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Efficiency Economic Of Chainsaw and Timber Jack 450C Skidder Evaluation in Felling Operation and Ground-Base Skidding System

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ABSTRACT

In this research, an empirical time study was carried out, to estimate effects of a tree felling and skidding operations on time consumption, productivity rate, cost, and present a regression model of chainsaw and Timber jack 450C skidder. The study revealed that the hourly production of felling with and without delay times was 51.6 (9.5 trees/hr) and 86.2 (16 trees/hr) cubic meters per hour, respectively. The survey of total production of tree felling operation using a chainsaw showed that, increasing tree diameter increase total production rate without delay time as power model, similar to this production cost for one cubic meter is decreased. The average net and gross time, of a felling cycle was equal 3.74, 6.24 min per cycle, respectively. The total production rate with and without delay times in skidding with Timber jack 450C model skidder was 7.92 and 12.1 cubic meters per hour, respectively. The rate of machine 687.69 US$ per hour was estimated. The cost of skidding with and without delay times was 117.19 US$ and 76.64 US$ per cubic meter, respectively. Therefore, total delay times in skidding with Timber jack 450C model skidder were devoted to the two working cycles as follows: travel loaded and travel empty. The effects of all variables affecting on change of the time-consuming and skidding cost firmed that increasing all variables increase skidding cost as power model.

Keywords: Cost, Felling, ground-base skidding, Production, Regression model, Time study.

1-INTRODUCTION

A harvesting system refers to the tools, equipment and machines used to harvest an area, while this system tends to heavy investment. According to Majnunyan (1989), the most important element of cost in a forestry unit belongs to the forest operations involved. Among all of the timber harvesting components, felling operation is more important than other. In Iranian forests, the application of advanced mechanization and equipments of felling and processing are limited because of the special topography, the existence of large-size trees and using selection systems in these forests. For these reasons, felling operations are commonly performed manually (Sarikhani, 2008).

The skidding system in northern forests of Iran refers mostly to the ground-base skidding, while this function also offers the greatest cost related to the timber operations. Although different types of machines are used in ground-base skidding; no economic considerations were taken into account (production system hour) on the systems' efficiency. It seems that such assessments are essential for qualitative control of timber operations and also provide a base for sustainable management of forests. The managed forests under these scenarios are able to be continued regarding to the products and their services; especially these managements may be profitable in the long-term.

Lortz et al (1997) studied manual felling and productivity in southern pine forests on sixteen stands which were harvested by either clear-cut, shelter wood, group selection, or single-tree selection methods showed that, factors affecting total felling time were DBH of harvested stems, inter-tree distance, and harvest intensity. Total felling time (including walk, acquire, fell, and limb-top times) was inversely related to harvesting intensity and directly related to stem DBH and inter-tree distance.

LeDoux and Haylr (2000) compared the production rate for break-even area for long and short cut-to-length systems in Northern mixed hardwood and softwood stands. They concluded that, in the short cut-to-length system the production rate was 11.08 and 14.83 m3/ PSH for the small and massive-size harvester.

Klepac and Rummer (2000) found that the productivity rates for two Skidders Timber jack models 460 and 660 were 46.7 and 51.7 tons per PSH, respectively in Southeastern USA forests.

Rummer and Klepac (2002) studied the productivity, cost and damage to residual stands on two timber harvesting systems including trees felling with chainsaw and harvester systems in National forests of Wayming. They found that the increasing tree diameter increases felling cycle time of a tree. The results of this research also led to develop a regression model to estimate the harvested tree time relate to the tree diameter.

Egan and Baumgras (2003) in West Virginia, USA examined the relation among several ground skidding and harvested stand attributes. They found a direct relation between skidding distance and cycle time, and an inverse relationship between the percent of trees removed from the stand and total cycle time.

Akay et al (2004) also studied the productivity of mechanized harvesting machines including Skidder, Feller-Buncher, Harvester, Loader and Forwarder in forests of Turkey.

Wang et al (2004) in hardwood stands of Appalachia studied production and the cost of felling operation using manual chainsaw and cable skidder. They found that, the felling cycle time of a tree was mainly affected by harvested stems tree DBH and inter-tree distance. The production of chainsaw for felled tree was 362 ft/m3/PSH; an average time of a felled tree was also 4.57 min. Similar to other parts of the world in Iran several studies were performed too, for example Feghhi (1989) studied the full tree method, by means of a high-lead system (whole-tree method) and combination of wheel skidder and crawler tractor (tree length method) in Shafaroud forests, northern Iran. He found that the productions of three systems were 6, 8.58 and 8.48 m3/PSH, respectively. The skidding cost of whole-tree and tree length methods were estimated 2.86 US$ and 1.5 US$, respectively.

Eghtesadi (1991) studied the economic distances of skidding and transportation operations in Neka-Choob forests. He reported that, the production rate and skidding operation cost of the TAF skidder were 10.46 m3/hr and 0.54 US$/ m3 respectively.

Naghdi (2005) compared the production rate and skidding cost when using the cut-to-length and tree length methods. The productivity rate of the cut-to-length and tree length methods with and without delay times were 11.75 and 17.1 m3/hr, respectively. The net skidding cost (without delay) of the two methods were 56.4 and 38.75 US$/m3, respectively.

Jour Gholami et al (2008) evaluated the productivity and cost of TAF wheeled skidder using the short cut-to-length method in forest research and training center of Kheirood, northern Iran. They indicated that the total production rates with and without delay times in skidding operation were 5.93 and 8.33 m3/hr, respectively; the rate of machine was also 4439.29 US$/hr.

Nikooy (2008) presented a mathematical model to predict the time of felling tree in Asalem forests. The model is functional of tree DBH and inter-tree distance. The production rates based on this model with and without delay times in felling operation were 53 and 67 m3/hr, respectively.

Jour Gholami and Majnounian (2010) investigated the efficiency of chainsaw in bucking operation on two short and long cut-to-length methods. They indicated that long cut-to-length method was better than short cut-to-length method in point of view of system hourly production and average net time of a working cycle (without delay). Till now, numerous studies on efficiency, productivity, cost and identifying the factors influencing production of mechanized timber harvesting have been performed in the world (e.g. Legault and Powell 1975; Landford et al. 1990; McDonald 1999; McDonald and Rummer

2002; Wang and Haarla 2002; Egan and Baumgras 2003; Wang 2003). Almost in all of these studies regression Models or predictor models of time study are commonly used to express timber harvesting performance. Unfortunately, there is paucity information in this regards on the harvesting performance in detail in Iran; because of different terrain conditions, environmental factors, types of machinery and harvesting methods. Thus, to fill in the gap in the knowledge of this field, the present study was conducted to investigate the production and harvested tree cost using chainsaw/skidder 450C under selection method in forest research and training center of Kheirood, northern Iran.

2- MATERIALS & METHODS

2.1 Study site

The study site was located in compartments 208, 209, 211 and 221 in the forest research and training center of Kheirood, northern Iran. The forest is uneven-aged, which managed under silvicultural and cutting regimes of single tree selection cut-to-length system. The total volume of primary transportation which was carried out by Timber Jack 450C model skidder in short and long logs were 2.20, 2.40, 2.60 and 2.80 m.

2.2 Methods

In this research, a time study in context of continues time recording method was applied to the collected data. The elements time read and recorded at each element of the felling cycle with a one hundredth second stopwatch. The elements of felling cycles were recorded as; sawyer to walk into a tree, decision time about felling tree direction, under-cut time, back-cut time, wedge time and miscellaneous time (fuelling and service). The other factors affecting on total felling time a tree were registered including; DBH of harvested stems (cm), inter-tree distance (m), inter-tree longitudinal slope (percent), transverse slope of felling area (percent) and direction of felling. Felling direction was recorded into three codes; the felling at the lead (Code 1), felling at the side of the lead from 0 to 90° (lateral) (Code 2 and felling against the lean from 0 to 180° (Code 3).

The number of samples needed for developing a felling tree model, using a chainsaw under single selection method, including 324 cycles. Three series of time-study data from each site are randomly set aside for model validation. As a wholly 329 cycles were recorded in the field working. All the work cycles were not measured, only some cycles with work progress were measured, randomize. A cycle time for skidder was split into the following elements; travel unloading, releasing (open and, extension of cable), hooking, winching, travel loaded, unhooking, pilling and delays (technical, operational and personal delay).

Apart from affecting elements on each cycles both felling and skidding; several factors were registered for example; skidding distance and slope, as well as number of logs, volume per a turn and species. The samples needed to determine mathematical model of skidding refer to reference were 53 cycles work. After collecting data, the data was entered into SPSS 14.0 as the statistical package for the data analysis. In this analysis the first step is to make sure that the data are distributed normally and this is done by using normal plot and Anderson-Darling method. Regression analysis with the stepwise method between independent variables and dependent variable was performed on time study data to develop an operational cycle time equation for felling and skidding times (Zar, 1999). As a statistic parameter used for selecting the best-fit model the P-value, F-value, and R2 were chosen. The relation between measured effective variables such as skidding distance, gradient, load volume, etc and their interaction with skidding time (felling and skidding time without delay) are also determined and analyzed.

3 - RESULTS

3.1 Felling

The relationships between stump diameter and time consumption (without delay), under-cut (mine) and back-cut (mine) elements in a working cycle of tree felling are presented graphically in Figures 1 to 3.

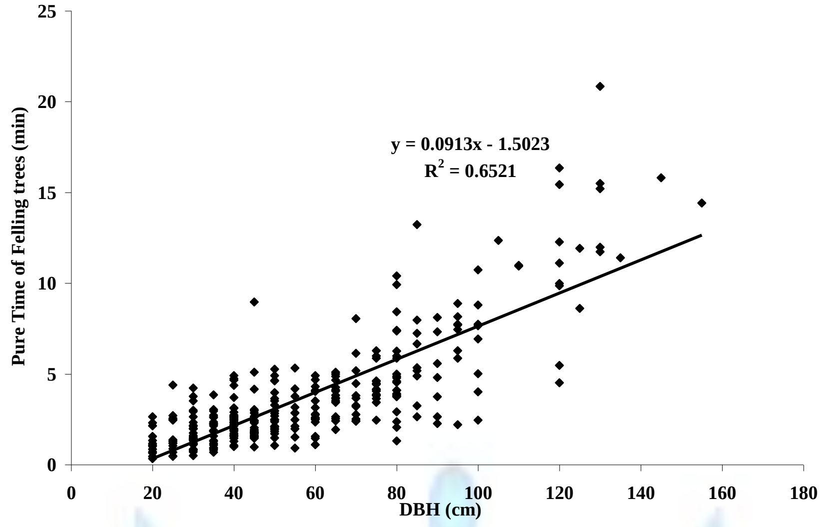

Figure 1: Distribution of dot diagram pure time of felling trees with tree diameter

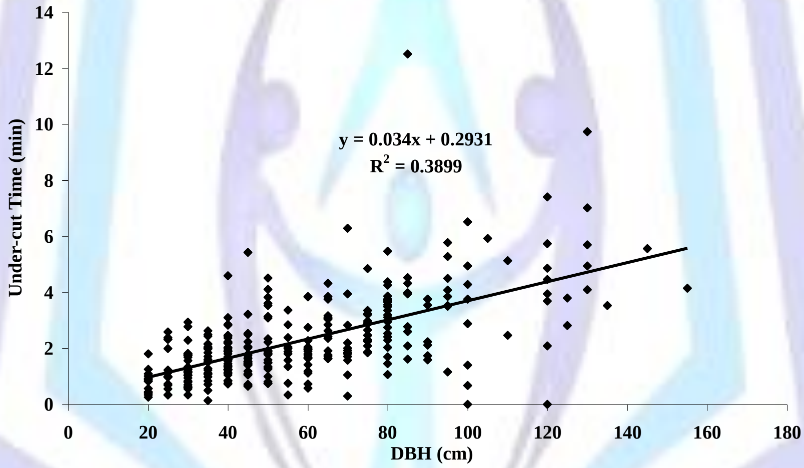

Figure 2: Distribution of dot diagram Under-cut time with tree diameter

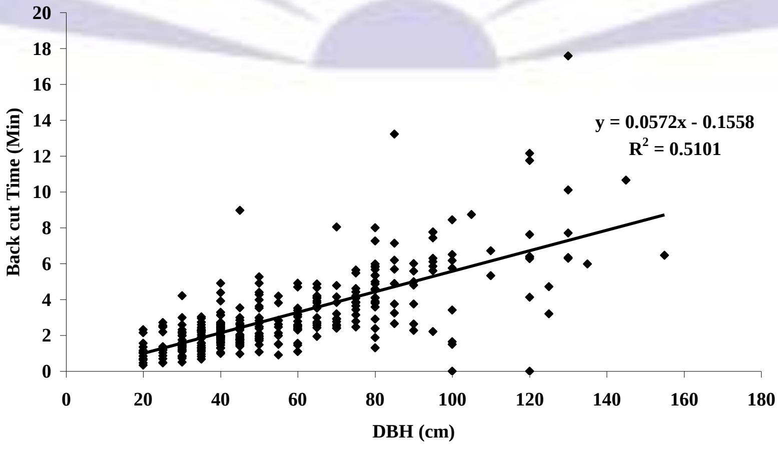

Figure 3: Distribution of dot diagram back cut time with tree diameter

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Table 1: General study area characteristics

Characteristics	C 208	C209	C211	C221
Are (ha)	31.30	27.80	40.90	36.80
Elevation (m)	830-970	800-1100	790-950	1085-1190
Aspect	South	South	Southwest	North
Forest type	Quercus castanifolia, Carpinus betulus and mixed fagus orientalis	Fagus orientalis, Carpinus betulus, Alnus spp and Acer spp	Fagus orientalis, Carpinus betulus, Alnus spp, Acer spp and Quercus castanifolia	Fagus orientalis, Carpinus betulus and Acer spp
Number/ha (N)	282	189	362	149
Volume/ha (silve)	403	566	201	347
Marked volum/ha (silve)	18	29	14	21
Skid trail length (m)	1300	800	1550	2

The results showed that time consumption (without delay) increases with increase tree DBH as a linear model. The results of working cycle of felling and the primary factor to affect the felling operation performance are shown in Table 2.

Table 2: The element of felling tree with chainsaw

Elements	Tree DBH (cm)	Walking (min)	Decision (min)	Under-cut (min)	Back-cut (min)	Wedging min)	Technical delay (min)	Total time (min)	Inter-tree distance (min)	Longitude slope (%)	Transverse slope (%)
Mean	57.42	0.66	0.28	1.34	0.88	0.43	0.18	6.24	33.90	17.50	33.28
Min	20.00	0.00	0.00	0.00	0.00	0.00	0.00	0.34	0.00	0.00	0
Max	15.50	2.56	1.67	10.02	8.20	6.45	2.68	66.40	170.00	65.00	80.00
S.D	27.52	0.64	0.21	1.22	1.00	1.17	0.50	8.38	30.20	12.70	14.70

Average felling time includes only under-cut, back-cut, while total time consumption of felling includes time consumption of all felling elements. The time consumed for felling a tree highly depends on the stump diameter. Felling element was divided into two sub-elements such as under-cut and back-cut, which was influenced by the stump diameter of the trees Figure 1.

The mathematical equation of the felling as a function of independent variables (e.g. tree DBH, felling direction and inter-tree distance) is as following:

$$Y = -1.82976 + 0.088X_1 + 0.01388X_2 \qquad \text{(Eq1)}$$

In this equation Y is time needed for felling a tree (minutes). The summarized results of analysis of variance (ANOVA) of the model are presented in Table 2. In the felling with a chainsaw; tree DBH, felling direction and inter-tree distance variables per each cycle were entered in model at significant level a = 0.01. The multiple correlation coefficient (R2) 0.669 is interpreted as 72.5% of total variability, which is explained by the regression equation with a fallen tree. The significant level of ANOVA shows that models are significant at a = 0.05 (Table 2).

3.1.1 Validity of the model

Previous to analyzing data, three series of time-study data from each site were randomly taken out from the data to be used for the model validity determination. Confidence limits of felling time estimated by the model were calculated and compared with real felling time data. The results show that the model has acquired statistical validity (Table 3).

Table 3: ANOVA table for regression equation in chinsaw

Factor	SS	df	MS	F= $\frac{MSK}{MSe}$	(%) R2	r	P
Regression	2104.78	3	1052.39	327.63	66.90	0.82	0.000
Residual	1037.52	323	3.21				
Total	3142.31	325					

3.1.2 Calculation of production unit of felling with chainsaw

In this research hourly productions of chainsaw with and without delay times was 51.6 (9.6 tree/hr) and 86.2 m3/hr (16 tree/hr), respectively. The hourly production of the chainsaw with the delay was 59.9% less than without delay/or net production time.

Production rate (m3/hr) of chainsaw increases with increased tree DBH. The relation between the production and tree DBH constituted a power model (Figure 4).

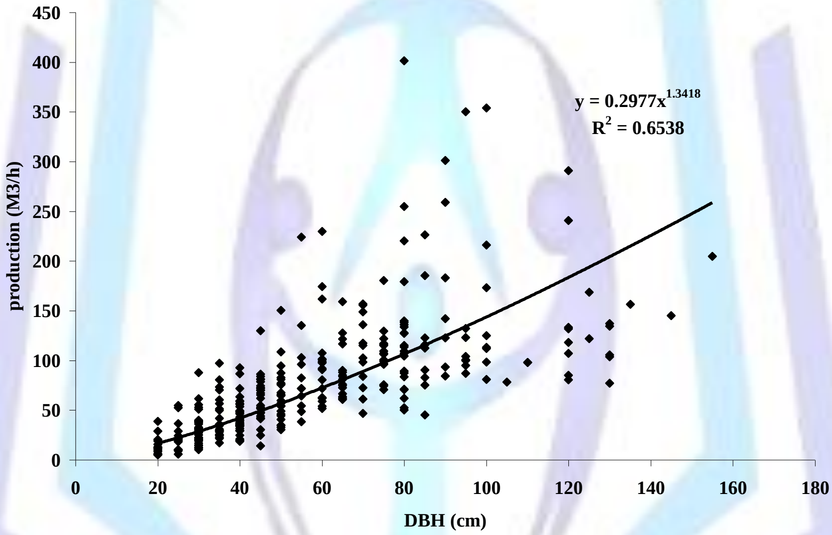

Figure 4: Distribution of dot diagram change production chain felling whit tree diameter

3.1.3 Calculation of production cost of felling with chainsaw

In order to determine the felling cost, the proposed instruction by Forest and Range Organization of Iran was used (Sobhani & Rafatnia, 1997). According to this manual, firstly the system costs consisting of the chainsaw costs simulation and labor costs are calculated and by dividing this by the production (tree or m3) over the location, the production costs for one cubic meter are calculated. Machine costing in US$ based on 2010 prices for chainsaw and other services was used. Scheduled daily work hours were 8 hours and useful work hours were 6 hours per day. The number of work days based on weather and local conditions was considered 180 days per year. Working group consists of sawyer, assistant sawyer and a labor.

Time consumption of felling was determined using two effective factors in the models including; tree DBH and tree lean, while holding the other variables constant and their mean value. Scrutinizing Figures 5 and 6 implied that the time consuming and felling cost increases with the increase in these variables as a Power Model. Parallel to these the production cost for one tree (m3) decreases sharply, as the tree DBH increases with respect to the power model.

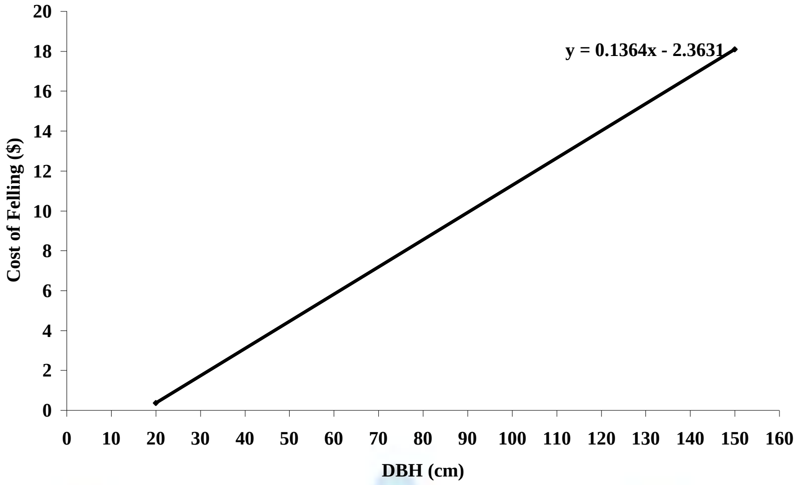

Figure 5: Effect of tree diameter to cost of felling

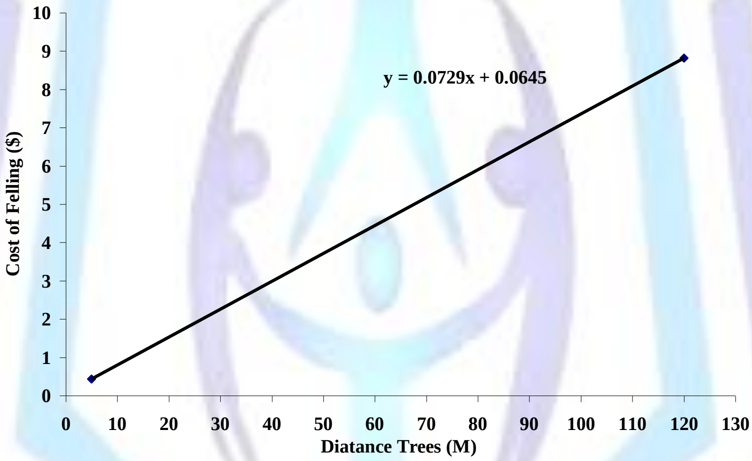

Figure 6: Effect of felling direction to cost of felling

3.1.4 Analysis of work element and delay times

Figure 8 shows the distribution of elementals time (percent) in felling . The most times were spent in under the cut, personal delay and back-cut phase were 20.9, 17.92 and 14.13% in felling cycle with chainsaw. An average from the total time of felling tree by about 59.9% was only devoted to the productive activities. Time consumptions in each cycle of felling with and without delay time were an average 6.24 and 3.74 min, respectively. Approximately 10.6% of the total time consumption in a felling cycle was spent in finding marked trees in a winching strip.

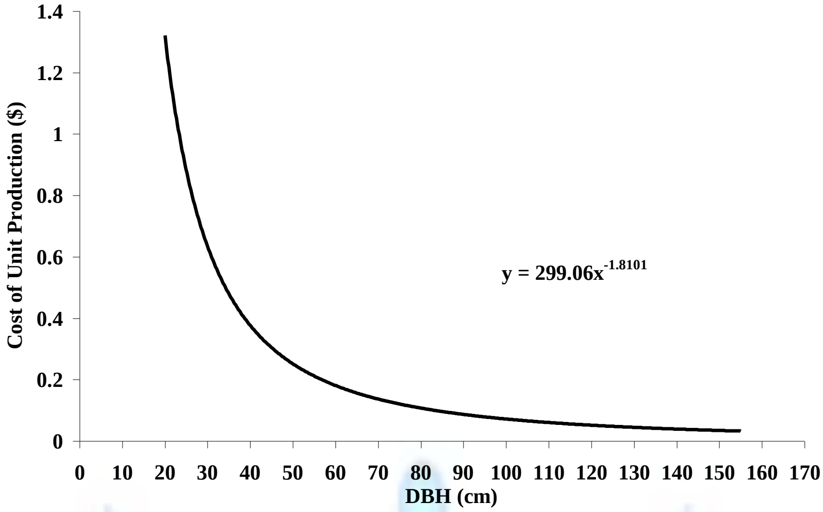

Figure 7: Effect of Changes on Unit Production Cost ($)

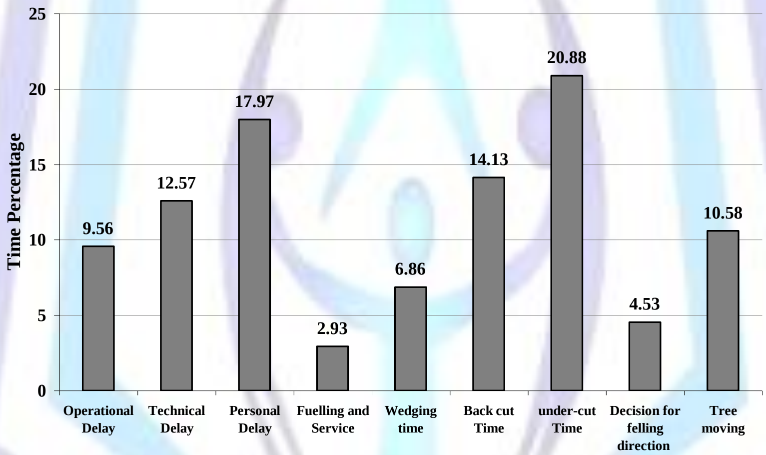

Figure 8: Percentage of time spent by parts once tree cutting saws including time delay

3.2 Skidding

3.2.1 Analysis the data of skidding with Timber jack

Analysis of variance (ANOVA) was used to determine the relationship between a dependent variable (total time) and independent variables and effective variables in each working. The relationship between the times spent for work elements in each skidding turn and effective variables was specified with the use of the dot plot technique.

The relation between measured effective factors in skidding model such as ; skidding distance, slope of the trail, number of log and volume per turn, winching distance and their interaction with skidding time (skidding time without delay) were also determined and analyzed (Figurers 9 to 11). The effective factors on skidding model with Timber jack 450C model skidder were identified (Table 5) and by using the stepwise regression best model was developed. According to the dot plots diagram, the relationship between time consumption (without delay) and measured effective variables such as skidding distance and number of log per turn is linear, while the dot plot diagram of other variables has irregular distributions (Figurers 10 to 11).

Confidence limit		Measured time (min)	Estimated time (min)	X3 (m)	X2 (code)	X1 (cm)	Sample
high limit	Low limit						
6.02	2.41	3.01	4.43	45	2	65	1
1.56	-0.07	0.93	0.75	8	1	20	2
7.75	4.63	5.80	6.18	8	2	110	3

Table 4: Validity of the model

Costing elements	Variable cost							Fixed cost			
	Maintenance and Repair	Fuel and Lubricant	Cable	Hourly O. C. per PMH	Total Machine Rat	Labor cost	Total System Cost	Depreciation	Interest	Tax and Insurance	Hourly F. C. per PMH
Cost (US$)	4200	1813	601.3	734.9	466.7	100	714.3	107.14	114.49	137.5	251.99

Table 5: Machine costing in US dollar ($) based on 2010 prices (for chainsaw)

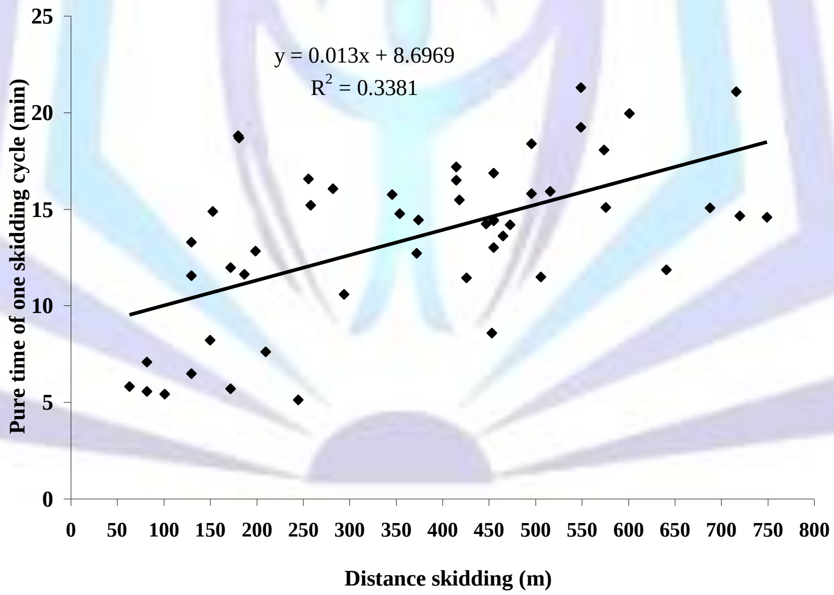

Figure 9: Distribution of dot diagram relationship between distance skidding and pure time

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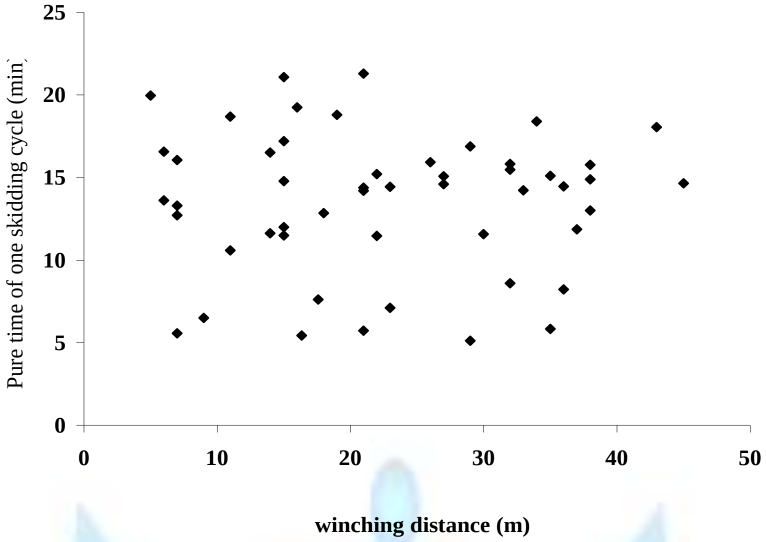

Figure 10: Distribution of dot diagram relationship between winching distance and pure time

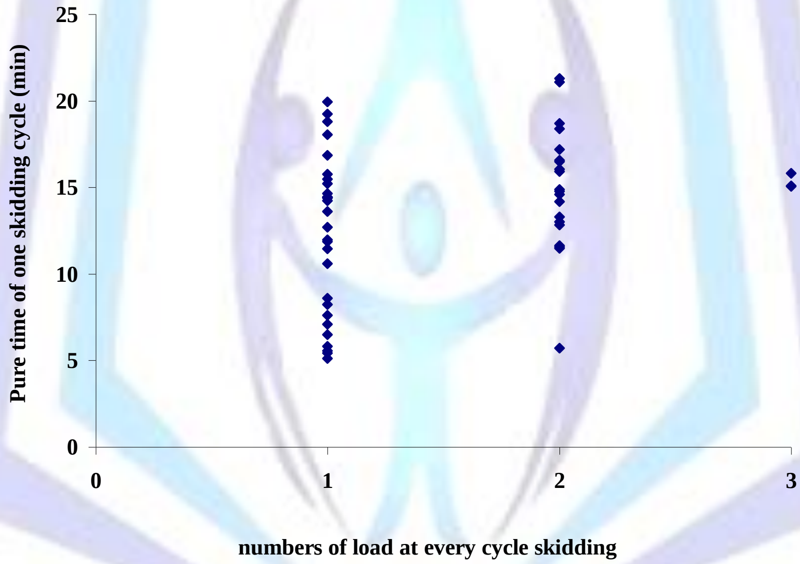

Figure 11: Distribution of dot diagram relationship between numbers of load at every cycle skidding and pure time

3.2.2 Mathematical equation of the skidding time as a function of effective factors

Mathematical method of skidding with Timber jack 450C model skidder is presented as following. Time consumption for skidding greatly depends on skidding distance and number of log per turn.

$$A = 0.175218 + 0.026697X_1 + 4.143835X_2 \qquad \text{(Eq2)}$$

The summarized results of analysis of variance (ANOVA) of the model are presented in Table 6. In skidding operation with Timber jack 450 C model skidder; skidding distance and number of logs per turn were entered in the model at significant level a = 0.01. The multiple correlation coefficient (R2) 0.7247 is interpreted as 75% of total variability, which is explained by the regression equation with a fallen tree. The significant level of ANOVA shows that models are significant at a = 0.05 (Table 6).

Parameters	Operational delay (min)	Technical delay (min)	Personal delay (min)	Logs displacement	Un-hooking	Travel loaded	Winching	Hooking	Cable unclose	Travel unloading
Mean	1.97	1.06	4.23	1.13	0.8	4.99	1.17	0.87	1.03	3.52
Sum	100.28	54.04	215.55	57.43	41.02	254.43	59.90	44.4	52.51	179.27
Min	0	0	0	0.23	0.23	1.48	0.10	0.11	0.16	0.92
Max	25.36	14.50	70	2.69	2.1	10.22	5.36	3.13	3.7	6.05
S.D.	4.56	3.37	12.32	0.55	0.36	2.15	0.98	0.72	0.78	1.35
Variance	20.81	11.36	151.66	0.31	0.13	4.62	0.95	0.52	0.61	1.81

parameters	Total delay (min)	Total skidding time (without delay)	Total skidding time (min)	Number of log per turn	Volume per turn (m3)	Skidding distance (m)	Trail Slope (%)	Winching distance (m)	Winching slope (%)
Mean	7.25	13.51	20.66	1.51	2.73	368.86	2.2	22.59	15.29
Sum	369.87	688.96	1053.47	77	138.99	18812	1112.43	1151.97	780
Min	0	5.11	5.43	1	1.13	63	-12.49	5	-34
Max	84.50	21.29	98.94	3	4.81	749	13.7	45	36
S.D.	14.36	4.26	14.83	0.61	0.95	189.69	6.59	11.02	14.76
Variance	206.33	18.11	219.88	0.37	0.9	359828	43.41	121.43	217.89

Table 6: Percentage of work element in a cycle time travel unloading, releasing (open and, extension of cable), hooking, winching, travel loaded, unhooking, pilling and delays

3.2.3Calculating production unit of Timber jack 450C model skidder

The production of skidder was calculated regarding to the following equations (3 and 4);

$$\text{The production with delay time} =$$
$$\frac{\text{Total volume of wood skidded towards landing } (m^3)}{\text{Total used time with considering delay time (hour)}} = \frac{138.993}{17.56} = 7.92 m^3/hr$$

(Eq3)

$$\text{The production without delay time} =$$
$$\frac{\text{Total volume of wood skidded towards landing } (m^3)}{\text{Total used time (hour)}} = \frac{138.993}{11.48} = 12.1 m^3/hr$$

(Eq4)

Hourly productions of machine (amount of logs which were dragged from the stump to the landing) with and without delay times were 7.92 and 12.1 (m3/hr), respectively per a turn. The hourly production of machine with delay time was 35% less than without delay/or net production. Production rate (m3/hr) of machine decreased with increased skidding distance. The relation between the production and skidding distance constituted a logarithmic model (Figure 4). The sharp decrease in the machine production rate was in first 300m, while the production rate rhythm after this distance decreased very slowly. The production rate in 100m and 350m were 23 and 14 m3/hr, respectively. However, in the 600m skidding distance was 9m3/hr.

3.2.4 Calculating production cost of skidding with Timber jack

Similar to chainsaw, felling cost was calculated by using the same manual (Sobhani & Rafatnia, 1997). Thus, the system costs consisting of machine costs simulation and labor costs were calculated and by dividing the system costs by the production over the location, the production cost for one cubic meter was calculated. Machine costing in US$ based on 2010 price of machine and other services was used. The number of working days based on weather and local conditions were considered 180 days per year. A machine life of 10 years was used, with a purchase price of US$, a utilization rate of 71.4% was considered. Working group for skidding operation with Timber jack 450C model skidder consist of driver, assistant driver and a labor. The other machine costing of Timber jack 450C model skidder is shown in Table 7.

Factor	SS	df	MS	F= $\frac{MSK}{MSe}$	(%) R2	r	P
Regression	1883.78	2	941.9	72.47	75.12	.87	0.000
Residual	623.83	48	12.9				
Total	2507.6	50					

Table 7: ANOVA table for regression equation in Timber jack skidder

3.2.5 Calculate production/or machine costing with Timber jack 450C

$$\text{unit cost } (\text{U\$\$}/m^3)\text{without delay tim}$$

$$\frac{\text{systemcost (US\$/hr)}}{\text{A.V productivity (m}^3\text{/hr)}} = \frac{927.69}{7.92} = 117.19U\$\$/m^3$$

$$\text{unit cost } (\text{U\$\$}/m^3)\text{with delay tim}$$

$$\frac{\text{systemcost (US\$/hr)}}{\text{A.V productivity (m}^3\text{/hr)}} = \frac{927.69}{12.1} = 76.640U\$\$/m^3$$

The production cost for one cubic meter with and without delay times with Timber jack 450C model skidder was 117188 and 76640 US$/m3. The skidding cost wit delay was greater than without delay/or net production cost. Extraction cost increase as power model with increase skidding distance in short cut-to-length method.

The total of three stages of winching stretching time of cable, closing and pulling devotes %14.9 of skidding time. The time of stretching the cable from buck in land includes %3.04 of the time of skidding. Since the team of skidding walking with Timber Jack were not compel, the driver had to get off and stretch the cable and it caused the time increase. The time of moving the buck (timber) takes %5.5 of the time of skidding which the main reason organist from not property of the land and lack of the its suitable designing and its make in the beginning of stripe road and beside the forest road.

Mean time of skidding per turn in short cut-to-length method with and without delay times was 20.66 and 13.51 min, respectively (Figure 14). The most time per a turn skidding is spent to the travel loaded phase with Timber jack (24.15% of total time). Scrutinizing Figures 14 revealed that, part from travel load per turn skidding; the most time was devoted to the personal delay and travel unloading (20.46 and 17.02% of total time, respectively). An average by about 7.25 of total time in each turn was devoted to the delays. The times consuming in the personal, technical and operational delay times were 58.3, 27.1 and 14.6%, respectively per turn.

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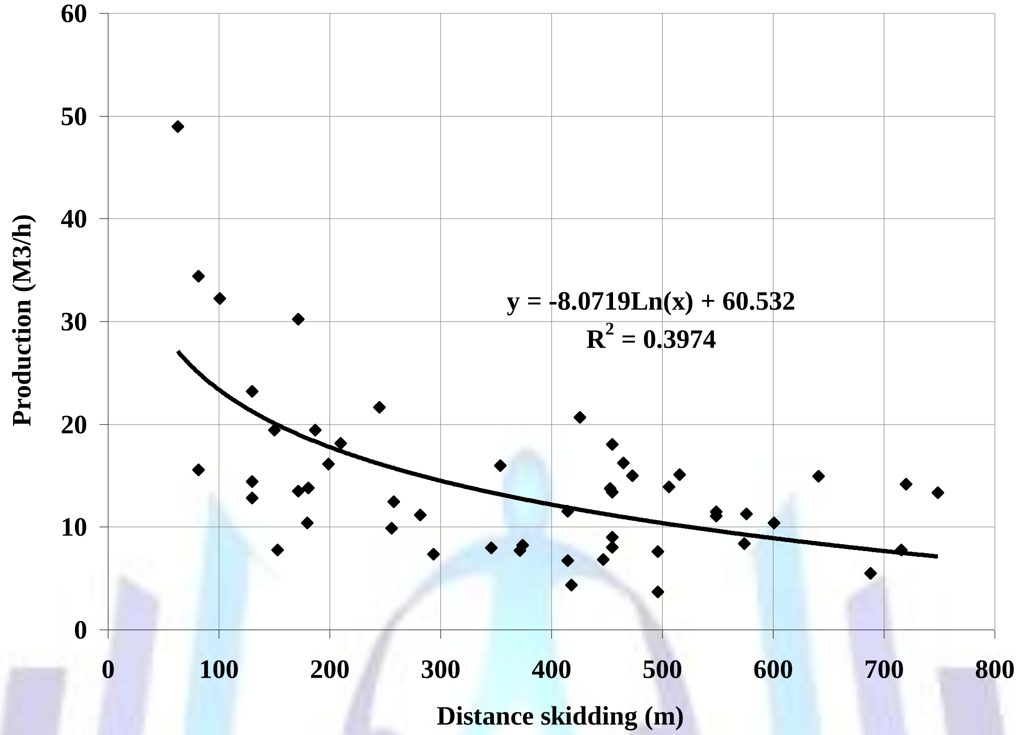

Figure 12: production changes in skidding with Timbejack in contact with distance skidding

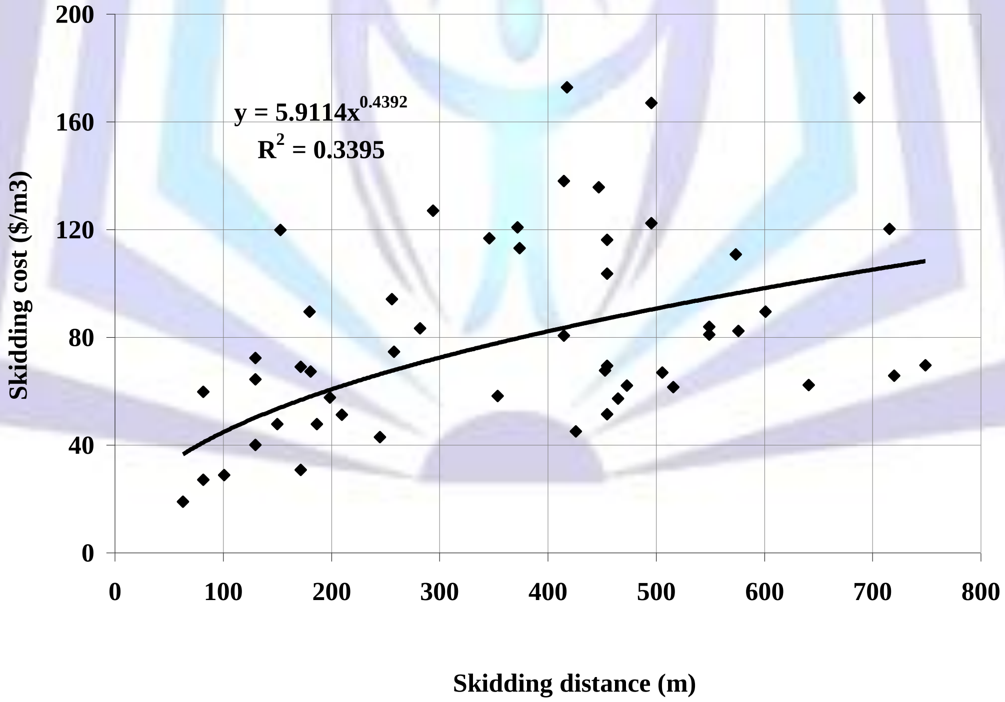

Figure 13: the changes of skidding cost in cut to length system with distance skidding

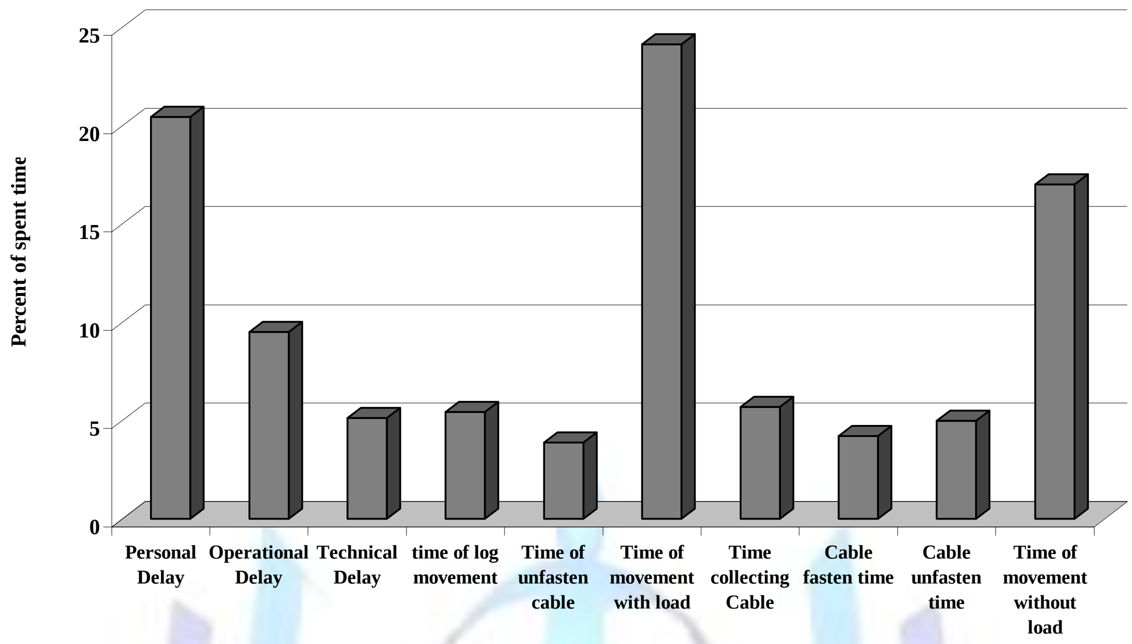

Figure 14: Percentage of time spent on skidding components with Timber jack 450C

Costing elements	Fixed cost				Variables cost					Machine rate	Workers cost	Total cost
	Depreciation	Interest	Tax and Insurance	Hourly F.C. per PMH	Maintenance and Repair	Fuel and Lubricant	tire	Cable	Hourly F.C. per PMH			
US$	128000	152440	28044	342.76	108	100.5	71.1	453.33	344.94	677.69	240	927.69

Table 8: Machine costing in US dollar ($) based on 2010 prices (for Timber jack skidder)

4 - DISCUSSION

Felling tree with chainsaw is a highly complex work and is one of the most important processes in forest harvesting. Due to several factors are affecting on the felling productivity in the field. However, many of these factors may be not recognized. However, many of these factors are difficult to identify and even more difficult to quantify. This paper identifies the variables that are the most significant on production rate and should be recognized prior to harvesting. In the previous studies several variables which are effective on felling time were identified following; tree DBH, inter-tree distance, harvest intensity and species, respectively (Wang et al, 2004; Li et al, 2006، Lortz et al, 1997; Rummer and Klepac, 2002; Sessions et al., 2007).

In this research parallel to previous studies, the key factors affecting on felling productivity were tree DBH (which is only interpreted more than 70% of variability in felling model) and inter-tree distance. Direction of felling with lean's tree is spent more time in a felling cycle, especially in large-size trees. In felling model this factor is devoted more time than other factors. This may be explained by existing highly percent of mature and over mature trees with large-size in our cut-block in northern Iran. According to international act regard to time study (Bjorheden and Thompson, 1995), maintenance and repair and fuelling times considered in total time of consuming in felling and analyzed.

In previous studies walking, finding tree, felling, delimbing and topping time was considered as elements of the felling, whereas in this study, besides above mention elements, felling element was divided into two parts following; back-cut and under-cut. In Iranian forests the bucking and delimbing was not performed in line to the tree felling, but these operations were done when all trees were felled.

The results of dot grid diagrams from the relation between tree DBH and other factors affecting on felling time model showed that back-cut and under-cut elements had significantly affect on time consuming, while walking and deciding elements had not significantly affect on time consuming in the field. These results are in the support with (Lortz et al. 1997). The hourly production (m3/hr) of chainsaw with delay was 60% less production (m3/hr) without delay. Personal delay is devoted more than 50 time- felling. Managing and control of delay can be increased the chainsaw productivity.

The production (m3/hr) and cost (US$/m3) for one cubic meter were increasing and decreasing, respectively when tree- size increased with chainsaw. The relation between the productivity and cost and tree DBH constituted a power model in felling with chainsaw (Sessions et al., 2007; Wang et al, 2004; Li et al, 2006; Lortz et al, 1997; Rummer and Klepac, 2002).

An average time consuming per feeling cycle without and with delay 3.47 and 6.24 mine, respectively. The increase felling time consuming with chainsaw my be attributed by single tree selection method, walking-inter tree and terrain condition The higher back-cut and under-cut depth times are related to the use of a wedge to lead the tree in the specified direction in order to prevent damage to the residual stand, regeneration and breakage to the tree being felled. The production cost for one cubic meter (US$/m3) with and without delay times for feeling a tree was 4880 and 2920 US$/m3. Production cost for a tree with and without delay times for feeling a tree was 26220 and 15700 US$/m3.

The regression equation of feeling time consumption which was developed based on the results of this study is applicable for any areas with the same working conditions and equipment. The mathematical model of time skidding with 450C model skidder is a multivariable regression equation per a turn as a function of independent variables such as: skidding distance and number of log per turn. Skidding distance was found to be the most influential factor on the mathematical model skidding with 450C model skidder.

The main reason for entered number of log per turn into skidding equation was referred to the cut-to-length system which using in this research. In our study Cut regime was short cut-to-length and the length of log was 6m. The direct effect of log number per turn on skidding model than volume load and trail slope may be explained by wrapped several logs together to full payload of the machine and hooking of logs. When the number of logs that should be winched increase and also be scattered in the winching strip, hooking time increases, especially when the logs need to be hooked repeatedly. After collecting several logs at the winching strip, because not commonly use of a choker in Iran, skidding cable wrapping directly around the logs.

As a consequence skidding time may be significantly increased also number of stems per cycle and machine payload may be decrease. Part from above reasons unwrapping cable around the logs during skidding and cable braking may be occurred resulting none using of choker in skidding operation, as a consequently the skidding cost may increased. These results are match with other (Nikooy, 2006; Naghdi, 2003; Legault and Powell 1975; Miyata 1980; Landford et al. 1990; McDonald 1999; McDonald and Rummer 2002; Wang and Haarla 2002; Egan and Baumgras 2003; Wang 2003).

The hourly production (m3/hr) without delay in skidding operation was 35% greater than production with delay. Results firmed that production of Timberjack is strongly related to skidding distance. So that the production rate of Timberjack decreases sharply, as the distance increases.

These results are match with other (Nikooy, 2006; Naghdi, 2003; Feghhi, 2007). Organization delay may strongly decrease production cost for one cubic meter at 35%, and increase the production rate of skidding operation. The extraction cost is increasing with increases skidding distance as power model. The reasonable reason for this increase may be explained by; skidding distance at study area (150m), increase winching time, current cut regime, hooking and wrapping of logs as well as hooked repeatedly for harvested trees and cable breaking. By examine efficiency of chainsaw and Timber jack 450C model skidder; forest manager could predict the time required for felling and skidding from a compartment. Better information about the likely productivity and cost of harvesting equipment is a necessary for improve management planning aimed at rehabilitation and utilization in Hyrcanian forest.

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