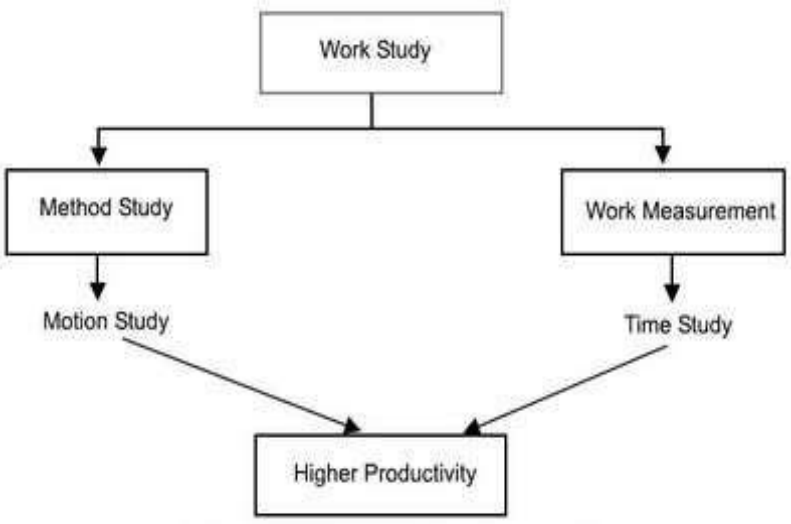

Figure 1. Framework of work study in production and operation
(Source: https://examnightslive.wordpress.com/work-study/)

2.2.1 Time study

Time study is a work measurement technique for recording the times and rates of working for the elements of a specified job carried out under specified conditions and for analysing the data to obtain the time necessary for carrying out the job at a defined level of performance. Time study is the systematic observation of the time consumption to define work performance during harvesting activities [16]. This method is applicable in determining a productivity of skidding based on each work element. Due to challenges in forest harvesting activities, work study including time studies and productivity studies can improve the work performance to increase the efficiency and effectiveness [13]. Steinlin proposes that productivity study of forest operations is obtained by measuring the time consumed and the quantity produced and then carrying out a statistical evaluation to relate the two quantities [4].

2.2.2 Measurement of productivity on skidding machine

The productivity of Crawler Tractor will be estimated by dividing the volume of log extracted by the time per cycle and expressed in m^3/PMH and m^3/SMH (where PMH meant productive machine hour and SMH, scheduled machine hour). The purpose is to find the relationship between the input of resources and resulting output. It is expressed as in equation below.

$$P \text{ (Crawler Tractor)} = \text{Output} / \text{Input} \quad (1)$$

SMH is a term and unit used for productivity measurement. It is a Total of productive time including all delay time and preparation (gross productivity). Further report that in addition to stem size also affects the productivity of harvesters as has been reported by Jiroušek et al. (2007) [14, 15] that harvester productivity is positively affected by an increasing dbh due to increasing piece volume. The scheduled time is the time during which equipment is scheduled to do productive work. The following formula is used for calculating crawler tractor productivity and skidding time:

a. Productivity calculation for machines

$$P = \text{Volume, } V / \text{Time, } T \quad (2)$$

(where $\pi = 3.142$, r = radius of log, h = length of log)
Overall time taken to skid a log, T (hour)

b. Estimating Skidding Time

$$T = a\,N + B_1\,X_1 + B_2\,X_2 \quad (3)$$

where: a = combined time for hooking and unhooking per log

N = Number of logs skidded

B1 = minutes (min) per meter (m) for unloaded travel B2 = the minutes (min) per meter (m) for loaded travel

X1 = distance (m) from the landing to load pickup point; and

X2 = distance (m) from the load pickup point to the landing

Equation data above will be analysed and related. Then statistical linear regression analysis will be used to know the relationship between the Distance and Time. Time and Productivity, and Distance and Productivity. Linear regression equations develop to determine those independent variables which significantly correlated to the dependent variable(s). By using these regression equations will be possible to estimate skidding productions under various working conditions. A determination of the efficient skidding distance will be made by choosing the distance which produces higher productivity.

3. Results and Discussion

A fieldwork for data collection was conducted in March 2020 and the total time for each elemental works were. The data were supplemented with or without delay time to measure the effectiveness of work production. Linear regression analysis was performed on the overall duration and productivity of timber skidding in the forest area.

3.1. Time Study

Five primary components have been identified from the time distributions that were recorded during the skidding process. Figure 2 shows each element's percentage was established by calculating these factors using an average of 17 full skidding cycles in the Pasoh Reserve Forest. In this investigation, unhooking time was the smallest component while delay was the biggest percentage of time. As a result, returning time was recorded at 24%, while skidding time was recorded at 29%.

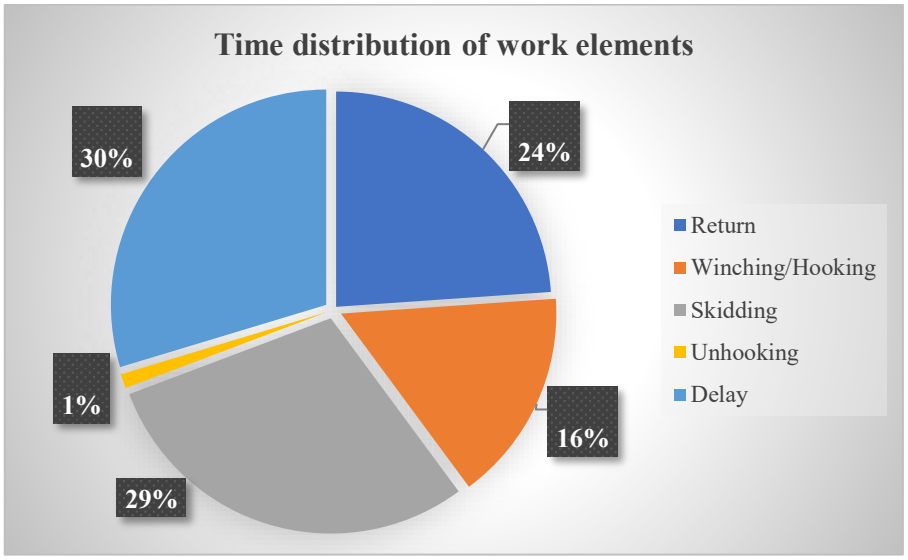

Figure 2. Time percentage distribution of work elements

Figure 3 shows that the number of logs in manual and in this study the crawler tractor only carried one log for each trip. Since both are dependent on the log volume and the number of trips made at that time, from the figure 3, it is seen that the distribution of the graph follows an uneven shape distribution on volume of log and trips relationship.

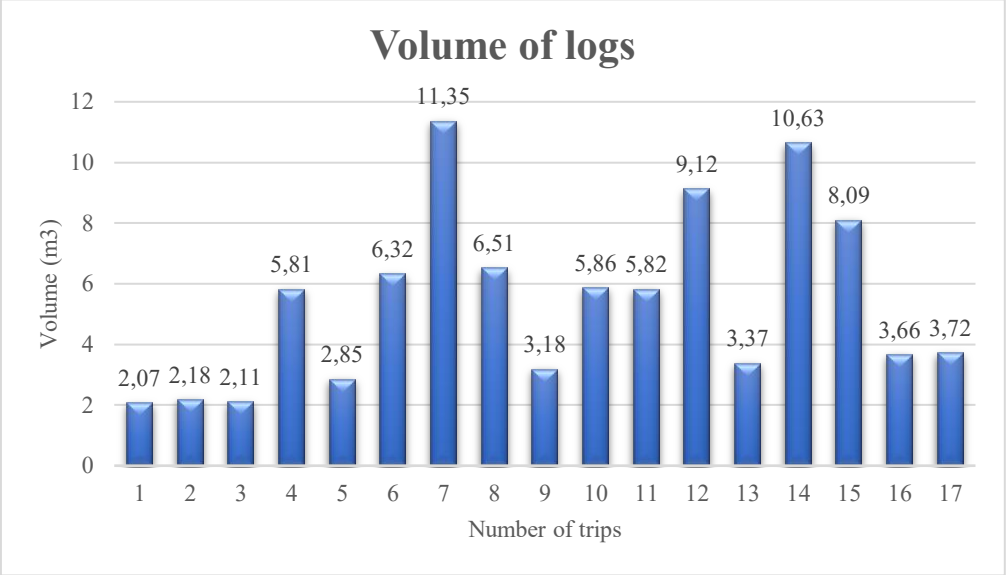

Figure 3. Distribution of volumes of logs in each trip cycle

There are four highest peak which is at seventh (11.35 m^3), twelfth (9.12 m^3), fourteenth (10.63 m^3) and fifteenth (8.09 m^3) trips of the skidding with the respective value. The reason why the standing growth in that area was mostly have unevenly aged due to the previous timber extraction because of the cutting limit's rules which made the trees cannot be cut yet at that time it has to be maintained there. Other related factors can also be considered such as domination of the same trees' species in that area. Since this data has been collected in the secondary forest. On average, about 5.45m^3 volume of log or one large log can be skidded on each trip.

Figure 4 shows that skidding distance is the most significant variable affecting skidding productivity and time. Between the distance and the number of trips showing inconsistent skidding distance to the temporary log yard. This means that the length of the skidding distance can be changed for each trip. For this type of relationship, it is normal because to harvest timber from inside of a natural forest, a newer skid trail will be established. After felling, winching, hooking and skidding process were moved, and logs were assembled with chain and crawler tractor will pull it's along the skid trails.

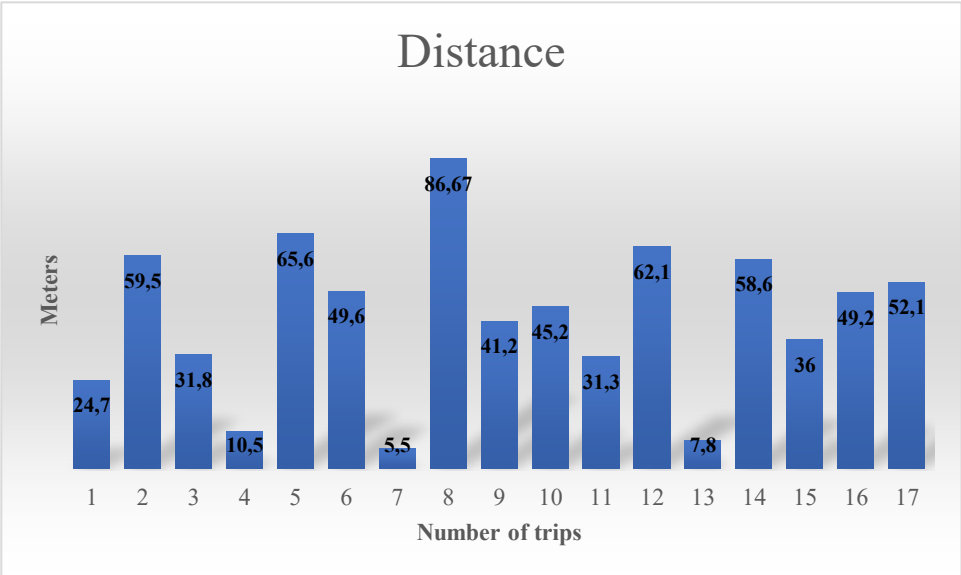

Figure 4. Distribution of distance in each trip cycle

The skid trails in the forest were basically constructed in a way that would make the crawler tractor easier to extract the wood along the trails. As the harvesting activity moves deeper into the wood, the length of the skid trails increases, leading to an increase in the cycle operation of skidding process. Besides that, form the figure 4, the shortest distance is at 5.5 meters and longest distance which is at 86.67 meters which is due to the position of the log. On average, about 42.19 meters trail length of distance travelled by crawler tractor on each trip. This is important information to be used to determine the best skidding distance for manual skidding as well as to reduce skidding time and to improve productivity.

3.2. Skidding Time and Productivity

Table 1 shows the skidding trips were listed according to distance duration and average productivity and time. In terms of skidding, the range of time per trip is from 0.125 hours to 0.331 hours. This is because the study was conducted on the skidding area close to the temporary landing, the skidding time and productivity were measured from the nearest felled trees until the seventeenth felled tree and still not far from the landing. Meanwhile, the productivity ranged from 13.727 m3/hour to 130.452 m3/hour, so the nearer the landing the less time of skidding and the higher the productivity. The average of skidding time and productivity is 0.225 hours per trip and 54.65 m3/hour, respectively.

Table 1. Skidding time and productivity

No. of Trip	Log Volume (m^3)	Time of Skidding (Hour) $T = aN + B_1 X_1 + B_2 X_2$	Productivity (m^3/hour)
1	2.07	0.194	10.67
2	2.18	0.258	8.45
3	2.11	0.240	8.79
4	5.81	0.201	28.91
5	2.85	0.168	16.96
6	6.32	0.251	25.18
7	11.35	0.153	74.18
8	6.51	0.278	23.42
9	3.18	0.331	9.61
10	5.86	0.151	38.81
11	5.82	0.151	38.54
12	9.12	0.308	29.61
13	3.37	0.125	90.86
14	10.63	0.243	43.74
15	8.09	0.289	27.99
16	3.66	0.205	17.85
17	3.72	0.283	13.14
Average	5.45	0.225	27.75

3.3. Relationship between time and productivity

According to the results, the longer the distance increases, and the productivity decreases. Therefore, these relationships were used for assumptions based on regression analysis as shown in Figure 5.

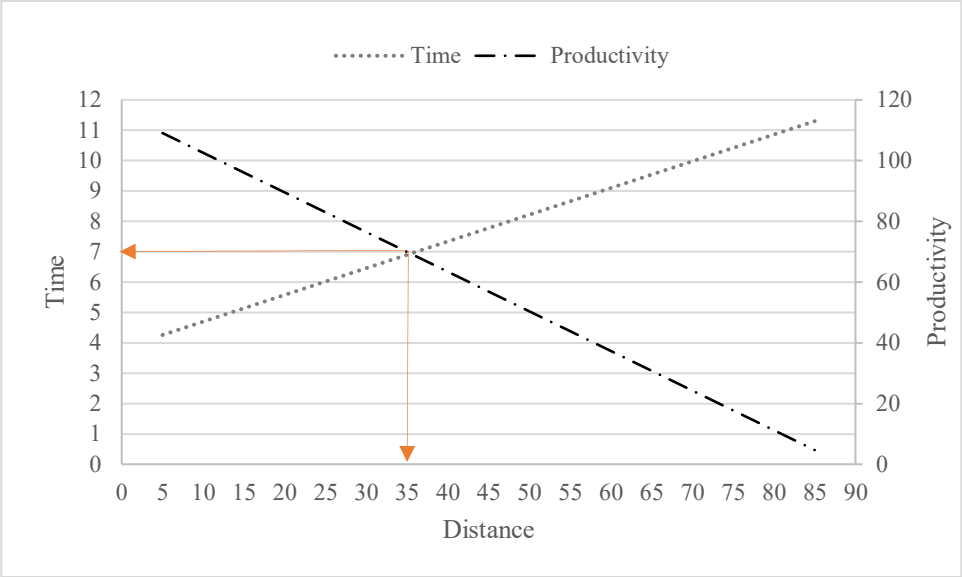

Figure 5. The efficiency of distance (m), time (min) and productivity

According to Figure 5, time will increase when the distance increases, and productivity will drop against time. The highest rate of productivity will achieve at 0700 minutes with the distance at 35 to 36 meters. At this time, the productivity will be reached at the highest rate which is 70 m^3. To get the highest rate of productivity, the time taken for crawler tractor to skid a certain log should be maintained at 0700 minutes and below. Hence, distance also should be considered to affect the time taken and productivity in this process. So, the increases by the distance of the load to skid will affect the total time taken to the crawler tractor to skid a certain log. Thus, productivity decreases against time. If the time taken increases, the productivity will decrease.

4. Conclusion

The average volume, productivity and time per trip for skidding operation at the initial skidding area where the nearest area close to landing using crawler tractor are 27.75, 54.65m^3 and 13.5 minutes respectively. The total distance travelling for crawler tractor to handle the load also influenced the efficiency of time and consequently affected the rate of productivity. This harvesting operation in Pasoh Forest Jelebu, Negeri Sembilan, Peninsular Malaysia is still well managed to produce timber products, and skidding operation in this site is efficient and productive. As the suggestion, more study need to be conducted in vary in term of distances, times, and volumes, and in various conditions representing the timber skidding operation in Pasoh Forest Jelebu, Peninsular Malaysia.

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