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WOOD EXTRACTION PERFORMANCES OF MOBILE TOWER YARDERS IN THE REPUBLIC OF SLOVENIA

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Abstract

The cableway wood extraction becomes more and more important in Slovenia. The results of investigation of the uphill wood extraction performed by mobile tower yarders in the Republic of Slovenia are presented in the article. The mounting and dismounting of cableways, the unproductive times by wood extraction or device transfer and the productive times of a single load extraction are discussed separately. Special attention is focused on the analysis of load formation. Some methods of evaluation of daily performances of wood extraction are presented in the last part of the article.

Key words: wood extraction, work study, cable cranes, performance, development of cableways

UČINKI SPRAVILA LESA Z VEČBOBENSKIMI ŽIČNIMI ŽERJAVI S STOLPI V REPUBLIKI SLOVENIJI

Izvleček

V študiji so opisani rezultati študija dela pri spravilu lesa navzgor z večbobenskimi žičnimi žerjavi v Republiki Sloveniji. Posebej je obravnavano postavljanje in razstavljanje naprav, neproduktivni čas pri spravilu in prestavljanju ter produktivni čas spravila enega bremena. Analizi oblikovanja bremena je dan poseben poudarek. V zadnjem delu študije so prikazani postopki za izračunavanje dnevnih učinkov spravila lesa.

Ključne besede: spravilo lesa, študij dela, žični žerjavi, učinki žičnih naprav, razvoj žičnih naprav

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CONTENTS

1 INTRODUCTION

Wood extraction is the most expensive phase of production in the mountain regions of Slovenia. In most cases tractors are used for wood extraction. The cableways are only used on the steep and difficult terrains (about 5% of wood extraction), mostly for the uphill wood extraction (88% of the cableway wood extraction in Slovenia). The importance of cableways for wood extraction is relatively small in our country. Yet there are some questions connected to it which have already for some time been a topical subject. The selection of the most appropriate method of wood extraction for a certain area is usually a long term decision with relevant economical and ecological consequences. The evaluation of suitability of a certain wood extraction method is still based on the expenses of wood extraction itself and on the expenses of building of the secondary forest communication system. The expenses of wood extraction depend on the costs of an operational hour of device and on its performance.

The performances of the cableways which are most frequent in Slovenia are discussed in the article. The dependence of the performance on the working conditions is presented as well.

2 DEVELOPMENT OF CABLEWAY WOOD EXTRACTION TECHNOLOGY IN SLOVENIA

The major part of Slovenia belongs to the Alpine and Subalpine territory. The country is rich in forests, which have always been a source of income for a good lot of people. It is no surprise that the first wood extraction devices in Slovenia appeared rather early (MAZI, 1955). The first forest cableways have already been used in the second half of the 19-th century (KOSTNAPFEL, 1974).

The first mechanized wood extraction in Slovenia was performed by cableways that worked as gravity cable cranes and were derived from similar devices which used to be driven by draught animals. Such was the development of the small cable crane of Gnezda (1932), which was the precursor of the Idria small cable crane (BELTRAM, 1954; BITENC, KOŠIR, SMOLEJ, 1989).

The first cable crane carriage "NAŠ" was designed and manufactured in 1949 (KOŠIR, 1987-b); its designer was dr. A. KOSTNAPFEL and its manufacturer the blacksmith ULČAR, Gorje pri Bledu (Slovenia). The production of a rather well known carriage KS-1 started only a year later (KOSTNAPFEL, 1950); its designer was dr. A. KOSTNAPFEL and its manufacturer the enterprise Žičnica, Ljubljana (Slovenia). The latter carriage remained a part of the forest technology up to the seventies. Some winches for the drive of cable cranes were produced as well (Žičnica, Ljubljana, Slovenia).

Table 1: The number of cableways in Slovenia after the year 1945

Type of cableway	1950	1960	1970	1980	1990
Cable droppers	5	3			
Swinging ropeways	2	3			
Twin cable with circulating carriages, Tolmin cableways	33	32			
Twin cables with circulating carriages and hanging stations		8			
Lasso cable	1	3			
Long distance cable cranes	8	40	55	28	20
Mobile tower yarders			14	15	35

In the sixties the first two types of modern mobile tower yarders were designed: 3BV 250 and 3BV 450 (KRIVEC, 1969, 1970). The type 3BV 450 remained a part of forest production up to the present time (the producer: SIP Šempeter, Slovenia). The basic vehicle of both of the cable cranes was a farm tractor. With it different types of carriages and various rope systems could have been used (the Idrian, the Tyler).

In these years several cableways and some parts of theirs were imported. Among these the most important were the classic and the clamping cable crane carriages (Wyssen, Baco, Hinteregger), various types of wynches and some complete cableways (Igland - Alp Wynch, Hinteregger - Urus).

The wood extraction performed by tractors made its greatest progress in the years 1960-1970. During that period the interest in forest cableways began to decrease gradually. Owing to the forest road network thickening, some types of cableways were given up completely, while some others were modernized. The tractor wood extraction seemed much more promissing then, so that most of the attention was payed to the tractors.

The development of modern cableways has by the end of the seventies made such a progress that most of the insufficiencies of the cableways were diminshed to the level, on which they became competitive to the previously higher appreciated tractors. The interest in cableways grew bigger and some new improvements were seeked (Table 2). In the last years a thought arose again of some cableways constructions of our own. Some of these ideas were realized, although following some foreign models, as the TVS 1500 for example (produced by Lesna Slovenj Gradec, Slovenia).

Table 2: The cableway wood extraction in Slovenia after 1960

Period	Average quantity of the extracted timber - an estimation (m^3)	Number of cable harvesting seminars	Number of participants
1961-65	110 000	3	43
1966-70	109 367	9	130
1971-75	79 956	4	77
1976-80	55 797	3	44
1981-85	72 073	5	111
1986	85 467	3	39
1988	96 493	2	27
1990	80 000		

There are several reasons for the renewed interest in wood extraction performed by cableways (KOŠIR, 1990). The most important reasons are:

- Bigger and bigger demands for the entire forest area management. Until now the tractor terrains were mainly made accessible by forest roads. The entire previously planned annual cut was used on these terrains and a part of the annual cut of the closed forests was used as well.
- Bigger and bigger demands for the more ecologically suitable methods of wood extraction - since the work in forests is more and more mechanized and since the forest management has been intensified. For wood extraction performed by tractors the skidding roads are needed. Building of these on the steep terrains is ecologically very unreasonable.
- The development of modern cableways contributed to their greater efficiency and to shorter time of mounting and dismounting. The cableways have in many cases become competitive to tractors.
- Rise of the expert knowledge of forest management. In spite of great troubles that originated in general economic and social conditions the awareness grew, that only a thorough preparation of work could give an assurance of its effective realization. Numerous studies formed a basis which made a complex estimation of wood production possible.

The cableway wood extraction is developing similarly in some other Central European countries. The cableways are becoming more and more important, especially for the extraction of wood on the difficult terrains (TRZESNIOWSKY, 1986, 1989).

3 METHODS OF DATA GATHERING AND DATA PROCESSING

3.1 Data gathering

The data gathering and all of the analyses were carried out in several directions:

- Evaluation of productive times of single operation periods and of entire cycles of wood extraction and evaluation of duration of mounting and dismounting of the cableways;
- Evaluation of wood extraction performances and an analysis of load size;
- Structure of unproductive times by wood extraction and by device transfer.

3.1.1 Measurements of times and performances by wood extraction

The method of evaluation of wood extraction performances has already been discussed rather thoroughly (KOŠIR, 1985-a; 1988; 1990).

The productive and unproductive times by wood extraction and by device transfers were measured. The remnant effective times and the unused part of the calendar time were treated in accordance with literature. For the evaluation of skidding time the snap back chronometric method was chosen and the timing record sheets were organized to suit it. For the evaluation of the times of mounting and dismounting the continuous chronometric method was used besides the snap back chronometric method and exceptionally sometimes the work sampling was done (for intervals of 30 seconds).

The measurements were being performed during a rather long period of time (1983 - 1988) by several researchers. Some of them later continued the work on the project on their own.

The necessary amount of data was not determined in advance. An effort was made to take as many measurements of the following parameters as possible:

- diverse terrains by the same type of cableway;
- diverse types of cableways of the same group (the heavy, the medium and the lightweight devices);
- entire working days, including the work preparation and termination time;
- device transfers.

By wood extraction the parameters concerning the cableways were measured while the labour of workers was measured by device transfers. So the time structure for each individual worker was got as well as the duration of the entire transfer.

3.1.2 Selection of devices and sites of measurements

As the cableway wood extraction is not very widely used, the experiment could not have been planned on the basis of the entire reliability. The measurements had to be done at the working sites, where wood was then extracted by the cableways, which we were interested in. About one third of the data was given to us by some authors, who had used the same methods of measurements for their own purposes. The number of the cycles for which valid measurements were taken was 2269.

During the processing of the data it soon became obvious that an evaluation of regression dependences for all the winch-carriage combinations would not be possible. So we decided to use a method of data treatment, which enabled us to take into consideration the widest possible spectrum of data. The comparability and sufficient number of cycles were preliminary conditions for the choice of the method.

Table 3: Some data about the studied cableways

Type of a cableway	The winch			The drive	The carriage	
	Drum number	Working area (m)	Tower height (m)		Type	Carrying capacity (t)
Urus III M III	4	400-600	8	truck	Baco BK202 R Hint. Gravimat Koller SKA 25	2,0 2,0 2,0
Mini Urus TVS 1500	3	400	6	cableway's own drive	original Koller SKA 10	1,5 1,0
Igland Telescope	2	200	6	tractor	original	1,0

Only three groups of mobile tower yarders were included in the final comparison (Urus,, Mini Urus - TVS 1500, Igland Telescope). By the first three of them the uphill wood extraction was studied.

The influence of certain variables upon the productive time and upon the load size was not included in the analyses, because these variables were either not of the same size range by all the devices or there were not enough data available. Some of these variables are: the weather conditions, the day of a week, the time of a day, the number of choker hooks on a carriage.

Table 4: Characteristics of the groupated data

Cableway/Carriage Basical data	The grouped data	The number of cycles	Note
Urus III/Unimog		120	The oldest Urus from Tolmin, inconvenient weather cond.
Urus III/FAP		190	The second oldest Urus from Kranj
Urus M III/TAM		341	Some newer cableways from Tolmin, Bled and N. Mesto
Mini Urus TO		134	The oldest Mini Urus from Tolmin, the VW engine drive
Mini Urus SG		240	Set on semi-trailer, Torpedo engine, Slovenj Gradec;
TVS 1500 (diversa)		318	
Igland telescope (diverse)		670	
	Urus	651	
	Mini Urus-TVS 1500	692	
	Igland telescope	670	

3.2 Data processing

3.2.1 Dependence of productime times on the working conditions

In the regression dependence calculation four joint operations and the productive time of entire cycle were taken into account. The limits of some individual parameters, for which the evaluations of the investigation are valid, could also be seen in Table 5.

The work in cutting area and the work in timber yard were done rather irregularly, because these two joint operations are mainly dependent on the work organization. The work in timber yard was expressed as a regression dependence, while the work in cutting area was considered a constant.

In the regression calculation the following independent variables were taken into consideration: the distance of skidding, the distance of wood gathering, the terrain inclination, the number of wood logs in a load and the load weight.

By performance measurements the volume of timber was evaluated on the field itself. The greatest part of loads was composed of both - the coniferous wood and the broadleaved trees wood (softwood and hardwood). The calculation of regression values was not at all suitable for our purposes. It was better for the size of the load to be expressed in its weight than in its volume. The transformation factors for the measurements performed in Slovenia were 0.95 t/m^3 for the conifers and 1.1 t/m^3 for the broadleaved trees.

Table 5: The basical data about independent variables and main and complementary times of the cycles

Measurement		Type of a cableway		
		Urus	Mini Urus - TVS 1500	Igland telescope
Data number		651	692	670
Skidding distance (m)	min. average max.	10 176 490	10 108 260	0 83 184
Bunching distance (m)	min. average max.	0 133 60	0 124 50	0 16.2 50
Terrain inclination (%)	min. average max.	6 37 66	14 50 80	14 42 56
Number of logs per load:	min. average max.	1 3.1 10	1 2.1 8	1 2.5 8
Load weight (t)	min. average max.	0.01 1.28 4.30	0.05 0.62 1.91	0.09 0.42. 1.50
Outhaul empty	(min/cycle)	1.10	0.63	0.64
Bunching of wood	(min/cycle)	3.80	2.56	1.63
Inhaul loaded	(min/cycle)	2.09	1.45	0.77
Unhooking	(min/cycle)	0.81	1.03	0.65
Duration of a cycle	(min/cycle)	7.81	5.68	5.32
Work in the timber yard	(min/cycle)	0.31	0.79	0.57
Work in the cutting area	(min/cycle)	0.03	0.29	0.30
Total time	(min/cycle)	8.14	6.76	6.19

In most cases the exponential type of regression equation gave better results. The general form of the equation was:

$$\mathbf{T = a.VLA^{b1} . ZBI^{b2} . KOS^{b3} . MAS^{b4} . NAK^{b5}}$$

T = productive time
VLA = distance of skidding
ZBI = distance of gathering
KOS = number of logs in a load
MAS = load weight
NAK = terrain inclination
a = constant
bi = regression coefficients

Only the regression dependences, where statistical significance of coefficients were smaller or equal to 0,05 were taken into consideration.

3.2.2 Dependence of the load size on the working conditions

Different types of carriages with various carrying capacities and characteristics (clamping or mechanical carriage, the possibility of choker or classical 'hook' load formation) can be used with the same type of wynch. For an exact forecast of the productive time of a cycle (or the use of time per unit) one must be as well as possible acquainted with the principles of load formation for a certain winch-carriage combination (KOŠIR, 1985-a; 1988). For this reason the regression dependences of number of logs in a load on an average log weight (both of these parameters have influence on the load size) and the number of choker hooks were calculated.

As the number of chokers normally remains constant at a certain working site, only the dependence of the load size on the weight of an average log in a load was taken into consideration. In this case and exponential regression equation was used becouse of the better results:

$$KOS = d. MAS^{e}$$

KOS = number of logs in a choker
MAS = weight of a single log (t/log)

The statistical significance (0.05) was of the same range as by the productive times regression dependence calculation.

3.3 Technologies, methods and ways of work

The working processes of cableway wood extraction by stump wood assortment preparation in the auxiliary storage place (or by the forest road) and by assortment preparation in the cental timber yard were measured. For the first technology, only the assortment method of work is suitable. For the other two technologies the method of multiples, the full-length and half-length method and the full-tree method were sometimes used, but these data are because of unsufficient amount of measurements not included in the results.

The differences in courses of working processes for which a certain technology and method of work were used were regarded as the ways of work. These differences are usually the consequence of a minor equipment variability, of adaptations to unusual working conditions, of different working habits of the teams and of organizational variety.

Because of this the ways of work were not studied separately. More attention was payed to them in cases when some other factors existed, which could have had influenced them: the organization of work or the variability in use of cableways and the equipment for example.

For the regression calculations all the measurements of the basic operations of timber transport (irrespective of the way of work) for an individual cableway or even a group of cableways were joined: no-load transportation, gathering of wood, full-load transportation and unfastening of wood.

On the other hand in some cases the analyses of times were done separately: when some phases of work were not treated as times of wood extraction but selective supplementing productive times instead. These time elements are:

- felling and partial working of the trees in the felling area, a result of which is a delay by wood extraction;
- finishing of wood by the forest road also causes a delay by wood extraction;
- assorting and leveling of wood along the forest road - performed by the third drum of the cableway;
- assorting and leveling of wood along the forest road - performed by a tractor.

Such an acces enables us to evaluate the effects of individual ways of work for most devices, although they were only measured for some of the devices. Indeed, these evaluations are connected with a certain risk, yet they are accurate enough for the comparison to the wood extraction performed by tractors.

The different organizational systems and the different ways of work can not be simply compared because of the fact, that certain working conditions in reality require a certain way of work.

If there is enough space in the timber yard, the additional leveling, performed by a cableway or a tractor is not necessary. More important it is to arrange the timber transport in a way that the delays caused by timber loading are as short as possible. A truck can pick the timber before the work starts, after the work is finished or in the middle of the working day. In the last case the workers can - have the main break - during the loading time.

In case the timber yard by the cableway is not large enough, three possibilities exist. If simultaneous removal of timber could be organized, the timber can be landed on the forest road itself. The forest road is for this reason closed to traffic. The timber loading is made difficult and the long logs can usually not be loaded. There are more delays and the work safety - either by timber loading or by the unloading (unfastening) is reduced.

If there is enough space along the road, the timber can be leveled by an additional cableway winch. In some cases the forest road can even remain opened to traffic. The timber loading is not much of a disturbance for wood extraction, yet the simultaneous removal of timber is necessary, because otherwise too great a quantity of wood soon piles up in the auxiliary storage place. Even with this way of work the safety is reduced.

With some types of cableways where tractors are needed for the device transfer (TVS - 1500, Mini Urus), a connection exists between the cableway - which takes the timber to the forest road - and the tractor - which assorts and levels the timber along the road. The organization of this kind of work is rather demanding and sometimes even more expensive, but it brings with it a series of advantages. Normally, the forest road could remain opened to traffic, the timber loading runs undisturbedly and is not dependent upon wood extraction and it also has no effect on the cableway operation.

The timber is assorted according to desires. This brings order in the forest in case the assorting in the central mechanized storage is not done and it also proves to be advantageous by the timber selling. The danger of injuries among the workers is smaller, because there is no necessity for them to climb the piled timber.

The workers at the cableway can as well be in charge of felling. The felling can either be performed simultaneously with wood extraction or independently. In the first case team work is possible. The influence of such an organization of work upon wood extraction efficiency depends on the division of labour and on the number of workers. When only two workers are doing the felling and the skidding (by Mini Urus TO for example), a third worker who does the cutting mainly can to the greatest extent reduce the delays by skidding (such a case was being observed by an Ingland Telescope). The probability of work accidents is greater.

In the second case the workers cut the trees along the line before the skidding starts. During this time the cableway is not in operation. This way of work is only justifiable when trully great effects can be reached at cutting - by the full-tree method for example. Because of the great effects at cutting, the delays by device operation are rather short. The probabilities of work accidents are smaller.

4 RESULTS OF THE INVESTIGATION

The results presented in the article are valid for the average working conditions of cableway wood extraction in Slovenia. The greatest part of cutting on the steep terrains are thinnings or sanitary cuttings. The passability of working sites is normally rather good, because there are very few wood residues left by which the movement would be made difficult. In fact the conditions can be either much better or much worse than the conditions that were studied in this investigation. Especially in case of device transfer the influence of working conditions upon the course of work is of a significant importance.

4.1 Structure of the calendar time

The exploitation of working time by cableway wood extraction was evaluated from the forestry enterprises' records. For the more thorough analysis of time exploatation the records about the use of Urus in the Forestry Enterprise of Novo mesto (Slovenia) were used.

Table 6: Exploitation of working days by some groups of cableways - the time by wood extraction

Type of a cableway	1984	1986	1988	1990
Urus	91	110,3	141,4	98,0
Mini Urus - TVS 1500	122	97,6	93,6	86,4
Igland Telescope	57	72,7	58,5	14,0

Table 7: The shares of various sorts of delays within the direct work time at wood extraction, performed by mobile tower yarders

Sort of a delay	% of productive time		
	Urus	Mini Urus - TVS	The average
Delays caused by workers	2,06	10,87	5,32
Delays caused by the cableways	4,78	2,81	4,05
Other delays	13,46	17,89	15,06
Together	20,30	31,57	24,46

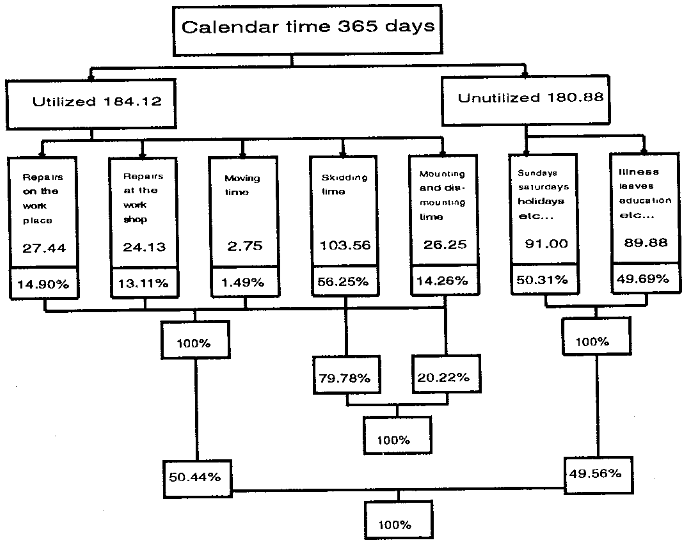

Figure 1: Distribution of calendar time for the Urus M III cableway (according to the records)

The indirect work time was evaluated by working process time studies of the cableways of the Urus and the Mini Urus group (KOŠIR, 1984). 14 measurements of the work preparatory time and 23 measurements of the main break were taken. By both types of devices the mean value of the work preparatory time was taken into consideration; no distinction between the cableways was made. The delays, which are part of the unavoidable delay time, were measured in the range showed in Table 7.

Unproductive time consists of a part destined to the whole working day (the work preparatory time, the main break, various delays of an organizational character) and of a part that originates from the productive time itself (the pauses and respites during the work, minor engine troubles and maintenance of the machinery, various other delays).

The share of delays caused by workers depends mainly upon the number of workers. By cableway wood extraction there are plenty periods when a worker can rest while the cableway performs productive work. There is much less intercovering of times if there are only two workers in a group. A greater number of pauses, respites and phisiological needs during the main and complementary time of a cycle is connected to the greater number of workers. The more workers there are in a group, the smaller is their occupation by productive work. Very rarely the transfer of mobile tower yarders takes more than a working day. Therefore only the portion of unproductive times which results from the main and complementary time could be reliably evaluated. Both - mounting and dismounting of devices - are technically and physically demanding phases of work. It is understandable that the unproductive times' share is bigger as by wood extraction. The comparison of both phases shows, that there are more unproductive times by mounting than by dismounting of a device. This comes up to the expectations, because mounting of a device is the more demanding phase and it is normal that there is more unproductive time connected to it.

Table 8: Dependence of the working time structure upon the number of workers (min)

Time structure	Number of workers			Average
	1	2	3	
Main and complementary work time	306	347	359	341
Work preparatory time Main break Maintenance time and unavoidable delays between cycles Pauses, respites, phisiological needs	26 30 65 53	26 30 65 12	26 30 65 0	26 30 65 18
Unproductive time - total	174	133	122	139
The unproductive time part (%) of Main and complementary time	38,56	22,19	18,11	24,34
The unproductive time part (%) of utilized time	36,25	27,71	25,21	28,96
The Main and complementary time part (%) of working time	63,75	72,29	74,79	71,04

There also are great differences among individual cableways. It can be anticipated that there are more unproductive times in case of transfer of larger devices or - in other words - when mounting takes a longer time. Because of tiring work the workers have more pauses and respites, while by shorter mountings the workers only have a rest after the work is done - or the other possibility is that the workers rest in turns during the following process of wood extraction.

4.2 Productive times of a cycle

The main and complementary time of a cycle were divided in:

- the time of a basic transport operations, which is less dependent on the way of work (travelling empty and loaded, bunching and unhookig the load);
- the supplementing auxiliary productive time, which depends on the organization of work, equipment variability and working habits of the

labourers (leveling and sorting of timber by the cableway winch, bucking and additional debranching in the timber yard for example).

Table 9: The structure of working time by device transfer (min)

	Mounting	Dismounting	Average
Main and complementary time	329	337	331
Work preparatory time Main break Unavoidable delays, maintenance time	26 30 95	26 30 95	26 30 95
Unproductive time - total	151	143	149
Unproductive time share (%) of main and complementary time	22,88	25,82	28,10
Unproductive time share (%) of utilized time	31,46	29,79	31,04
Main and complementary time share (%) of utilized time	68,54	70,21	68,96

From Table 5 the limits of individual factors, for which the results of this investigation are valid, could be observed. The terrain inclination is a variable by which only a very small part of variability can be explained, and was for this reason not included in the performance calculations.

Table 10: Dependence of the main and complementary time of a cycle (min) on the skidding and bunching distances (m) and on the number and weight of logs in a load (t)

Cableway	Regression coefficients				
	a	Skidding distance VLA (m) b1	Bunching distance ZBI (m) b2	Number of logs per load/KOS b3	Load weight MAS (t) b4
Urus	0,6912	0,3619	0,1549	0,1888	0,0673
Mini Urus TVS	0,5100	0,3948	0,1982	0,2947	0,1920
Igland Telescope	0,4877	0,3653	0,1691	0,4524	0,0586

$$Y = a * VLA^{b1} * ZBI^{b2} * KOS^{b3} * MAS^{b4}$$

The value of supplementing productive time has to be added to the total work time of a cycle which is calculated by regression dependences (Table 11).

Table 11: A review of optionaly complementary times of a cycle

The working procedure	Urus and Mini Urus-TVS
Leveling by the cableway winch	0,43
Leveling by a tractor	1,43
Leveling by winch and bucking	3,32
Cutting of broadleaved trees	1,37

4.3 Load size

There were some more loads of conifers than these of broadleaved trees. In average the shares of both types of loads were rather satisfactory, so that separate analyses could be done, if the structure of loads extracted by different cableways was not so dissimilar. There are several factors which influence the number of logs in a load. The most important one is the weight of an average log. The others are: the number of choker hooks on a carriage, the style of fastening and the distance of bunching and skidding.

All the methods, presently used in Slovenia, were included in the investigation. The prevailing methods are the assortment method (4m length) and the method of multiples (8 - 12m length). Unbarked softwood is extracted mainly.

The skidding distance has indirect influence upon the number of logs in a load: in case of longer distances the workers normally spend more time for fastening and the load is usually heavier (KOŠIR, 1985a, 1988). Besides the load size also the proportion between the main and the complementary time influences upon the final effect.

The next characteristic of the cableway carriages which influences the size of a load is the way of bunching. We distinguished between two types: gathering by rope sling hung up on hooks or on sliders, which made the choker hook gathering posible. By some cableways both types of gathering were being observed, so that a comparison could have been done.

The three pairs of curves on Figure 2 illustrate the comparison of both wood bunching methods for the types of carriages for which enough data were available. The relation of each pair of curves is moreless similar in all three cases, yet the curve of the choker hook gathering always shows a greater number of logs per load. The curves of individual types of carriages are arranged in accordance to their carrying capacity with an exception of extremely small sized wood, where the Koller SKA 10 carriage transported the greatest number of wood logs.

Table 12: Dependence of the log number upon the weight of a single log

Type of a carriaged	Rope sling gathering				Choker hook gathering			
	Data number	Const. d	Regress. coeff. Load weight MAS (t) e	R^2	Data number	Const. d	Regres. coeff. Load weight MAS (t) e	R^2
Bacco+Gravimat	310	1,6276	-0,53536	0,5370	211	210865	-0,39205	0,2716
Koller SKA 10	148	1,0851	-0,62505	0,8041	45	1,1695	-0,79928	0,7039
Koller SKA 25	130	1,6644	-0,35888	0,3820				
Mechanical, Mini Urus-TVS	498	1,0736	-0,34459	0,2524				
Igland Telescope	83	0,78188	-0,93373	0,5649	587	0,8540	-0,5506	0,6900

$$KOS = d * MAS^e$$

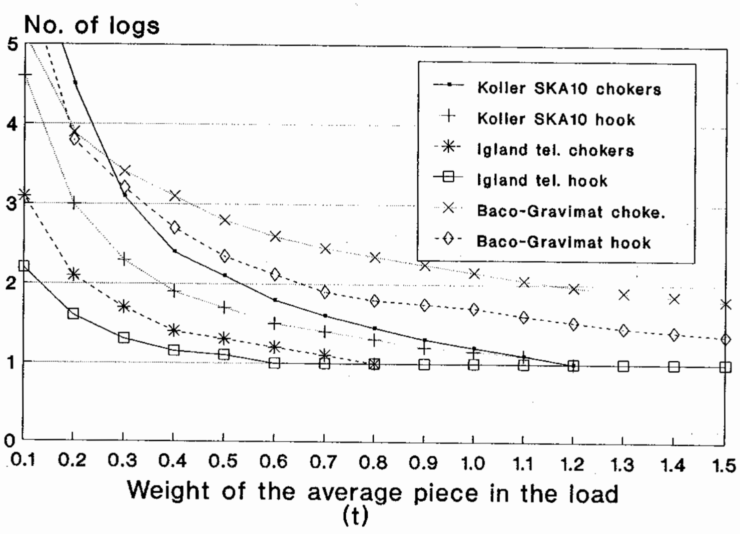

Figure 2: Dependence of the log number upon the weight of a single log and upon the style of fastening

The number of logs in a sling becomes smaller in case the weight of an average log increases and when the number of slings on a carriage is greater. A greater sling number is rather advantageous. The burden could be heavier, yet a single sling is not so heavily loaded.

In Figure 3 the load weight dependence of the weight of a single log is showed. By all the curves the load weight increases degressively according to the increasing single log weight. However, there are significant differences among the different types of carriages and among the different styles of wood fastening.

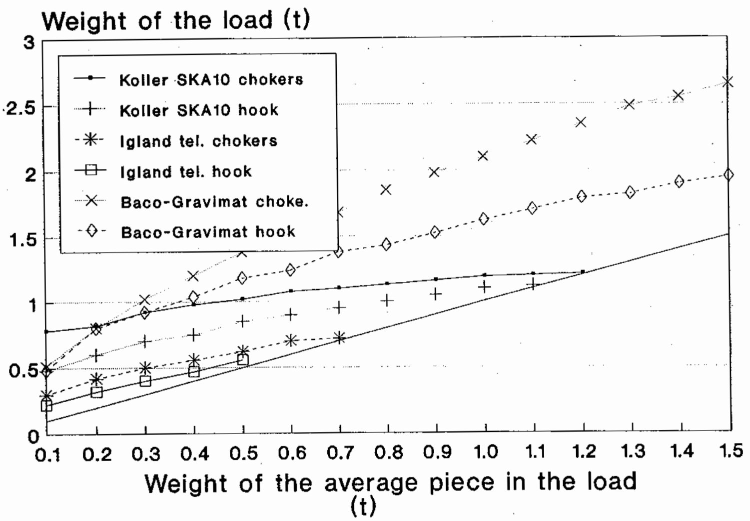

Figure 3: The load weight dependence upon a single-log weight and upon the style of wood fastening

By all the three pairs, the curves representing the load-weight by choker hook gathering are higher than the curves of the load-weight by rope snare gathering.

4.4 Mounting and dismounting

The work by the processes of mounting and dismounting is not cyclic as the work by wood extraction. Both of the phases include several procedures. Each time all the procedures have to be performed, but in different working conditions they may vary significantly. The way of execution and thus the work itself depends on the actual conditions. The division of labour mainly depends on a group of workers itself but it is a rule that the most difficult part of work is done by the machinist, while the other workers assist him. During the productive time there is quite a lot of - so called - waiting, when workers can not continue with work before a certain procedure has been accomplished. Because of this reason a statistical analysis of both individual processes was done. The durations of each of the processes were afterwards summed up, so that the joint duration was gotten.

The length of the lines by which the mountings and dismountings of cableways were measured was between 126 and 350m. The minimum terrain inclination was 14% and the maximum terrain inclination 71%. The average total time of all workers was between 189 and 1057min by mounting and between 80 and 114min by dismounting of cableways (KOŠIR 1985-b).

Both processes - the mounting and the dismounting - were only measured by some cableways. For this reason a statistical analysis of both of the individual processes was done. The durations of each of the processes were afterwards summed up, so that the joint duration was gotten. The operation times were in the time analysis joint in the following joint operations:

- device transfer: the time is very slightly dependent upon the type of device, therefore only the mean value of transfers was taken into consideration for all types of cableways. In case of fan shaped layout one third of the mean value of transfers was taken into account;
- mounting and dismounting of the cableway: the time depends mainly upon the type of a cableway, therefore the average values for individual types of cableways were taken into consideration. In case of fan shaped layout one half of the average time value was taken into account;
- mounting and dismounting of the intermediate cable supports: the time depends on the type of a cableway. In case of too small an amount of data available, the average value of the most similar cableway was taken into account;
- organizing and arranging of the timber yard: the time depends upon the type of device, upon the workers' habits and upon some other factors;
- mounting and dismounting of the lines (sky- and main line): the time depends only slightly on the type of a cableway. The most important factors are the skyline length and the terrain inclination. The regression dependences of time for both factors were calculated separately for mounting and dismounting. The results showed, that the skidding line length influences statistically characteristical only upon the time of mounting, while the terrain inclination influences both: the time of mounting and the time of dismounting.

5 CALCULATION OF WOOD EXTRACTION PERFORMANCES OF MOBILE TOWER YARDERS

The presumptions and results which are described in the previous chapters make the calculation of working times and effects of cableways possible. A great number of combinations exists between the ways of work and the various types of cableways and also the ways of tracing of the lines and the styles of load fastening.

The norms of wood extraction performed by cable cranes can be calculated for the wood extraction alone. The second possibility is that the times of device transfers also are included in the norm values.

Table 13: Results of the analysis of productive times by mounting and dismounting of cableways

Phase	Cableway	Type of organ-ization	Device moving	Device transfer	Organization of timberyard	Together	Mounting + dismounting support	Skidding distance - rop line
Mounting	Urus	Parallel	21,03	164,62	37,97	223,62	135,53	
		Fan shaped	7,01	82,31	18,99	108,31	135,53	-15,20
	Mini Urus	Parallel	21,03	61,51	44,42	126,96	34,67	+0,03655*LL^2
	TVS	Fan shaped	7,01	30,75	22,21	59,97	34,67	+2380,6/NAK
	Igland tele.	Parallel	21,03	49,07	4,42	74,52	34,67	
		Fan shaped	7,02	24,54	2,22	33,77	34,67	
Dismounting	Urus	Parallel		59,35	10,68	70,03	23,76	
		Fan shaped		29,68	5,34	35,02	23,76	
	Mini Urus	Parallel		29,49	12,49	41,98	14,70	92,24-0,7417
	TVS	Fan shaped		14,75	6,25	21,00	14,70	*NAK
	Igland tele.	Parallel		32,83	1,24	34,07	14,70	
		Fan shaped		16,42	0,62	17,04	14,70	
Together	Urus	Parallel	21,03	223,97	48,65	293,65	159,29	
		Fan shaped	7,01	111,99	24,33	143,33	159,29	77,13+
	Mini Urus	Parallel	21,03	91,00	56,91	168,94	49,37	0,003655*LL^2
	TVS	Fan shaped	7,01	45,50	28,46	80,97	49,37	+2380,6/NAK
	Igland tele.	Parallel	21,03	81,90	5,66	108,59	49,37	-0,7417*NAK
		Fan shaped	7,01	40,96	2,84	50,81	49,37	

LL= skyline length /by ground/ (m)
NAK= terrain inclination (%)

5.1 Device transfer

The time of transfer is a sum of the time of mounting and the time of dismounting. It is expressed in manhours or calendar hours. The length of a line, the number of intermediate supports and the corridor layout all influence upon the time of transfer.

TMD (manhours) = TL + TC + TT + TN

TL = the time dependent on the line length (manhours)
TC = the time dependent on the number of intermediate supports (manhours)
TT = the time dependent on the corridor layout (manhours)
TN = the time dependent on terrain inclination (manhours)

The time dependent on the line length:

TL (manhours) = 0.00008888 * LL^2

The time dependent on the number of intermediate supports(NCE):

TC (manhours) = 3.86 * NCE for Urus
TC (manhours) = 1.19 * NCE for Mini Urus, TVS and Igland Telescope

Table 14: The time dependent on the style of line tracing (manhours)

Cableway	The style of line tracing		
	Paralel	Fan shaped with common tailhold	Fan shaped
Urus	9,09	7,63	5,57
Minu Urus / TVS	6,19	5,56	4,06
Igland Tlescope	4,72	4,56	3,33

The time dependent on terrain inclination is identical for all types of the cableways. It is calculated by the following equation:

TN(manhours) = 57.89/NAK - 0.018 * NAK

NAK = terrain inclination (%)

The time of transfer within the actual time is calculated so, that the TMD value (manhours) is divided by the number of workers in a group.

TMDU (hours) = TMD/NDEL

TMD = the time of cableway transfer (manhours)
NDEL= the number of workers in a group

5.2 Wood Extraction

For determination of norms, the dependence of productive time of a single load extraction upon working conditions has to be known. Besides also the supplementing time coefficients, the load weight dependence upon an average log weight and the supplementing productive time value are needed. The general equation for the determination of norms is:

NTS (min/t) = fb * fd * (Y + YD)/BRE

fb	=	coefficient of the elementary norm corrections
fd	=	supplementing time coefficient
Y	=	productive time of a single cycle
YD	=	supplementing productive time of a single cycle (min/load)
BRE	=	load weight (t)

The load weight:

BRE (t) = KOS * MAS

KOS	=	number of logs in a load
MAS	=	weight of an average log in a load (t)

Table 15: Duration of transfers (manhours) for the terrain inclination of 40%

Cableway	Line lenght (m)	Number of intermediate support	Style of line tracing		
			Parallel	Fan shaped with common tailhold	Fan shaped
Urus	100	1	14,57	13,11	11,05
	200	1	17,24	15,78	13,72
	300	2	25,54	24,08	22,02
	400	2	31,76	30,30	28,24
	500	3	43,62	42,16	40,10
	600	3	53,40	51,94	49,88
Mini Urus TVS	100	1	9,00	8,37	6,87
	200	1	11,67	11,04	9,54
	300	2	17,30	16,67	15,17
	400	2	23,52	22,89	21,39
Igland Telescope	100	1	7,53	7,37	6,14
	200	1	10,20	10,04	8,81

The size of an average log in a load can be estimated for each working site individually or it can be calculated from the equations, which have already been in use for quite a long period. Two different coefficients form the first part of the equation of the wood extraction norm (NTS). In the first coefficient (fb) the corrections of the elementary norm are included, because of the factors that may anyhow obstruct wood extraction (steep terrain, ground obstacles, undergrowth). The value changes from 0% (fb = 1) in favourable conditions to 11% (fb = 1.11) in unfavourable conditions.

With the second coefficient fd, the supplementing time (in which also the main break is included) is expressed. The fd depends on a number of workers in a group (see Table 8):

2 workers: fd = 1.57
3 workers: fd = 1.38
4 workers: fd = 1.34

The most important part of the abovementioned equations is the dependence of productive time of a single load extraction (Y) upon working conditions. The equations from Table 10 could be used. The supplementing productive times can be estimated for each way of work separately. The other way is to use Table 11. The regression dependence of the number of logs in a load upon the size of an average log is presented in Table 12.

The calculation of daily norms can be simplified. The equation of the wood extraction norm (NTS) calculation can be written in the following form:

$$NTS = fb * fd * (a * VLA^{b1} ZBI^{b2} * (MAS * d * MAS^{e})^{b3} * MAS^{b4} + YD) / MAS * d * MAS^{e}$$

$$NTS\ (min/t) = fb * fd * a * d^{(b3-1)} * VLA^{b1} * ZBI^{b2} * MAS^{(e * b3 + b4 - e - 1)} + fb * fd * d^{-1} * YD * MAS^{-(1+e)}$$

fb	= coefficient of the elementary norm corrections
fd	= unproductive time coefficient
Y	= main and complementary work time of a single cycle
YD	= optional productive time of a single cycle (min/load)
BRE	= load weight (t/load)
VLA	= skidding distance (m)
ZBI	= bunching distance (m)
KOS	= number of logs in a load
MAS	= weight of an average log in a load (t)
a	= the constant factor of the regression for Y
b1	= regression coefficient of the variable VLA
b2	= regression coefficient of the variable ZBI
b3	= regression coefficient of the variable KOS
b4	= regression coefficient of the variable MAS
d	= the constant factor of the regression for KOS (Table 12)
e	= regression coefficient of the variable MAS in the regression for KOS

When the organizational system of work remains unchanged, the unproductive time coefficient also remains constant. The coefficient does not depend upon working conditions, so the former equation can be simplified. If the following substitutions are done:

$$g = -(e + 1)$$
$$h = e * b3 + b4$$
$$v = d^{-1}$$
$$u = a * d^{(b3-1)}$$

and the equation is rearranged, the following equation is gotten:

$$NTS = fb * fd * MAS^{g} * (u * VLA^{b1} * ZBI^{b2} * MAS^{h} + v * YD)$$

This is the basical equation of the wood extraction norms calculation in this researh work. The values of exponents and coefficients of the abovementioned equation are for diverse winch carriage combinations given in Table 16.

Table 16: The values of exponents and coefficients of the calculation of wood extraction performances (min/t) for various winch-carriage combinations.

Cableway	Carriage	Exponent and coefficient values					
		g	u	b1	b2	h	v
Urus	Baco-Gravimat	-0,608	0,377	0,362	0,155	-0,00672	0,474
	Baco-Gravimat	-0,465	0,465	0,362	0,155	-0,03371	0,614
	Koller SKA 25	-0,641	0,457	0,362	0,155	-0,00046	0,601
Mini Urus/ TVS	Mechamical	-0,655	0,485	0,395	0,198	0,09045	0,931
	Koller SKA 10	-0,201	0,457	0,395	0,198	-0,04355	0,855
	Koller SKA 10	-0,375	0,481	0,395	0,198	0,00778	0,922
Igland Telescope	Mechanical	-0,449	0,532	0,365	0,169	-0,19049	1,171

Carriage = choker hook gathering

With a computer it is very easy to calculate the performances (min/t) and norms (t/day, t/hour) for diverse combinations of winches and carriages for different organizational systems of work and various working conditions.

The daily norms were calculated for three men crew (fd=1.38) for average working conditions (fd=1.0) without optional works (YD=0). The bunching distance was 10m (ZBI=10). The results are presented in the following tables.

Table 17: Daily norms for the combination of the Urus cableway and the Baco-Gravimat carriage; choker hook fastening,bunching distance 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	38.04	74.74	102.32	125.83	146.85
100	29.60	58.16	79.61	97.90	114.26
150	25.56	50.22	68.74	84.54	98.66
200	23.03	45.25	61.94	76.18	88.90
250	21.24	41.74	57.14	70.27	82.00
300	19.89	39.07	53.49	65.78	76.77
350	18.81	36.95	50.58	62.21	72.60
400	17.92	35.21	48.20	59.27	69.17
450	17.17	33.74	46.19	56.80	66.29
500	16.53	32.48	44.46	54.67	63.81
550	15.97	31.38	42.95	52.82	61.64
600	15.47	30.40	41.62	51.18	59.73

Table 18: Daily norms for the combination of the Urus cableway and the Baco-Gravimat carriage; fastening to the hook, bunching distance 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	40.29	69.68	89.90	106.32	120.52
100	31.35	54.22	69.95	82.73	93.78
150	27.07	46.82	60.40	71.44	80.97
200	24.39	42.19	54.43	64.37	72.97
250	22.50	38.91	50.20	59.38	67.30
300	21.06	36.43	47.00	55.58	63.00
350	19.92	34.45	44.45	52.57	59.59
400	18.98	32.82	42.35	50.09	56.77
450	18.19	31.45	40.58	48.00	54.40
500	17.51	30.28	39.06	46.20	52.37
550	16.91	29.25	37.74	44.63	50.59
600	16.39	28.34	36.57	43.25	49.02

Table 19: Daily norms for the combination of the Urus cableway and the Koller SKA 25 carriage; fastening to the hook, bunching distance 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	29.51	59.71	82.86	102.81	120.80
100	22.96	46.46	64.47	80.00	93.99
150	19.83	40.11	55.67	69.08	81.16
200	17.87	36.15	50.16	62.25	73.13
250	16.48	33.34	46.27	57.42	67.46
300	15.43	31.21	43.31	53.75	63.15
350	14.59	29.52	40.96	50.83	59.72
400	13.90	28.13	39.03	48.43	56.90
450	13.32	26.95	37.40	46.41	54.53
500	12.82	25.94	36.00	44.67	52.49
550	12.39	25.06	34.78	43.16	50.71
600	12.00	24.29	33.70	41.82	49.14

Table 20: Daily norms for the combination of Mini Urus or TVS 1500 cableways and the mechanical carriage; bunching distance 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	26.42	49.13	65.55	79.26	91.35
100	20.09	37.36	49.85	60.28	69.47
150	17.12	31.83	42.47	51.36	59.19
200	15.28	28.41	37.91	45.84	52.83
250	13.99	26.01	34.71	41.97	48.37
300	13.02	24.21	32.30	39.06	45.01
350	12.25	22.78	30.39	36.75	42.35
400	11.62	21.61	28.83	34.86	40.18

Table 21: Daily norms for the combination of Mini Urus or TVS 1500 cableways and the Koller SKA 10 carriage; choker hook fastening, distance of gathering 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	58.58	76.64	86.84	94.29	100.27
100	44.55	58.28	66.04	71.71	76.25
150	37.96	49.66	56.27	61.09	64.97
200	33.88	44.32	50.22	54.53	57.99
250	31.02	40.58	45.99	49.93	53.10
300	28.87	37.76	42.79	46.46	49.41
350	27.16	35.53	40.26	43.72	46.49
400	25.77	33.71	38.19	41.47	44.10

Table 22: Daily norms for the combination of the Mini Urus or TVS 1500 cableways and the Koller SKA 10 carriage; fastening to the hook, bunching distance 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	41.97	62.82	75.78	85.75	94.04
100	31.92	47.78	57.63	65.21	71.52
150	27.19	40.71	49.10	55.56	60.93
200	24.27	36.33	43.83	49.59	54.39
250	22.22	33.27	40.13	45.41	49.80
300	20.68	30.96	37.34	42.25	46.34
350	19.46	29.13	35.14	39.76	43.60
400	18.46	27.63	33.33	37.72	41.36

Table 23: Daily norms for the Igland Telescope cableway; bunching distance 10m, 3 workers

Skidding distance (m)	Size of a single log in a load (t)				
	0,1	0,3	0,5	0,7	0,9
50	24.40	49.23	68.23	84.59	99.33
100	18.94	38.22	52.98	65.69	77.13
150	16.34	32.97	45.69	56.65	66.52
200	14.71	29.68	41.14	51.00	59.89

At the distances below 600m the wood can only be extracted by the Urus type of cableways equipped with diverse types of carriages. In Slovenia, heavier loads are transported mainly by the Baco carriages, and therefore the daily performances are better. Sometimes the choker hook fastening is used for this type of carriages - a certain appliance on the carriage itself makes this way of fastening possible. The choker hook gathering is much more efficient, because much heavier loads can be transported this way.

For the distances up to 400m the cableways of the Urus, the Mini Urus or the TVS 1500 type can be used. For a single log weight of 0.5t (that is an approximate average for Slovenia), the Urus - Baco combination is the most efficient, no matter whether the choker hook gathering or the classical way of gathering is used. The difference between the Urus - Koller SKA 25 combination (classical gathering) and the Mini Urus - Koller SKA 10 combination (choker hook gathering) is very small.

The lower carrying capacity can thus be somehow compensated by the use of choker hook gathering. The analyses showed that in case of small sized wood the effects of wood extraction by Koller SKA 10 carriage and choker hook gathering can and sometimes even do exceed the effects reached by the bigger Urus cableway and the heavier carriages used with it.

The performance of the combination of Mini Urus - TVS 1500 and mechanical carriage is not very good - it only reaches about one half of the performance of the most effective combination for these distances. This very combination is the worst in general. Its performance only can compete the performance of Igland Telescope - and even this only in case of short skidding distances and extremely small sized wood.

For the distances up to 200m, the Igland Telescope can also be used beside the already mentioned combinations. The performance of this cableway is lower, because the carrying capacity of the carriage is small. For a single log weight of 0.5t the curves of other cableways are arranged similarly as by wood extraction for the distances up to 400m.

The performances showed in the diagrams and tables are only valid in cases when no delays resulting from piling of timber on the storage place or loading of timber on truck occur.

6 DISCUSSION

In Slovenia cableway wood extraction becomes more and more popular. There are several reasons for its popularity, among which the more friendly relationship of the cableway wood extraction to forest is one of the most important.

Several types of cableways, which were united in the following three groups were studied:

- a group of mobile tower yarders on the vehicle - Urus,
- a group of independent devices - Mini Urus - TVS 1500,
- a group of devices used as machine attachments - Igland Telescope.

The basic amount of data for all three groups is moreless equal.

The times of mounting and dismounting and the times of wood extraction were measured in the research. An analysis of unproductive times for both working phases was done. A greater amount of unproductive times is connected to transfers of cableways than to wood extraction.

The unproductive times share by wood extraction depend mainly upon the organizational system of work. For a large group of workers the share of unproductive times is lower than for a small group of workers.

The load size for the various types of carriages depends upon the average log size and upon the type of wood fastening. The analysis of these parameters were done separately. It was discovered that the choker hook fastening is much more efficient than the classical fastening to the hooh, especially in case of small sized wood. The comparison shows clearly that individual types of cable cranes were designed for the extraction of various wood sizes and for different skidding distances. For the large timber extraction the Urus group is the most effective, while the Mini Urus - TVS and Koller SKA 10 carriage equipped with choker hook are much better for the small sized wood extraction.

The chosen form of regression equations proved to be accurate and simple enough for the time studies data treatment, because it makes the calculation of performances of various cable crane - carriage combinations possible. Compared to some similar earlier analyses, this one enables us to foretell the effects of wood extraction much more easily. The calculated standard performances are valid for average working conditions - especially passability, which could be a main obstacle to better effects.

The elementary standard performance corrections are presented with regard to the stage of development of a certain forest stand and the terrain inclination. It was presumed that depositing of timber along the forest road is greater problem in case of steep terrains, because building of special standing places for cable cranes is not always possible. The corrections are rather moderate (11% at the most). It is necessary to have them verified with real work.

The tolerable deviation limits of the cable crane transfer are most uncertain, because in this case the influence of working conditions and the specialities of the working site is much greater. Our opinion was that the real times' variability from average value (which is presented in the results of this research) could be 50% at the most. This anticipation also needs to be verified by some additional analyses.

In the further investigations it would be advisable to compare the results of the cable cranes' performances from this study with the performances of the same types of machines in some other countries. Of course such a comparison is only possible within a limited extent, because very often the evaluation of the basic data is different.

On the basis of this study the calculation of cable crane performances could be simplified, but before that, the data concerning the performances of some other cableways which have lately appeared in Slovenia still have to be gathered.

For an estimation of the economy of wood extraction for an individual machine, the calculations of the expences pro working hour will have to be done and these will have to be compared to the wood extraction performances in various working conditions.

7 SUMMARY

7.1 In English

In Slovenia, the cableway wood extraction becomes more and more popular. There are several reasons for its popularity, among which the more friendly relationship of the cableway wood extraction to forests is one of the most important. The times and effects of wood extraction performed by mobile tower yarders - (Urus, Mini Urus - TVS 1500 and Igland Telescope) in various conditions - were measured. The wood extraction, the mounting and dismounting of cableways and the formation of loads were analysed separately. An analysis of main and complementary times of both phases of work was done.

The comparison shows clearly that individual types of cableways were designed for the extraction of various wood sizes and for different wood extraction distances. For the large timber extraction the Urus group is the most effective, while the Mini Urus

- TVS and the Koller SKA 10 carriage equipped with choker hook are much better for the small sized wood extraction.

Compared to some similar earlier analyses, the chosen form of regression equations enables us to foretell the effects of wood extraction much more easily. The calculated standard performances are valid for average working conditions - especially passability, which could be the main obstacle to the better performances.

7.2 In Slovene

V Republiki Sloveniji postaja žičnično spravilo vedno bolj zanimivo. Razlogov je več, med njimi pa je med važnejšimi bolj prijazen odnos te oblike spravila do gozda.

Čase in učinke spravila lesa z večbobenskimi žičnimi žerjavi s stolpi smo merili v različnih delovnih razmerah. Posebej smo analizirali spravilo lesa ter postavljanje in razstavljanje naprav ter načine oblikovanja bremena. Izdelali smo analizo neproduktivnih časov za obe fazi dela. Proučevali smo več žičnih naprav, ki smo jih združili v skupino večbobenskih žičnih žerjavov s stolpi na vozilih - Urus; skupino samostojnih naprav (Mini Urus - TVS 1500) in skupino naprav, ki delajo kot priključki strojev (Igland teleskop).

Delež neproduktivnih časov pri spravilu lesa je odvisen največ od organizacijske oblike dela. Pri številčnejši skupini je neproduktivnih časov manj kot pri majhni skupini delavcev. Pri prestavljanju naprav je več neproduktivnih časov kot pri spravilu lesa.

Posebej smo analizirali odvisnost velikosti bremena pri posamezni vrsti vozička od velikosti povprečnega kosa v bremenu ter načina vezanja. Ugotovili smo, da je vezanje v navezi precej učinkovitejše od vezanja z zankami na kavelj, posebej pri zelo drobnem lesu.

Primerjava med napravami pokaže, da so grajene za spravilo različno debelega lesa ter za spravilo na različnih spravilnih razdaljah. Tako je pri spravilu debelega lesa najučinkovitejša skupina Urus, pri spravilu drobnega lesa pa spravilo z Mini Urusom-TVS in vozičkom Koller SKA 10 z navezo.

V primerjavi s predhodnimi podobnimi analizami omogoča izbrana oblika regresijskih enačb bolj preprosto napovedovanje učinkov pri spravilu lesa. Izračunane norme veljajo za povprečne delovne razmere, kar velja zlasti za prehodnost, ki lahko pomeni na težkih terenih pomembno oviro za učinkovitejše delo.

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