PERFORMANCES OF TWO PROTOTYPES OF LOG EXTRACTION TECHNIQUES USING THE SKYLINE SYSTEM

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Received: 25 August 2015, Revised: 16 December 2016, Accepted: 10 January 2016

PERFORMANCES OF TWO PROTOTYPES OF LOG EXTRACTION TECHNIQUES USING THE SKYLINE SYSTEM. Timber extraction from felling area to road side is not an easy job. This activity facing a number of difficulties particularly due to geo-biophysical conditions, such as steep terrain, up and/or down-hill, valley or river-to be crossed, slippery road and also the size of the timber and low accessibility. To anticipate those obstacles two engineering designs of the skyline system had been tried, the so called Expo-2000 Generation-1, using gasoline engine of 6 HP (G-1), and Expo-2000 Generation-3 using diesel engine of 12 HP (G-3). G-1 model has been tested in Cimeong and Rancaparang in 2011. G-3 model has been examined in Cibatu Canjur and Cibaliung Banten in 2013. This paper evaluates the modification of skyline system for steep terrain and to compare the performance between two modified skyline systems, in term of productivity and cost. The data collected included working time, log volume extracted, log extraction distance and fuel used. Data were analyzed to get the average productivity and cost of operation. Results show that prototype G-3 with logs in horizontal position at a distance of 130-430 m, can extract logs averaging 1.72 m^3/hr, while prototype G-1 and logs in vertical position at a distance of about 50-320 m, could only extract logs averaging ± 0.85 m^3/hr at a cost of about Rp 156,351/$m^{3.}$ It suggests that prototype Expo-2000 G-3 is more effective for log extraction logs in steep terrain.

Keywords: Skyline, log extraction, horizontal load, efficiency, steep terrain

KINERJA DUA PROTOTIPE TEKNIK PENGELUARAN KAYU DENGAN MENGGUNAKAN SISTEM KABEL LAYANG. Kegiatan pengeluaran kayu untuk dibawa dari areal tebangan ke pinggir jalan angkutan bukan pekerjaan mudah. Kegiatan ini menghadapi berbagai kendala terutama kondisi biofisik misalnya lereng yang curam, naik turun lereng, menyebrangi lembah dan sungai, jalan yang licin dan kayu yang berbobot berat serta aksesibilitas yang rendah. Untuk mengantisipasi kendala tersebut, telah dilakukan rekayasa alat sistem kabel layang berupa Expo -2000 Generasi-1, bermesin bensin 6 HP (G-1) dan Expo -2000 Generasi-3, bermesin diesel 12 HP (G-3). Uji coba telah dilakukan di Cimeong dan Rancaparang untuk mesin (G-1) pada tahun 2011 dan untuk mesin (G-3) di Cibatu Cianjur serta di Cibaliung Banten pada tahun 2013. Uji coba ini dilakukan untuk mengetahui kinerja kedua mesin dalam pengeluaran kayu yang mengarah ke atas bukit serta membandingkan keduanya dalam hal produktivitas dan biaya. Data yang dikumpulkan antara lain waktu kerja, volume kayu yang dikeluarkan, jarak angkut, dan penggunaan bahan bakar. Data dianalisa untuk memperoleh nilai rata-rata produktivitas dan biaya operasi pengeluaran kayu tersebut. Hasil penelitian ini menunjukkan bahwa prototipe G-3 dengan jarak uji coba antara 130-430 m dengan posisi kayu horizontal bisa mengeluarkan kayu 1,72 m^3*/jam, sedangkan prototipe G-1 dengan posisi kayu vertikal pada jarak sekitar 50-320 m, hanya bisa mencapai ± 0,85* m^3*/jam. Ini berarti prototipe Expo-2000 G-3 lebih efektif digunakan untuk mengeluarkan kayu di medan curam.*

Kata kunci: Kabel layang, pengeluaran kayu, muatan, horizontal, vertikal, efisiensi

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doi: http://dx.doi.org/10.20886/ijfr.2017.4.1.1-14

I. INTRODUCTION

Timber extraction from felling area to road side is not an easy job. The problem is because this activity will face a number of difficulties in geo-biophysical conditions, such as steep terrain, up and/or down-hill, valley or river-to be crossed, slippery road, size of timber, low accessibility and so on. The traditional method of log extraction until now still exists, but it is not effective especially at steep terrain areas (Olund, 2001).

Although reliable data are scarce, logging is clearly more costly on steep terrain. The Reduced Impact Logging (RIL) guidelines typically set limits on the slopes that can be accessed by ground-based yarding equipment. Such limits for skid trails range from 17° slope limit suggested by Dykstra and Heinrich (1996) and 15° for major skid trails and 25° for minor skid trails suggested in the Code of Practice for Forest Harvesting in the Asia Pacific (APFC 1999), to 35° slope limit used by the Forest Department of Sabah, Malaysia (Pinard, Putz, Tay, & Sullivan, 1995). It is therefore on steep terrain that other alternative method of log extraction is required.

Various machines of skyline or ground skidding types have been applied for log extraction. These systems are separated based on type of machines, capacity, setting up the method and their operations, carriage models, and other complements. Those machines are categorized as heavy vehicles because according to definition, heavy equipment is the vehicle which is using motor power > 5kW, include trucks with Gross Vehicle Weight (GVW) > 20 ton. Those machines are mostly big sized, heavy, powerful and sophisticated. Those machines among others is the TTY-70 for skyline and skidder tractor for ground skidding.

Those machines besides being sophisticated, are also expensive, costly in operation and maintenance, needs operators with high skills, and many complementary equipments which are all heavy. It is therefore, in order to have a more appropriate technology, meaning that the machine should not be too big, it should be simple, lighter, not too expensive and techniqally easy to operate for log extraction. The technology of skyline might be feasible to be applied whether in advanced or developing countries (Lloyd, 2007). In the skyline technology, the technique of log extraction can be operated either in vertical or horizontal position.

This paper evaluates the modification of skyline system in steep terrain and to compare the performance between two modified skyline systems, in term of productivity and cost.

II. MATERIAL AND METHOD

A. Material and Location

The prototypes are known as Expo-2000 Generation-1 (G-1) and Generation-3 (G-3). The location for studying the modified machine G-1 was at Cimeong and Rancaparang Cianjur, and for G-3 at Cibatu Cianjur and Cibaliung Banten. The prototype G-1 was powered by a benzene engine of 6 HP while the G-3 was powered by solar engine of 12 HP. The logs were hauled afterward the carriage by rigging ropes. The carriage for G-1 hauling the logs had both vertical and horizontal head, but for G-3 extraction was only done with horizontal head. The slopy terrains at Cimeong and Rancaparang are similar, i.e. about 40-60%, and at Cibatu is about 60% and at Cibaliung Banten is about 30%. The distance of log extraction at Cimeong was 200 m, at Rancaparang was about 350 m, and at Cibatu was about 160 m and at Cibaliung was about 430 m. The species extracted at all experiments was teak with a length of 2-3.5 m and about 15-40 cm diameter.

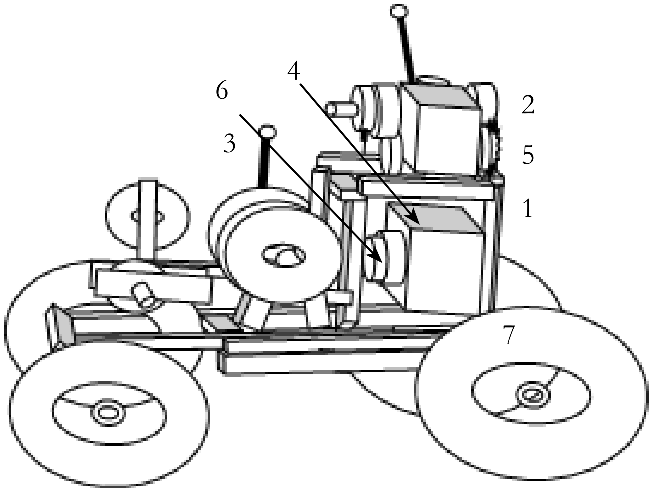
To facilitate the experiment some preparation activities were carried out: (a) choosing the location of the study area purposefully in which there was still forest harvesting activity with steep-very steep terrain; (b) finding some trees to be used as tail tree and spar tree; (c) cleaning 2-3 wide path along the cable line; (d) fixing the site area for loading and unloading of logs (log extraction distance was not more than 450 m); (e) rigging of cable line and do checking and re-checking before real operation begun; (f) provide manpower to operate skyline; (g) observe and note each log extraction process and (h) measure distance and fuel consumed before and after operation each day.

The construction of prototype machine Expo-2000 G-1 and G-3 and their components as seen on Figures 1 and 2.

B. Model of Carriage

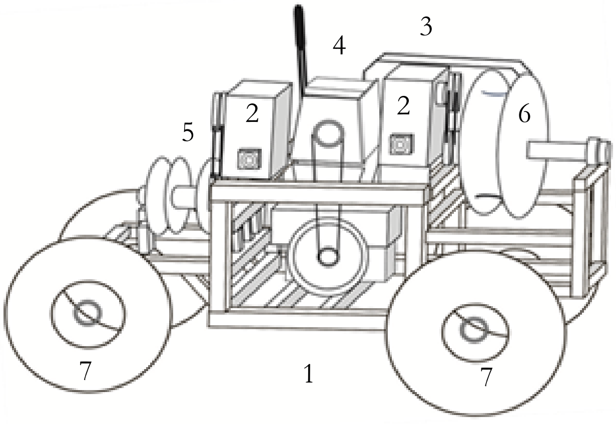
1. Carriage of logs in vertical position

Figure 3 shows one sophisticated carriage for log extraction using vertical position techniques (a) and two prototype carriages that were made locally (b, c). The skyline carriage hauls logs using the rised head position. On the left side the carriage hauls big size logs (weight up to > 0.5 ton). It is laborious to take and set-up the rigging ropes which could be very heavy. On the



Main specification:
1. Machine power
2. Handle for power-on machine
3. Stick for moving of drum
4. Reducer 1: 100
5. Gear box marine 1: 2.5
6. Endless drum
7. Tractor tire

Figure 1. Former prototype modified (G-1/6HP/gasoline)



Main specification:
1. Diesel ME 195 13 PK with 2000 rpm
2. Reducer 1 : 100 (2 pieces)
3. Excentric gear and chain of type 60 B (2 pieces)
4. Gear box marinewith 1 : 2 reducer of 2200 rpm
5. Drum of diameter 35 cm
6. Drum of endless diameter 70 cm
7. Wheel agriculture tractor

Figure 2. Latest prototype modified (G-3/12HP/diesel)

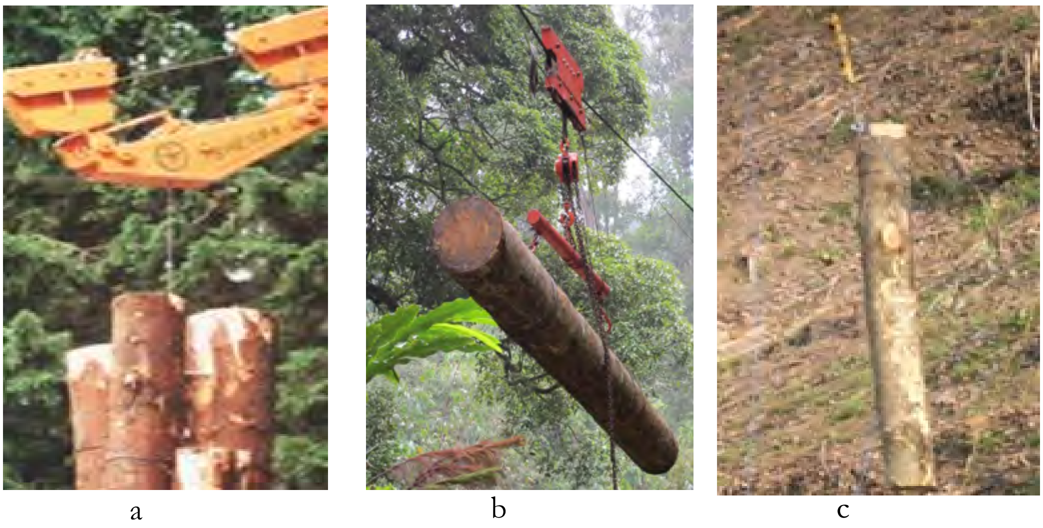


Figure 3. The modern and sophisticated carriage (a) the simple carriage (b and c) that was made locally. All extraction were carried out by vertical or rised head operation

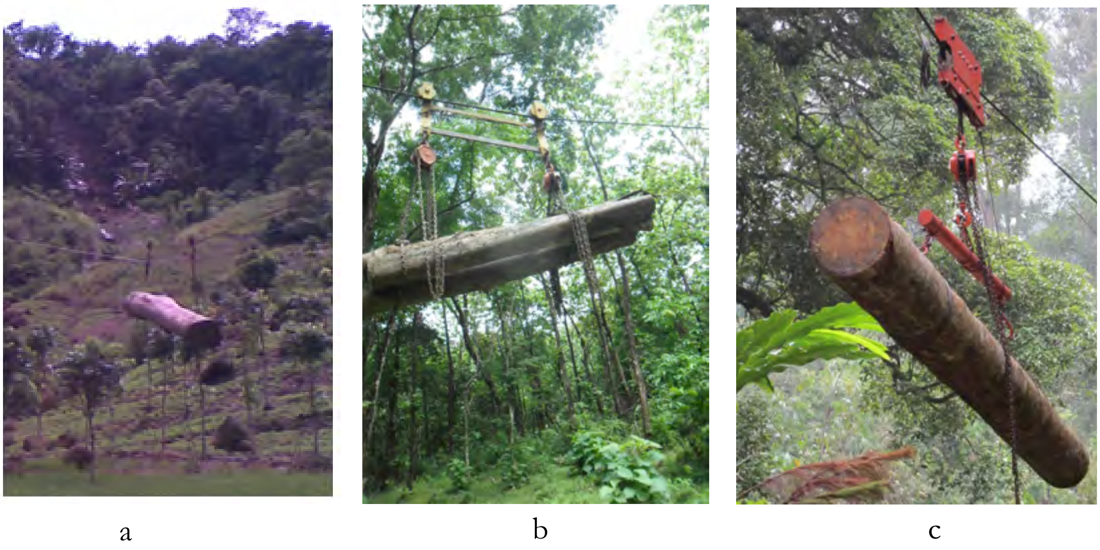


Figure 4. Log extraction by horizontal head position using variation of carriages

centre picture, the weight of the carriage was about 35 kg while on the right side it was about 6 kg. However, both carriages are simple but strong enough to haul logs. The weakness of the rised head extraction is that logs may often go encircling and this typical occurrence of the transport may affect the rope, and slowly could reduce the power of the rope. So, the rope will be damaged sooner or later and would be very dangerous that should be avoided. However, in this system, the carriage is very powerful it could lift up logs even at the bottom of the valley (Endom, 2013, 2014).

An example of skyline that use rised head system was intended to be tried in natural production forest at PT. Sumalindo, East Kalimantan, using the Thunderbird TTY-70. Unfortunately, the sophisticated machine could not be used automatically anywhere because of too many things have to be prepared especially in low access areas.

2. Carriage of logs in horizontal position

At this operation logs are extracted by horizontal head as seen in Figure 4.

Here it can be seen that the process of log extraction was made as simple as possible by three types of carriages. In Figure 4a, the carriage is the so called tighten carriage. The log is hanging on two carriages and hauled using endless cable that is tightened at the carriage. Logs are extracted from the site to the location at a certain hill. In Figure 4b, log was extracted by hanging on two cables that lifts-up and lifts down using one tackle. The carriage is in the form of a thick box which is pulled by a 6 mm small cable that is connected to the drum on the machine. Logs from the felling site were brought to the road side. In Figure 4c the carriage became simpler, it is only built by two pieces of square pipes that is connected to the wheel by iron that hung on the main cable. At the two edges of this instrument is the set-up tackle that is used for lifting up and down of the logs to be extracted. By endless cable one or more logs can then be extracted from the felling site to a certain log yard. By using the tackle instrument which even can be used for skidding logs on the ground, if it is too short then we can add another rope for about 10-15 m distances. Therefore we can extract on a line which is 30 m in width.

C. Design of the Study

The design scheme of the study is shown in Figure 5.

D. Data Collection

Data collection was done in 2011 for study of (G-1) and in 2013 for study of (G-3) by observations and notes of all information related to the study, i.e. productivity of log extraction (diameter, length, number of logs, time consumed for loading, travelling, unloading, breaks and others) and also cost of operation.

E. Data Processing

Calculation of log volume was done using the empirical model of Brereton formula (Direktorat Jenderal Pengusahaan Hutan, 1993) as follows:

$$VL = 1/4\pi \left\{ \frac{1/2\left(D_p + D_u\right)}{100} \right\}^2 \times p \quad \text{....................(1)}$$

where: VL = volume of log (m^3); D_p = top diameter (cm); D_u = down diameter (cm); P = length (m); π = constant (3.14)

Productivity of machine was calculated using the formula as follows (Mulyadi, 2002):

$$P = \frac{V}{W} \quad \text{................................(2)}$$

where: P = productivity (m^3/hr); V = volume of log (m^3); W = time performance (hour)

Working hour of skyline operation was calculated as follows:

Extraction time = fixed time + variable time

where: fixed time = chocker time + release, variable time = travel time of extraction + empty travelling

To calculate the costs, the formula of Mujetahid (2010) was used:

1. Fixed cost of extraction
   a) Depreciation was calculated by formula:

   $$D = \frac{M - R}{N \times t} \quad \text{...(3)}$$

   where: D = depreciation (Rp/hr;
   M = machine investment (Rp); R = Cost of residue 10% (Rp); N = life time of machine (yr); and t = yearly working hour of machine (hr/yr)

   b) Interest rate was calculated by the formula:

   $$B = \frac{\left[\frac{(M-R)(N+1}{2}\right] + R \times 0,0p}{N \times t} \quad \text{......(4)}$$

   where: B = interest cost (Rp/hr; $0,0p$ j = interest rate /year (18%)

   c) Tax
   Tax amount is 5% of machine investment and was calculated by formula:

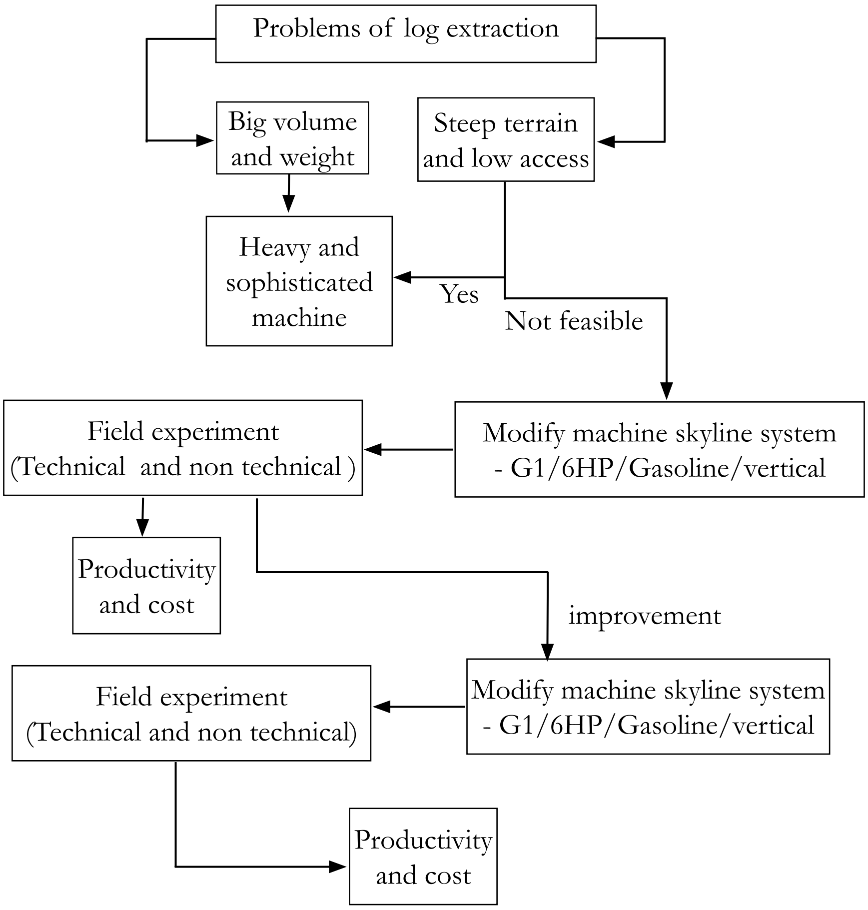


Figure 5. The schematic procedure of the study

$$P_j = \frac{\left[\frac{(M-R)(N+1)}{2}\right] + R \times 0.5}{t} \text{ ...(5)}$$

where P_j = tax (Rp/hr)

d) Insurance cost

Insurance cost was calculated as 5% of machine investment by formula:

$$A_{sj} = \frac{\left[\frac{(M-R)(N+1)}{2N}\right] \times 0.5}{t} \text{ ....(6)}$$

where A_{sj} = insurance (Rp/hr)

The amount of fixed cost (BT) in unit (Rp/hr) was calculated by formula:

$$BT = D + B + P_j + A_S \text{ ....(7)}$$

2. Variable cost of exraction

a) Maintenance of machine (P_{lb})

Maintenance cost of machine was calculated based on residual value of 10% of the investment divided by working hours per year in unit of Rp/hr.

Reparation (P_{rb})

Repairing the machine is aimed to fix the machine that had several small problems so the machine unit could be used again. Cost of repairing was calculated by dividing the cost of spare parts by working hours and the value was in unit of Rp/hr. Cost of reparation was based on direct observations in the field.

b) Fuel (B_{bk})

Cost of fuel was based on direct field observations by calculating the amount of fuel used (liter) during log extraction. Cost of fuel was calculated by formula:

$$B_{bk}\,(\text{Rp/hr}) = \frac{\text{Fuel used (liter) x price (Rp/liter)}}{\text{Working hours (hr)}} \quad ....(8)$$

c) Oil (P_{lo})

Cost of oil was based on direct field observations by calculating the amount oil used (liter) during log extraction. Cost of oil was calculated by formula:

$$\text{Oil (Rp/hr)} = \frac{\text{oil used (liter) x price (Rp/liter)}}{\text{Working hours (hr)}} \quad ....(9)$$

Sum of variable costs was calculated by formula:

$$BV = P_{lb} + P_{rb} + B_{bk} + P_{lo} \quad ....(10)$$

3. Cost of machine operation (B_{opr}) was calculated by formula:

$$B_{opr} = BT + BV \quad ....(11)$$

4. Salary of workers (U_p)

   Salary of workers was calculated based on working hours (Rp/hr) or (Rp/m^3)

5. Cost of business (B_{ush}) was calculated by formula:

$$B_{ush} = B_{opr} + U_p \quad ....(12)$$

6. Cost of log production (B_{prod}) was calculated by formula

$$B_{prod} = \frac{B_{ush}}{P_{tp}} \quad ....(13)$$

where: B_{prod} = Cost of log production (Rp/m^3); B_{ush} = cost of business of extraction (Rp/hr); P_{tp} = Productivity of log extraction (m^3/hr)

III. RESULT AND DISCUSSION

The experiment of both prototype machines had been done, and the result of the study is described as follows.

A. Performances of Two Prototype Machines for Log Extraction

In general, performance of the two prototype machines in log extraction operation is shown in Table 1-3. Unfortunately the G3/12HP/Diesel/vertical did not yet worked properly, then data on its effectiveness and efficiency are limited. However, from the physical machine construction it could be assumed that the productivity perhaps is higher than for G3/12HP/Diesel/horizontal, because the process of loading and unloading could be done faster, but the safety aspect is lower than for the horizontal loading and unloading process.

It can be seen clearly that for the time being the productivity of the latest prototype (G-3/12HP/Diesel) achieved 1.72m^3/hr with a coefficient of variation of about 23.9%. The former prototype (G-1/6HP/gasoline) achieved 0.63 m^3/hr with a coefficient of variation of 35.1%. G-1 has half the power of G-3. Perhaps if G-1 has a similar power as G-3, the productivity could be estimated to increase to about 1.2 m^3/hr. However, it cannot be directly calculated like that because the construction unit of machine G-1 is different from G-3. The G-1 machine unit is completed only with smaller and a single chain (type B50), while G-3 with bigger and double chains (type B60). The G-1 productivity may not reach that of G-3. Besides that G-1 construction uses only one drum while G-3 are set-up with two drums which can be operated separately or jointly.

In the previous study, the prototypes were also assessed by using some calculations for cost analysis. The result of the calculation for both prototypes is given in Table 4.

Table 4 showing that the process of extraction of logs can be done either in vertical or horizontal head position. However, because the engine power is different as well as the size of logs, distance and slopes, therefore the productivity of G-3 is much bigger than that of G-1. As regards fuel consumption, there is no much difference between both machines. It means that the prototype machine of G-3 would be useful for extracting logs especially at location where conventional method cannot work well.

Table 1. Result of G1/6HP/gasoline/vertical

No	Pulling and putting down the logs at log-yard					Productivity (m^3/hr)
	Length (m)	Diameter (cm)	Distance (m)	Time (min)	Volume (m^3)	
Mean	2.12	21.00	50-350	6.54	0.080	0.6363
Sd	0.233	4.031	-	1.297	0.034	0.3184
CV (%)	1.221	2.1328	-	2.204	5.013	5.5599

Table 2. Result of G3/12HP/Diesel/horizontal

No	Pulling and putting down the logs at log-yard					Productivity (m^3/hr)
	Length (m)	Diameter (cm)	Distance (m)	Time (min)	Volume (m^3)	
Mean	3.93	37.8	250.8	8.7	0.18	1.72
Sd	6.55	0.36	90.3	1.7	2.9	0.52
CV (%)	7.76	16.9	36.02	3.01	33.3	35.09

Table 3. Result of G1/6HP/gasoline/horizontal

No	Pulling and putting down logs at log-yard					Productivity (m^3/hr)
	Length (m)	Diameter (cm)	Distance (m)	Time (min)	Volume (m^3)	
Mean	2.430	27.667	350	19.433	0.046	0.523
Sd	0.879	6.218	0	3.520	0.022	0.280
CV (%)	36	22	0	18	48	53

The cost of log extraction for G-3 was about Rp 80,346.45/m^3 while for G-1 it was about Rp 156,351/m^3. Compared to conventional method at this typical location, skyline method was cheaper than that of blandong (local worker), cost of blandong was about ± Rp 200,000 - Rp 300,000/m^3. On the other hand, the skyline method is more ergonomic because it is able to avoid heavy physical load and reduces the risk during the operation process, as shown in Figure 6.

In Figure (6a), the worker is trying hand-pulling the rope to go uphill with small diameter log of pine on his shoulder, in Figure (6b) some workers are trying to push the log to be rolled uphill and someone at hilltop helping them using the rope, and in Figure (6c) some workers were trying to lift-up the log to the carriage that already hung at the cable line at certain height (25 m). These pictures are telling us how difficult it was extracting a piece of log on a sloping terrain, although the distance to move the log was not far, about 5-8 m. It proves that the problem of the terrain is very significant, as well as the productivity of the manual method that could be relatively low and full of risk.

To anticipate this weakness, perhaps the skyline technology which is made in a simple construction can help very much. Figure 7 shows the prototype that could be appropriate and a

Table 4. Productivity of prototype Modified Expo-2000 G-1 and G-3

Items	Engineering design of Expo skyline machine	
	Modified Expo 2000 G-1 (vertical head operation)	Modified Expo 2000 G-3 (horizontal head operation)
Completion assessories	No excentric gear, one reducer, one media for double pulley, one drum	Two excentric gear, two drums and two reducers
Control of machine operation	Easy just move forward or backward the panel on the box marine	Easy just to control theexcentric gear panel and then move the panel forward or backward onthe box marine
Engine power	6 HP	12 HP
Speed	70 m/minute	70-120 m/min
Operation	One way operation	Two ways operation
Performance	< 0.63 m^3/hr	1.72 m^3/hr
Fuel consumption	< 1 benzene litre /hr	1 -1.5 litre solar/hr
Extraction distance	50-350 m	130-430 m
Cost of operation	Rp 102,986/hr Rp 156,351/m^3	Rp138,587,39/hr Rp 80,346,45/m^3

good prospect to be used for log extraction on sloping terrain, and could be used not only for removing wood but also other materials such as agriculture products. The slope at the study area was about 60% and the distance about 135 m. Here, it can be seen clearly that the operation of hauling logs could be worked out easily, calmly and safely. This could solve local problems technically and economically in remote areas that is common anywhere in this country; the skyline method could be used significantly in anticipation of field challenges. The minimum wood volume that should be extracted in order to pay back return on investment, can be seen in the calculation below.

$$\text{Cost or investment} = \text{Volume} \times \left(\frac{\text{Cost of log extraction}}{\text{Productivity of extraction}} \right) \text{....(14)}$$

$$Rp\ 72.500.000\ = V\left(m^3\right)\left(\frac{Rp\ 138{,}587{,}39/hr}{1.72\ m^3/hr}\right)$$

$$V\left(m^3\right) = \times \frac{\text{Rp } 72{,}500{,}000 \times 1.72 m^3/\text{hr}}{\text{Rp } 138{,}587.39/\text{hr}}$$

$$= 899.79\ m^3 \sim 900\ m^3$$

a b c

Figure 6. Manual uphill extraction of logs with hand held rope (a), three workers rolling log uphill and helped by pulling the rope uphill (b), and pulling lift-up logs to skyline carriage (c)

This simple calculation gets the result that after effective working extraction of a minimum of 900 m^3 or after the machine has operated 524 hours, the investment can get profit. If working hours per day are 6 hours, the profit will be earned after 88 days or in about 3 months. As a comparison study the cost is given below for another type of machine, the so called Koller K 300, for log extraction by skyline.

One study of Koller K300 cable system at Salalet Hill used the machine with an engine of 50 HP. It had been operated for log extraction at distances of 100, 200 and 250 m, and each operation needed in average 6.24, 8.05 and 10 minutes. The variation of productivity was 6.6 m^3/hr (100 m), 5.5 m^3/hr (200 m) and 4.9 m^3/hr (250 m). The average extraction for each trip was two logs and the cost was about $4.2 per m^3 or Rp 40,000/m^3 (Senturk, Ozturk, & Demir, 2007). In present value it is corresponding to Rp 150,354 which is relatively higher than the cost of production by prototype Expo-2000 Generation-3. In case of the productivity, Koller K.300 was somewhat higher than prototype Expo-2000 of Gen-3 because the power was also 4 times larger. In Perum Perhutani Unit III of West Java, in 2000 there had been an experiment using the yarder machine of IWAFUJI 115. The productivity was in average 33.33 m^3/hr (Basari, 2002). It is also easy to understand if the production was relatively higher, because the engine used was much bigger of IWAFUJI 115 which had a power of 200 HP.

Today there are many different technologies of skyline such as TTY 70, Koller K 800, Trailer Mounted Undercarriage (TRLM), Self Propelled Crawler Mounted Undercarriage (SPCM), Self Propelled Rubber Mounted Undercarriage (SPRM) TTY 70, Koller 300, Trailer Mounted Undercarriage (TRLM), Self Propelled Crawler Mounted Undercarriage (SPCM), Self Propelled Rubber Mounted Under carriage (SPRM). Those machines may be used in either developing or advanced country (Lloyd, 2007) and with big power engine, which are able to extract big logs. For example, the TTY 70 has capability to remove logs of a volume of >12 m^3 or a weight of about 10-15 ton. Another research which used small machine power was carried out by Escobar and García (2013). The model machine and its operation is shown in Figure 8.

In conclusion, Escobar and García (2013) mentioned that this system may be used technically for logging of small logs in forest harvesting operations. The advantage is that all profile types are environmentally friendly, require low investment and technically simple. However, the productivity is still low (6 ton/day for distances of 500-750 m, 8 ton/day for distances of 250-500 m and 9 ton/day for distances of 100-250 m), and labour use and cost is therefore high. Cost of operations are Col$ 26, 18 and 14 for distances of 750-500 m, 250-500 m and 100-250 m, respectively. On the other hand, Spinelli, Maganotti & Visser (2015) mentioned that in general, cable logging is more complex and expensive than ground-based logging, which places steep terrain forestry generally at disadvantage in terms of pure harvesting cost. However, modern cable yarding technology can reduce this gap, and productivity models can assist users in refining their work techniques, so as to maximize the productive potential of their machines. In his experiment the machine was studied while harvesting selective patch cuts (gap cutting) in similar even-aged Norway Spruce stands, extracting logs between 3-6 metres long. The productivity ranged between 8.5 and 10 m^3/hour, including all delays, but excluding set-up and dismantle time.

Another study by Acuna, Skinnell, Mitchell, and Evanson (2010) mentioned that in good clear felling conditions in steep terrain a tracked self levelling feller buncher can achieve a high rate of productivity. Bunching the trees increased the productivity of the swing yarder by 25% and 19% cost reduction. Mechanized felling improves safety and value recovery.

The information above does mean that extracting logs by skyline machine is powerful and useful that should be applied at extreme

Figure 7. Field situation at operation of log extraction at Cibatu, Cianjur

Figure 8. Machine unit version 6.1

Remarks: transmission are pulleys and bands, dimensions 100x75x30 cm, 4 possible separate parts, net weight 50 kg, diesel engine power 6.5 HP (4.85 kW + 35 kg weight).

Source: Escobar and García (2013).

conditions. However, in operation of skyline there are high range variations with coeficient variation ranging from 31 to 79% (Pyles, Womack & Laursen, 1994). According to Lloyd (2007), compared with skidding tractor, the cost of operation and maintenance of skyline crane system was lower and the life time was longer. Actual extraction cost/m^3 varies very significantly depending on field conditions.

B. Comparison of the Manual and Skyline System

Safitri (2000) mentioned that on the average the size of logs which could be able to be shouldered in the manual system is the log with small diameter, i.e. top diameter of 21 cm and down diameter of 19.91 cm and length of 1.5 m, with a distance of about 32 m and the maximum distance would be 48 m. The limit of this manual method is decided by the weight of logs, weakness of workers and terrain conditions.

Figure 9. Logs extracted using simple hoist made by small pulleys and nylon string loading -unloading.
Source: Escobar and García (2013).

The two problems faced in applying the skyline technology are: choosing appropriate machine and skilled operators to operate the job. First about the machine, the constraint was how to find an appropriate machine rather than only sophisticated ones which have big engine power, because it cannot be directly used due to low accessibility conditions. The suitable forest road is rarely found especially in remote areas, the road constructions are usually dreadful. Therefore, the machine should be relatively small, have good flexibility to field condition, not too expensive but it could be built domestically and efficiently. Second, operators should have skill in technical rigging of ropes and capable of switching rope if once the rope is broken. Furthermore, it needs some instruments for setting the rope well, and the team should also be capable on deciding the right location for setting the ropes. Those jobs are not easy to execute, therefore control of operation is also important (Biller & Johnson, 1988).

Figure 10 shows the sophisticated and the simple machines, one as a locally made product prototype machine. It shows that operation of machine Expo-2000 of G-3 could be much simpler than TTY 70. It requires only handling panel of gear connection of the machine to the drum for hauling logs and backward in the air of the felling areas, and handling the panel for going forward or backward of the carriage. From this simple operation it could be concluded that it would be better and important to start building local industries for machines, including skyline that could be useful for helping regional and local development, especially for sloping areas. To support this conducive climate, the initial innovative approach should be continued and enlarged with wider scope of discipline involved (Endom, Soenarno, & Idris, 2014)

Seeing that topographic condition is the main factor that limits forest harvesting including skyline in which a convex slope, rough/not flat terrain and direction of the slope are not similar, those situations may also cause new problems. It is therefore the identification of field areas should be done well to choose which lane should be selected (Greulich, Hanley, McNeel, & Baumgartner, 1996). That is why based on this experience, foresters should be able to identify well existing conditions for defining what technique and equipment should be used for that logging operation.


a b

Figure 10. Sophisticated skyline machine of TTY 70 (a) and a simple prototype G-3 (b)

IV. CONCLUSION

The prototypes of modified Expo-2000 G-1 and G-3 using skyline system for log extraction operation had been assembled by a team of the Forest Products Research Center, Bogor. The first prototype was tested with vertical removal position and the second one with horizontal removal position. The prototype of G-3 show edit is more appropriate to be applied in Indonesia with a productivity of about 1-3 m^3/hr and on the average 1.72 m^3/hr. The cost of log extraction reached about Rp 80.348/m^3.

Referring to many Indonesian areas that have low accessibility for log extraction, a suitable machine for supporting operation could be made in a simple construction with medium power engine. Moreover, the operator and the team must have high skill for operating the skyline to enable it to work well. It is therefore promotion and education of this discipline that should be eagerly done.

ACKNOWLEDGEMENT

The authors would like to thank to Mr. Maman Mansyur Idris as the Former Head of the Forest Products Research and Development Center and also the Director of Perum Perhutani Unit III of West Java in particular Head of Forests District of Cianjur and Banten, which have already helped the authors in many ways. After all, appreciation is also given to technicians for valuable jobs and their thorough assistance for helping creative design of prototypes, since at the Laboratory and all fields' tests.

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