Promotion of teamwork in mountain thinning stands of middle-aged broadleaf stands

Zečić, Željko

Ž. Zečić: Promotion of teamwork in mountain thinning stands of middle-aged broadleaf stands.
Glas. šum. pokuse 41: 51–133, Zagreb, 2005.

UDK: 630*308+242

Original scientific paper
Izvorni znanstveni članak

PROMOTION OF TEAMWORK IN MOUNTAIN THINNING STANDS OF MIDDLE-AGED BROADLEAF STANDS

UNAPREĐENJE SKUPNOGA RADA PRI PRORJEĐIVANJU BRDSKIH SREDNJEDOBNIH BJELOGORIČNIH SASTOJINA

ŽELJKO ZEČIĆ

Department of Forest Engineering
Faculty of Forestry, University of Zagreb, PP 422, HR – 10002 Zagreb

Received – *Prispjelo*: 12. 9. 2004. Accepted – *Prihvaćeno*: 3. 7. 2005.

The paper presents the research results and the optimisation of teamwork in the exploitation of broadleaf thinning stands in a hilly area. The field research was carried out in the forestry administration area of Bjelovar, the management unit of Ivanska Prigorska Šuma, with a team consisting of six workers. The research was focused on the following: cutting and processing; tractor skidding; adidd processing; wood assortment delivery, and stacking of long timber by tractor crane on landing. The teamwork was carried out in a 66-year-old thinning beech stand. The work team consisted of two cutters, two tractor drivers, one cutter-customer, and one crane driver. The team is controlled daily by a foreman. All members of the team were surveyed by a snap-back chronometry method with the related timber volume. Based on the recorded time, time study analysis was made by individual operations and totally. The structure of the single effective times and delays was determined, and the added time was formed. The cutters spent 38.14% and 48.73% respectively of the effective time out of the total time. Out of the total time, the cutter-customer spent 16.55%, and the tractor crane 25.12% of the effective time. The average added time factor of the cutters was 1.57, while the one of the tractor was 1.29. The respective values of the cutter-customer and the crane tractor were 1.88 and 1.87. Using the mathematical/statistical methods of a multiple linear regression, the data of the measured and calculated values were processed. The obtained mathematical models of the effective time calculation plus added time factor were used for the calculation of the standard time and the daily output of each member of

the team. Standard times and daily outputs were calculated in several variants for better modelling of the team. The total standard time of the sub team depends on the tractor skidding distance. With the distance of 150 m – 750 m, the standard time of one sub team ranged between 44.67 min/m^3 and 59.10 min/m^3, while the respective values of the second sub team were 47.78 min/ m^3 and 61.27 min/ m^3. The daily output per team member may be achieved in the amount of between 10.23 m^3/day at a distance of 150 m, and 5.38 m^3/day at a distance of 650 m. The costs per unit ranged between 83.91 kn/m^3 (150 m) and 159.52 kn/m^3 (650 m).

Key words: cutting and processing, skidding, optimal team, productivity, costs

INTRODUCTION
UVOD

The paper presents the research results and the optimisation of a forest worker team at cutting, processing, skidding, crosscutting, and wood assortment stacking in a hilly broadleaf thinning stand. The choice of work technology applied in logging presents a significant problem. In long-term planning, based on the analysis of sustainability and the revenues relations (main, previous), the use of machines is evaluated in relation of the conditions of their application.

Logging requires a great deal of human labour. In the past, cutting, processing, skidding and transport of timber required both human and animal power. The invention of machines enabled the replacement of human labour by mechanical. In Croatia today, cutting and processing is carried out by chain saws and is transported by special forest machines or cableways. A great proportion of Croatian timber production comes from thinning stands. The costs of timber production combined with forest road building should be regarded as an integrated system.

Great changes in timber production took place thanks to new technologies in logging, processing and skidding. Besides the assortment method, the methods related to full-tree, tree-longth, half-tree, cutt to longth and trunk processing where also introduced. The choice of particular method depends on the stand conditions and the technical/technological features of the skidding machines.

Thorough understanding of the technical/productional features of the work devices is significant for environmental care. Particular attention should be paid to the protection of standing trees and soil erosion. Logging should be based on ecology, increased work humanisation, and the least costs obtained by careful choice of the optimal work method. This particularly refers to the logging from natural stands, where logging costs are the highest, which is the subject of this research.

RESEARCH ISSUES
PROBLEMATIKA ISTRAŽIVANJA

Forest workers often work as teams, either during seed sowing, planting seedlings, tending, or in logging. For many centuries, cutting trees and processing forest products have been regarded as teamwork. Prior to the introduction of manual/mechanical and mechanical logging procedures, low education and technical/technological levels with rigorous division of work, strict hierarchy and poor cooperation were the characteristic features of forest work. Croatian forest teams often count up to 15 members. The introduction of chain saws (1963) gradually reduced the size of cutter teams. Tomičić (1986) wrote that between 1964 and 1967 in some parts of the country three to eight workers used one chain saw, with an average daily output of 2.4 m^3. Later (1968-1977), the extensive use of chain saws entailed new work organisation. One chain saw per two workers was aligned in the cutting procedure. In the time to follow, individual work was organised by schedules of 2+1, 2+2, and 1+1. This has been applied until today. The same author wrote that the average daily output of that period was up to 50%, i.e. from 3.1 m^3 to 3.9 m^3. In 1969, technical standards for two workers per one chain saw were introduced for the first time. In the period 1978 – 1989, the productivity of cutting and processing increased, ranging between 3.7 m^3/day and 8.8 m^3/day. A significant increase of the daily output was the result of introducing teamwork and the processing of long stacked wood.

Mechanised roundwood skidding in Croatia was in full swing in the 1960ies, when farm tractors were adjusted for logging purposes. Skidders first appeared in 1968, marking intensive development of mechanised skidding in Croatia.

New organisational forms of work with improved and ergonomically refined machines enabled the progress in technical and technological sense. With the modernisation of the technical devices, the organisation of skidding procedures was not always optimal, so that higher production costs were inevitable.

The output of the tractor in skidding is the function of the total human work, work conditions and the working/technical properties of the machine (Krpan 1984). Numerous authors investigated the producibility and the costs of producing small-sized stacked wood by using different work technologies. Branz et al. (1983), Mikleš and Suchomel (1999) determined the dependency between the terrain conditions and the work of skidders.

The logging in thinning stands is subject to the law on production and the laws on piece volume (Grammel, 1988). On the average, processed timber from thinning stands is of considerably lower value than the timber from regeneration cuts. The law on piece volume says that smaller volumes of cut and processed roundwood from thinnings increase labour costs per product unit. Compared with selection and

regereration cuts, the skidding from thinning is more complex due to bigger number of trees per area unit and more complicated load winching.

Accordingly, improved work organisation had to be applied in order to increase the productivity and decrease unit costs.

The classical work method in logging lasted too long, often for several months, because the work phases were chronologically separated. The basic market principles, i.e. the demand and supply of particular timber types and assortments require efficient forest exploitation. The response to new demands for increased productivity should be sought in better work organisation and use of work time. The introduction of teamwork as a higher work organisation in forest exploitation leads to higher productivity. Teamwork has been described as the work involving several workers (cutters and tractor drivers) in the same workday, on the same site and on the same task. Such work functions as mutual collaboration of all members of the team, with the all-day presence and coordination of the foreman, who influences the quality of the work procedure.

Krivec (1979) wrote about the necessity of changing the organisation of tractor skidding. Considering the degree of mechanisation, productivity, and objective/subjective causes, the efficiency of the present work organisation is on the decrease. He assumes that these are good reasons for designing new organisation procedures, primarily the ones of teamwork. There are several basic advantages related to the present work organisation. The disadvantages are frequent tractor defects, which should be repaired through quick intervention of the service section. According to Krivec, a possible solution for achieving the use of 200 tractor/days in a year would be complex workers' training, and the introduction of spare tractors. Krivec emphasises the necessity of constant staff training and better forest work evaluation.

Teamwork in Croatian forest exploitation was first applied in 1979 in the forest administration area of Bjelovar, in regeneration cuts, later also in thinning. In 1984 the work was introduced over the whole area (Tomičić 1986). The basic reasons for this were the increase of production with long stacked timber and cost reduction per product unit.

In the forest administration area of Požega teamwork was first applied in 1982 in the final felling of sessile oak. In the years that followed, teamwork was organised with the aim of achieving the best team structures. The result of the long-term organisation of work teams was that the optimal number of team members was 4 – 8, with 2 – 4 tractors and the corresponding number of cutters. The team may vary in size, while the number of members is adjusted to the site factors.

A work team may quickly adjust to the change of the felling plan sequence, and safely and timely carry out the task. Older workers developed professional diseases

as the consequence of long-term work with chain saws and whole-day shifts for the reasons of better earnings. The usual health disturbances were deafness and vibration disease of the arms. The search for easier jobs with higher salaries accounts for the shortage of young workers. Accordingly, the planned tasks could not be completed while the workers looked for better-paid and easier jobs in other places, or simply left the country where their services would be better valuated. This issue, too, required a new work organisation.

Versatile training could reduce the probabilities of developing professional diseases, i.e. a single person should be trained for felling, tractor driving, com-bus driving, or operating building machines, etc., enabling the interchange of the work activities during the teamwork.

With the prolonged production resulting in high exploitation costs, the aim was to reduce the work cycle to the shortest possible time. Using the teamwork model, a tree may be felled, processed, cut, hauled to the side landing, and transported to the main storage, i.e. to the buyer in a single day. Such work organisation model came closer to industrial production. Benić (1971) wrote that parallel run of work operations shortens the total length of the phase or process of work.

TEAMWORK CHARACTERISTICS
ZNAČAJKE SKUPNOGA RADA

A work team is a coordinated group formed in order to carry out the assigned task as an independent unit with the necessary work devices. The task of this work team is to coordinate and carry out the procedures ranging from work preparation to the delivery of the forest assortment to the buyer.

The basic feature of the teamwork is the work assignment, which is calculated according to the single day norms of the individual team members. The daily output is calculated and presented by average values per each team member. The workers carry out the work on the same site, with the common work devices. A particular number of workers collaborate in the teamwork with the aim of completing the work task. The work technology is adjusted to the site factors. The workers evenly distribute the output and the personal earning according to the days spent at work during the calculation period. The team establishes mutual responsibility related to the work task. All members of the team leave for work and return to the place of their residence together. The use of fuel and lubricants is distributed equally with two or three cutters and tractors according to the amount of the obtained output, i.e. the number of days. Every team has a foreman, who is daily present on the site. The output is measured by the amount of the daily output of two, or more tractors.

ADVANTAGES OF TEAMWORK WHEN COMPARED TO INDIVIDUAL WORK
PREDNOSTI SKUPNOGA RADA U ODNOSU NA INDIVIDUALNI

Compared to individual work, the advantages of teamwork live in reduced time of timber production. The activities within the team are mutually coordinated, resulting in increased productivity without additional energy investment. Work organisation is at a higher level and of higher quality, when compared to individual work, because the delivery of wood assortments should be carried out within a shorter time period, frequently in a daily work. The turnover is related to a shorter time period. The output of the load/transport capacities is increased, and the commercial effect is better.

The work of the team runs with a varying number of members, depending on the type of felling. Fresh and healthy timber is delivered, so that the infestation of pests in wood assortments should be avoided. While preparing the wood assortments, the losses resulting from processing and delivery are reduced. Owing to the daily presence of the foreman, the assortment processing on the landing is improved.

With the interactive tasks of the cutter and tractor driver (pair work), team members are less absent from work. Cutters fell trees in the skidding direction and bind the load, so that they are partly relieved from constant work with chain saws.

The team adjusts to the weather conditions. The work is also humanised by the interchange of the workers on felling and processing, i.e. on the landing and skidding. The motivation of the team psychology makes the less capable workers try to keep pace with the others. Within a team, the development of creativity and capability of each member is a characteristic feature. The personality of the individual member develops, workers become motivated to achieve higher work effects. A vehicle on the site promises quick repair of defects and fast medical help in case of injury.

RESEARCH AIM
CILJ ISTRAŽIVANJA

The aim of the research is the study of the organisation and efficiency, and the optimisation of work teams at the exploitation of the hilly broadleaf thinning stands related to the selected most remarkable factors of the stand and terrain. The following sub-targets were set:

- Selection of the research object presents the average work conditions;
- Data collection related to the research, carrying out preliminary work, and the selection of impact factors;

- o Selection of the methods for data collection and processing, and the mathematical model;
- o Efficiency assessment of the team as a whole and its component parts;
- o Formation of the production team models;
- o Dynamic optimisation of the team.

PLACE AND METHODS OF THE RESEARCH
MJESTO I METODE ISTRAŽIVANJA

The research on the teamwork was carried out in the Forestry Administration area of Bjelovar (Figure 1), the Forest Management Unit Ivanska (Figure 2).

Figure 1 Map of the Republic of Croatia with the location of the Forest Administration Area of Bjelovar

Slika 1. Karta Republike Hrvatske s prikazom položaja UŠ Bjelovar

This forestry area is located in the central part of the northern continental Croatia. The area of 130,750 ha encompasses one part of Podravina (Drava valley), one part of the northern Mt. Papuk, northern Mt. Psunj, the whole Mt. Bilogora, and the hilly and lowland parts around the towns of Čazma and Vrbovec.

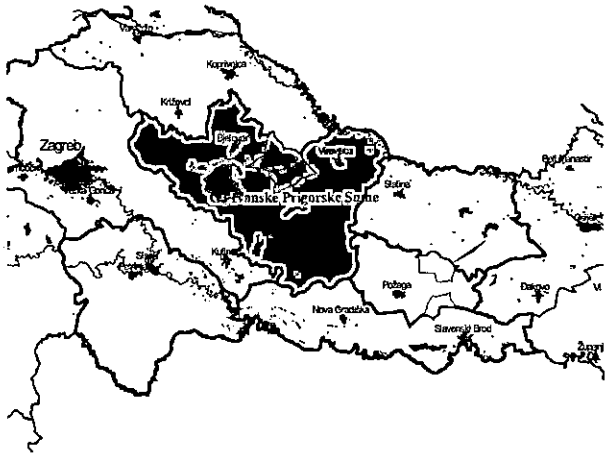


Figure 2 FAA Bjelovar with the Forest Management Unit Ivanske Prigorske Šume
Slika 2. UŠP Bjelovar s prikazom G. j. Ivanske prigorske šume

SITE CHARACTERISTICS
ZNAČAJKE RADILIŠTA

The basic site characteristics are given in Table 1. The field research was carried out in the summer 1999.

Table 1 Some general characteristics of the Ivanska research site
Tablica 1. Neke opće značajke radilišta Ivanska

Forest Office / *Šumarija*		*Ivanska*
Management unit / *Gospodarska jedinica*		*Ivanske Prigorske Šume*
Compartment, Sub-compartment / *Odjel, odsjek*		32 c
Soil condition / *Stanje tla*		Humid / *Vlažno*
Longitudinal terrain inclination *Uzdužni nagib terena*	maximal *maksimalni*	+ 17 %
	average *prosječni*	+ 7 %
Air temperature *Temperatura zraka*	morning *jutro*	9 – 16 °C
	day *dnevna*	18 – 26 °C
	average *prosječna*	18 °C
Precipitation *Oborine*	rain *kiša*	Occasional, light *Povremeno, slaba*

The beginning and the end of site data collection are also given in the same table. Air temperatures significantly influence the workers' activity. Morning and day temperatures were monitored and their average values were calculated. The day air temperature ranged from 18°C to 26°C.

Upon a very even terrain configuration, the soil was predominantly moist throughout the research operation. The surveyed tractor tracks and hauls had an average longitudinal inclination of +7%. On the Ivanska work site, loaded tractors moved uphill this slope.

Figure 3 Forest work site Ivanska – 3D terrain model
Slika 3. Radilište Ivanska – 3D model terena

STAND FACTORS
SASTOJINSKI ČIMBENICI

The stand characteristics are presented in Table 2. With a rotation of 120 years, the 66-year-old stand counted 500 trees per ha. The volume of the mean stand tree is 0.640 m^3. The growing stock per ha is 320 m^3/ha, while the current annual increment is 8.9 m^3/ha with a prescribed felling volume of 40 m^3/ha.

Table 2 Stand factors on the work sites
Tablica 2. Sastojinski čimbenici radilišta

Forest office *Šumarija*	Ivanska
Management Unit *Gospodarska jedinica*	Ivanske Prigorske Šume
Compartment, Sub-compartment *Odjel, odsjek*	32 c
Compartment area, ha *Površina odjela, ha*	16.43
Stand age, years *Starost sastojine, godina*	66
Ecological-economic type *Ekološko- gospodarski tip*	II - D - 11
Management class *Uređajni razred*	Beech from seed *Bukva iz sjemena*
Rotation, years *Ophodnja, godina*	120
Cover, 0.1 – 1.0 *Obrast, 0,1 - 1,0*	1.02
Number of trees, items/ha *Broj stabala, kom/ha*	500
Mean tree diametar at breast height, cm *Srednji prsni promjer stabla, cm*	28
Mean stand height, m *Srednja sastojinska visina, m*	27.3
Mean tree volume, m^3 *Srednji obujam stabla, m^3*	0.640
Growing stock, m^3/ha *Drvna zaliha, m^3/ha*	320
Growing stock, m^3/compartment *Drvna zaliha, m^3/odsjeku*	5240
Annual current increment, m^3/ha *Godišnji tečajni prirast, m^3/ha*	8.9
Annual current increment in the compartement, m^3/ha *Godišnji tečajni prirast u odsjeku, m^3/ha*	145
Harvesting volume, 10-year, m^3/ha *Etat, 10-godišnji, m^3/ha*	40
Harvesting volume, 10-year, m^3/compartement *Etat, 10-godišnji, m^3/odsjeku*	656

EXPLOITATION FACTORS
EKSPLOATACIJSKI ČIMBENICI

Table 3 shows exploitation factors on the work sites. The structure of the total felling volume and the net wood volume shows varying values, depending on the felling and processing method applied. By using a combined method, on the Ivanska site the use was 92.99%.

Table 3 Factors relating to the exploitation of work sites
Tablica 3. Eksploatacijski čimbenici radilišta

Forest office *Šumarija*		Ivanska	
Management Unit *Gospodarska jedinica*		Ivanske Prigorske Šume	
Compartement, Sub-compartement *Odjel, odsjek*		32 c	
Type of *Vrsta*	yield *prihoda*	Intermediate *Prethodni*	
	cut *sijeka*	Thinning *Proreda*	
Skidding distance (from OG), m *Udaljenost privlačenja (iz OG), m*		250	
Distance from tree to tree m *Udaljenost od stabla do stabla, m*		19.5	
		m^3	%
Total cut timber volume *Ukupno posječeni drvni obujam*	Gross *Bruto*	656	100.0
	Total net *Ukupno neto*	610	92.99
	Technical roundwood *Tehnička oblovina*	193	31.6
	Long stackwood *Višemetarsko prostorno drvo*	417	68.4

The average space between the assigned trees depends on stand age, terrain exploitation, assignment intensity, etc. Based on the values measured during felling and processing on the Ivanska site, an average value of 19.5 was calculated. The tree distance per area unit on a felling site is calculated by the following mathematical equation:

$$R_s = \sqrt{\frac{10000}{N}} \ldots (m), \tag{1}$$

where R_s = mutual tree distance (m), N = number of trees per area unit (pcs/ha)

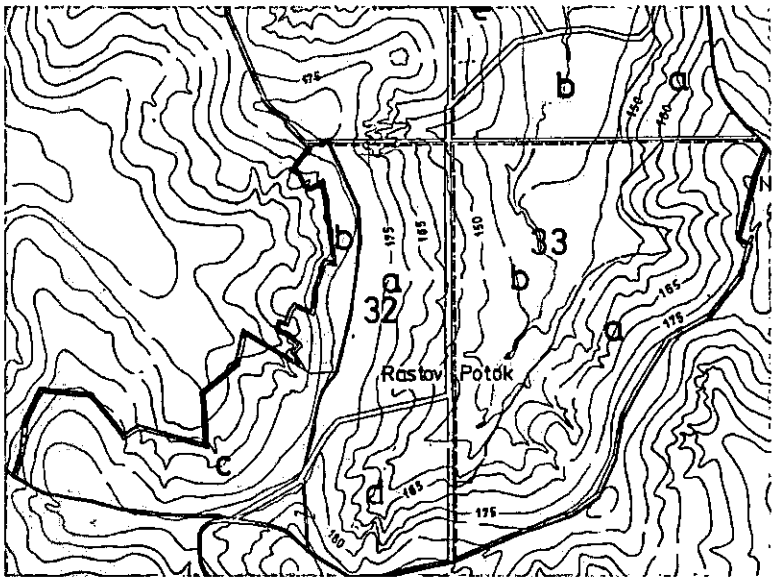


Figure 4 Management map of FMU Ivanska Prigorska Šuma showing Department 32, Map scale: 1:10,000

Slika 4. Dio gospodarske karte G. J. Ivanske prigorske šume s prikazom odjela 32, M = 1 : 10 000

SITE ORGANISATION IN TEAMWORK APPLICATION
ORGANIZACIJA RADILIŠTA PRI PRIMJENI SKUPNOGA RADA

A team of six, i.e. two cutters, two tractor drivers, one cutter-customer on the landing, and one crane driver, worked on the Ivanska site. The foreman was daily present. The workers gathered together every morning and drove to the felling site by a vehicle (small bus) that was assigned to them for this purpose. At the end of the day, they went back to their abiding places in the same way. For the reasons of economising, the driver of the bus parked the vehicle in his own yard. On the arrival to the felling site, i.e. the landing, the work preparation began. The tractors were parked on the landing. The drivers poured in the fuel into the tractors. During that time, the cutters prepared their equipment, tools and chain saws. During the morn-

ing work preparation, the foreman gives instructions, collects the information of the preceding day, and organises the workday on the basis of the felling area state. Same as on the preceding areas, the cutter and the tractor work in pair. Each of the cutters works with one tractor, preparing the sufficient quantity of timber for every load, and during every work cycle helps the tractor driver with load binding. Besides load binding, at longer distances the cutters produce and drive poles along the root areas of standing trees along the tractor routes.

The crane driver prepares the tractor and the crane, waiting for the arrival of the first tractor load, and also participates in all other activities on the landing.

The cutters walked to the felling area, drove back to the landing at the time of lunch break, and then drove back by tractor to the felling area.

According to the work assignment and the calculation of the total work days, this team of six plans to cut an average timber amount of 5.00 m^3/day per team member.

The cutters cut and processed trees taking into consideration the mutual distances. At every roundwood tree, the cutters first separated one part of the technical roundwood, and then started the crown delimbing, during which procedure they measured the 4 m, 8 m, and 12 m-logs. On the landing, the cutter-customer unfastened the long timber, while the tractor continues skidding the technical roundwood. The crane driver joins the operation by helping to measure the long stackwood and to cut it into 4 m-pieces. The foreman records the mean diameter and the number of long roundwood pieces into the workbook. The crane driver stacks the processed long timber. The procedure is repeated with every tractor load.

The foreman and a worker buck and customize the technical roundwood in the place where the tractor driver unloads one part of the trunk. After hauling technical timber, the next tractor piles it.

METHOD OF COLLECTING AND PROCESSING DATA
METODA PRIKUPLJANJA I OBRADA PODATAKA

Work and time study is applied to site research. In forest exploitation, the data on time use are recorded with a mechanical or digital chronometer. The usual recording methods are the continuous method and the snap-back method, both of which have advantages and disadvantages. The method of current observations is applied less frequently.

The snap-back chronometry method, recommended by REFA (1984) and Taboršak (1987) was used in this research. The disadvantages are the following: long training of surveyors; high concentration of surveyors; chronometers of special design; losses due to the return of the chronometer arm to the starting position,

etc. The following are the advantages: instant display of incorrect work, or justified breaks; no delays in the calculation of individual times; in case of breaks for any reasons, the recording can be continued, and the possibility of displaying very short work operations.

Compared to the current method, the snap-back methods according to Barnes (1964) have the advantage of instantly displaying the time of every single work operation on the display sheet, so that the surveyor and the analyser can detect the differences in the course of the recording procedure.

SPREADSHEETS
OPAŽAČKI LISTOVI

Record sheets are adjusted to the work organisation of cutters, tractors, those working on measuring wood assortments, and the crane tractors. The final design of the record sheet was made according to the analysis of the existing work organisation and the method/techniques of surveying. There were four display sheets for recording all work operations, breaks and general data. One sheet can contain one or more trees, or tractor cycles, and the number and quantity of the processed wood assortments on the landing, i.e. the number of the pieces and crane operations. On the back of every sheet go the following data: general data on the work site, soil condition, air temperature, general work conditions, work organisation and other significant site factors.

SURVEYORS AND THEIR EQUIPMENT
SNIMATELJI I OPREMA

The surveyors are educated and well trained for operating the recording equipment. They are all graduated forestry engineers. Before surveying, the spreadsheet and work cycle were prepared on the site. Every surveyor has been specially trained before the surveying begins. The surveyors must be informed on the site and work technology in detail, in order to notice and record every piece of work, both cyclical and occasional, and to classify them into the corresponding categories. Concentration and skill are very important (Taboršak 1987). The terrain surveying ran simultaneously for the whole team. It began at the same time, and ended with the last work operation of the last team member.

The surveyor's equipment consists of surveyor's board, chronometer, spreadsheets, hand watch, pencil, surveyor's chain, and the wheel for measuring driving distances. Ergonomically adjusted to writing in the forest, the surveyor's board bears special fittings for the chronometer and the hand watch, and serves as the writing

desk for the spreadsheets. The chronometer of the Heuer type with calibration 1/100 min, and reading precision of 0.01 min, is adjusted to the work using the regression surveying method.

FIXED POINTS
FIKSAŽNE TOČKE

Fixed points are particularly important in the terrain research time study. They are determined before surveying. Every work task, work phase, or operation has its beginning and its end. A fixed point is the moment at which one work operation ends and another begins, i.e. the moment of changing the equipment and tools. For objective measurement of the spent time, fixed points should be described as accurately and as clearly as possible. If there are two or more surveyors employed in the same work phase, the time and place of the end and beginning of the work job should be adjusted.

MEASUREMENT OF OTHER SITE FEATURES
MJERENJE OSTALIH ZNAČAJKI RADILIŠTA

Before starting the site surveying, it is necessary to carefully plan the work on every research object. Based on the data of the regular felling plan (FP2), and the agreement with the managing forestry engineering staff of the relating area, a felling site is selected to best represent the whole area. The number of assigned trees is determined on the felling site. The analysis of the plan felling/processing norms is carried out of the following: felling and processing, classifying the wood assortments, and the categorisation of the tractor skidding terrain. The daily tractor norm at skidding is analysed together with the necessary number of norms – the days per work phases. The work time period is agreed upon. The selected trees are marked with ordinal numbers. In the same way are the tractor hauls and skidd trails marked by ordinal numbers. The lengths of all skidd trails and skid roads inscribed on the trees that are not assigned for the felling site measured. The parts of the trails and roads with corresponding lengths and slope are written in the schematic presentation on the management map. The lengths of the tractor trails and roads are measured and calculated using 3D Model in GIS.

DATA PROCESSING
OBRADA PODATAKA

The finished terrain surveying data are stored with the Institute for Forest Exploitation of the Forestry Faculty in Zagreb. All the data recorded in the spreadsheets

are entered into the computer database. Using the programme *Microsoft Word, Excel 6.0, Corel 10, Autocad 2000, Statistics 6 and Arcwevu,* the data are fully processed.

SPREADSHEET PROCESSING
OBRADA OPAŽAČKIH LISTOVA

The spreadsheets with the corresponding data on wood volume are processed twice. At the end of the workday, each surveyor established the difference between the surveyed and elapsed time, of the member of the team the particular surveyor has observed. The surveying error is used to establish the validity of every spreadsheet. The second spreadsheet processing took place after the entrance of the data into the personal computer before the beginning of further data processing. Database is created for every member of the team and formatted according to the surveying sheet, i.e. the number of work tasks.

TIME DIFFERENCE
RAZLIKA VREMENA

The surveyed times and the work devices were summed for each member of the work team per work day, and the elapsed time was calculated in the same units as the surveyed times. The difference between the elapsed and surveyed time was calculated using the following equation:

$$G_S = \left(\frac{T_p - T_s}{T_p} \right) \bullet 100 \cdot\cdot (\%); \qquad (2)$$

where G_s is the surveying time error in %, T_p elapsed time, T_s sum of surveyed times.

Based on the time error (G_s), the decision is made on the validity of the spreadsheet. In manual/machine work, a time error within ± 3.0 % is tolerated (Bojanin 1984, Hilf 1963, Samset 1956, REFA 1986). Taboršak (1987) tolerates an error of ± 1.5 %. Surveying sheets with errors below ± 3.0 % are accepted in processing.

SURVEYED TIME PROCESSING
OBRADA SNIMLJENIH VREMENA

The surveyed times are processed according to the time division in the teamwork, as used in the Department of Forest Engineering of the Zagreb Forestry Faculty. The processing of the surveyed times of each work team member and work devices

was done individually. The fixed and the variable times were processed separately. In felling and processing, the effective time is processed using the multi-variant regression analysis, by which the dependence of the effective time use for each tree was observed in relation to the breast height diameter and height.

In tractor skidding, one part of the effective time is processed as fixed, another as variable time. The fixed times do not depend on the skidding distance, or winching, but relate in this case to the effective work time on the felling site (loading) and the work on the landing (unloading). For the fixed times, the arithmetic means, the dispersion measures, the percentage error of the arithmetic means, and the number of needed observations are all calculated. The variable times are processed by multiple regression analysis in the computer programme *Statistica 6.* Four variables were used for the calculation of the loaded drive time: skidding distance, load volume, number of pieces in the load, and the skid trail slope. The driving distance and track slope are observed for the calculation of the unloaded tractor drive.

The time use of the cutter-customer at the landing for the processing, measuring and cross-cutting the wood assortments is also processed by multiple regression analysis. The observed factor is the dependence of the effective time use in relation to the processed volume and the number of pieces. The used effective work time of the crane for stacking the long timber is observed in relation to the number of pieces and the total operation volume.

TIME DISTRIBUTION
RASPODJELA VREMENA

The time distribution of the individual work team members is adjusted to the conditions and the work organisation of a particular felling site. The existing time distributions that are used in Croatia in the individual work research are similar to the time distribution applied in other European countries, and the work conditions similarities enable that we apply their results (Bojanin 1977).

The research on the work and time study in German Forestry began in 1912, the year when Max-Planck Institute was established. In 1924 the work study association *Verband für Arbeitsstudien* REFA e.V.) was established (Krpan 1984).

In the process of felling, processing and skidding by tractor by applying teamwork, the time distribution differs from the standard ones, because besides the driver, in particular operations and places (felling site, skid trail, landing) the cutter and the crane driver also participate.

The total surveyed times of the team members are divided into effective time and delay times. The effective time consists of cyclic times and individual non-cyclic times, spent in terms of carrying out the work assignment (production of product unit).

The effective time at felling and processing is divided into tree time and assortment time. The time used by the cutter for load binding is also calculated as a part of the effective time a tractor uses for the work on the felling site. The effective time of the tractor cycle is divided into fixed and variable times (Bojanin 1982).

The delay times are all times of interruption, occasional jobs and the preparation/finishing time. According to Bojanin (1977) and REFA (1986), the delay times are the times of interruption, the time of resting, and the preparation/finishing time. The interruption time may be justified and unjustified. The justified interruptions are the ones necessary for the realisation of the given task. The unjustified ones are those that happen either consciously, or unconsciously, and do not serve the given task. Occasional tasks happen without any rules, from time to time, and are aimed at the completion of the given task. The preparation/finishing time is a part of delay times. The preparation time encompasses the arrival of the team member at the felling site, landing, and the work devices respectively. The finishing time encompasses all the times spent at collecting the equipment and work devices, and the walk to the transportation vehicle.

STATISTICAL DATA PROCESSING
STATISTIČKA OBRADA PODATAKA

When the data of all team members are entered into the PC, the statistical data processing using the *Microsoft Excel* and *Statistica 6* is carried out. The effective times are processed using the programme *Statistica 6*, which has a module of basic statistical analysis method using the same terms as the one used for the calculation of the fixed methods. The programme package *Statistica 6* of the firm StatSoft Inc. is a system offering a wide choice of basic and advanced analytical procedures for the use in business, science and engineering via integrated data analysis, graphical presentations, database control and the development of one's own applicative approach to the research.

To describe the basic features of an observed team of data (the data presentation on the composition of one site, the work times of machines and people) descriptive statistics is used: mean variable values expressed by arithmetic means, while their variability is expressed by range, variance and standard error. In their presentation, tables, simple and multiple (for comparison) histograms and dispersion diagrams were used.

The research on the particular variable dependence (effective work time) on the site features during the skidding of timber or the felled trees involves a multiple regression analysis with the regression coefficient calculated as the principle indicator of the regression model tolerance. The best results are obtained with the linear

regression model with one, two, three, or four independent variables, depending on the features of the research place and the type of the completed work.

The regression analysis is the one of the functional (cause/consequence) links between the dependent variable and one or more independent ones. The analysis of several regression models has shown that the total work times on the sites depend on the height and diameter of the trees (volume), terrain slope, and the number of pieces that may be encompassed by one operation – and that this dependence is linear. The following simple linear model was used:

$$\hat{Y} = a + bX, \tag{3}$$

where Y is the dependent variable (effective work time), X is independent variable (or several of them in the extended model), and a and b are coefficients of the regression straight line.

The coefficient of the linear regression is calculated by the method of least squares, i.e. as the square root of the relation between the part of the variance that may be explained by the deviations of the values estimated by the regression function of the arithmetic means and the total variance.

$$r = \sqrt{\frac{\sum_i (\hat{y}_i - \bar{y})^2}{\sum_i (y_i - \bar{y})^2}}, \tag{4}$$

where: $\bar{y}$ is the arithmetic means of the observed numerical description (total work time); yi - its measured values; $\hat{y}i$ - the values of the same numerical description adjusted by the regression function.

The nearer r is to 1, the higher is the proportion of the explained deviations within total deviations, i.e. the better the regression function explains the phenomenon itself.

A special analysis was made for the purpose of comparing the variables of different sites. The aim was to test, whether the site factors (slope, soil condition, skidding distance, tractor load volume) and the ones of the assigned trees (height, breast height diameter) were such that they significantly affected the different work efficiency of the people and machines. For this purpose, t- and F- tests were used for proving the hypothesis on the equality of the arithmetic means of two or more teams.

The hypothesis of the equality of two or more basic teams is tested by variance analysis. This analysis dissects the total sum of the deviation squares of the measured numerical values from its arithmetical means into components according to the variation sources. The alternative hypothesis claims the opposite, i.e. that the arithmetic means of the samples are different.

To compare the arithmetic means of two teams, we use *t*-test and the procedure for testing the hypothesis on the difference between the arithmetic means of two basic teams. The initial, or zero hypothesis, claims that this difference equals zero ($H_0 ... \bar{x}_1 - \bar{x}_2 = 0$), while the alternative hypothesis claims the opposite. The desired value is the allowed estimate interval by using the indicators t or z (depending on the team size).

COLLECTION OF WOOD VOLUME DATA
PRIKUPLJANJE PODATAKA O DRVNOM OBUJMU

Every surveyor entered into his spreadsheet the data on the wood volume related to the observed work team member. In felling and processing, the DBH and height of every tree were measured. Entered are also the numbers of the plates marking the technical roundwood, and the length and mean diameter of the long timber. Based on these data, total volume of the felled trees was calculated using the Schumacher-Hall equation:

$$V = b^0 \cdot d^{b1} \cdot h^{b2} \cdot f ... (m^3), \tag{5}$$

where V – tree volume (m^3); b_0, b_1, b_2 – equation parameters; f – Mayer's correction factor.

The processed volume of every tree, i.e. of the wood assortments, was calculated by the Huber formula,

$$V = \frac{d^2 \pi}{40000} \cdot l ... (m^3), \tag{6}$$

where V – wood assortment volume (m^3); d – mean diameter (cm); l – assortment length (m).

During tractor skidding, the surveyor recorded load data of each cycle: the number of identification plate (technical roundwood) and the wood species, length and diameter (long stackwood). When site surveying was finished, we obtained from the forest office the volume data of each piece of the technical roundwood according to the entered plate numbers. The data from the spreadsheets were integrated with the ones obtained in the Forest Office from the programme records of HŠ. With thus integrated data, we calculated the total wood volume and the ones of each tractor tour separately. The quantity of the corresponding wood volume related to the cutter-customer that measures and receives the wood assortments was taken from the receipt workbook.

The data on the wood volume established at stacking the long timber of the crane tractor upon landing were recorded separately for each tractor and each cycle respectively. At measuring each work operation of the crane full run, the numbers of

the pieces, lengths, means diameters and wood species were recorded during the full run measuring of every work operation of the crane.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

FELLED, PROCESSED, SKIDDED AND STACKED WOOD
POSJEČENO, IZRAĐENO, PRIVUČENO I SLOŽENO DRVO

The following is the data presentation of the corresponding wood volume of each team member. The data relate to the felled trees and the processed wood per each cutter, and to the wood volume skidded by tractors to the landing.

WOOD VOLUME OF FELLED TREES
DRVNI OBUJAM POSJEČENIH STABALA

Table 4 contains the data on the felled trees related to two cutters, and the data on the processed wood assortments on the landing. The combined method was applied to the felling and processing. Technical roundwood was separated from the stacked wood, while the long roundwood was measured and processed in sizes between 4 m and 12 m.

Table 4 The data on the wood felled and processed by cutters (Figures 1 and 2) with tractors Ecotrac 1 (E1) and Ecotrac 2 (E2)

Tablica 4. Podaci o drvu koje su posjekli i izradili sjekači (S1 i S2) uz traktore Ecotrac (E1) i (E2)

Processed timber components *Sastavnice izrađenog drva*		Cutters *Sjekači*					
		Cutter with Ecotrac 1 *Sjekač uz Ecotrac 1 (S1)*			Cutter with Ecotrac 1 *Sjekač uz Ecotrac 2 (S2)*		
		*	x	**	*	x	**
Processed trees *Posječena stabla*	Processed trees, pieces *Broj posječenih stabala, kom*	-	273	-	-	289	-
	Total volume of cut trees, m^3 *Ukupni obujam stabala, m^3*	-	201.79	-	-	232.9	-
	Diameter at breast height, cm *Prsni promjer, cm*	13	26.4	50	10	27.9	54
	Tree height, m *Visina stabla, m*	13	23.1	32	13	22.5	31
	Tree volume, m^3 *Obujam stabla, m^3*	0.076	0.739	2.645	0.045	0.805	3.396
	Distance from tree to tree, m *Udaljenost od stabla do stabla, m*	1	19.7	160	1	17	70

Table 4 continued – *Nastavak tablice 4.*

Processed timber assortment *Izrađeni drvni sortimenti*							
Technical roundwood *Tehnička oblovina*	Number of pieces *Broj komada*	-	182	-	-	142	-
	Processed volume, m^3 *Izrađeni obujam, m^3*	-	73.88	-	-	69.42	-
	Diameter, cm *Promjer, cm*	14	28.1	44	19	30.6	48
	Length, m *Duljina, m*	2.4	6.4	10.0	3.0	6.4	10.0
	Piece volume, m^3 *Obujam komada, m^3*	0.114	0.408	0.914	0.113	0.489	1.660
Long stackwood *Višemetarsko drvo*	Number of pieces *Broj komada*	-	508	-	-	596	-
	Processed volume, m^3 *Izrađeni obujam, m^3*	-	110	-	-	142.37	-
	Diameter, cm *Promjer, cm*	10	18.4	46	11	20.2	49
	Length, m *Duljina, m*	4.4	7.8	8.0	4.0	7.1	10.0
	Piece volume, m^3 *Obujam komada, m^3*	0.031	0.217	0.726	0.038	0.239	1.005
Total *Ukupno*	Number of pieces *Broj komada*	-	690	-	-	738	-
	Processed volume, m^3 *Izrađeni obujam, m^3*	-	183.86	-	-	211.8	-
	Diameter, cm *Promjer, cm*	10	21.0	46	11	22.9	49
	Length, m *Duljina, m*	2.4	7.4	10.0	3.0	6.9	10.0
	Piece volume, m^3 *Obujam komada, m^3*	0.031	0.266	0.914	0.038	0.287	1.660

* Minimal value x Total or mean value ** Maximal value
* *Najmanja vrijednost* *x Ukupna ili srednja vrijednost* ** *Najveća vrijednost*

Each cutter felled and processed wood for his Ecotrac tractor. Cutter C1 (Ecotrac1) felled 273 trees with a total volume of 201.79 m^3, a DBH of 26.4 cm, a mean height of 23.1 m, and a mean volume of 0.739 m^3 (Table 4). The second cutter, S2 (with Ecotrac2), felled 289 trees with a total volume of 232.85 m^3, a DBH of 27.9 cm, a mean height of 22.5 m, and a mean volume of 0.805 m^3. The mean mutual distance of the assigned trees was 12.6 m.

SKIDDED WOOD ON IVANSKA SITE
PRIVUČENO DRVO NA RADILIŠTU IVANSKA

Table 5 contains the data on the skidded timber. On the Ivanska site, the wood was skidded by two Ecotrac tractors, E1 and E2. The first skidded 188.18 m^3 wood assortments with a mean piece volume of 0.264 m^3 in 142 tours.

Table 5 Overview of skidded wood by a Ecotrac 1 (E1) and Ecotrac 2 tractors (E2)
Tablica 5. Prikaz privučenog drva traktorima Ecotrac 1 (E1) i Ecotrac 2 (E2)

Components of skidded timber *Sastavnice privučenog drva*	Ecotrac 1 (E1) *Ecotrac 1(E1)* * - x - **	Ecotrac 1 (E2) *Ecotrac 2 (E2)* * - x - **
Total skidded timber volume, m^3 *Ukupno privučeni drv. obujam, m^3*	188.18	170.18
Total number of pieces *Ukupan broj komada*	713	644
Total length of pieces, m *Ukupna duljina komada, m*	5399.7	5140.1
Total cycle number *Ukupan broj turnusa*	142	114
Mean load volume, m^3 *Srednji obujam tovara, m^3*	0.530 – 1.330 – 1.890	0.730 – 1.490 – 2.710
Average number of pieces in a load *Prosječni broj komada u tovaru*	2 – 5.0 – 9	2 – 5.6 – 9
Mean piece length, m *Srednja duljina komada, m*	2.4 – 7.4 – 10.0	3 – 6.9 – 10
Mean piece volume, m^3 *Srednji obujam komada, m^3*	0.031 – 0.264 – 0.914	0.038 – 0.264 – 1.660
Mean piece diameter, cm *Srednji promjer komada, cm*	10 –20.3 – 4	11 – 22.9 – 49

The mean volume of one load was 1.330 m^3, with an average of 5.0 pieces per load. The second tractor, E2, skidded 170.18 m^3. The mean load volume was 1.490 m^3. An average of 5.6 pieces were skidded per cycle, and the mean piece volume was 0.264 m^3.

STRUCTURE OF PROCESSED AND DELIVERED WOOD ON LANDING
STRUKTURA IZRAĐENOG I PREUZETOG DRVA NA POMOĆNOM STOVARIŠTU

Table 6 contains the data on the processed wood assortments on the landing. On the Ivanska landing, assisted by the crane driver, the cutter-customer processed

and took over the wood assortments. In this team, the surveying ran simultaneously with all team members. Altogether 517 pieces of technical roundwood with a mean volume of 0.249 m³, and 2,132 pieces of long stacked wood with a mean volume of 0.108 m³ were processed during 11 surveying days. A total of 385.36 m³ with an average piece volume of 0.135 m³ was processed and delivered.

Table 6 Wood delivered on the Ivanska landing
Tablica 6. Prikaz preuzetog drva na pomoćnom stovarištu Ivanska

Processed timber components *Sastavnice izrađenog drva*		Cutter-customer (PS) *Sjekač-preuzimač (PS)*		
		*	x	**
Technical roundwood *Tehnička oblovina*	Number of pieces *Broj komada*	-	517	-
	Processed volume, m³ *Izrađeni obujam, m³*	-	128.78	-
	Diameter, cm *Promjer, cm*	20	28.4	76
	Length, m *Duljina, m*	2.0	3.9	7.5
	Piece volume, m³ *Obujam komada, m³*	0.090	0.249	1.315
Long stackwood *Višemetarsko prostorno drvo*	Number of pieces *Broj komada*	-	2132	-
	Processed volume, m³ *Izrađeni obujam, m³*		229.58	-
	Diameter, cm *Promjer, cm*	9	17.9	45
	Length, m *Duljina, m*	4.0	4.0	4.0
	Piece volume, m³ *Obujam komada, m³*	0.015	0.108	0.636
Total *Ukupno*	Number of pieces *Broj komada*	-	2649	-
	Processed volume, m³ *Izrađeni obujam, m³*	-	358.36	-
	Diameter, cm *Promjer, cm*	9	20.0	76
	Length, m *Duljina, m*	2.0	4.0	7.5
	Piece volume, m³ *Obujam komada, m³*	0.015	0.135	1.315

* Minimal value
** Najmanja vrijednost*

x Total or mean value
x Ukupna ili srednja vrijednost

** Maximal value
*** Najveća vrijednost*

Table 7 contains the data on the stacked long wood on the landing. A crane tractor is a component of the team on the Ivanska site. The crane work was surveyed for eleven days. Altogether 217.07 m³ of long timber were stacked on the site, which amounted to a daily average of 19.63 m³.

Table 7 The data on the wood stacked by a tractor crane on the landing
Tablica 7. Podaci složenog drva traktorskom dizalicom (DZ) na pomoćnom stovarištu

Processed timber components *Sastavnice izrađenog drva*	Ivanska		
	*	x	**
Total stacked timber *Ukupno složeno drvo, m³*	-	217.07	-
Total number of pieces *Ukupan broj komada*	-	2019	-
Total length of pieces, m *Ukupna duljina komada, m*	-	8076.0	-
Total number of crane grasp *Ukupan broj zahvataja dizalicom*	-	520	-
Mean volume of crane grasp, m³ *Srednji obujam zahvataja dizalice, m³*	0.053	0.417	1.582
Mean number of pieces in crane grasp *Prosječni broj komada u zahvataju dizalice*	1	3.9	9
Length of pieces, m *Duljina komada, m*	4.0	4.0	4.0
Mean piece volume, m³ *Srednji obujam komada, m³*	0.011	0.108	0.916
Mean piece diameter, cm *Srednji promjer komada, cm*	9	17.9	54

* Minimal value x Total or mean value ** Maximal value
* *Najmanja vrijednost* *x Ukupna ili srednja vrijednost* ** *Najveća vrijednost*

Two tractors skidded on this site. The crane completed 520 stacking operations, i.e. 47.3 operations a day. All long wood was processed in 4 m-lengths. An average volume of a crane operation was 0.417 m³. A single crane grasp contained between one and nine pieces, i.e. an average of 3.9 pieces. An average piece volume of a processed long wood was 0.108 m³.

WORK ANALYSIS
ANALIZA VREMENA

This subchapter presents the total used times of the cutters at felling, processing, assortment delivering, the total times of the tractor at skidding, and the crane

tractor on the landing. This is followed by a structure of delay times of all team members by the order of sequence as stated of the total used times. The structure of added times and the added time factors were presented in the same way.

TOTAL TIME CONSUMPTION OF THE CUTTERS
UKUPNO UTROŠENO VRIJEME SJEKAČA

Table 8 contains the data on the total time used by two cutters. Cutters S1 and S2 working on the felling and processing of standing trees were surveyed for eleven work days simultaneously. These data relate to the ones in Table 4. Cutter S1 was surveyed for 4,491.88 minutes, while cutter S2 was surveyed for 4,556.27 minutes.

Table 8 Time structure of felling and processing; time percentage according to the total and the effective time, and the time use per tree in Ivanska

Tablica 8. Struktura vremena na sječi i izradbi, postotni udio vremena prema ukupnom i efektivnom vremenu i utrošak vremena po stablu u Ivanskoj

Type of operation or procedure *Vrsta radne operacije ili zahvata*	Cutters / Sjekači							
	S1 / S1				S2 / *S2*			
	Time consumption *Utrošak vremena*	Time share *Udio vremena*		Time share per tree *Udio po stablu*	Time consumption *Utrošak vremena*	Time share *Udio vremena*		Time share per tree *Udio po stablu*
		per total *prema ukupnom*	per effective *prema efektivnom*			per total *prema ukupnom*	per effective *prema efektivnom*	
		time / *vremenu*				time / *vremenu*		
	min	%		min	min	%		min
1. Felling and processing time *1. Vrijeme sječe i izradbe*	1465.48	32.63	85.54	5.37	1712.97	37.60	77.15	5.93
1.1 Tree time *1.1 Stablovno vrijeme*	977.06	21.75	57.03	3.58	1238.97	27.19	55.80	4.29
1.2 Assortment time *1.2 Sortimentno vrijeme*	488.42	10.87	28.51	1.79	474.00	10.40	21.35	1.64
2. Work on preparation and binding load *2. Rad na pripremi i vezanju tovara*	247.72	5.51	14.46	0.91	507.45	11.14	22.85	1.76
3. Effective time *3. Efektivno vrijeme*	1713.20	38.14	100.00	6.28	2220.42	48.73	100.00	7.68
4. Delay times *4. Opća vremena*	2778.68	61.86		10.18	2335.85	51.27		8.08
5. Total time *5. Ukupno vrijeme*	4491.88	100.00		16.45	4556.27	100.00		15.77

Within the total used time, the effective time of cutter S1 was 38.14%, and the delay times were 61.86%. The effective time of cutter S2 was 48.73%, and the delay times were 51.27%. Table 8 shows that the effective S2 time used for felling and processing amounts to 1,465.48 minutes, i.e. 85.54% of effective time, or 5.37 minutes per tree. Cutter S2 used for felling and processing 1,712.97 minutes, i.e. 77.15% of effective time, or 5.93 minutes per tree.

The tree time with cutter S1 was 57.03%, or 3.58 minutes of effective time per tree, while the respective values with S2 were 55.80% and 4.29. The assortment time proportion is considerable with these cutters, 28.51% of effective time with S1, and 21.35% with S2. The work on preparation and binding of the load required 14.46% of S1 effective time, i.e. 0.91 minutes per tree, while the respective values of cutter S2 were 22.85% and 1.76. The effective tree time of cutter S1 was 6.28 minutes, while the one with S2 was 7.68 minutes.

Cutter S1 spent 9.23 min/m^3 of effective for felling processing of 183.86 m^3, and 15.11 min/m^3 of delay times, which amounts to a total of 24.43 min/m^3. The respective values of S2 were 211.79 m^3, 10.48 min/m^3, 11.03 min/m^3, and 21.51 min/m^3.

The following is a review of the authors and some research results under similar work conditions. Vondra (1991) wrote that the delay times for the processing of roundwood of various lengths and the long technical timber in teamwork amount to 77.9% of pure work time. Martinić (1990) wrote that the daily used time of the cutter with the tractor in two research cases amounted to 88 min/day and 95 min/day respectively, while 60% of the work time with tractor was required for load binding. The same author (1990) wrote that the delay times in Sweden were 45%, in Austria 56%, and in Germany 61% of the pure times used for felling and processing.

Bojanin et al. (1989) wrote that the effective felling and processing time for peduncled oak amounted to 6.20 minutes, the one for black alder was 5.23 minutes, related to a tree of 20 cm DBH, in a thinning stand of peduncled oak and black alder.

Bojanin and Krpan (1994) wrote that the felling and processing of beech in mountainous area required an assortment time use of 8.3 min/ m^3 for a tree with a DBH of 19 cm, while the tree of 22 cm DBH required 10.5 min/ m^3.

TOTAL TIME CONSUPTION OF A TRACTOR
UKUPNO UTROŠENO VRIJEME TRAKTORA

Table 9 shows the total used times of both tractors, E1 and E2 (Ecotrac V 1033 F). The same table shows the relative proportion of the individual times according to the total and effective times. The work of tractor E1 was surveyed for 11 days, and

142 tours were recorded. Tractor E2 was also surveyed for 11 days, and a total of 114 cycles were recorded. A total of 256 tractor cycles were surveyed.

Table 9 Total used times of tractors E1 and E2 (Ecotrac V 1033 F) on the Ivanska site
Tablica 9. Ukupno utrošena vremena traktora E1 i E2 (Ecotrac V 1033 F) na radilištu Ivanska

Tractors / *Traktori*	E1 (Ecotrac V 1033 F)			E2 (Ecotrac V 1033 F)		
Type of operations *Vrsta aktivnosti*	Total time *Ukupno vrijeme*	Percentage per *Postotni udio prema*		Total time *Ukupno vrijeme*	Percentage per *Postotni udioprema*	
		total *ukupnom*	effective *efektivnom*		total *ukupnom*	effective *efektivnom*
		time / *vremenu*			time / *vremenu*	
	min	%		min	%	
1. Unloaded tractor travel *1. Vožnja neopterećenog traktora*	342.36	7.35	14.14	394.52	7.88	14.12
2. Loaded tractor travel *2. Vožnja opterećenog traktora*	527.98	11.34	21.81	659.02	13.17	23.59
3. Felling site work *3. Rad na sječini*	1017.26	21.84	42.02	1280.12	25.58	45.83
4. Landing work *4. Rad na pomoćnom stovarištu*	533.06	11.45	22.02	459.70	9.19	16.46
4.1. Loaded tractor travel *4.1. Vožnja opterećenog traktora*	105.04	2.26	4.34	91.45	1.83	3.27
4.2. Unfastening load *4.2. Odvezivanje tovara*	-	-	-	-	-	-
4.3. Unloaded tractor travel *4.3. Vožnja neopterećenog traktora*	61.91	1.33	2.56	63.17	1.26	2.26
Effective time - *Efektivno vrijeme*	2420.66	51.98	100.00	2793.36	55.82	100.00
Delay times - *Opća vremena*	2236.42	48.02	-	2211.30	44.18	-
Total time - *Ukupno vrijeme*	4657.08	100.00	-	5004.66	100.00	-
Total skidded timber volume, m^3 *Ukupno privučeni drvni obujam, m^3*	188.18	-	-	170.18	-	-
Effective time per unit, min/m^3 *Efektivno vrijeme po jedinici, min/m^3*	12.86	-	-	16.41	-	-
Total time per unit, min/m^3 *Ukupno vrijeme po jedinici, min/m^3*	24.75	-	-	29.41	-	-
Realised daily output, m^3/day *Ostvareni dnevni učinak, m^3/dan*	17.11	-	-	15.47	-	-

Tractors E1 and E2 were surveyed for 4,657.08 and 5,004.66 minutes respectively. The effective times of the two tractors were 51.98% and 55.82% respectively. Tractor E2 achieved a better effective time by 3.84% compared to tractor E1. The delay times of the two tractors were 48.02% and 44.18% respectively of the total time. Tractor E1 had an effective time of 12.86 min/m^3 per unit, while the respec-

tive value of tractor E2 was 16.41 min/m³. The total used times per unit of the two tractors were 24.75 min/m³ and 29.41 min/m³ respectively. The average daily output of tractor E1 was 17.11 m³/day, while the respective value of tractor E2 was 15.47 m³/day. Tractor E1 skidded an average of 1.64 m³/day more than tractor E2.

TOTAL CONSUMPTION TIME FOR CUSTOMIZING WOOD ASSORTMENTS
UKUPNO UTROŠENO VRIJEME PRI PREUZIMANJU DRVNIH SORTIMENATA

Table 10 shows the use of effective and delay times of cutters-customers on the Ivanska site for processing and taking over wood assortments at the landing. This worker carried out the cutting of long roundwood into 4 m-lengths by using the tractor crane. The crane driver held the skidded load while the cutter worked it up. The cutter-customer was altogether surveyed for 4,577.31 minutes during 11 days, i.e. for 416.12 min/day. The effective time was 757.59 minutes, or 16.55%, while the delay times were 3,819.72 minutes, or 83.45% of the total time.

Table 10 Time use for customizing wood assortments on the landing of Ivanska
Tablica 10. Utrošak vremena pri preuzimanju drvnih sortimenata na pomoćnom stovarištu Ivanska

Type of operation or activity *Vrsta radne operacije ili zahvata*	Total time *Ukupno vrijeme*	Time share per *Udio vremena prema*			
		total *ukupnom*	effective *efektivnom*	timber assortment *drvnom sortimentu*	m³ *m³*
		time *vremenu*			
	min *min*	%		min *min*	
1. Walking to the load *1. Hod do tovara*	240.31	5.25	31.72	0.09	0.67
2. Load unbinding *2. Odvezivanje tovara*	10.42	0.23	1.38	0.00	0.03
3. Finalisation *3. Dorada*	8.96	0.20	1.18	0.00	0.03
4. Bucking timber assortments *4. Prikrajanje drvnih sortimenata*	15.02	0.33	1.98	0.01	0.04
5. Cross-cutting *5. Trupljenje*	210.6	4.60	27.80	0.08	0.59

Table 10 continued – *Nastavak tablice 10.*

6. Turning and clamp positioning *6. Okretanje i zabijanje klanfica*	1.56	0.03	0.21	0.00	0.00
7. Measuring *7. Mjerenje*	240.98	5.26	31.81	0.09	0.67
8. Setting plastic boards *8. Zabijanje pločica*	29.74	0.65	3.93	0.01	0.08
Effective time *Efektivno vrijeme*	757.59	16.55	100.00	0.29	2.11
Delay times *Opća vremena*	3819.72	83.45		1.44	10.66
Total time *Ukupno vrijeme*	4577.31	100.00		1.73	12.77

A total of 358.36 m^3 wood was processed. Of this, there were 517 pieces medium-volume technical roundwood amounting to 0.249 m^3, and 2,132 pieces long medium-volume stackwood of 0.108 m^3. The highest use of effective time was 0.67 min/ m^3 for the walk to the load, and the same time was used for measuring. The working up of wood assortments required 0.59 min/m^3. The average used effective time was 2.11 min/m^3, while the average delay times were 10.66 min/m^3, which amounted to a total of 12.77 min/m^3.

According to Martinić (1990), a cutter at landing works in team effectively 134 minutes a day, i.e. 27.9% of the total time. The use of the net time of customizing wood assortments at landing, so Štefančić (1989), amounts to 6.27min/m^3, while the respective total time is 19.26 min/m^3.

TOTAL TIME CONSUPTION OF THE CRANE TRACTOR AT LANDING

UKUPNO UTROŠENO VRIJEME TRAKTORA S DIZALICOM NA POMOĆNOM STOVARIŠTU

Table 11 shows the use of effective times and delay times of the crane tractor at Area D (Ivanska) for stacking long wood at landing. Same as with the previous site, long wood was worked up to the lengths of 4 m. The crane driver held one part of the tractor load, while the cutter carried out the trimming.

Table 11 Total consumption times of crane tractors for stacking wood assortments on the landing Ivanska

Tablica 11. Ukupno utrošena vremena traktora s dizalicom (DZ) pri slaganju drvnih sortimenata na pomoćnom stovarištu Ivanska

Type of operation *Vrsta operacije ili zahvata*	Time use *Utrošak vremena*	Proportion *Udio prema*		Time use per *Utrošak vremena po*	
		total time *ukupnom vremenu*	effective time *efektivnom vremenu*	piece *komadu*	m^3 m^3
	min *min*	%		min/pcs min/kom	min/m^3 *min/m^3*
1 Crane operation *1. Radni zahvati dizalice*	630.23	13.91	55.38	0.31	2.90
1.1 Empty crane run *1.1 Prazan hod dizalice*	108.34	2.39	9.52	0.05	0.50
1.2 Grasp *1.2 Hvatanje*	141.64	3.13	12.45	0.07	0.65
1.3 Load holding at cross-cutting *1.3 Držanje tovara kod trupljenja*	173.16	3.82	15.22	0.09	0.80
1.4 *Full crane run* *1.4* Puni hod dizalice	154.68	3.41	13.59	0.08	0.71
1.5 *Unloading* *1.5* Otpuštanje tereta	52.41	1.16	4.61	0.03	0.24
2. Periodical crane tractor jobs *2. Periodični radovi traktora s dizalicom*	300.20	6.63	26.38	0.15	1.38
2.1 Roadside storage drive *2.1 Vožnja po pomoćnom stovarištu*	40.13	0.89	3.53	0.02	0.18
2.2 Setting the position *2.2 Zauzimanje položaja*	34.57	0.76	3.04	0.02	0.16
2.3 Descent and ascent driwer moving *2.3 Silazak i penjanje*	17.53	0.39	1.54	0.01	0.08
2.4 Crane preparation *2.4 Priprema dizalice za rad*	24.98	0.55	2.20	0.01	0.12
2.5 Tractor move *2.5 Premještanje traktora*	27.87	0.62	2.45	0.01	0.13
2.6 Moving logs *2.6 Premještanje trupaca*	2.25	0.05	0.20	0.00	0.01
2.7 Arrangement of storage *2.7 Uređenje stovarišta*	28.64	0.63	2.52	0.01	0.13

Table 11 continued – *Nastavak tablice 11.*

2.8 Stacking *2.8 Poslagivanje složaja*	75.03	1.66	6.59	0.04	0.35
2.9 Truck loading *2.9 Utovar na kamion*	49.20	1.09	4.32	0.02	0.23
3. Other crane jobs *3. Ostali radovi dizaličara*	207.53	4.58	18.24	0.10	0.96
3.1 Setting plastic boards *3.1 Zabijanje pločica*	74.37	1.64	6.54	0.04	0.34
3.2 Cross-cutting and processing of wood assortments *3.2 Trupljenje i dorada drvnih sortimenata*	44.72	0.99	3.93	0.02	0.21
3.3 Industrial roundwood measuring *3.3 Mjerenje tehničke oblovine*	70.27	1.55	6.18	0.03	0.32
3.4 Clamp positioning *3.4 Zabijanje klamfica*	18.17	0.40	1.60	0.01	0.08
4. Effective time *4. Efektivno vrijeme*	1137.96	25.12	100.00	0.56	5.24
5. Delay times *5. Opća vremena*	3392.58	74.88		1.68	15.63
6. Total time *6. Ukupno vrijeme*	4530.54	100.00		2.24	20.87

The crane tractor was altogether surveyed for 4,530.54 minutes during 11 days, i.e. for an average of 411.87 minutes a day. The effective time of the crane tractor and the crane driver was 1,137.96 minutes, or 25.12%, while the respective delay values were 3,392.58 minutes and 74.88%.

The structure of the effective time consists of crane grasp (55.38%) and occasional grasps (26.38%). The remaining crane work is 18.24% of effective time, which relates to the work on processing, measuring and customizing the wood assortments on the landing. Within a crane operation, the holding of the load during cutting into lengths lasts the longest – 15.22% of the effective time. This is followed by the loaded run of the crane (13.59%), grasping (12.45%), and the empty run of the crane (9.52%). This tractor crane piled altogether 217.07 m^3, i.e. 2019 pieces of long 0.108 m^3-medium-volume stackwood. An average volume of crane grasp was 0.417 m^3. One crane grasp contained an average of 3.9 pieces.

As to the effective time distribution, the proportion of the crane work was 2.90 min/m^3, and 1.38 min/m^3 spent for occasional operations. Other crane jobs within

effective time were 0.96 min/m³. The average used effective time of the tractor crane and the crane driver was 5.24 min/m³. The delay times amounted to 15.63 min/m³, while the total used time was 20.87 min/m³. As to the crane work alone, the effective time was 4.28 min/m³, while the total time was 19.91 min/m³.

TOTAL CONSUMPTION TIMES OF THE TEAM
UKUPNO UTROŠENA VREMENA SKUPINE

Table 12 shows the consumption of the effective times and delay times of each team member and totally. The same table shows the relative relation of the effective times and delay times ratios of all members of the team and totally, i.e. the average values of the team. Further on, there is the average used time of all team members and totally according to the number of the monitores days. In the end, there is the percentage of the average used time in relation to the prescribed daily work time of 480 minutes.

Table 12 Effective times and delay times of the team and the percentage of the average used time per day

Tablica 12. Efektivno i opća vremena skupine te postotni udio prosječno utrošenog vremena po danu

Team members/ Total *Članovi skupine/ Ukupno*	Effective time *Efektivno vrijeme*		Delay times *Opća vremena*		Total time *Ukupno vrijeme*		Work-days *Dani rada*	Average used time/day *Prosječno utrošeno vrijeme po danu*	
	min	%	min	%	Min	%		min	% of 480 min *% od 480 min*
Ivanska site *Radilište Ivanska*									
S1	1713.2	38.14	2778.68	61.86	4491.88	100.00	11	408.35	85.07
S2	2220.42	48.73	2335.85	51.27	4556.27	100.00	11	414.21	86.29
E1	2420.66	51.98	2236.42	48.02	4657.08	100.00	11	423.37	88.20
E2	2793.36	55.82	2211.3	44.18	5004.66	100.00	11	454.97	94.79
PS	757.59	16.55	3819.72	83.45	4577.31	100.00	11	416.12	86.69
DZ	1137.96	25.12	3392.58	74.88	4530.54	100.00	11	411.87	85.81
Total *Ukupno*	11043.19	39.70	16774.55	60.30	27817.74	100.00	66	421.48	87.81

A team of six workers achieved an average of 37.70% of effective time and 60.30% of delay times on the Ivanska site. Based on the total time of the individual members of the team and the number of days, the average used times per workday

were analysed. The team on the Ivanska site used an average of 87.81% of the prescribed work time.

DELAY TIMES
OPĆA VREMENA

DELAY TIMES OF CUTTERS
OPĆA VREMENA SJEKAČA

The biggest time proportion is the one of meal and rest break. With cutter S1, this break takes 16.11% of the delay times, while the respective value with cutter S2 is higher and amounts to 28.72%. The breaks for meal last for an average of 43.42 minutes (S1) and 60.99 minutes (S2) respectively. The prolonged meal breaks of the two cutters take 20.30% and 9.18% of the delay times respectively. Justified breaks amount to 11.07 and 9.27% respectively. Unjustified ones amount to 18.37% and 14.45% respectively. The respective least percentages are the ones of the occasional jobs – 2.30% and 4.50%. Technical breaks of these cutters were 5.59% and 6.07% respectively, the most time of which was spent for refuelling. The highest proportions of the preparatory-finishing times were spent on the preparation and collection of tools: 12.77% and 12.82% respectively.

Martinić (1990) calculated that the breaks in teamwork took 40% of the delay, while the proportion of unjustified breaks amount to 6.62% of the total used work time. The preparatory-finishing time in teamwork according to the same author amounts to 44 min/day, or 9.17% a day, regardless of the felling and processing method. Vondra (1989) established that the proportions of the preparatory/finishing times are presented by the respective values of 5.4% and 10%.

DELAY TIMES OF TRACTOR
OPĆA VREMENA TRAKTORA

The respective percentages of meal breaks of the two tractors are 26.42% and 22.17% of the delay times. The respective rest break percentages were 4.67% and 8.64% with tractors E1 and E2. Justified breaks were 14.55% (E1 and 13.29% (E2). Breaks due to rain were classified as justified only with tractor E2 (4.07% or 90 minutes). Unjustified breaks were 19.31% and 17.88% respectively. With occasional jobs the respective values were 6.14% (E1) and 0.65% (E2), while technical breaks were mainly accounted for by the defects in tractors and winches. Their respective proportions were 8.76% and 19.44%. The proportions of the preparatory-finishing time within delay times were considerable with respective percentages of 20.16% and 18.50%.

DELAY TIMES OF CUTTER-CUSTOMER
OPĆA VREMENA SJEKAČA-PREUZIMAČA

The highest time proportion relates to unjustified breaks (64.49%). A percentage of 52.53% is used for waiting for the load from felling. This is followed by meal breaks (13.81%) the average time value of which is 48.97 minutes. Rest breaks amount to 4.89%. The worker - cutter rests while waiting for the load and after meal breaks. Compared to other breaks within the delay times, the justified ones amount to only 9.19%. The breaks during occasional work take 1.10% of the delay times. Technical breaks have also a low percentage (1.49%). The preparatory-finishing time had a proportion of 5.02%, or a daily average of 17.44 minutes.

DELAY TIMES OF CRANE TRACTOR ON LANDING
OPĆA VREMENA TRAKTORA S DIZALICOM NA POMOĆNOM STOVARIŠTU

Total time contains 74.88% of delay times. During 11 workdays, a total of 3,600.11 minutes were used, i.e. a daily average of 327.28 minutes of the delay times. The highest proportion of it refers to unjustified breaks (63.39%), of which a proportion of 54.36% accounts for waiting for the tractor load. This is followed by meal breaks (13.33%) and regular breaks (1.68%), the proportion of which is so low, because the tractor driver rests while waiting for the load. The percentage of the justified breaks is 5.42%, mainly relating to consultations and breaks due to rain. Occasional work relates to the help to other members of the team on the landing, taking 7.59% of the delay times. Technical breaks take 1.78% (crane defects). The preparatory-finishing time requires a proportion of 6.81%.

ADDED TIME IN THE TEAM
DODATNO VRIJEME SKUPINE

Added time consists of the parts of the delay required for carrying out the work task Added time is defined for the calculation of the standard time and the output norm, and is added to the effective time in the form of an added time coefficient, or as an absolute amount. According to the data from Table 13, total added time values are summed for each team member, to calculate the total added time of the team. The sums of the effective and added times of the team are put into the absolute proportion of the monitored workdays. This relation is used to calculate the added time proportion of the team on the Ivanska site, i.e. 32.71%.

Table 13 Analysis of the effective and added times of the team
Tablica 13. Analiza efektivnog i dodatnog vremena skupine

Team members/ Total *Članovi skupine/ Ukupno*	Effective time *Efektivno vrijeme*		Added time *Dodatno vrijeme*		Total time *Ukupno vrijeme*		Work-days *Dani rada*	Average time/day *Prosječno vrijeme po danu*	
	min	%	min	%	min	%		min	% of 480 min % od 480 min
Work site Ivanska *Radilište Ivanska*									
S1	1713.2	60.15	1134.92	39.85	2848.12	100.00	11	258.92	53.94
S2	2220.42	67.89	1049.96	32.11	3270.38	100.00	11	297.31	61.94
E1	2420.66	76.66	737.17	23.34	3157.83	100.00	11	287.08	59.81
E2	2793.36	78.17	779.87	21.83	3573.23	100.00	11	324.84	67.67
PS	757.59	53.06	670.08	46.94	1427.67	100.00	11	129.79	27.04
DZ	1137.96	53.35	995.04	46.65	2133.00	100.00	11	193.91	40.40
Total/ Average *Ukupno/ Prosječno*	11043.19	67.29	5367.04	32.71	16410.23	100.00	66	248.64	51.80

The effective time was taken as realised during the given number of workdays. Total time is the sum of effective and added times. The average time per day was calculated by dividing the total time by the number of workdays. The percentage of the average time per day was calculated in relation to the prescribed work time of 480 minutes. The team could realise 51.80% of the work time, because the respective total modelled times of tractors E1 and E2 were 59.81% and 67.67%.

In the calculation of the added time of the individual team members of 30 minutes within eight work hours are allowed for meal break. Other allowed breaks can last five minutes at most, while justified breaks within the total amount as they happened. The added time of cutter S1 was 66.25%; the respective time of cutter S2 was 78.81%. Meal breaks of cutters S1 and S2 were 24.74% and 27.12% respectively. Other breaks were 16.63% (S1) and 9.94% (S2) of added time. Occasional work amounts to 5.62% (S1) and 19.47% of the added time. The proportion of the preparation-finishing time within the added time was 22.39% (S1) and 23.52 (S2). The added times of cutters S1 and S2 were 6.17% min/m^3 and 4.96 min/m^3 respectively. The factors of added time were 1.66 (S1) and 1.47 (S2), i.e. an average of 1.56.

Bojanin et al. (1994) assessed the added time of 51% of the effective time used for felling and tree processing on hilly terrain. Backhaus (1990) wrote that during the calculation of felling and processing norms, the added time in the whole Germany amounts to an average of 40%.

The added times within the effective time were 30.45% (E1) and 27.92% (E2) respectively. Meal breaks were 37.63% (E1) and 36.22% (E2) respectively of the added time. Resting and personal needs took 8.82% (E1) and 9.62% (E2) of the added time. Justified breaks were 10.31% (E1) and 26.13% (E2) of the added time. Occasional work amounted to the respective values of 10.31% and 1.86%. Technical breaks took 11.78% and 12.18% respectively of the added time. The preparation-finishing times were 21.11% (E1) and 14.00% (E2) of the additional time.

Bojanin (1975) mentions the added time of adjusted agricultural tractors ranging between 11.7% and 38.4%, while Krpan (1984) calculated the respective values from 13.4% to 25%; the respective added time factors were 1.30 and 1.28, i.e. an average value of 1.29.

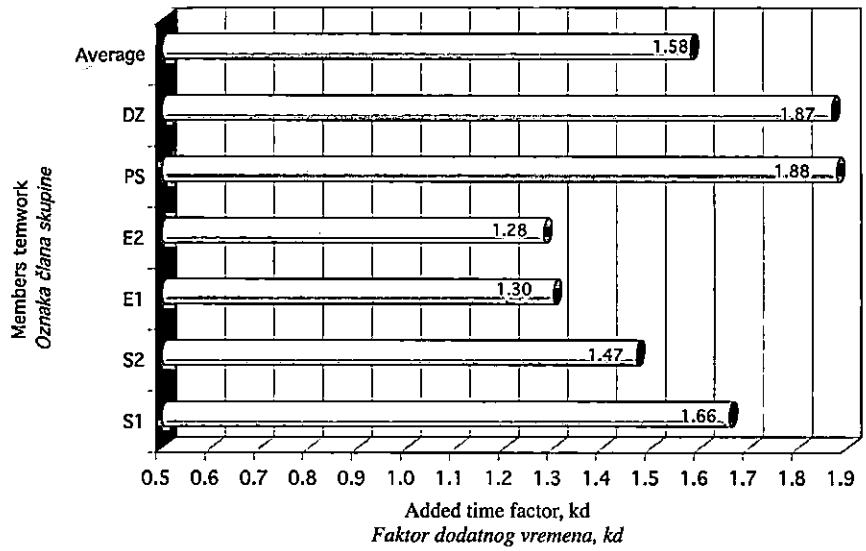


Figure 5 Added time factors of the team members, and the average values of the team
Slika 5. Faktori dodatnog vremena članova skupine i prosječno za skupinu

The added time of the cutter-customer on the landing was 88.45% (PS) of the effective time. The high percentage of the added time is the consequence of the low usage of the effective time, i.e. the insufficient usage of the prescribed work time of 480 minutes. During the workday, the interruptions are necessary, depending on how busy the worker is. The interruptions for meal take 42.69% of the added time. The breaks are justified up to 5 minutes, and are used between twice and five times during the workday, amounting to 14.32% of added time. Justified breaks are allowed to the total amount of 20.89%. Preparation finishing time is 14.39% (PS). The allowed time for preparation and tool collecting is up to 15 minutes/day – 10

minutes for preparation and 5 minutes for tool collecting. The time needed for the arrival at the felling site and back is calculated in the total amount.

The added time of the crane tractor (CT) is 87.44% of the effective time. He daily used an average time of 85.81% of the prescribed time (480 minutes). This worker was as busy as two tractors managed to skid, stacking the long timber that had been prepared by two cutters. The meal break with this worker is shorter than the one of the other team members – 28.46% of the added time. Of the added time, this worker spent only 6.09% for resting, and 19.60% for justified breaks. Occasional breaks had a considerable proportion – 27.46%. This worker participated in the common work with the cutter-customer during the measuring and taking over the wood assortments at the landing. Technical breaks amount to 6.44%, while the preparation-finishing time takes 11.96% of the added time. The added time factor of the crane tractor (CT) on landing is 1.87.

ANALYSIS OF SOME WORK TEAM RESULTS
ANALIZA NEKIH REZULTATA SKUPINE RADNIKA

Table 14 presents some results of the work team. When speaking of teamwork, it is important to mention that the total work result depends on the quantity of the skidded timber during one workday, month or year. This means that the team output equals the skidded quantity of wood assortments to the landing. Therefore are tractors the most significant part of every team, and the whole output of the team is planned according to the their possibilities.

Table 14 Analysis of some work team results
Tablica 14. Analiza nekih rezultata skupine

Team members/ Total *Članovi skupine/ Ukupno*	Work-days *Dani rada*	Plan skidding norm *Planska norma privlačenja*	Plan norm per member *Planska norma po članu*	Mean skidding distance *Srednja udaljenost privlačenja*	Realised skidding output/ *Ostvareni učinak privlačenja*		Realised team output/ *Ostvareni učinak skupine*	Realised output per member *Ostvareni učinak po članu*	
		m^3/dan	m^3/dan	m	m^3/dan	%	m^3	m^3/dan	%
S1	11		4.99					5.43	108.82
S2	11		4.99					5.43	108.82
E1	11	14.60	4.99	234	17.11	117.17	188.18	5.43	108.82
E2	11	14.60	4.99	274	15.47	105.97	170.18	5.43	108.82
PS	11		4.99					5.43	108.82
DZ	11		4.99					5.43	108.82
Total/ Average *Ukupno/ Prosječno*	66	29.2	4.99	254	32.58	111.57	358.36	5.43	108.82

According to the plan norms, the team had to realise a daily output of 29.20 m^3, which means 4.99 m^3/day per team member. According to the mean tractor skidding distance of 254 m, an output of 32.58 m^3/day was realised, which is by 11.57% more than planned. The average realised daily output per team member is 5.43 m^3/day, i.e. by 8.82% more than planned, although 85.59% of the day work time was used. The cutters and tractors worked in pairs, so that they are considered as sub teams in further analyses. Table 15 presents the analyses of the effective time and delay per product unit, i.e. per 1 m^3, for all teams and every member.

Table 15 Analysis of effective/delay/total times consumption of the team per product unit
Tablica 15. Analiza utroška efektivnog i općih vremena te ukupnog vremena skupine po jedinici proizvoda

Team members / Total *Članovi skupine / Ukupno*	Effective time *Efektivno vrijeme*		Delay times *Opća vremena*		Total time *Ukupno vrijeme*	
	min/m^3	%	min/m^3	%	min/m^3	%
Ivanska site *Radilište Ivanska*						
S1	9.32	38.15	15.11	61.85	24.43	100.00
S2	10.48	48.72	11.03	51.28	21.51	100.00
E1	12.86	51.97	11.88	48.03	24.74	100.00
E2	16.41	55.81	12.99	44.19	29.40	100.00
PS	2.11	16.55	10.66	83.45	12.77	100.00
DZ	5.24	25.12	15.63	74.88	20.87	100.00
Total / *Ukupno* P1(S1+E1+PS+DZ)	29.54	35.66	53.28	64.34	82.82	100.00
Total / *Ukupno* P2(S2+E2+PS+DZ)	34.25	40.50	50.31	59.50	84.56	100.00

A team of six worked on the Ivanska site. The cutter and the tractor worked as a pair. The sub team consisted of the cutter, tractor, cutter-customer, and crane tractor. Four members of the sub team P1 (S1+E1+PS+DZ) used 29.54% of the effective time, i.e. 53.28 min/m^3 of the delay times, or 82.82 min/m^3 of the total time. The second sub team P2 (S2+E2+PS+DZ) spent 34.25 min/m^3 of the effective time, i.e. 50.31 min/m^3 of the delay times, or a total of 84.56 min/m^3.

STATISTICAL PROCESSING OF THE TEAM MEMBERS' EFFECTIVE TIME

STATISTIČKA OBRADA EFEKTIVNOG VREMENA ČLANOVA SKUPINE

THE EFFECTIVE TIME OF THE CUTTERS AT FELLING AND TREE PROCESSING

EFEKTIVNO VRIJEME SJEKAČA PRI SJEČI I IZRADBI STABALA

We regard the effective felling/tree processing time as variable in relation to the DBH and tree height. A detailed descriptive statistics was developed for all monitored cutters, resulting in an optimal model of the DBH/height dependence with a cutter's effective time. The model of multiple linear regression best describes cutters' behaviour. Based on the total surveyed cutters' times, statistical processing was carried out. The felling/processing effective time was separated, and their variability was monitored. Multiple linear regression was applied, with the independent variables of DBH, tree height and corresponding effective times of each tree.

Table 16 Descriptive statistics of the basic distributions: breast height diameter, tree height, and the effective times of cutters S1 and S2

Tablica 16. Opisna statistika temeljnih raspodjela: prsnog promjera, visine stabla te efektivnog vremena sjekača

Cutter/ *Oznaka sjekača*	Variable *Varijable*	Number of trees *Broj stabala*	Arithmetic means *Aritmetička sredina*	Minimum value *Najmanja vrijednost*	Maximum value *Najveća vrijednost*	Standard deviation *Standardna devijacija*
		N	x	min	max	s_x
S1	DBH / *Prsni promjer*, $d_{1,30}$ (cm)	258	26.1	13.0	41.0	6.36
	Tree height / *Visina stabla*, h (m)	258	23.2	13.0	32.0	3.94
	Effective time / *Efektivno vrijeme*, (min)	258	5.04	0.92	11.22	2.10
S2	DBH / *Prsni promjer*, $d_{1,30}$ (cm)	286	27.7	10.0	50.0	6.94
	Tree height / *Visina stabla*, h (m)	286	22.3	13.0	31.0	3.40
	Effective time / *Efektivno vrijeme*, (min)	286	5.41	1.06	17.0	3.04

Table 16 shows the descriptive statistics encompassing a total number of trees (N), the variables (medium, minimum, and maximum values), and the standard deviation. With cutter S1, 258 trees were monitored, while the respective value of cutter S2 was 286. The smallest breast height diameter was 13 cm, and the biggest was 41 cm with the first cutter, while 10 cm and 50 cm were the respective values of the

second cutter. The breast height diameters were 16.1 cm and 27.7 cm respectively. The respective medium heights of the monitored sample trees were 23.2 m and 22.3 m, ranging between 13 m and 32.0 m, and 13 m to 31 m. The arithmetic means of the effective times were 5.04 minutes and 5.41 minutes respectively.

Figure 6 presents the value scattering of the effective felling/tree processing times (S1) depending on the DBH and tree height. This dependence (S1) is expressed by equations in the same Figure. Figure 7 shows the respective values with cutter S2).

Based on the tree number distribution and the values of the descriptive statistics, a computer-aided multiple regression analysis was chosen as the most favourable form of mathematical calculation of the effective felling/tree processing time with both cutters.

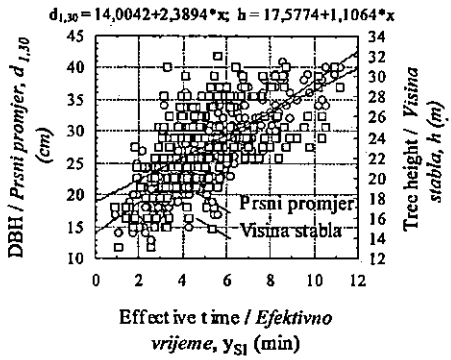


Figure 6 Values scattering of the effective felling/tree processing times depending on the DBH and tree height with cutter S1

Slika 6. Rasipanje vrijednosti efektivnog vremena sječe i izradbe stabala u odnosu na prsni promjer i visinu stabla kod sjekača S1

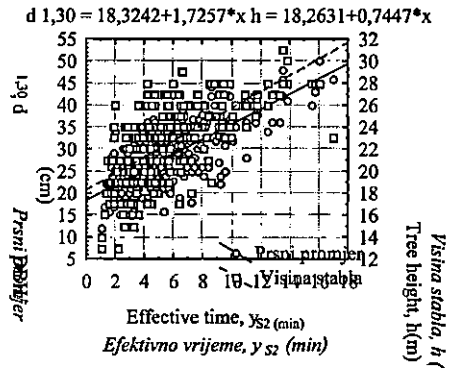


Figure 7 Values scattering of the effective felling/tree processing times depending on the DBH and tree height with cutter S1

Slika 7. Rasipanje vrijednosti efektivnog vremena sječe i izradbe stabala u odnosu na prsni promjer i visinu stabla kod sjekača S2

Table 17 shows the multiple regression values with cutter S1, and the data of the second cutter are processed in the same way. Other statistical values and terms are described below the table. The same table presents the regression indices and the parameters of regression equation of the S1 effective time. Red colour marks the variable that has a significant impact upon the cutters' effective time; while the variables marked in black have insignificant impacts.

Table 17 Regression indices and the parameters of the effective time regression equation of S1 on Ivanska site

Tablica 17. Pokazatelji regresije i parametri regresijske jednadžbe efektivnog vremena sjekača S1 na radilištu Ivanska

N=258	Regression Summary for Dependent Variable: Var3 (Spreadsheet2 in Workbook1.stw) R= ,78976185 R2= ,62372379 Adjusted R2= ,62077260 F(2,255)=211,35 p<0,0000 Std.Error of estimate: 1,2939				
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(255)
Indepedent member/*Nezavisni član*			-1.400591	0.4852197	-2,88651
DBH/*Prsni promjer*, d1,30	0,835941	0,061183	0.275978	0.02019912	13,66286
Tree height/*Visina stabla*, h	-0,060505	0,061183	-0.0322739	0.03263611	-0,98890

Columns Std.Err. of Beta and Std.Err. of B are the values of the standard error B and the B parameter according to which we calculate the effective cutter's time, i.e. the work technology with the calculated independent member of each function.

Two cutters worked in the team on the Ivanska site. Both cutters worked using the Ecotrac tractors. The first cutter (S1) spent 5.04 minutes of the effective time for a mean tree of a DBH 26.1 cm and a height of 23.2 m, according to the mathematical formula

$$y_{S1} = -1{,}40059 + 0{,}275980 \cdot d_{1,30} - 0{,}032270 \cdot h \quad \text{(min)} \qquad (7),$$

while the second cutter needed 5.41 minutes for a mean tree with the respective values of 27.7 cm and 22.3 m, and the mathematical formula

$$y_{S2} = -5{,}785140 + 0{,}263600 \cdot d_{1,30} + 0{,}175170 \cdot h \quad \text{(min)} \qquad (8).$$

Further on, the curves of the measured and adjusted effective time values are also presented for both cutters, which were automatically plotted by the computer programme.

TESTING OF THE CUTTERS' EFFECTIVE TIME
TESTIRANJE EFEKTIVNOG VREMENA SJEKAČA

The previously calculated effective times of the cutters were compared in order to establish whether there was a significant difference between them (and why). The statistical programme Statistica 6 calculates the values of the arithmetic means on the basis of the variables (effective time), i.e. the surveyed values of each cutter.

The comparative analysis of the effective times of S1 and S2 on the Ivanska site, carried out by t-test and expanded by F-test, showed that the measuring series of

both effective times do not differ significantly. Accordingly, there is a 95%-certainty that their arithmetic means were the same.

VARIABLE TRACTOR TIMES
VARIJABILNA VREMENA TRAKTORA

LOADED DRIVING TIME OF TRACTOR E1 ON SKID TRAIL AND FELLING SITE
VRIJEME VOŽNJE OPTEREĆENOG TRAKTORA E1 NA VLACI I SJEČINI

The time analysis of the loaded drive by linear regression considers the following values: load volume, skidding distance, average road slope, and the number of load pieces. In the same way as with cutters, multiple regression analysis is applied to the data processing, where four independent variables are monitored. The loaded E1 tractor moved uphill. Te soil was wet. The driving times variables of the loaded E1 over the skid trail and felling ground are separately processed and presented in Table 18.

Table 18 One part of the variables database of the loaded E1 tractor on the skid trail and felling site of Ivanska

Tablica 18. Primjer dijela baze podataka varijabli opterećenog traktora E1 na vlaci i sječini u Ivanskoj

Number of pieces *Broj komada*	Load volume *Obujam tovara*	Distance *Udaljenost*	Surveyed time *Snimljeno vrijeme*	Slope *Nagib puta*	Adjusted time *Izjednačeno vrijeme*
kom	m^3	m	min	%	min
3	1.205	328	4.9	2	5.52
5	1.237	328	5.4	2	5.52
5	1.586	328	5.3	2	5.60
9	1.446	328	5.2	2	5.55
7	1.525	258	4.75	2	4.40
6	1.401	278	4.5	2	4.71
7	1.470	285	4.72	2	4.84

The equation for time use calculation (YOE1) of the loaded E1 on skid trail and felling site is as follows:

$$y_{OE1} = -0,508557 + 0,236151 \cdot q + 0,016905 \cdot l + 0,104514 \cdot p - 0,003676 \cdot n \quad (9)$$

In case of the monitored sample, the average load volume q = 1.328 m^3, while the mean skidding distance l = 205.1 m. The average terrain inclination p = 3.6%, while the average number of pieces in the tractor load is n = 5.4. The time of the loaded E1 is 3.36 minutes. The coefficient of multiple correlation R = 0.94193373 of the loaded E1 tractor on the skid trail and felling site shows perfect correlation.

Table 19 Regression indices and regression equation parameters of the loaded E1 tractor driving times over skid trail and felling site.

Tablica 19. Pokazatelji regresije i parametri regresijske jednadžbe vremena vožnje opterećenog traktora E1 po vlaci i sječini

N=136	ion Summary for Dependent Variable: Var4 (Spreadsheet10 in ECO1) R= ,94193373 R2= ,88723914 Adjusted R2= ,88379606 F(4,131)=257,69 p<0,0000 Std.Error of estimate: ,72729				
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(13
Indepedent member/*Nezavisni član*, b0			-0,508557	0,427508	-1,189
Number pieces/*Broj komada*, n (kom)	-0,002877	0,029754	-0,003676	0,038021	-0,096
Load volume/*Obujam tovara*, q (m3)	0,028308	0,032701	0,236151	0,272794	0,865
Distance/*Udaljenost*, l (m)	0,953347	0,033276	0,016905	0,000590	28,649
Inclination terrain/*Nagib puta*, p (%)	0,101717	0,030958	0,104514	0,031809	3,285

UNLOADED DRIVING TIME OF TRACTOR E1 ON THE SKID TRAIL AND FELLING SITE

VRIJEME VOŽNJE NEOPTEREĆENOG TRAKTORA E1 NA VLACI I SJEČINI

Unloaded driving time of Tractor E1 on the skid trail and felling site was considered dependent on the independent variables of the skidding distances and slope. Table 20 shows the regression values and equation parameters (column B) of unloaded driving times E1 over skid trail and felling site.

Table 20 Regression indices and regression equation parameters of the unloaded driving times of Tractor E1 over skid trail and felling site

Tablica 20. Pokazatelji regresije i parametri regresijske jednadžbe vremena vožnje neopterećenog traktora E1 po vlaci i sječini

N=137	ion Summary for Dependent Variable: Var3 (Spreadsheet2 in Ecotrac1Ivanska-pra R= ,92932969 R2= ,86365368 Adjusted R2= ,86161866 F(2,134)=424,40 p<0,0000 Std.Error of estimate: ,59516				
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(134)
Indepedent member/*Nezavisni član*, b0			-0,461263	0,150675	-3,0613
Distance/*Udaljenost*, l (m)	0,952516	0,032820	0,012628	0,000435	29,0223
Inclination terrain/*Nagib puta*, p (%)	0,142854	0,032820	0,110390	0,025362	4,3526

The equation of the unloaded tractor time calculation during the downhill drive, on skid trail and felling site is as follows:

$$y_{NE1} = -0,461263 + 0,012628 \cdot l + 0,110390 \cdot p \qquad (10)$$

In case of the monitored sample, the mean skidding distance is l = 202.1 m, while the average terrain inclination is p = 3.6 %. Based on Equation 10, the unloaded tractor E1 drive over skid trail and felling site is 2.494 minutes. The coefficient of the multiple correlation is R = 0.92932969, showing a perfect correlation of the measured and adjusted time.

LOADED DRIVING TIME OF TRACTOR E1 ON LANDING
VRIJEME VOŽNJE OPTEREĆENOG TRAKTORA E1 NA POMOĆNOM STOVARIŠTU

Loaded driving time on landing was monitored in dependence of the independent variables: load volume, skidding distance and number of pieces in the load. The skidding took place on a macadam road. The processing of the described variables distribution of the loaded driving was carried out in the same way as with the one on skid trails and felling sites. Based on the load volume distribution and the number of pieces in the load, the computer programme chooses the most suitable form of the mathematical calculation of the loaded tractor times on landing.

Table 21 presents the regression indices and the parameters of the mathematical regression model, i.e. the equation of Tractor E1.

Table 21 Regression indices and parameters of mathematical regression model of the loaded E1 tractor driving on landing

Tablica 21. Pokazatelji regresije i parametri regresijske jednadžbe vremena vožnje opterećenog traktora E1 po pomoćnom stovarištu

N=136	Beta	Std.Err. of Beta	B	Std.Err. of B	t(132)
Indepedent member/*Nezavisni član*, b0			0,080435	0,125699	0,63990
Number pieces/*Broj komada*, n (kom)	-0,056151	0,061436	-0,011577	0,012666	-0,91398
Load volume/*Obujam tovara*, q (m3)	0,115933	0,062035	0,147183	0,078757	1,86883
Distance/*Udaljenost*, l (m)	0,684463	0,061775	0,015644	0,001412	11,07990

Regression Summary for Dependent Variable: Var4 (Spreadsheet2 in I-E1, stov-pun.s
R= ,71138245 R2= ,50606499 Adjusted R2= ,49483919
F(3,132)=45,081 p<0,0000 Std.Error of estimate: ,23427

The mathematical expression of the loaded E1 driving on landing is presented by the following equation:

$$y_{E1o} = 0{,}080435 + 0{,}147193 \cdot q + 0{,}015644 \cdot l - 0{,}011577 \cdot n \qquad (11)$$

The calculation of the times in Equation 11 consists an average load volume of q = 1.332 m^3, the mean skidding distance 1 = 35.1 m, and an average number of pieces in the load n = 5.4. The calculated loaded driving time of E1 was 0.764 minutes.

UNLOADED DRIVING TIME OF TRACTOR E1 ON LANDING
VRIJEME VOŽNJE NEOPTEREĆENOG TRAKTORA E1 NA POMOĆNOM STOVARIŠTU

The same model of multiple linear regression that was used in preceding calculations was used in the processing of the unloaded tractor driving on landing. The unloaded driving times were processed with only one independent variable, i.e. with the driving distance. An unloaded tractor moves over forest roads. The regression indices and parameters of regression equations are presented in Table 22. The red colour marks significant parameters of the regression function for the calculation of the unloaded tractor driving time on the landing, while the black colour marks insignificant parameters.

Table 22 Regression indices and parameters of regression equations of the unloaded Tractor E1 driving time on landing

Tablica 22. Pokazatelji regresije i parametri regresijske jednadžbe vremena vožnje neopterećenog traktora E1 po pomoćnom stovarištu

N=128	ression Summary for Dependent Variable: Var2 (Spreadsheet2 in I-E1, PS R= ,69824455 R2= ,48754545 Adjusted R2= ,48347835 F(1,126)=119,88 p<0,0000 Std.Error of estimate: ,14540					
	Beta	Std.Err. of Beta	B	Std.Err. of B	t(126)	p-level
Indepedent member/*Nezavisni član*; b0			0,152107	0,030711	4,95280	0,000002
Distance/*Udaljenost*,l (m)	0,698245	0,063774	0,010057	0,000919	10,94877	0,000000

Table 22 contains the E1 data. The following is the equation for the unloaded driving time of E1 on landing:

$$y_{E1n} = 0{,}152107 + 0{,}010057 \cdot l \qquad (12).$$

According to Equation 12, the unloaded driving time of E1 is 0.457 minutes. An average driving distance is 1 = 30.4 m.

LOADED DRIVING TIME OF TRACTOR E2 ON SKID TRAIL AND FELLING SITE
VRIJEME VOŽNJE OPTEREĆENOG TRAKTORA E2 NA VLACI I SJEČINI

The time analysis of the loaded E2 tractor by using multiple linear regression – same as with Tractor E1 – used the same independent variables: load volume, skidding distance, average slope, and the number of pieces in the load. Multiple regression analysis was also used in data processing. The loaded E2 moved uphill under the same conditions as the first tractor. Computer-aided with Statistica 6 and applying the database, independent variable parameters were calculated. The time use equation (YOE2) of the loaded E2 on skid trail and felling site is as follows:

$$y_{OE2} = -0,417294 + 0,710050 \cdot q + 0,019550 \cdot l + 0,094665 \cdot p - 0,032880 \cdot n \qquad (13)$$

In 107 tractor cycles, an average load volume is q = 1.485 m^3; mean skidding distance 1= 254.7 m; mean average terrain inclination p= 5.0%, and an average number of pieces in the tractor load is n = 5.90 minutes. The coefficient of multiple correlation R = 0.85508191 of the loaded E2 on skidd trail and felling site shows a very strong correlation.

UNLOADED DRIVING TIME OF TRACTOR E2 ON SKID TRAIL AND FELLING SITE
VRIJEME VOŽNJE NEOPTEREĆENOG TRAKTORA E2 NA VLACI I SJEČINI

The unloaded driving time E2 on skid trail and felling site was monitored in dependence with the skidding distance and slope. The equation of the unloaded E2 time on skid trail and felling site is the following:

$$y_{NE2} = 0,669522 + 0,011849 \cdot l - 0,004239 \cdot p \qquad (14)$$

With a mean skidding distance of 1 = 253.3 m and an average terrain inclination of p = 5.0%, the unloaded E2 time on skid trail and felling site as calculated by Equation 14 is 3.649 minutes. A very strong correlation is presented by the coefficient of multiple correlation R = 089854920.

LOADED DRIVING TIME OF TRACTOR E2 ON LANDING
VRIJEME VOŽNJE OPTEREĆENOG TRAKTORA E2 NA POMOĆNOM STOVARIŠTU

Loaded driving time on landing was monitored in dependence of the following: load volume, skidding distance and the number of pieces in the load. The skidding also took place on a macadam road. The processing of the described variables distribution of the loaded driving was carried out in the same way as with the one on skid trails and the felling site. Based on the load volume distribution and the number of pieces in the load, the computer programme chooses the most suitable form of the mathematical calculation of the E2 loaded tractor times on the landing. The mathematical expression of the loaded driving time of E2 on the landing is expressed by the following equation:

$$y_{E2o} = 0{,}171592 + 0{,}059979 \cdot q + 0{,}017412 \cdot l - 0{,}007716 \cdot n \qquad (15)$$

The calculation of the times in Equation 15 consists of an average load volume of q = 1.485 m^3, the mean skidding distance l = 37.3 m, and an average number of pieces in the load n = 5.9. The calculated loaded driving time of E2 was 0.855 minutes

UNLOADED DRIVING TIME OF TRACTOR E2 ON LANDING
VRIJEME VOŽNJE NEOPTEREĆENOG TRAKTORA E2 NA POMOĆNOM STOVARIŠTU

The processing of the unloaded tractor time on the landing is the same as in the preceding ones. The unloaded driving times were processed with only one independent variable, i.e. with the driving distance. An unloaded tractor moves over forest roads. The following equation is used for the calculation of the unloaded driving time of E2 on landing:

$$y_{E2n} = 0{,}110627 + 0{,}012122 \cdot l \qquad (16).$$

The unloaded time of E2 according to Equation 16 is 0.567 minutes. The mean driving distance was l = 37.7 m.

CUTTERS' TIMES AT PROCESSING AND CUSTOMIZING WOOD ASSORTMENTS

VREMENA SJEKAČA-PREUZIMAČA PRI DORADI I PREUZIMANJU DRVNIH SORTIMENATA

This subchapter will present the workers' times at processing and customizing wood assortments. The effective (used) time of the workers who process and customize wood assortments is related with the volume and number of pieces of the processed wood assortments. A detailed descriptive statistics was developed with an optimal model of effective time dependence on the wood volume and the number of pieces. A model of multiple linear regression best describes the behaviour of the cutters-customers.

Table 23 contains the data, i.e. the dependent and independent variables of the cutter-customer (PS). These descriptive data are summarised in Table 24, and the regression model indices of mathematical equations are in Table 25.

Table 23 One part of the variable base of the cutter-customer at processing and customizing the wood assortments at the landing

Tablica 23. Prikaz dijela baze varijabli sjekača-preuzimača (PS) pri doradi i preuzimanju drvnih sortimenata na pomoćnom stovarištu

Number of work operations *Broj radnih operacija*	Dependent/independent variables / *Zavisne/nezavisne varijable*			
	Consumption time *Utrošeno vrijeme*	Number of pieces *Broj komada*	Wood volume *Drvni obujam*	Adjusted time *Izjednačeno vrijeme*
	y_i	n_p	q_p	y_{iz}
	min	kom	m^3	min
1	6.45	6	1.205	2.77
2	2.90	4	1.558	3.30
3	2.30	12	1.237	2.85
4	5.14	11	1.586	3.38
5	5.33	13	2.173	4.29
6	3.39	12	1.446	3.17
7	3.64	11	1.493	3.24

At the Ivanska site, the cutter-customer carried out the processing and customizing of the wood assortments at the landing. In this team, the foreman is daily present whilethe cutter-customer processed and customized the wood assortments. When the load arrived, he separated the long wood from technical wood. The tractor continued to skid technical wood and unloaded it on the corresponding place.

Table 24 Descriptive statistics of the basic distributions: effective time, number of pieces, and the wood volume of the cutter-customer at processing and customizing the wood assortments

Tablica 24. Opisna statistika temeljnih raspodjela: efektivnog vremena, broja komada, i drvnog obujma sjekača-preuzimača pri doradi i preuzimanju drvnih sortimenata

Cutter-customer *Oznaka sjekača-pruzimača*	Variables *Varijable*	Number of surveys *Broj opažanja*	Arithmetic means *Aritmetička sredina*	Minimum value *Najmanja vrijednost*	Maximum value *Najveća vrijednost*	Standard deviation *Standardna devijacija*
		N	x	min	max	s_x
PS	Effective time *Efektivno vrijeme*, y_{ps}	245	3.09845	0.160000	6.73000	1.143173
	Number of pieces *Broj komada*, n_p (kom)	245	10.37959	3.000000	19.00000	3.217331
	Grasp volume *Obujam zahvata*, q_p (m^3)	245	1.40390	0.534326	2.70869	0.291636

Table 24 contains the descriptive statistics encompassing the total number of loads/pieces (N), the medium, minimum, and maximum variables, and the standard deviation. The column of number of loads/pieces (N) contains the number of the work operations. Two tractors realised a total of 256 cycles. The worker on the landing processed two tractor loads simultaneously in eleven cases. In this way, instead of 256 loads, the cutter-customer was surveyed in 245 work operations with an average wood assortments volume of 1,404 m^3, with an average 10.4 customized pieces and an average used effective time of 3.10 minutes.

According to the distribution of the number of pieces/volume of the processed wood assortments, with the descriptive statistics value (Table 24), the computer programme chose the most favourable form of the mathematical calculation of the cutter-customer effective time.

Table 25 Regression indices and parameters of the effective time regression equation of the cutter-customer PS on the Ivanska landing.

Tablica 25. Pokazatelji regresije i parametri regresijske jednadžbe efektivnog vremena sjekača-preuzimača PS na pomoćnom stovarištu Ivanska

	ion Summary for Dependent Variable: yl-PS (Spreadsheet8 in Pomocno-D-Ivar R= ,39596682 R2= ,15678972 Adjusted R2= ,14982104 F(2,242)=22,499 p<,00000 Std.Error of estimate: 1,0541				
N=245	Beta	Std.Err. of Beta	B	Std.Err. of B	t(242)
Indepedent member/*Nezavisni član*, bc			0,890667	0,351426	2,534435
Number pieces/*Broj komada*, n1 (kom)	0,016417	0,062617	0,005833	0,022249	0,262182
Wood volume/*Drvni obujam*, q1 (m3)	0,390186	0,062617	1,529477	0,245450	6,231311

Based on the regression indices and the parameters of the effective time regression equations, the mean effective time of the average realised value of the number of pieces and the customized wood volume is calculated. This was carried out on the Ivanska site as follows:

$$y_{PS} = 0,890667 + 0,005833 \cdot n_1 + 1,529477 \cdot q_1 \ldots (\text{min}) \qquad (17).$$

The calculated effective time with the monitored sample of the average number of pieces n_p = 10.4 and the average volume q_p = 1.404 m^3, using equation 17, was 3.10 minutes. The correlation coefficient R = 0.39596682 after Roemer-Orphal's scale shows a medium correlation strength.

WOOD STACKING TIMES ON THE LANDING
VREMENA SLAGANJA DRVA NA POMOĆNOM STOVARIŠTU

This subchapter will present the crane tractor times at stacking long timber. The effective time of the crane tractor is considered in relation to the volume and the number of long stacked wood pieces (Table 26). A detailed descriptive statistics was developed for this crane tractor, and an optimal dependence model of the effective time and the volume (number of pieces was obtained. The model of multiple linear regression was also applied here, as it best describes the behaviour of the crane tractor. Table 27 contains the descriptive statistics encompassing the total number operations, medium, minimum and maximum variable values, and the standard devia-

Figure 8 A crane tractor during long timber stacking on the landing
Slika 8. Traktor s dizalicom (DZ) pri slaganju višemetarskog drva na pomoćnom stovarištu

tion. On the Ivanska site, the crane tractor realised 511 stacking cycles. The volume of the work operation ranged from 0.05 m^3 to 0.97 m^3, or an average of 0.41 m^3. One crane grasp included 1 – 9 pieces, or an average of 3.9 pieces. The effective time ranged from 0.25 minutes to 3.43 minutes, or an average of 1.12 minutes.

Table 26 One part of the variable database of the crane tractor
Tablica 26. Prikaz dijela baze podataka varijabli traktora s dizalicom (DZ)

Number of work operations *Broj radnih operacija*	Dependent/independent variables *Zavisne/nezavisne varijable*			
	Grasp volume *Obujam zahvata*	Number of pieces *Broj komada*	Consumption time *Utrošeno vrijeme*	Adjusted time *Izjednačeno vrijeme*
	q_{DZ}	n_{DZ}	y_i	y_{iz}
	m^3	kom	min	min
1	0.232	2	0.95	0.88
2	0.865	1	0.33	1.00
3	0.368	6	2.10	1.32
4	0.869	6	0.48	1.49
5	0.511	4	1.40	1.17
6	0.707	5	0.50	1.33
7	0.338	2	1.90	0.92

Table 27 Descriptive statistics of the basic distributions: effective time, number of pieces, and the grasp volume of the crane tractor at stacking long timber
Tablica 27. Opisna statistika temeljnih raspodjela: efektivnog vremena, broja komada i obujma zahvataja za traktor s dizalicom (DZ) pri slaganju višemetarskog prostornog drva

Crane tractor *Oznaka traktora s dizalicom*	Variable *Varijable*	Number of grasps *Broj zahvataja*	Arithmetic means *Aritmetička sredina*	Minimum value *Najmanja vrijednost*	Maximum value *Najveća vrijednost*	Standard deviation *Standardna devijacija*
		N	x	min	max	s_x
DZ	Load volume *Obujam tovara,* q_{DZ} (m^3)	511	0.411485	0.053000	0.974970	0.158181
	Number of pieces *Broj komada,* n_{DZ} (kom)	511	3.868885	1.000000	9.000000	1.363542
	Effective time *Efektivno vrijeme,* y_{DZ}	511	1.122290	0.250000	3.430000	0.602261

Based on the distribution of the grasp wood volume, the number of pieces, and the value of the descriptive statistics, the computer programme chose the most favourable form of the mathematical calculation of the effective crane tractor time. Table 28

shows the data of the regression analysis and the mathematical equation parameters for the calculation of the crane tractor effective time at piling long stacked wood.

Table 28 Regression indices and regression equations of the crane tractor effective time at piling long stacked timber on the landing

Tablica 28. Pokazatelji regresije i parametri regresijske jednadžbe efektivnog vremena traktora s dizalicom DZ pri slaganju višemetarskog drva na pomoćnom stovarištu

| | egression Summary for Dependent Variable: Var3 (Spreadsheet2 in Workbook
R= ,27878264 R2= ,07771976 Adjusted R2= ,07408873
F(2,508)=21,404 p<,00000 Std.Error of estimate: ,57952 | | | | |
|---|---|---|---|---|---|
| N=511 | Beta | Std.Err. of Beta | B | Std.Err. of B | t(508) |
| Indepedent member/*Nezavisni član*, b0 | | | 0,605723 | 0,083856 | 7,22337 |
| Grasp volume/*Obujam zahvata*, q2 (m3) | 0,089244 | 0,050525 | 0,339790 | 0,192370 | 1,76633 |
| Number of pieces/*Broj komada*, n2 (kom | 0,220470 | 0,050525 | 0,097379 | 0,022316 | 4,36356 |

The following equation of the general regression form and the effective time calculation is based on the previous statistical data processing. On the Ivanska site, the general mathematical model of the crane tractor effective time is expressed by this equation:

$$y_{DZ} = 0,083965 + 0,339790 \cdot q_2 + 0,097379 \cdot n_2 \ldots (\text{min}) \qquad (18).$$

With an average crane grasp volume of q_{DZ} = 0.411 m^3 and an average number of pieces n_{DZ} = 3.9, the effective time by equation 18 amounts to 1.12 minutes.

TRACTOR CYCLE TIMES
VREMENA TURNUSA TRAKTORA

DISTRIBUTION OF THE EFFECTIVE TRACTOR CYCLE TIME
RASPODJELA EFEKTIVNOG VREMENA TURNUSA TRAKTORA

A tractor tour consists of four cyclic work operations. Two of them are considered as variable time, another two as fixed time. The times of loaded and unloaded drive are variable times, while the work on the felling site and the landing are considered as fixed times.

The average used effective time per one cycle (E1) was 17.05 minutes and 24.50 minutes (E2) respectively. The respective fixed times were 9.74 min/tour and 13.94 min/tour. Within fixed times, the work on the felling site required between 7.16 min/cycle (E1) and 11.23 min/ cycle (E2). Working on the landing, Tractor E1

needed 2.58 min/tour, while E2 needed 2.68 min/ cycle of the effective times. The use of the fixed tractor cycle times was, as a rule, higher when compared to the variable times. With the monitored tractors, the use of the fixed time was 57.14% (E1) and 56.76% (E2) of the effective time. The work on the felling site used the most of the effective time. Tractor E1 spent 42.02%, while E2 spent 45.83% of the effective time for the work on the felling site.

Load binding used the most time. Tractor driver (E1) spent 8.42%, while the cutter needed 9.02%, or a total of 17.44% of the effective time. The respective values of E2 were 7.57%, 17.38%, and 24.95%.

Wire rope uncoiling and winching are presented as fixed times. On the Ivanska site, the wire rope was uncoiled at an average length of 21.2 m (E1), taking 6.18% of the effective time, while winching took 7.16% of it. The respective values of tractor E2 were 36.9 m, 4.07%, and 5.24%.

VARIABLE TRACTOR CYCLE TIMES
VARIJABILNA VREMENA TURNUSA TRAKTORA

In the calculation of the tractor tour times, the previously presented mathematical models (equations) were used, while the fixed times were calculated as the average used time. Table 29 contains the mathematical model parameters of the variable time calculation of the E1 tractor tour. The general form of this equation is

$$T_v = t_{nv} + t_{ov} + t_{nps} + t_{ops} \ldots (\text{min}) \qquad (19),$$

where Tv = variable time, t_{nv} = unloaded tractor drive on skid trail and felling site, t_{ov} = loaded tractor drive on skid trail and felling site; t_{nps} = unloaded tractor drive on landing, and t_{ops} – loaded tractor drive on landing.

The first tractor (E1) is presented here, while the second one has also been processed in this way.

Table 29 presents the calculation of the variable tractor (E1) cycle time of the distances from 150m to 650 m, with an average load volume of 1.33 m³. The tractor moved downhill upon wet soil, and an average inclination of 3.6%. The load contained an average of 5.4 pieces. The effective loaded driving time on skid trail and felling site ranged from 1.85 minutes (100 m) to 10.30 minutes (600 m). The unloaded tractor spent from 1.20 minutes to 7.51 minutes over the same distances. The loaded tractor on the landing needed 1.00 minutes for covering 50 m, while the unloaded one needed 0.65 minutes.

Table 29 A case of variable time calculation (T_{vEl}) of tractor cycle E1
Tablica 29. Primjer izračuna varijabilnog vremena (T_{vEl}) turnusa traktora E1

Mathematical model parameters *Parametri matematičkog modela*									
Independent member *Nezavisni član*	Load volume, q *Obujam tovara, q*		Distance, l *Udaljenost, l*		Slope, p *Nagib puta, p*		Number of pieces, n *Broj komada, n*		Time, T_v *Vrijeme, T_v*
b_0	b_1	m^3	b_2	m	b_3	%	b_4	kom	min
Loaded tractor driving time on skid trail and felling site, t_{ov} (yO) *Vrijeme vožnje opterećenog traktora po vlaci i sječini, t_{ov} (yO)*									
-0.508557	0.236151	1.33	0.016905	100	0.104514	3.6	-0.003676	5.4	1.85
				200					3.54
				300					5.23
				400					6.92
				500					8.61
				600					10.30
Unloaded tractor driving time on skid trail and felling site, t_{nv} (yN) *Vrijeme vožnje neopterećenog traktora po vlaci i sječini, t_{nv} (yN)*									
-0.461263			0.012628	100	0.11039	3.6			1.20
				200					2.46
				300					3.72
				400					4.99
				500					6.25
				600					7.51
Loaded tractor driving time on landing, t_{ops} (y_o) *Vrijeme vožnje opterećenog traktora po pomoćnom stovarištu, t_{ops} (y_o)*									
0.080435	0.147193	1.328	0.015644	50			-0.011577	5.4	1.00
Unloaded tractor driving time on landing, t_{nps} (y_n) *Vrijeme vožnje neopterećenog traktora po pomoćnom stovarištu, t_{nps} (y_n)*									
0.152107			0.010057	50					0.65
Total variable cycles times *Ukupna varijabilna vremena turnusa*									
				150					4.70
				250					7.65
				350					10.61
				450					13.56
				550					16.51
				650					19.47

TOTAL TRACTOR CYCLE TIME
UKUPNO VRIJEME TURNUSA TRAKTORA

With the tractor cycle time equalling the product of effective time (T_e) and added time factor (k_d), the equation is

$$T_u = T_e \cdot k_d \ldots (\text{min}) \quad (20),$$

with T_u = total tractor cycle time; T_e = effective time of tractor cycle, and k_d = added time factor.

The effective tractor tour time (Te) was calculated using the equation

$$T_e = T_v + T_f \ldots (\text{min}) \quad (21),$$

with T_e = effective tractor cycle time; Tv variable tractor cycle time, and T_f = fixed tractor cycle time.

According to the mentioned mathematical models and the effective parameters (load volume, inclination, distance, and number of pieces), we can model, i.e. calculate the required time for similar conditions of tractor work.

To calculate the fixed tractor cycle time, we use

$$T_f = t_u + t_i \ldots (\text{min}) \quad (22),$$

with T_f = fixed cycle time; t_u = loading time (tractor work on felling site), and t_i = unloading time (tractor work on landing).

Table 30 contains the tractor cycle time distribution in minutes with driving distances between 100 m and 600 m, over skid trails and felling site, and on the landing, at an average distance of 50 m. The same table presents the added time factors and the total tractor cycle time for the given distances. The added time factor amounts to 1.30 (E1) and 1.28 (E2), with an average value of 1.29.

Table 30 Tractor cycle time distribution per skidding distance with the use of the mathematical model of the variable times calculation

Tablica 30. Raspodjela vremena turnusa traktora prema udaljenosti privlačenja uz primjenu matematičkih modela izračuna varijabilnih vremena

Tractor/ *Oznaka traktora*	Variable times/ *Varijabilna vremena*					Fixed times *Fiksna vremena*			Total effective time *Ukupno efektivno vrijeme*	Added time factor/ *Faktor dodatnog vremena*	Total cycle time/ *Ukupno vrijeme turnusa*
	Skid trail and felling site *Vlaka i sječina*		Landing *Pomoćno stovarište*		Total time/ *Ukupno vrijeme*						
	Drive/ *Vožnja*										
	unloaded *neopterećenog*	loaded/ *opterećenog*	unloaded/ *neopterećenog*	loaded/ *opterećenog*		Work on felling site *Rad na sječini*	Work on landing *Rad na pom. stov.*	Total time *Ukupno vrijeme*			
	Tractor/traktora										
	t_{nv}	t_{ov}	t_{nps}	t_{ops}	T_v	t_u	t_i	T_f	T_e	k_d	T_u
	Min										min
Distance/ *Udaljenost*, 150 m											
E1	1.20	1.85	0.65	1.00	4.70	7.16	2.58	9.74	14.44	1.30	18.77
E2	1.83	2.87	0.72	1.09	6.51	11.23	2.68	13.91	20.42	1.28	26.14
Distance/ *Udaljenost*, 250 m											
E1	2.46	3.54	0.65	1.00	7.65	7.16	2.58	9.74	17.39	1.30	22.61
E2	3.02	4.83	0.72	1.09	9.66	11.23	2.68	13.91	23.57	1.28	30.17
Distance/ *Udaljenost*, 350 m											
E1	3.72	5.23	0.65	1.00	10.60	7.16	2.58	9.74	20.34	1.30	26.44
E2	4.20	6.78	0.72	1.09	12.79	11.23	2.68	13.91	26.70	1.28	34.18
Distance/ *Udaljenost*, 450 m											
E1	4.99	6.92	0.65	1.00	13.56	7.16	2.58	9.74	23.30	1.30	30.29
E2	5.39	8.74	0.72	1.09	15.94	11.23	2.68	13.91	29.85	1.28	38.21
Distance/Udaljenost, 550 m											
E1	6.25	8.61	0.65	1.00	16.51	7.16	2.58	9.74	26.25	1.30	34.13
E2	6.57	10.69	0.72	1.09	19.07	11.23	2.68	13.91	32.98	1.28	42.21
Distance/ *Udaljenost*, 650 m											
E1	7.51	10.30	0.65	1.00	19.46	7.16	2.58	9.74	29.20	1.30	37.96
E2	7.76	12.65	0.72	1.09	22.22	11.23	2.68	13.91	36.13	1.28	46.25

LOADED AND UNLOADED TRACTOR SPEEDS
BRZINE OPTEREĆENIH I NEOPTEREĆENIH TRAKTORA

The speeds of loaded and unloaded tractors is calculated on the basis of the variable time values presented in Tables 29 and 30. Tractor speed is the function of

the covered distance and used time. The following equation is used to calculate tractor speed:

$$v = \frac{l}{t} \ldots \left(m/\min\right) \tag{23},$$

where v = speed (m/min), 1 = distance (m), t = driving time (minutes).

Only general forms of formulae for speed calculation are shown here, and the calculated values are shown in Figures 9 and 10. To calculate loaded tractor speed on skid trail, we use the following equation:

$$v_{ov} = \frac{l_{ov}}{t_{ov}} \cdot \left(\frac{60}{1000}\right) \ldots \left(km/h\right) \tag{24},$$

with v_{ov} = loaded tractor drive on skid trail and felling site; l_{ov} = skidding distance of loaded tractor, and t_{ov} = loaded driving time

If we replace t_{ov} with mathematical model parameters, then we shall use

$$v_{ov} = \left(\frac{l_{ov}}{\left(b_0 + b_1 \cdot q + b_2 \cdot l_{ov} + b_3 \cdot p_{ov} + b_4 \cdot n\right)}\right) \cdot \left(\frac{60}{1000}\right) \ldots \left(km/h\right) \tag{25},$$

where v_{ov} = speed of loaded tractor on skid trail and felling site; q = load volume; l_{ov} = skidding distance; p_{ov} = slope, and n = number of pieces in tractor load.

The calculation of tractor speed in other work operations, corresponding mathematical time models are used.

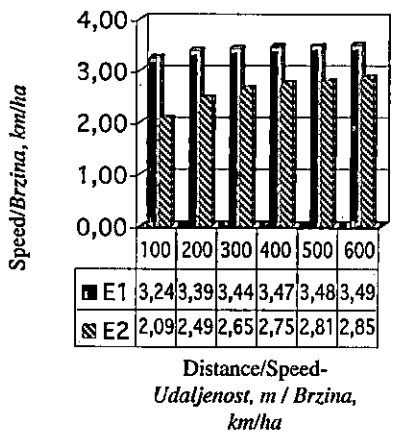


Figure 9 Loaded tractor speeds on skid trail and felling site

Slika 9. Brzine opterećenih traktora na vlaci i sječini

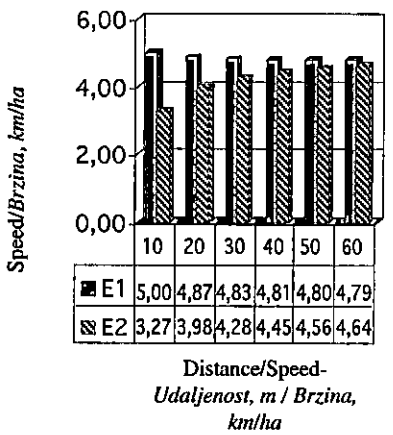


Figure 10 Unloaded tractor speeds on skid trail and felling site.

Slika 10. Brzine neopterećenih traktora na vlaci i sječini

Loaded tractor speed on skid trail and felling site are calculated by formula 25, as presented in Figures 9 and 10. Tractors E1 and E2 move uphill. Speed rises in proportion with rising distance. At a distance of 100 m, loaded tractor speed amounts to 2.09 km/h (E2) and 3.24 km/h (E1). At a distance of 600 m, the respective values are 2.85 km/h and 3.49 km/h. At a distance of 100 m, unloaded tractors move at a speed of 3.27 km/h (E2) and 5.00 km/h (E1). At the distance of 600 m, they move at 4.64 km/h and 4.79 km/h respectively. With unloaded E1 on skid trail and felling site, the speed slightly falls in proportion with rising distance.

Average unloaded tractor speed on skid trails and felling site amount to 4.82 km/h (E1) and 4.38 km/h (E2) respectively. The same values with loaded tractors were 3.45 km/h (E1) and 2.71 km/h (E2). Krpan (1984) wrote that the speed of unloaded tractor IMT 558 under lowland conditions in rainless days was 4.93 km/h on hillock; 6.77 km/h was the this value on lowland, and 5.33 km/h – 6.38 km/h on rainy days.

STANDARD TIME AND OUTPUT OF TEAMWORK
NORME VREMENA I UČINKA SKUPINE

CUTTERS' STANDARD TIME AND DAILY OUTPUT
NORME VREMENA I DNEVNI UČINAK SJEKAČA

A cutter's standard time is expressed as the used felling and tree processing time per product unit (m^3). In the team, two cutters (S1 and S2) simultaneously cut and processed trees. The work developed in pair (cutter + tractor), using a combined method of felling and tree processing characteristic for teamwork. The customizing of wood assortments was carried out on the landing.

Table 31 Cutters' effective and delay times at felling, tree processing, and load binding per product unit (m^3) and tree

Tablica 31. Prikaz utrošenog efektivnog i općih vremena sjekača pri sječi i izradbi stabala te na vezanju tovara traktora po jedinici proizvoda (m^3) i po stablu

Cutters/ *Sjekači*	Number of trees *Broj stabala*	Average net tree volume *Prosječni neto obujam stabla*	Preparation and binding of load *Priprema i vezanje tovara*		Felling and processing *Sječa i izradba*						Total time of felling and processing + load binding *Ukupno vrijeme sječe i izradbe + vezanje tovara*	
					Effective time *Efektivno vrijeme*		Delay times *Opća vremena*		Total time *Ukupno vrijeme*			
	kom	m^3	min/m^3	min/st.	min/m^3	min/st.	min/m^3	min/st.	min/m^3	min/st.	min/m^3	min/st.
S1	273	0.673	1.29	0.87	7.98	5.37	15.13	10.18	23.11	15.55	24.40	16.42
S2	289	0.733	2.32	1.70	8.09	5.93	11.02	8.08	19.11	14.01	21.43	15.71

Table 31 contains the data on the effective and delay times of cutters at felling and tree processing, with the use of effective time at tractor load binding. The same table contains the number of the simultaneously cut and processed trees. There are also the data on the net volume of the cut and processed tree. The work on preparation and load binding is the component part of the work organisation of one worker team. The load binding time is shown in Table 8, calculated so that the total time used for preparation and load binding is divided by the total number of cut trees. The cutters (S1) used 0.91 min/tree for load binding, and 1.76 min/tree (S2), or 1.29 min/m^3 and 2,32 min/m^3.

Table 32 contains the data on cutters' average used time per day, and the time used for felling, processing and load binding per product unit. There is also the average realised daily output and the possible daily output for the prescribed 480 minutes/day.

Table 32 Cutter's used time and daily output at felling, processing and load binding
Tablica 32. Utrošeno vrijeme i dnevni učinak pri sječi, izradbi i vezanju tovara sjekača

Cutters *Sjekači*	Variant 1 *Inačica 1*			
	Average used time *Prosječno utrošeno vrijeme*	Used time (felling and processing+load binding) NV_{s1} *Utrošeno vrijeme (sječa i izradba + vezanje tovara), NV_{s1}*	Realised daily output, DU_{s1} *Ostvareni dnevni učinak, DU_{s1}*	Daily output (DU_{s2}), in 480 minutes *Dnevni učinak, (DU_{s2}) za 480 min*
	min/dan	min/m^3	m^3/dan	m^3/dan
1	2	3	4	5
S1	408.35	24.40	16.73	19.67
S2	414.21	21.43	19.33	22.40

Table 33 presents the calculated values of both cutters. The mathematical model parameters are taken from Formulae 7 and 8, while the mean values of DBH and tree height are taken from Table 16. The calculated effective time relates only to the time used for felling and processing per tree. The effective time used for load binding per tree is shown in Table 33. The calculation of the realised time (Table 32) and the realised daily output will be used in further discussion, according to the variants 1 and 2 (Tables 32 and 33), in the determination of the work success of the individual teams.

Table 33 contains the data on the effective and total times of felling, processing and load binding (Variant 2). The same table shows the coefficient of added time of each cutter and totally per tree.

The effective time of felling, processing and load binding per tree was calculated by using

$$I_{eu} = (b_0 + b_1 \cdot d_{1,30} + b_2 \cdot h) + I_f \ldots (\min) \quad (26),$$

where I_{eu} = total effective cutter's time; I_f = average used load binding time.

Total time used for cutting, processing and load binding per tree was calculated by using

$$I_u = ((b_0 + b_1 \cdot d_{1,30} + b_2 \cdot h) + I_f) \cdot k_d \ldots (\min) \quad (27),$$

where I_u = total cutter's time; I_f = average used time for load binding; k_d = additional cutter's time factor

Net tree volume was calculated by dividing the total volume of processed wood assortments by the number of cut and processed trees. The standard time (NV_s) for Variant 2 was calculated by dividing the total time per tree (I_{u2}) by the net tree volume (q_n), i.e. by

$$NV_s = \frac{I_u}{q_n} \ldots \left(\min/m^3\right) \quad (28),$$

where NV_s = cutter's standard time; I_u = cutter's total time, and q_n = net tree volume.

If we include all relevant parameters of the mathematical model for the norm calculation of the felling time, processing and load binding, we get the equation

$$\frac{((b_0 + b_1 \cdot d_{1,30} + b_2 \cdot h) + I_f) \cdot k_d}{q_n} \ldots \left(\min/m^3\right) \quad (29),$$

where NV_s = cutter's standard time; I_f = average time used for load binding; q_n = net tree volume, and k_d = cutter's added time factor.

The daily effect of the prescribed work time of 480 minutes was calculated according to the following:

$$DU_s = \frac{480}{NV_s} \ldots \left(m^3/dan\right) \quad (30),$$

where DU_s = cutter's daily effect, and NV_s = cutter's standard time.

The effective time per product unit was calculated using the effective time used for felling and tree processing, and the average net tree volume (Table 32). Cutters use 7.98 min/ m³ (S1) of the effective time for felling and tree processing and 8.09 min/ m³ (S2) respectively.

Table 33 Standard time and daily output at felling, processing and load binding in Variant 2
Tablica 33. Norma vremena i dnevni učinak pri sječi, izradbi i vezanju tovara za inačicu 2

Cutter *Oznaka sjekača*	Variant 2 *Inačica 2*							
	Effective time *Efektivno vrijeme*, I_e	Load binding *Vezanje tovara*, I_f	Total effective time *Ukupno efektivno vrijeme*, I_{ef}	Factor of added time *Faktor dodatnog vremena*	Total time *Ukupno vrijeme*, I_{u2}	Net tree volume *Neto obujam stabla*, q_n	Standard time *Norma vremena*, NV_{s2}	Daily output *Dnevni učinak*, DU_{s2}
	min/st.	min/st.	min/st.	k_d	min/st.	m^3	min/m^3	m^3/dan
S1	5.04	0.87	5.91	1.66	9.81	0.673	14.58	32.93
S2	5.41	1.70	7.11	1.47	10.45	0.733	14.26	33.66

In Variant 2, we shall see the cutter's standard time (NV_{s2}) calculated according to the mathematical model parameter of multiple linear regression. The mathematical processing of cutters' data considered the monitored DBH and tree height as independent variables. Standard time (NV_{s2}) of Variant 2 (Table 33) was calculated by equations 28 and 29 respectively. The standard time where 14.58 min/m^3 (S1) and 14.26 min/m^3 (S2).

The daily output cutter's effect (DU_{s2}) in Variant 2 (Table 33) is 32.93 m^3/day (S1) and 33,60 m^3/day (S2), or by 2.0 and 1.7 times higher effect than the one of Variant 1.

Figure 11 Standard time of felling, processing and load binding per product unit (m^3) of Variants 1 and 2
Slika 11. Norma vremena sječe, izradbe i vezanja tovara po jedinici proizvoda (m^3) za inačicu 1 i 2

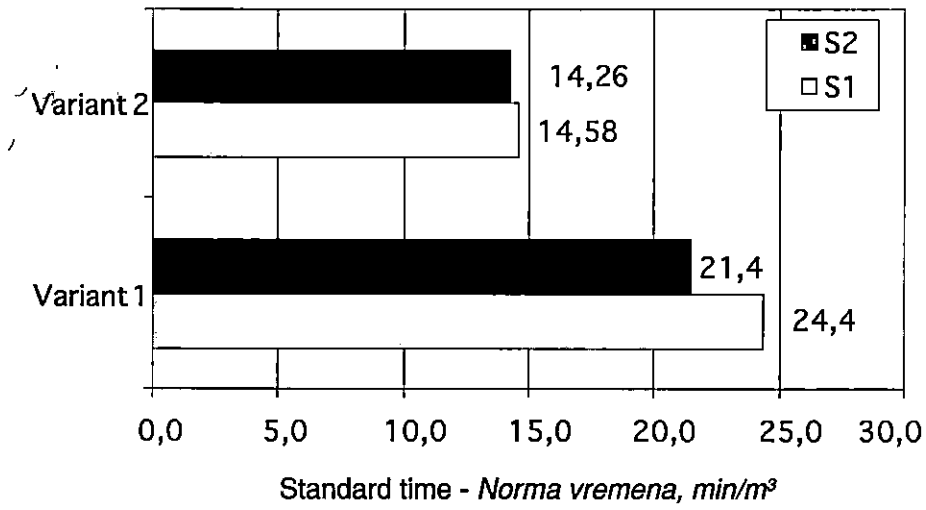


Figure 12 Comparative presentation of cutter's daily output at felling, tree processing and load binding in Variants 1 and 2

Slika 12. Poredbeni prikaz dnevnog učinka sjekača na sječi, izradbi stabala te vezanju tovara za inačicu 1 i 2

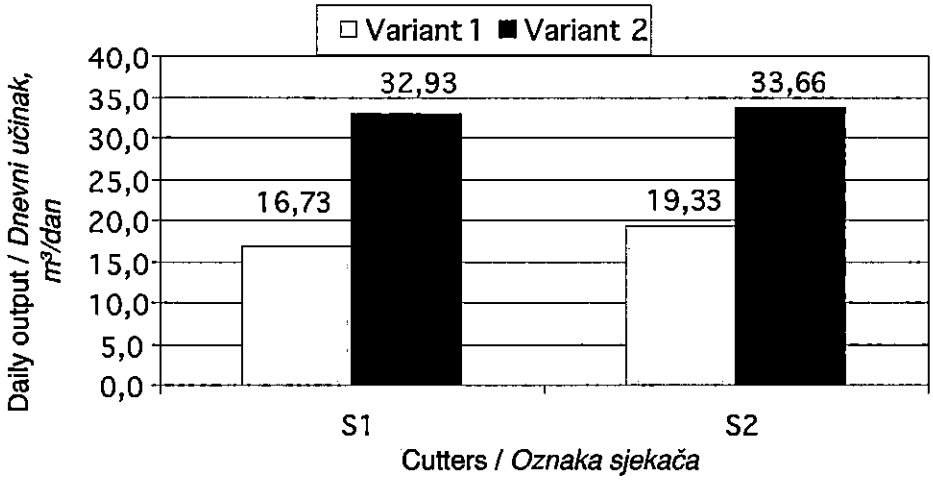


Figure 12 presents the comparative daily output of two variants that best illustrate the behaviour of the cutters in teamwork. Variant 1 presents the realised daily output according to the used work time, while Variant 2 presents the modelled daily output of the corresponding work technology in the prescribed work time of 480 minutes.

STANDARD TIME AND TRACTOR'S DAILY OUTPUT
NORME VREMENA I DNEVNI UČINAK TRAKTORA

Standard time was calculated as an average of the used time at skidding the product unit (1 m³) at distances of 150 m do 650 m. The components of the standard time are variable and fixed times that composed the effective time and added time. The subchapter titled *Distribution of effective tractor cycle time* explains in detail all components of the used time of one tractor cycle. The subchapter titled *Tour times* presents the variable times, the calculation and the values of the given distances. The total tractor cycle time was calculated by mathematical equations 9 and 16, and are presented in Tables 29 and 30. According to the total tractor cycle time, the standard time (NV_t) and the daily output (DU_t) were calculated.

Standard time (NV_t) was calculated form the total used cycle time (T_u) and the average load volume by using

$$NV_t = \frac{T_u}{q_t} \ldots \left(\text{min}/m^3\right) \quad (31),$$

where NV_t = tractor standard time (min/m³); T_u = total cycle time (min), and qt = average tractor load volume (m³),
and the equation:

$$NV_t = \frac{\left(\left(t_{nv} + t_{ov} + t_{nps} + t_{ops}\right) + \left(t_u + t_i\right)\right) \cdot k_d}{q_t} \ldots \left(\text{min}/m^3\right) \quad (32),$$

where NV_t = tractor standard time (min/m³); q_t = average load volume (m³), k_d = added time factor; t_{nv} = unloaded driving time on skid trail and felling site; t_{ov} = loaded driving time on skid trail and felling site; t_{nps} = unloaded driving time on landing; t_{ops} = loaded driving time on landing; t_u = loading time, and t_i = unloading time.

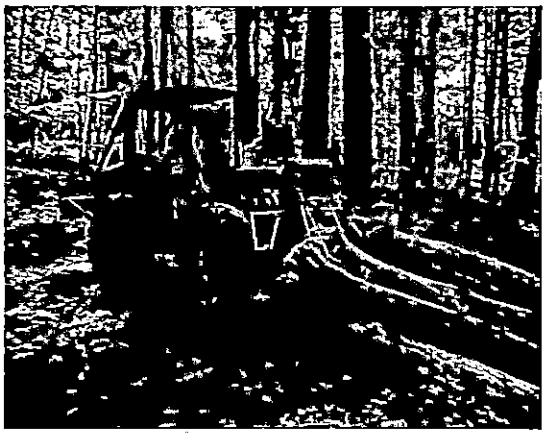


Figure 13 Tractor Ecotrac 1033 F (E1) at skidding
Slika 13. Traktor Ecotrac 1033 F (E1) pri privlačenju drva na vlaci

The daily output is calculated according to the number of cycles and the average load volume. The daily output is calculated so that the prescribed work time of 480 minutes is divided by the corresponding standard time and presented by

$$DU_t = \frac{480}{NV_t} \ldots \left(m^3/dan\right) \quad (33),$$

where DU_t = is the daily tractor output (m³/dan), and NV_t = standard time of the tractor (min/m³).

The increase of skidding distance is proportional with the daily output decrease. The average tractor output is calculated according to the average data of particular

Table 34 Total cycle time, standard time and daily output of Tractors E1 and E2 in the team.
Tablica 34. Ukupno vrijeme turnusa, norme vremena i dnevni učinak traktora E1 i E2 u skupini

Tractor *Oznaka traktora*	Skidding distance, m *Udaljenost privlačenja, m*						
	Realised *Ostvareno*	150	250	350	450	550	650
Total cycle time *Ukupno vrijeme turnusa*							
E1	22.22	18.77	22.61	26.44	30.29	34.13	37.96
E2	31.86	26.14	30.17	34.18	38.21	42.21	46.25
Load volume, m^3 *Obujam tovara, m^3*							
E1	1.330						
E2	1.490						
Standard time, min/m^3 *Norma vremena, min/m^3*							
E1	16.70	14.11	17.00	19.88	22.77	25.66	28.54
E2	21.38	17.54	20.25	22.94	25.64	28.33	31.04
Daily output, m^3/dan *Dnevni učinak, m^3/dan*							
E1	17.11	34.01	28.24	24.14	21.08	18.71	16.82
E2	15.47	27.36	23.71	20.93	18.72	16.94	15.46

mathematical-statistical methods, without the output degree estimate. The output degree is the relation between the real and normal output. The latter is the realisation of a capable, skilful and perfectly equipped worker during and in the middle of his shift, by using the previously defined breaks (Krpan 1984). In the development of the local norms, the average output is considered as normal. In teamwork, the tractor with all its properties and terrain factors, affects the cutter's daily outputs.

Standard time and daily outputs are presented in Table 34. The increase of the standard times in proportion with the distance increase is shown in Figure 14. The work conditions of the tractors are similar, but the difference is obtained by the calculation of the standard time, their differences being affected by the average load volume. The standard times at a skidding distance of 150 m are 14.11 min/m^3 (E1) and 17,54 min/m^3 (E2), or 28,54 min/m^3 (E1) and 31,04 min/m^3 (E2) at a skidding distance of 650 m.

Figure 15 presents the daily tractor's output at skidding. The daily output decreases in proportion with the increasing distance. We can conclude that the speed of the tractor does not affect the daily output significantly, while the load volume and the use of the cycle fixed time significantly affect the tractor's daily output. The

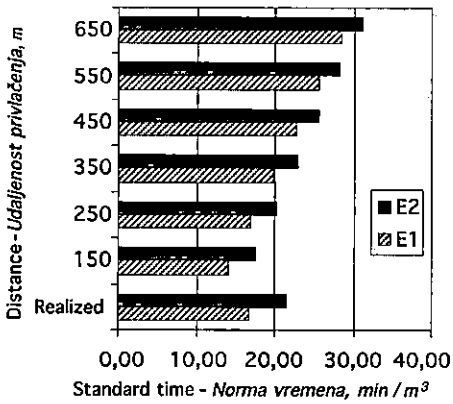


Figure 14 Realised time and standard time of the E1 and E2 team tractors

Slika 14. Ostvareno vrijeme i norma vremena traktora E1 i E2 u skupini

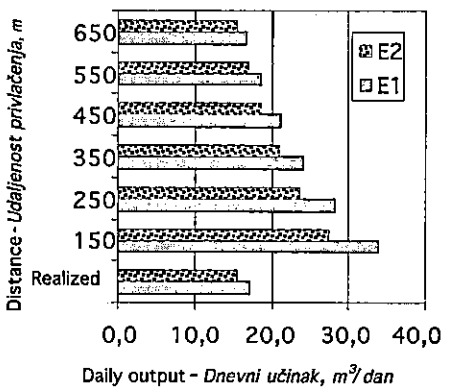


Figure 15 Realised and modelled daily outputs of the E1 and E2 team tractors

Slika 15. Ostvareni i oblikovani dnevni učinak traktora E1 i E2 u skupini

daily output of the tractor at a skidding distance of 150 m is 34,01 m³/day (E1) and 27,36 m³/dan (E2); at a skidding distance of 650 m, the respective values may be 16.82 m³/day and 15,46 m³/day

STANDARD TIMES AND DAILY OUTPUT OF THE CUTTER-CUSTOMER

NORME VREMENA I DNEVNI UČINAK SJEKAČA-PREUZIMAČA

Standard time (NV_p) of the cutter-customer is expressed as the time used for processing and customizing of tree parts per product unit (m³). The cutter-customer worked on processing and customizing of wood assortments on the landing.

Table 35 contains the effective and delay times of the cutter at processing and customizing wood assortments. The work on processing and customizing is the component part of a team's work organisation. In calculating the effective and delay times, and the total time per product unit, the used time is divided by the total volume of wood assortments and the number of pieces. The cutter-customer spent 2.11 min/m³ of effective time and 10.66 min/m³ of delay time on the landing, or a total of 12.77 min/m³.

The data in Table 35 on time use of the cutter-customer for processing and customizing wood assortments can be used to calculate the daily output of the total used work time of 416.12 min/day, or the prescribed work time of 480 minutes. Based on the parameters of the mathematical model, i.e. the equation 17, the effective time of

Table 35 Used effective and delay times+total times of cutter-customer at processing and customising wood assortments

Tablica 35. Prikaz utrošenog efektivnog i općih vremena te ukupnog vremena sjekača-preuzimača pri doradi i preuzimanju drvnih sortimenata

Cutter-customer *Sjekač-preuzimač*	Processing and customising wood assortments *Dorada i preuzimanje drvnih sortimenata*					
	Effektive time *Efektivno vrijeme*		Delay times *Opća vremena*		Total time *Ukupno vrijeme*	
	min/m³	min/piece *min/kom*	min/m³	min/piece *min/kom*	min/m³	min/piece *min/kom*
	Variant 1 – *Inačica 1*					
PS	2.11	0.29	10.66	1.44	12.77	1.73

the cutter-customer was calculated in teamwork. The effective time of processing and customizing (I_{eps}) was calculated according to the equation

$$I_{eps} = y = b_0 + b_1 \cdot n_1 + b_2 \cdot q_1 \ldots (\text{min}) \qquad (34),$$

where I_{eps} = effective time of processing and customizing; n_1 = number of pieces in one grasp; q_1 = wood volume in one grasp

Table 36 Effective and total times and the standard times, daily output of the cutter-customer at processing and customizing wood assortments

Tablica 36. Efektivno i ukupno vrijeme te norma vremena i dnevni učinak pri doradi i preuzimanju drvnih sortimenata sjekača-preuzimača

Cutter customer/ *Oznaka Sjekača-preuzimača*	Average used time *Prosječno utrošeno vrijeme*	Total used time *Ukupno utrošeno vrijeme*	Realised daily output *Ostvareni dnevni učinak*	Effective time *Efektivno vrijeme* I_{eps}	Added time factor *Faktor dodatnog vremena*, k_d	Standard time *Norma vremena*, NV_{ps}	Daily output *Dnevni učinak* DU_{ps}
	min/dan	min/m³	m³/dan	min/m³		min/m³	m³/dan
	Variant 1 *Inačica 1*			Variant 2 *Inačica 2*			
PS	416.12	12.77	32.59	2.21	1.88	4.15	115.68

The average number of pieces in 1.m³ was calculated by using the data on the total processed wood volume and the total number of pieces. Total time of processing and customizing wood assortments was calculated by the equation

$$I_{ups} = (b_0 + b_1 \cdot n_1 + b_2 \cdot q_1) \cdot k_d \ldots (\text{min}) \qquad (35),$$

with I_{ups} = total processing/customizing time; n_1 = number of pieces in one grasp; q_1 = wood volume of one grasp; k_d = added time factor.

The processed wood assortment volume was calculated by using the mean diameter and the lengths of every piece. Standard time (NV_{ps}) of the cutter-customer was calculated by Formula 35. This mathematical formula contains 10.4 pieces of 1.404 (m^3) of processed wood assortments.

The daily output was calculated for the prescribed work time of 480 minutes/day according to the formula

$$DU_{ps} = \frac{480}{NV_{ps}} \ldots \left(m^3/dan\right) \qquad (36),$$

with DU_{ps} = daily output of cutter-customer; NV_{ps} = standard time of cutter-customer.

Table 36 presents the realised daily output of 32.59 m^3/dan of Variant 1. Significantly, the cutter-customer may realise his daily output to the amount that equals the amount felled by the cutters, i.e. the amount skidded to the landing.

In the same table, Variant 2 has an effective time (I_{eps}) per product unit. The calculated and adjusted effective time is divided by the average volume of the cutter-customer's work operation. The effective time is 2.21 min/m^3. The factor of added time is 1.88. Such a high added-time factor is the result of a relatively low use of effective time during one workday. The stanadard time of the cutter-customer is 4.15 min/m^3, and the daily output is 115.68 m^3/day. This daily output is by 3.1 times higher than the realised one.

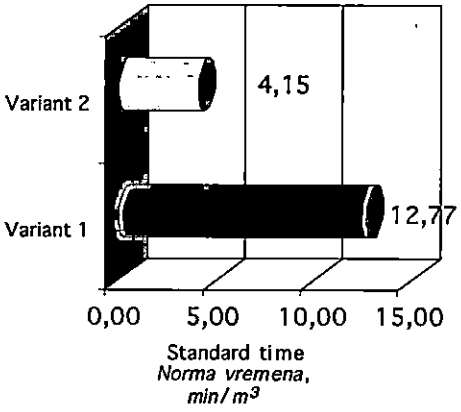


Figure 16 Time used per m^3 (Variant 1) and standard time of wood assortment customizing in Variant 2

Slika 16. Utrošeno vrijeme po m^3 (inačica 1) i norma vremena preuzimanja drvnih sortimenata za inačicu 2

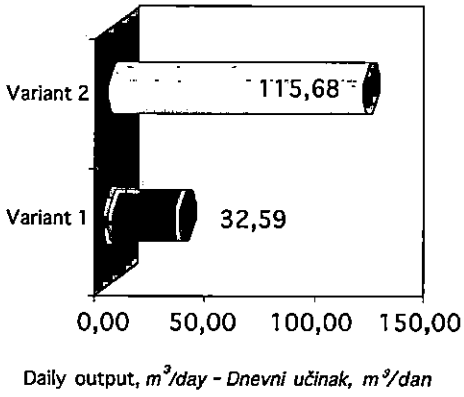


Figure 17 Daily output of cutter customer at processing and wood assortment customizing

Slika 17. Prikaz dnevnog učinka sjekača-preuzimača na doradi i preuzimanju drvnih sortimenata

Figure 17 is a comparative presentation of the daily output in processing and customizing wood assortments. The realised daily output of Variant 1 is presented by the used time. Variant 2 presents the modelled daily output for the corresponding work technology in the prescribed work time of 480 minutes according to the existing work conditions.

STANDARD TIMES AND DAILY OUTPUT OF THE CRANE TRACTOR AT LANDING

NORME VREMENA I DNEVNI UČINAK TRAKTORA S DIZALICOM NA POMOĆNOM STOVARIŠTU

Crane tractor is the component part of the work team in Ivanska, serving for stacking long wood on the landing. The used work time is presented in Table 11, while the data on the stacked wood volume are in Table 7.

For stacking long timber, the crane tractor used 5.24 min/m³ of the effective time; 15.63 min/m³ of the delay times, i.e. a total of 20.87 min/m³. With the presented data on the crane tractor time use for wood stacking, it is possible to calculate the daily output of the total used work time. The crane tractor used 411.87 min/day. The total used time was 20.87 min/m³, on the basis of which the daily output of 19.74 m³/day was calculated (Variant 1).

The effective time of stacking long wood (I_{eDZ}) was calculated by the formula

$$I_{eDZ} = y_{DZ} = b_0 + b_1 \cdot n_2 + b_2 \cdot q_2 \ldots (\text{min}) \qquad (37),$$

with I_{eDZ} = effective crane time; n_2 = number of pieces in the crane grasp; q_2 = crane grasp volume.

Table 37 presents the adjusted effective crane time of 4.80 min/m³, calculated according to the average realised number of 3.9 pieces in one crane grasp, and the average crane grasp volume of 0.411 m³. The same Table contains the added time factor.

Table 37 Standard time and daily output of the crane tractor at stacking long timber on landing

Tablica 37. Norma vremena i dnevni učinak traktora s dizalicom pri slaganju višemetarskog prostornog drva na pomoćnom stovarištu

Crane tractor/crane *Dizaličar / dizalica*	Effective time *Efektivno vrijeme*	Added time coefficient *Koeficijent dodatnog vremena*	Standard time *Norma vremena*	Daily output *Dnevni učinak*
	I_{eDZ}		NV_{DZ}	DU_{DZ}
	min/m³	k_d	min/m³	m³/dan
	Variant 2 *Inačica 2*			
DZ	4.80	1.87	8.97	53.53

The total time of the crane cycle (I_{uDZ}) at stacking long timber was calculated by using the formula

$$I_{uDZ} = (b_0 + b_1 \cdot n_2 + b_2 \cdot q_2) \cdot k_d \ldots (\min) \quad (38),$$

with I_{uDZ} = total crane cycle time; n_2 = number of crane grasp pieces; q_2 = crane grasp volume.

Standard time NV_{DZ} of crane tractors was calculated by Formula 39. The given mathematical formula includes the corresponding number of pieces with the corresponding average volume of one crane grasp.

$$NV_{DZ} = \frac{(b_0 + b_1 \cdot n_2 + b_2 \cdot q_2) \cdot k_d}{q_2} \ldots \left(\min/m^3\right) \quad (39),$$

with NV_{DZ} = crane satndard time; $n_{2=}$ number of pieces in the crane grasp; q2 = crane grasp volume, and k_d = added time factor of the crane.

The daily output was calculated for the prescribed work time of 480 minutes a day by the mathematical formula

$$DU_{DZ} = \frac{480}{NV_{DZ}} \ldots \left(m^3/dan\right) \quad (40),$$

with DU_{DZ} = daily crane output, and NV_{DZ} = crane standard time.

The effective crane time used for stacking long timber was calculated according to the mathematical model parameters. The effective time and the added time factor were used in the calculation of the standard time and daily output. Table 37 presents the data on the effective time, standard time and the daily output in Variant 2 per unit product. The number of team tractors rises proportionally with the increase of the crane effective time and the decrease of added time. Using these mathematical formulae, the effective time of stacking long timber by tractor crane was calculated as 4.80 min/m³. Standard time is 8.97 min/m³, daily crane output 53.53 m³/day. The

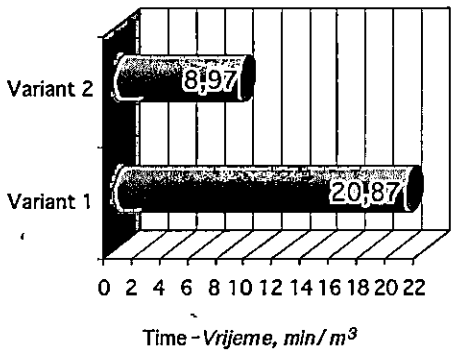


Figure 18 Total used time (Variant 1) and the standard time (Variant 2) of the crane tractor at stacking long timber on the landing

Slika 18. Ukupno utrošeno vrijeme (inačica 1) i norma vremena (inačica 2) traktora s dizalicom pri slaganju višemetarskog prostornog drva na pomoćnom stovarištu

modelled daily output of the crane was higher by 33.79 m³/day or 2.7 times more than the realised one.

Figure 19 shows that the realised daily output (Variant 1) was considerably lower compared to the possible one (Variant 2). The crane tractor (Variant 2) could stack 2.7 times more than Variant 1.

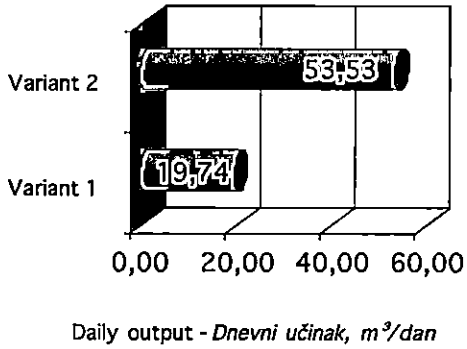


Figure 19 Daily crane output at stacking long timber at landing

Slika 19. Prikaz dnevnog učinka traktora s dizalicom pri slaganju višemetarskog prostornog drva na pomoćnom stovarištu

TEAMWORK STANDARD TIME
NORMA VREMENA SKUPINE

Table 14 presents the analysis of the used time per team member/total at unit product production. With the present work organisation, this work team uses 82.79 minutes (P1) and 84.48 minutes (P2) for producing the unit product. By work study principles, the effective, added and total times of the team members were calculated. The individual standard time calculations of the cutters, tractors, and the cutters-customers with crane tractor were presented before.

The individual calculations of the standard times of each team member will be used in the calculation of the sub team time norm and their relation will be presented.

According to the current teamwork organisation, the standard time or the daily output is written in the work order of every team member, so that they make efforts to complete the given task. At shorter skidding distances in pair work, the cutter makes more efforts, because he prepares a bigger wood quantity than at longer distances, with the tractor waiting for the next skidding. The cutter-customer is not sufficiently employed if the wood is skidded by only two tractors. The crane tractor is also insufficiently busy with only two skidders (and three skidders resp.). The use of the tractor crane is justified by sufficient skidded wood quantity.

The standard time of the team is calculated as the sum of the individual standard time of each team member: cutter and tractor who work in pair; cutter-customer, and crane tractor. The standard time of the work team per product unit is expressed by the following mathematical formula:

$$NV_{SK} = NV_s + NV_t + NV_{ps} + NV_{DZ} \cdots \left(\min/m^3\right) \quad (41),$$

with NV_{SK} = worker team standard time; NV_S = cutter's standard time; NV_t = tractor's standard time; NVp_S = standard time of cutter-customer, and NVDZ = crane tractor standard time.

If we include all parameters of each individual team members from the mathematical formulae into mathematical formula 41, we shall get the following formula:

$$NV_{SK} = \left(\frac{^1\left((b_0 + b_1 \cdot d_{1,30} + b_2 \cdot h) + I_f\right) \cdot k_{ds}}{q_n} \right) + \left(\frac{^2\left(\left(t_{nv} + t_{ov} + t_{nps} + t_{ops}\right) + \left(t_u + t_i\right)\right) \cdot k_{dt}}{q_t} \right) +$$

$$\left((b_0 + b_1 \cdot n_1 + b_2 \cdot q_1) \cdot k_{dps}\right) + \left(\frac{\left(b_0 + b_1 \cdot n_2 + b_2 \cdot q_2\right) \cdot k_{dDZ}}{q_2} \right) \cdots \left(\min/m^3\right) \cdots\cdots\cdots\cdots (42)$$

with b_0, b_1, b_2 = parameters of the linear mathematical regression model ([1] each team member gets the corresponding mathematical model parameter); $d_{1,30}$ = DBH (cm); h – tree height (m); I_f = load binding time (min); k_{ds} = cutter's added time; q_n = net tree volume (m³); t_{nv} = unloaded skidding time of the tractor on the skid trail and the felling site (min); t_{ov} = loaded skidding time of the tractor on the skid trail and the felling site (min); t_{nps} – unloaded skidding time of the tractor landing (min); t_{ops} = loaded skidding time of the tractor landing (min); t_u = tractor's work time on the felling site (min); ti = tractor's work time on the landing (min); k_{dt} = tractor's added time; q_t = average tractor load volume (m³); n_1 = average number of pieces in the work operation of the cutter-customer (pcs); q_1 = average wood volume of grasp at customizing wood assortments (m³); k_{dps} = added time factor of the cutter-customer; n_2 = number of pieces in one crane grasp (pcs); q_2 = average wood volume of the crane grasp (m³); k_{dDZ} = added time factor of the crane tractor at landing.

[2] Note: *In the calculation of the effective tractor tour time, mathematical regression models are used, i.e.* t_{ov}, t_{nv}, t_{ops}, t_{nps}, *and the loading time* (t_u) *and the unloading time* (t_i) *are calculated as the average (fixed) tractor cycle time.*

Table 38 contains the data on the work time of the sub teams per product unit. It also presents the calculated standard times of the skidding distances 150 m – 650 m. The time norm was calculated by the mathematical formula 42.

Because of the mathematical procedure, the team contains two sub teams, P1 and P2. This sub team works in pair (cutter+tractor), so that each sub team is a production/time series. The cutter-customer is at the landing with the crane tractor. Sub team P1 used 82.79 min/m³, for the product unit, while the sub team P2 used 84.48 min/m³. At a distance of 150 m, the respective values were 41.81-min/m³ and 44.92 min/m³, which is by 49.5% (P1) and 46.8% (P2) less in relation to the used time. The respective values at a skidding distance of 350 m were 42.5% and 40.4%

less than the realised time. The respective values at a distance of 650 m were 32.1% and 30.9% less than the realised ones (Table 38).

Table 38 Realised time and standard time of the sub team per product unit with the skidding distance of 150 m to 650 m (min/m³)

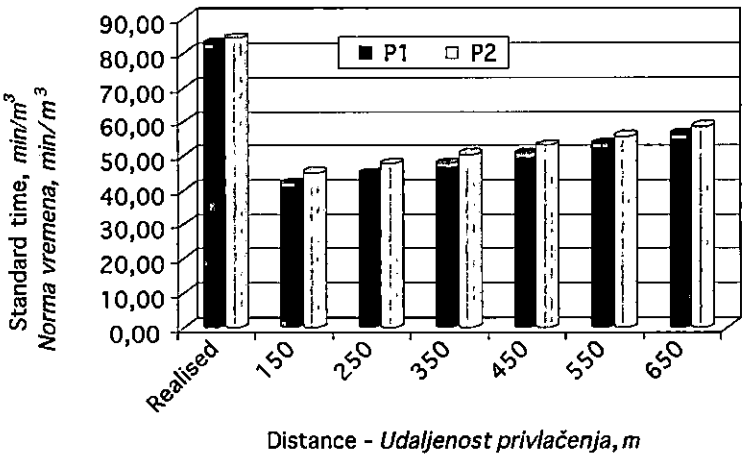
Tablica 38. Ostvareno vrijeme i norma vremena podskupine radnika po jedninici proizvoda za udaljenost privlačenja traktorom od 150 m do 650 m (min/m³)

Subteams *Podskupine*	Skidding distances, m *Udaljenost privlačenja traktorom, m*						
	Realised *Ostvareno*	150	250	350	450	550	650
	Standard times of subteams, min/m³ *Norma vremena podskupine radnika, min/m³*						
P1 (S1+E1+PS+DZ)	82.79	41.81	44.69	47.58	50.47	53.35	56.24
P2 (S2+E2+PS+DZ)	84.48	44.92	47.62	50.31	53.02	55.71	58.41

The individual standard times and tie outputs of cutters, tractors, cutters-customers, and crane tractors were presented before. We shall present here only the variants that best describe the work teams and the teamwork at the exploitation of thinning stands. The comparative presentation of the cutter standard times and the daily output were developed through a number of variants. The presented variants open the possibility of multiple combining in the work organisation of one work team related to the impact factors.

Figure 20 Used time and standard times of the sub team workers per product unit.

Slika 20. Prikaz utrošenog vremena i norme vremena podskupina radnika po jedninici proizvoda



STANDARD TIMES AND THE SUB TEAM RELATIONS
NORME VREMENA I MEĐUSOBNI ODNOSI U PODSKUPINI

Table 39 presents the standard time and the mutual relations among two cutters, two tractors, one cutter-customer and the tractor crane. The standard time of the cutter is included into the relation with the tractor at the skidding distances between 150 m and 650 m, the cutter-customer and the crane tractor. The standard time of Cutter S1 in the team is 14.58 min/m³. The tractor (E1) standard time ranges from 14.11 min/m³ (150 m) to 28.54 min/m³ (650 m). The standard time of the cutter-customer at processing and customizing on the landing was 7.01 min/m³, and was applied to both tractors.

Table 39 Standard time and mutual relations of cutters, tractors, cutter-customers, and tractor cranes per subteams

Tablica 39. Norma vremena i međusobni odnosi sjekača, traktora, sjekača-preuzimača i traktorske dizalice po podskupinama

Skidding distance, m *Udaljenost privlačenja, m*	Standard time, min/m³ *Norma vremena, min/m³*								
	Cutter *Sjekač*	Tractor *Traktor*	Cutter-customer *Sjekač-preuzimač*	Tractor crane *Traktorska dizalica*	Total *Ukupno*	Cutter *Sjekač*	Tractor *Traktor*	Cutter-customer *Sjekač-preuzimač*	Tractor crane *Traktorska dizalica*
	P1 (S1+E1+PS+DZ)								
	min/m³					Mutual relations among standard time *Međusobni odnos norme vremena*			
150	14.58	14.11	7.01	8.97	44.67	1.03	1.00	0.50	0.64
250	14.58	17.00	7.01	8.97	47.55	0.86	1.00	0.41	0.53
350	14.58	19.88	7.01	8.97	50.44	0.73	1.00	0.35	0.45
450	14.58	22.77	7.01	8.97	53.33	0.64	1.00	0.31	0.39
550	14.58	25.66	7.01	8.97	56.21	0.57	1.00	0.27	0.35
650	14.58	28.54	7.01	8.97	59.10	0.51	1.00	0.25	0.31
	P2 (S2+E2+PS+DZ)								
150	14.26	17.54	7.01	8.97	47.78	0.81	1.00	0.40	0.51
250	14.26	20.25	7.01	8.97	50.48	0.70	1.00	0.35	0.44
350	14.26	22.94	7.01	8.97	53.17	0.62	1.00	0.31	0.39
450	14.26	25.64	7.01	8.97	55.88	0.56	1.00	0.27	0.35
550	14.26	28.33	7.01	8.97	58.57	0.50	1.00	0.25	0.32
650	14.26	31.04	7.01	8.97	61.27	0.46	1.00	0.23	0.29

The standard time of Cutter S1 in the team was 14.58 min/m³. The standard time of Tractor E1 ranged from 14.11 min/m³ (150m) to 28.54 min/m³ (650 m). The same table (39) contains the calculated coefficients of the standard time relations. Tractor E1 needs 1.03 cutters at a distance of 150 m, 0.50 cutters-customers, and 0.64 crane tractors. At a distance of 350 m, the proportion of cutter : tractor : cutter-customer : crane tractor was 0.73 : 1.00 : 0.35 : 0.45; the respective standard time values at a distance of 650 m were 0.51 : 1.00 : 0.25 : 0.31.

With the second sub team (P2) and Tractor 2, a distance of 150 m required 0.81 cutters, 0.40 cutter-customers on the landing, and 0.51 crane tractors. At a distance of 350 m, the same tractor needed 0.62 cutters and 0.31 customizing workers, and 0.39 crane tractors. The respective values with 650 m were 0.46, 0.23, and 0.29 (Table 39).

OPTIMAL CALCULATION OF THE WORK TEAM
IZRAČUN OPTIMALNE VELIČINE SKUPINE RADNIKA

Table 40 presents the calculation of the optimal size of the work team based on the mutual relation of the individual standard times of cutters, tractors, and cutter-customers at customizing wood assortments, and the crane tractor.

Table 40 Optimal team size related to the interrelation of the stanadard time
Tablica 40. Optimalna veličina skupine s obzirom na međusoni odnos norme vremena

Skidding distance, m *Udaljenost privlačenja, m*	Cutter *Sjekač*	Tractor *Traktor*	Cutter-customer *Sjekač-preuzimač*	Tractor crane *Traktorska dizalica*	Cutter *Sjekač*	Tractor *Traktor*	Cutter-customer *Sjekač-preuzimač*	Tractor crane *Traktorska dizalica*	Optimal team size *Optimalna veličina skupine*
	Standard time, min/m³ *Norma vremena, min/m³*				Number of team members *Broj članova skupine*				Number of workers *Broj radnika*
150	14.42	15.83	4.15	8.97	3.47	3.81	1.00	2.16	10.45
250	14.42	18.62	4.15	8.97	3.47	4.49	1.00	2.16	11.12
350	14.42	21.41	4.15	8.97	3.47	5.16	1.00	2.16	11.79
450	14.42	24.21	4.15	8.97	3.47	5.83	1.00	2.16	12.47
550	14.42	26.99	4.15	8.97	3.47	6.50	1.00	2.16	13.14
650	14.42	29.79	4.15	8.97	3.47	7.18	1.00	2.16	13.81

The optimum value of the work team is calculated on the basis of the least standard time of the individual member, and is taken as the basic unit. The average

standard times of the cutters, tractors, cutter-customers and crane tractors were calculated for all work teams.

The team consists of two cutters, two tractors, one cutter-customer and one crane tractor. The average standard time of a two-cutter-team is 14.42 min/m³, while the average tractor time norm ranges from 15.83 min/m³, (150 m) to 29.79 min/m³ (650 m). The standard time of the cutter-customer on the landing is 4.15 min/m³ (Table 40). The basic unit was the least standard time of the team, i.e. the standard time of the cutter-customer on the landing. Related to the least standard time of 4.15 min/m³, the optimal work of the team requires 3.47 cutters, 3.81 (150 m) to 7.18 (650 m) tractors, and 2.16 crane tractors. The optimal size of Team D ranges between 10.45 members (150 m) and 13.81 members. In one workday, the optimal team can process 115.66 m³/day of wood assortments.

DAILY TEAMWORK OUTPUT
DNEVNI UČINAK SKUPINE

Table 41 contains the daily output of a team calculated as the sum of the daily outputs of two and three tractors according to skidding distance. The daily output of a single tractor is calculated as the relation of the prescribed work time of 480 minutes and the tractor standard time. The work team realises a daily output of the quantity that equals the wood volume skidded to the landing.

Table 41 Daily output (m³/day) of a work team according to the current number of members

Tablica 41. Dnevni učinak (m³/dan) skupine radnika prema postojećem broju članova

Tractors *Oznaka skupine (traktori)*	Skidding distance, m *Udaljenost privlačenja traktorom, m*					
	150	250	350	450	550	650
	Daily output teamwork, m³/dan *Dnevni učinak skupine, m³/dan*					
(E1 + E2)	61.37	51.95	45.07	39.79	35.65	32.28
Number of team members *Broj članova skupine*	Daily output per team member, m³/dan *Dnevni učinak po članu skupine, m³/dan*					
(6)	10.23	8.66	7.51	6.63	5.94	5.38

The team counts six members, and the daily output ranges from 10.23 m³/day (150 m) to 5.38 m³/day (650 m). This is by 88.4% (150 m) – 9.4 % more than the

daily output of 4.19 m³/day per team member. At a distance of 650 m, the calculated daily output is by 0.05 m³/day more that the realised value.

TEAM AND SUB TEAM COSTS
TROŠKOVI SKUPINE (PODSKUPINE)

The calculation included the daily output of each team member and the work devices used. The presented combinations of the sub team relate to the total duration of the work in one day, and the work organisation. In the sub teams P1 and P2, cutters S1 (S2) and tractor E1 (E2) work in pairs. The cutter-customer PS carries out the processing and customizing of wood assortments for both tractors. The sub team calculation includes the daily output of the cutter (S1) and tractor (E1), and half of the daily output of cutter-customer (PS) on the landing. The total sub team P1 costs are 2,574.79 kn/day involving 2.5 workers, which is an average of 858.26 kn/day per one worker. In sub team P2, the daily calculation is the same as with P1. The work team daily costs are 5,149.58 kn/day, i.e. an average of 858.26 kn/day/member (Table 42).

Table 42 Cost calculation of the work team per product unit related to the modelled daily output.

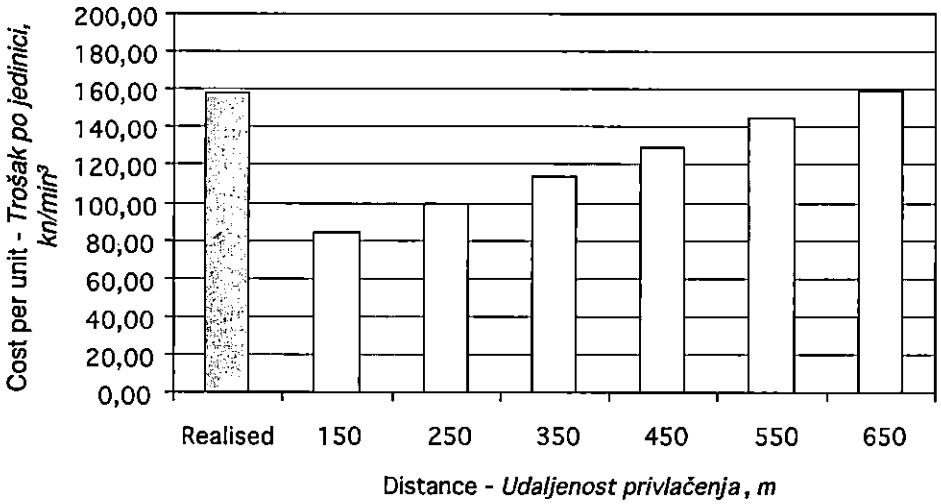
Tablica 42. Prikaz kalkulacija i troškova skupine radnika po jedinici proizvoda prema oblikovanom dnevnom učinku

Number of team members *Broj članova skupine*	Skidding distance, m *Udaljenost privlačenja traktorom, m*					
	150	250	350	450	550	650
	Daily team calculation, kn/day *Dnevna kalkulacija skupine, kn/dan*					
(6)	5149.58					
Number of team membes *Broj članova*						
	Costs per product unit, kn/m³ *Trošak po jedinici proizvoda, kn/m³*					
(6)	83.91	99.14	114.26	129.40	144.45	159.52

The team costs range between 83.91 kn/m³ (150 m) and 159.52 kn/m³ (650 m). Related to the realised costs of 158.07 kn/m³, this is by 46.9% (150 m) – 8.6 % (550 m) less, but with the distance of 650 m, it is by 0.9 % more than the realised value.

Figure 21 Calculated costs per product unit (kn/m³) related to the realised and modelled daily output of the team

Slika 21. Prikaz izračunanog troška po jedinici proizvoda (kn/m³) prema ostvarenom i oblikovanom dnevnom učinku skupine radnika



CONCLUSIONS
ZAKLJUČCI

The aim of this study is the research on the organisation form, the efficiency of the teamwork, and the dynamic optimisation of the team related to the number of workers and the technical devices in the exploitation of the broadleaf thinning stands. The research was carried out in the area of FA Bjelovar (Ivanska).

The research involved the work and time study, so that each worker had his own surveyor. The snap-back chronometry method and the workday surveys were applied.

The statistical data processing was carried out with *Microsoft Excel and Statistica 6.* The used times of cutters, cutter-customers, tractors, crane tractors, and variable times were investigated by multiple regression analysis. The number and type of impact factors varied in relation to the work type.

Each of the team members was monitored separately. In this way, the following values were established: time use; time structure per components; use of effective times and delay times per unit, and the realised daily output of each cutter, cutter-customer, skidding tractors and crane tractors on landing.

The use of the teamwork time is 87.81 % of the prescribed daily time. The average effective time of the team is 39.70 % of the total time. The difference amounting to 100% relates to the use of the delay times during work.

The tractors use 12.86 min/m³ (E1) and 16.41 min/m³ (E2) of the effective time. The delay times are 11.89 min/m³ (E1) and 13.00 min/m³ (E2). The total times per unit are 24.75 min/m³ (E1) and 29.41 min/m³ (E2). The effective times of the crane tractor are 25.12 % of the total time and 5.24 min/m³ respectively.

The realised daily outputs of the cutters are 16.73 m³/day (S1) and 19.33 m³/day (S2), while the output of the cutter-customer is 32.59 m³/day. The realised daily outputs of the tractors in skidding are between 17.11 m³/day (E1) and 15.47 m³/day (E2), while the one of the crane tractor on the landing is 19.74 m³/day. The realised average daily output per team member is 5.43 m³/day.

The average speeds of the loaded tractors on skid trailes and felling sites are 3.45 km/h (E1) and 2.71 km/h (E2). The average speeds of unloaded tractors are 4.82 km/h and 4.38 km/h respectively.

The added times of each cutter, cutter-customer, winch tractors and crane tractors are modelled according to the used delay times structure. The calculated added time of the team is 32.71 % of the total time.

The use of the effective times per tree and m³ of all cutters were investigated by multiple linear regression. Mathematical models of multiple regression were developed for all cutters to calculate the dependence of the used effective time and the dbh/tree height. The multiple regression analysis was also applied to the crane tractor, and the mathematical model for the calculation of the dependence of the effective time use and the volume/number of pieces in the grasp was developed.

The research on the time of the loaded tractor drive by multiple regression analysis resulted in linear mathematical models on the impacts of four most significant variables: distance, load volume, inclination and the number of pieces in the load. The variable times of the tractor cycle are 4.70 min (E1) and 6.51 min (E2) at a distance of 150 m; the distance of 650 m required the respective time values of 19.46 min and 22.22 min. The work on the felling site has the proportions of 7.16 min (E1) and 11.23 (E2) of the effective time, while the work on the landing lasted for 2.58 min (E1) and 2.68 (E2) of the effective time. The variable time of the tractors increase proportionally with the skidding distance, and the parallel proportional decrease of the fixed times in the cycle.

The standard time of the cutters (min/m³) was investigated in two variants (1 and 2). The standard times in Variant 2, which best describes the cutters, range from 14.26 min/m³ (S2) and 14.58 min/m³ (S1). The modelled daily outputs are 32.93 m³/day (S1) and 33.66 m³/day (S2). The standard time of the tractor was calculated from the total used times of the tours and the average load volume, amounting to the values of 14.11 min/m³ (E1) and 17.54 min/m³ (E2) with a skidding distance of 150 m. The respective values with the distance of 350 m are 19.88 min/m³ and 22.94 min/m³. With the distance of 650 m, these values are 28.54 min/m³ (E1) and

31.04 min/m³ (E2). The increased load volume at the monitored skidding distances decidedly affects the daily output of the tractor.

The daily outputs of the tractors E1 and E2 at a skidding distance of 150 m were 34.01 m³/day and 27.36 m³/day; at a skidding distance of 350 m, it is possible to realise outputs of 24.14 m³/day and 20 93 m³/day respectively; with the distance of 650 m, the possible daily outputs are 16.82 m³/day and 15.46 m³/day.

The standard time of the cutter-customer in Variant 2 is 4.15 min/m³. The corresponding daily output can be realised in the amount of 115.68 m³/day. In relation to the realised daily output, a 3.1 times higher daily output is possible. With the crane time norm of 8.50 min/m³ and a daily output of 56.47 m³/day, the crane tractor can stack 2.7 times more than Variant 1.

According to the standard times of the tractors, cutters, cutter-customers, and the crane, the mutual relations and the required number of the team members were calculated. Considering the team (sub team) standard times, dynamic models were set. In this case the least standard time (cutter-customer) was taken, and according to it the number of other team members was determined.

The average standard time of the team's two cutters is 14.42 min/m³, while the average standard times of the tractor are 15.83 min/m³ (150 m) and 29.79 min/m³, (650 m). The standard time of the cutter-customer on the landing is 4.15 min/m³, which was taken as the basic unit as the least standard time. In relation to this least standard time, an optimal teamwork needs 3.47 cutters, 3.81 (150m) or 7.18 (650 m) tractors, and 2.16 tractor cranes. The optimal team size ranges between 10.45 members (150 m) and 13.81 members. During one workday, an optimal team can process 115.66 m³/day of wood assortments.

According to the data on the number of member and the daily output, the daily output per team member was calculated. It decreases proportionally with the increase of the skidding distance. The research on the team of six revealed the daily output per team member of 10.23 m³/day (150 m) and 5,38 m³/day (650), which is by 88.4% (150) – 9.4 % (550 m) more than the realised daily output of 4.19 m³/day per team member.

At a skidding distance of 650 m the calculated daily output was by 0.05 m³/day lower than the realised one.

The average realised cost per product unit in the team is 158.07 kn/m³. The modelled costs ranges between 83.91 kn/m³ (150 m) and 159.52 kn/m³ (650 m), which are by 46.9% (150 m) or by 8.6% (550m) less compared to the realised; at a distance of 650 m, the modelled cost is by 0.9% higher than the realised.

A higher form of work organisation, teamwork has been accepted by Croatian forestry and has yielded better results when compared to individual work. This research on teamwork is an indication of the imperfection of the present organisation

teams and offers the possibilities of improvements. The investigated factors are the basis for dynamic optimisation of teamwork, which should make a better use of the work time, machines and labour, in order to increase production and reduce costs. Dynamic optimisation of team workers and work devices will highlight the advantages of teamwork.

REFERENCES
LITERATURA

Backhaus, G., 1990: Die Allgemeinen Zeiten im forstlichen Arbeitsstudium. Forsttechnische informationen, 42, 1. 15.

Barnes, R. M., 1964: Studij pokreta i vremena. 1726, Zagreb, Panorama.

Benić, R., 1971: Organizacija rada u drvnoj industriji 126. Zagreb, Znanje.

Bojanin, S., 1975: Izvlačenje tanje tehničke oblovine pomoću traktora. Drvna industrija 26 (11/12): 263–269.

Bojanin, S., 1977: Studij rada i vremena u eksploataciji šuma. Znanstvena studija, Šumarski fakultet Sveučilišta u Zagrebu, str. 163.

Bojanin, S., 1982: Određivanje najpovoljnije metode rada kod izrade industrijskog i tehničkog drva u proredama. Mehanizacija šumarstva 7 (12), 720.

Bojanin, S., Krpan, A. P. B., 1994: Eksploatacija šuma pri različitim radnim uvjetima u Hrvatskoj, Šumarski list 118 (9/10), 271–282.

Bojanin, S., Krpan, A. P. B., Beber, J., 1989: Komparativno istraživanje sječe i izrade u prorednim sastojinama hrasta lužnjaka i crne johe. Šumarski list 113 (9/10), 591–602.

Branz, H., Dummel, K., Helms, A., 1983: Verfahrenbeispiele zur Rationellen Schwachholzernte. Forsttehnische Informationen, 35 (45), 30–51.

Conway, S., 1986: Logging practices, Principles of timber harvesting systems. Miller Freeman Publications, 14–32.

Grammel, R., 1988: Holzernte und Holztransport. Verlag Paul Parey, Hamburg Berlin, 12–42.

Hilf, H., 1963: Nauka o radu. Rijeka, Otokar Keršovani, 13–51.

Krivec, A., 1979: Učinkovitost in oblikovanje novih organizacijskih postopkov pri spravljanju lesa s traktorji (Neue Formen der Arbeitsorganisation bei Holzruecken mit Traktoren). Gozdarski vestnik, XXXVII, 78, 305–360.

Krpan, A. P. B., 1992: Iskorišćivanje šuma. Prilog monografiji „Šume u Hrvatskoj", Šumarski fakultet Sveučilišta u Zagrebu i J.P. „Hrvatske šume", Zagreb, 153–170.

Krpan, A.P.B., 1984: Istraživanja upotrebljivosti traktora IMT – 558 na privlačenju oblovine u uvjetima nizinskih šuma šumarije Lipovljani. Magistarski rad, Šumarski fakultet Sveučilišta u Zagrebu, 1136.

Martinić, I., 1990: Interakcije metoda rada, radnih uvjeta i proizvodnosti rada pri sječi i izradi drva u proredama sastojina. Magistarski rad, Šumarski fakultet Sveučilišta u Zagrebu, 1–100.

Mikleš, M., Suchomel, J., 1999: Relationship between terrain conditions and operating condition of forest skidders. Proceedings of IUFRO symposium "Emerging harvesting issues in technology transition" Opatija, 33–35.

REFA, 1984: Methodenlehre des arbeitsstudiums. Teil 1 Grundlagen, 7. überarb. Aufl. C. Hanser München, 11–07.

Samset, I., 1956: Timber Transport with Horse and Tractors on Compact Snowroads. Vollebekk.

Štefančić, A., 1989: Komparativno istraživanje proizvodnosti rada, troškova proizvodnje i oštećivanja stabala primjenom deblovne i sortimentne metode rada u prorednim sastojinama. Mehanizacija šumarstva 14(56), 93–102.

Taboršak, D., 1987: Studij rada. str. 12–14, Zagreb, Tehnička knjiga.

Tomičić, B., 1986, Razvoj mehanizacije, tehnologije i organizacije rada u iskorišćivanju šuma, u šumskom gospodarstvu "Mojca Birta" u Bjelovaru. Šumarski list, CX 12, 29–44.

Ugrenović, A., Benić, R., 1957: Eksploatacija šuma. Grafički zavod Hrvatske, 14–81.

Vondra, V., 1991: Istraživanje i primjena matematičkih modela za planiranje i kontrolu radova u šumarstvu. Disertacija, Šumarski fakultet Sveučilišta u Zagrebu, str. 13–34.

Winkler, I., 1990: Skupinsko delo v gozdni proizvodnji. Zbornik gozdarstva in lesarstva, Ljubljana, 35, 69–82.

Zečić, Ž., 1998, Skupni rad pri proredama u sastojinama Požeškog gorja s posebnim osvrtom na privlačenje drva traktorima. Magistarski rad, Šumarski fakultet Zagreb, 11–61.

Zečić, Ž., Poršinsky, T., Šušnjar, M., 1999: Time study in the exploitation of mountainous thinnings by group labor. Procedings of IUFRO symposium "Emerging harvesting issues in technology transition" Opatija, 115–117.

Zečić, Ž., 2002: Proizvodnost i troškovi traktora u brdskim proredama. Znanstvena knjiga: Znanost u potrajnom gospodarenju hrvatskim šumama, 507–523. Šumarski fakultet Sveučilišta u Zagrebu.

Zečić, Ž., 2003: Optimizacija skupnoga rada pri eksploataciji bjelogoričnih prorednih sastojina panonskog gorja. Disertacija. Šumarski fakultet Sveučilišta u Zagrebu, 13–13.

Planske kalkulacije cijene radniko dana za 2003. godinu, Hrvatske šume, Zagreb.

Ž. Zečić: Promotion of teamwork in mountain thinning stands of middle-aged broadleaf stands.
Glas. šum. pokuse 41: 51–133, Zagreb, 2005.

UNAPREĐENJE SKUPNOGA RADA PRI PRORJEĐIVANJU BRDSKIH SREDNJEDOBNIH BJELOGORIČNIH SASTOJINA

SAŽETAK

Rad prikazuje rezultate istraživanja te optimizaciju skupine radnika pri eksploataciji bjelogoričnih prorednih sastojina u brdskom području. Terenska su istraživanja provedena na području UŠP Bjelovara u G. j. "Ivanske prigorske šume" u skupini radnika od šest članova. Istraživana je sječa i izradba, privlačenje traktorima, dorada i preuzimanje drvnih sortimenata te slaganje višemetarskog drva traktorskom dizalicom na pomoćnom stovarištu. Rad skupine se odvijao u prorednoj bukovoj sastojini starosti 66 godina. Skupinu čine dva sjekača, dva traktorista, jedan sjekač-preuzimač i jedan dizaličar. Skupinom svakodnevno rukovodi poslovođa. Istovremeno su svi članovi skupine snimani povratnom metodom kronometrije s pripadajućim drvnim obujmom. Na temelju ukupno snimljenog vremena izvršena je analiza studija vremena prema radnim zahvatima i ukupno. Utvrđena je struktura efektivnog vremena svakog člana skupine kao i općih vremena te je oblikovano dodatno vrijeme. Sjekači su utrošili 38,14 %, odnosno 48,73 % efektivnog od ukupnog vremena. Sjekač-preuzimač je utrošio 16,55 %, a traktorska dizalica 25,12 % efektivnog od ukupnog vremena. Faktor dodatnog vremena kod sjekača prosječno iznosi 1,57, a kod traktora 1,29. Kod sjekača-preuzimača faktor dodatnog vremena iznosi 1,88, a kod traktora s dizalicom iznosi 1,87. Podaci su izmjerenih i izračunanih veličina obrađeni matematičko-statističkim metodama multiple linearne regesije. Dobiveni su matematički modeli izračuna efektivnog vremena na temelju kojih je uz faktor dodatnog vremena izračunana norma vremena i dnevni učinak svakoga člana skupine. Norme su vremena i dnevni učinci računani u nekoliko inačica radi boljeg modeliranja skupine. Ukupna norma vremena podskupine zavisi o udaljenosti privlačenja traktora. Za udaljenost od 150 m do 750 m norma vremena se jedne podskupine kreće od 44,67 min/m^3 do 59,10 min/m^3, a druge podskupine od 47,78 min/m^3 do 61,27 min/m^3. Dnevni se učinak po članu skupine može ostvariti u iznosu od 10,23 m^3/dan pri udaljenosti od 150 m do 5,38 m^3/dan pri udaljenosti privlačenja traktorom od 650 m. Trošak se u skupini po jedinici proizvoda kreće od 83,91 kn/m^3 (150 m) do 159,52 kn/m^3 (650 m).

Ključne riječi: sječa i izradba, privlačenje, optimalna skupina, proizvodnost, troškovi