World Applied Sciences Journal 14 (5): 726-730, 2011
ISSN 1818-4952

Time Study and Efficiency (Production and Costs) of Wheeled Skidder HSM 904 in Caspian Forests

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Abstract: In order to evaluate the efficiency of wheeled skidder HSM, the Iran Wood and Paper Industry Forests which is located in north of Iran was selected. The Ground Skidding System was performed and trees were logged downhill. In this study, 50 working cycle were concerned. The elemental time study method was applied to develop the skidding time predicting model. This time model was mainly affected by skidding distance and volume per turn. The system cost was predicted 56 Euro/h. The gross and net production rate in the 525 m skidding distance was 8.7 and 7.6 m^3/h, respectively. The unit cost considering the gross and net production rate was 6.37and 7.29 Euro/m^3, respectively. The time of setting and removing the logs in roadside landing was the third important part of skidding cycle time.

Key words: Wheeled Skidder HSM904 · Mathematical model · Skidding · Time study

INTRODUCTION

One of the most important and most principal aims of forest management system is wood harvesting which has the most incomes and costs of a forest management plan [1]. Forest harvesting is composed of four key components including tree felling, primary transportation, loading and secondary transportation. Primary wood transportation is one of the most sensitive and most expensive operations and a hard level of forest utilization [2]. Before 20th century, forest utilization and relevant operations were conducted by human. Thus, tree felling was carried out by means of axe and saw and woods were logged with animals and water energy [3]. Nowadays, with expansion of mechanization besides the environmental considerations, it is necessary to determine machine efficiency in skidding operations. Information on the efficiency, costs and applications of the logging system is the key component in the evaluation of management plans for utilization of the Caspian forests. With the disappearance of traditional harvesting and the need for suitable forest mechanization systems, it is essential to transform the forest harvesting sector [4]. For this reason, this study is carried out for evaluating the efficiency of wheeled skidder HSM which works in wood logging operations in northern forests of Iran. Previous studies addressed the production and costs of harvesting stands under different machine and harvest prescriptions; conducted the production analysis of wheeled skidder Timber jack 450C in northern forests of Iran. The variables including volume per turn, skidding distance, winching distance and number of logs in each turn were significantly entered to the model. The gross and net production rate was 13.38 and 10.56 m^3/h, respectively. The unit cost considering the gross and net production rate was 2.5 and 2.05 Euro/m^3, respectively [5], studied the productivity of wheeled skidder HSM 904 in Caspian forests of Iran. The time model was mainly affected by skidding distance and number of logs per turn. The productivity of the skidder was 6.53 m^3/h and the unit cost considering the net production rate was 30 Euro/m^3 [6].

In time study and skidding capacity of the wheeled skidder Timber jack 450C in Caspian forests indicated that the skidding cycle time was mainly affected by skidding distance, winching distance and interaction between skidding distance and slope. The net production rate was

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22.93 m^3/h [7], compared the production and cost of three wheeled skidders in forests of Sokoine University. Results showed that differences between three skidders were affected significantly by size and type of machine, operator dexterity and slope of the area [8] stated that the variables stem size, ground slope, skidding distance and volume of logs per turn were significantly effective on extracting logs from stump to roadside landing [9] indicated that among effective variables on skidding time, the ground slope and the skidding distance caused a raise in skidding costs and the volume per turn caused a reduction in skidding costs [10], stated that harvesting intensity, skidding average distance, volume per turn and bunching are the most effective factors in skidding system [11].

MATERIAL AND METHODS

Study Area: The research was carried out in compartment number 6 of Mazandaran Wood and Paper Industry forests in the north of Iran, with the altitude ranging from 520 to 720m above sea level. The slope of the compartment was below 30%. The aspect of the slopes was south west. The forest was mixed, uneven-aged and its type was *Carpinetum (Carpinus betulus)*. The total volume of primary transportation which was carried out by skidder was 1965m^3. Long and short logs were logged from the stump area to downhill roadside landing by a ground based skidding system. The skidder type used in this study was wheeled skidder HSM. A cycle of skidding turn is the time which skidder departs from roadside landing for extracting logs from stump area. In this research the cycle of skidding turn was broken into different elements as follow:

- Travel empty
- Preparing: the time needed to prepare for returning
- Pooling the hook
- Hook
- Winching
- Travel loaded
- Release
- Piling

In addition to these elements, there is a series of delay times in each turn. The delays were divided into three groups:

- Operational delay
- Technical delay
- Personal delay

Methods: Times and operational variables were measured using a stopwatch and recorded on paper [10]. The work cycle for each operation consisted of certain elemental functions and factors. The times for each function and the value of each factor were recorded in the field. The functions of the wheeled skidder were travel empty, establishment time, release and pulling, hook, winching, travel loaded, unhook, piling [6]. In addition to the measurement of time for each work element, factors such as skidding distance from landing to stump, number of logs per turn, tree species, mean diameter and length of logs, gradient of the skid trail, ground slope and winching distance were measured. In order to estimate production and cost of a unit volume of wood, the work study techniques was used. Huber formula was used to calculate volume of logs. Table 1 presents the statistics of operational variables of wheeled skidding in the study area.

With the use of following formula the required samples were chosen and 50 samples were recorded.

$$n = \frac{t^2 \times (s\%)^2}{(E\%)^2}$$

Where n is number of samples, t is t-student, s is standard deviation and E is standard error.

Table 1: the statistics of operational variables of skidding in the study area

Variable	Mean	Deviation	Minimum	maximum
Number of logs per turn	2.4	0.88	1	4
Skidding distance (m)	322	108.60	120	525
Volume per turn (m^3)	3.28	0.78	1.03	4.9
Winching distance (m)	23.28	7.38	8	40
Gradient of skid trail (%)	11.3	2.4	7	16
Gradient of winching trail (%)	4.04	1.82	1	8

Table 2: ANOVA model of skidding time

source	SS	df	MS	F-value	R^2- value	sig
Regression	844.36	2	422.18	36.03	0.68	00.0
Residual	597.44	47	11.71			
Total	1441.81	49				

RESULTS

The Mathematical Equation of Skidding Time Prediction Model: In order to apply the skidding time prediction model, the SPSS software and the Stepwise regression is used to determine fixed coefficients. Two series of time-study information are randomly taken out from the data to be used for determining the model validity. The relation between measured effective variables such as skidding distance, gradient, load volume and etc and their interaction with skidding time are also determined and analyzed. The best model for skidding time is a function of independent variables: skidding distance and volume per turn. The cycle time equation calculated for the HSM took the following form:

$$Y = 6.47 + 0.033\,D + 1.71\,V\ (\text{min})$$

Where Y is the time needed for one skidding turn in minute, D is number of logs in each turn and V is load volume in m^3

The significance level of the ANOVA table (table 2) shows that the model is significant at $\alpha = 0.01$. This multiple correlation coefficient is interpreted as the 0.68 % of total variability, which is explained by the regression equation.

Validity of the Model: Confidence limits of skidding time estimated by the model are calculated and compared with real skidding time. The validity of the model was tested using the confidence intervals for each coefficient [12]. The real time of witness samples were in the confidence intervals, so the model is valid. In order to test the validity of model, 10 samples were randomly selected from the time study database and were not used in modeling process. These samples were applied as witness samples to test if developed model is reliable or not. To calculate confidence limits estimated by model (estimated time) following formula is used:

$$\gamma \pm = \%5\sqrt{(Mse)(1+\frac{1}{n}+\xi^1 sp^{-1}\xi)}$$

Where Y is estimated time by model for each turn of skidding without considering delay time, Mse is mean square error, n is number of skidding turns used in the model, ξ is numeric value obtained from time study of effective variables in the model to calculate time for each turn of skidding *and sp* is inversion of sp^{-1} Matrix.

Table 3: Validity of model in control samples

Confidence limit	Measured time	Estimated time
3.75< 25 < 35.59	23.25	25
7.28 < 21.28 <28.91	19.20	21.28

The validity test using witness samples confirmed that developed model is valid at a=0.05

Calculating the Production Unit

$$\text{The production} = \frac{\text{Volume of wood skidded toward landing}}{\text{Time needed for skidding operation}}$$

$$\text{The net production rate} = \frac{\text{Total used time (hour)Total volume of wood skidded towards landing (m}^3\text{)}}{\text{Total used time (hour)}}$$

$$= \frac{167.82}{19.29} = 8.69\ m^3/h$$

$$\text{The gross production rate} = \frac{\text{Total volume of wood skidded towards landing (m}^3\text{)}}{\text{Total used time with considering delay time (hour)}}$$

$$= \frac{167.82}{22.07} = 7.60\ m/h$$

Calculating the Production Cost: In order to calculate production cost, FAO manual was used. Thus, using this manual the system costs consisting of machine costs simulation and labor costs are calculated and dividing this by the production over the location. These calculations are in accordance with machinery and instruments price list for the year 2003. Scheduled daily work hours were 8 h and useful work hours were 6 h per day and productivity is calculated based on a 6 h day. The number of work days was considered 150 days per year. The unit cost considering the gross and net production rate was 6.37and 7.29 Euro/m^3, respectively.

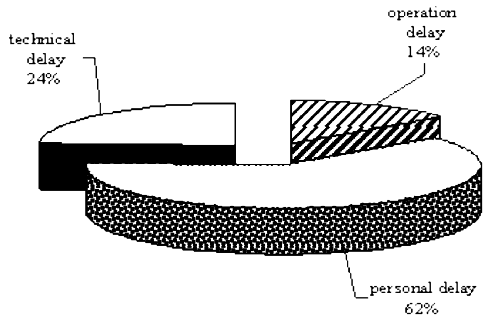

Fig. 1: percentages of delays

Table 4: Average time and share of time segments in the study area

Elemental times of working cycle (sec)	Mean	Deviation	Minimum	maximum	(%)
Travel empty	447.76	174	200	895	32
Establishment time	40.55	41.12	10	230	3
Release the winch	88.08	55.20	10	230	6
Hook	123.3	64.36	10	240	9
Winching	92.50	47.76	15	230	6.6
Travel loaded	409.09	141.02	160	660	2.9
Unhook	68.28	54.63	15	240	4.9
Piling	131.98	82.11	12	400	9.5
Skidding cycle time*	1389.58	327.47	580	2175	-
delay	219.52	125.98	0	600	-

* Skidding cycle time does not include delays

Figure 1 shows the percentages of delays. Obviously, personal delays were the most frequent. After the personal delays, operational delays were the most frequent.

Table 4 shows the average working time and the share of elemental times of working cycle obtained in the study area with the skidder HSM.

The Total Skidding Time Prediction Model: The SPSS 16 statistical program was applied according to its series of phases in Table 4. These series are independent variables. The dependent variable is total time (A). The stepwise regression analysis was applied. The most effective variables with 99% confidence intervals are:

- $A = 0.776 + 0.979\ Te + 1.02\ Tw + 0.999\ Tj + 0.988\ Toc + 1.028\ Tc + 0.970\ Tl + 0.897\ Ts + 1.012\ To$
- *Te* = Travel empty
- *Ts* = Establishment time
- *To* = Release the winching cable
- *Tc* = hooking
- *Tw* = Winching
- *Tl* = Travel loaded
- *Toc* = Unhook
- *Tj* = piling (min)
- R^2= 0.99 F = 35320.03 Durbin-Watson = 2.2

The Durbin-Watson coefficient value was found as 2.2. If this coefficient is near 2 or above, this means that autocorrelation between residues is negative.

CONCLUSION

After analyzing the data and applying the skidding time prediction model, it became clear that the best model for skidding time is a function of independent variables: skidding distance (m) and volume per turn (m^3). Skidding distance and volume per turn are the major factors that influenced elemental times and productivity especially in the times of travel empty and travel with load. The gross and net production rate was 8.7 and 7.6 m^3/h, respectively. The unit cost considering the gross and net production rate was 6.37and 7.29 Euro/m^3, respectively. 6 percents of total time was belonged to delays which varied in different logging steps. Due to improper management and poor observation of supervisors in the study area, personal delays were the most frequent. Therefore with good management this kind of delay could be decreased in order to decrease skidding cost. Without any delays, we will have 0.54 USD profit per m^3. After the personal delays, technical delays were the most frequent. Hence, with time managing and usage of proper techniques during the wood extracting process, delays will reduced and machine marginal utilization will increased. Because of not having enough room in roadside landing, the logs were high gathered. Thus, the times of unhook and piling the logs, after the times of travel empty and travel with load were the most frequent. Regarding to the exclusive design of skidder HSM, only 3 percents of the total time was belonged to establishment time. Because of steep slopes, high elevation and sensitive sites, harvesting and extraction operations in the Caspian forests of Iran need to be carefully planned and executed. This study is conducted to establish a quantitative base for harvesting management and planning in Iran. Information on the productivity, costs and application of harvesting equipment and system is a key component in the evaluation of management plans for the rehabilitation and utilization of the Caspian forests.

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