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ZA ŠUMSKE POKUSE

ANNALES
EXPERIMENTIS SILVARUM CULTURAE PROVEHENDIS

41

SVEUČILIŠTE U ZAGREBU
ŠUMARSKI FAKULTET
UNIVERSITAS STUDIORUM ZAGRABIENSIS
FACULTAS FORESTALIS

Glasnik za šumske pokuse

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CONTENTS
SADRŽAJ

UDK: 630*681

Original scientific paper
Izvorni znanstveni članak

ESTABLISHMENT OF THE FORESTRY CONTRACTOR CERTIFICATION MODEL

USPOSTAVA MODELA POTVRĐIVANJA IZVODITELJA ŠUMSKIH RADOVA

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The paper presents the parts of the research necessary for the establishment of a licensing model of forest operations in Croatia. The present state of the issue has been estimated on the basis of a comprehensive analysis of the contractors and the accomplished work in the period 1998 – 2002. The estimate says that the present forest service and the completed forestry operations, notwithstanding their considerable proportion in the achievement of the productive tasks, are neither organised, nor qualified, and are thus not a stable partner in the production area of the Croatian forest management. Based on the assessed situation and the profiles of the service staff, and considering the developed forestry experience, a model for confirming the forestry contractors has been suggested, in order to enable the creation of the first formally authorised and qualified contractors. The suggested model is used to assess the possible licensors, the minimum conditions for entering the assessment procedure, the protocols and the participants in the assessment process, the legislations and the legal mechanisms (documents, administration process, etc.), the specialist institutions, and bodies involved in the licensing.

The model suggests the implementation of the assessment procedure in two phases:

1. Authorisation of the forest contracting;
2. Licensing, i.e. the assessment of qualifications and capabilities for carrying out forest operations.

In order to win the licence that makes them qualified for the forestry contractor competition, besides the formal ones, in both phases the following additional conditions have to be fulfilled: special technical-technological, specialist/staff, economical/organisational, and ecological. Along with the licence, the mark of the business ability level is also acquired – Licence I, II, or III.

The suggested model relies on the criteria, bodies, institutions and procedures that would assure objective evaluation and unbiased affirmation of the operators' qualifications, as a guarantee for expert, good, timely and economically successful performance of the forest operations.

Key words: forestry, forestry contractors, entrepreneurship, licensing, Croatia

INTRODUCTION
UVOD

Since their first appearance on the market, forestry contractors have been observed differently. To ones they presented a symbol of efficiency and modern business models, to others they were "Cinderellas", to which the crumbles were left from forest operations! Others still accepted them as a hazard to forest work – as insecure, unskilled and clumsy. However, over time forest operators became important links between forest owners and wood industry. In the last twenty-five years, in most countries forest offices, the companies in charge of state forest management, and other forest owners have rather relied upon independent forestry contractors. In some countries, therefore, independent contractors became crucial factors in forest exploitation, while the number of workers and devices multiply decreased in forestry companies. Independent contractors have thus become a regular feature of the Croatian forestry, as well as in the forestry of other countries.

The employment of forestry contractors and the transition to contract work entail many advantages. These are mainly higher flexibility, better financial results, and higher-quality work due to the contractors' specialist skills. The economical reasons for including contractors are obvious. Under the conditions of limited supply of forest jobs and the great number of qualified contractors, the available jobs are given to those who are organised in the most rational ways and therefore able to offer the lowest prices. The choice of the most favourable contractor reduces the production costs within the whole cost chain. The forest owner as the investor and seller of wood products can thus expect higher profits at the same selling prices of wood assortments. The weak parts of the contract work are the absence of investment into equipment and training, questionable qualification level of the operating staff, a low level of workers' safety, a dubious efficiency of workers' health protection, ineffective work supervision, etc.

The basic question related to the forestry contractors is, who and under what conditions can be a forestry contractor, and how to legalise this kind of entrepreneurship. While one part of the contractors are specially trained for the offered services, i.e. have considerable experience in the jobs they carry out, there are too many contractors of dubious qualification with little or no experience. The latter remain on the market due to unrealistically low prices (dumping prices) for their services. They are able to offer such low prices by avoiding the legal obligations related to the workers' rights, social obligations and safety standards. The achieved economical effects in such cases may only at first glance be favourable to forestry. Such situation is sustainable neither in the short, nor in the long run.

How to provide expert, good-quality, timely and economically successful forest work performance – considering the present status and the profile of the contractors – is an issue the solution of which had to be investigated. The to date preliminary research on this issue (Vondra et. al. 1997, Martinić 1998) shows that the present forestry contractors are neither organised, nor sufficiently qualified and economically stable. They thus promise questionable production potentials in the Croatian forestry branch. The research has likewise shown that the conditions for the development of qualified and reliable forestry contractors, as well as a model that would assure the quality of their work, are as yet to be created.

SUBJECT AND AIM OF THE RESEARCH
PREDMET I CILJ ISTRAŽIVANJA

Over the last decade, «Hrvatske šume», the company for the management of the Croatian national forests, has greatly relied on forestry contractors for the activities of cutting, processing, hauling and transportation. It was believed that the market mechanisms would create a selection of the best contractors that would turn into reliable and efficient executors of forest services. However, there is little evidence of such results.

After the change of registration to trade company («Hrvatske šume» Ltd. of April 8th 2002), it is expected that the types and quantities of the jobs carried out by contractors would further increase. Many issues, however, still remain to be solved in terms of the contractors' profiles, and the basic qualifications required for high-quality forestry work. These conditions reate to the aspects of professionalism/technique, organisation/safety, and economics/law. While the countries with developed forestry largely take care of these conditions, our forestry practice lacks even a preliminary concept for the solution of this issue.

A crucial prerequisite for professional and quality forestry work is a qualified and capable contractor. Such attributes are acquired either by strictly legislative provisions (laws, regulations, statutes), or by exactly defined models. Accordingly, this paper discusses three main instruments for the certification of a contractor in terms of business capability, i.e. the programmes of acknowledging their activities:

- *Registration*
- *Certification*
- *Licensing.*

The term *registration* contains the registration of an individual, a trade company, or an entrepreuner into the Registry kept with trade courts, with all the data defined by law.

Certification is the identification of an individual with certain qualifications, including the work experience and training programmes. It is given as an attribute status to those who fulfil the required conditions.

Licensing is the authorisation for carrying out certain activities, among others forestry jobs. It is exclusive, i.e. the lack of a licence means that an individual may not carry out the activities that are subject to licensing.

Table 1 Advantages and disadvantages of registration, certification and licensing of forestry contractors (McKay 1995)

Tablica 1. Prednosti i nedostaci registracije, certifikacije i licenciranja izvoditelja šumskih radova (MacKay 1995)

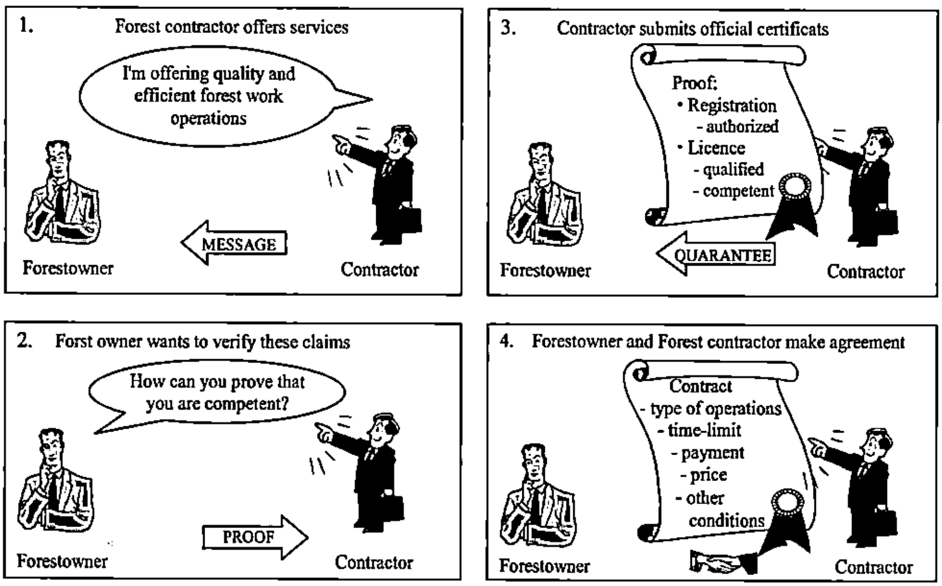
Improvements – *Prednosti*	Problems – *Nedostaci*
Image of forestry – *Imidž šumske industrije*	Resources for program enforcement and administration are limited – *Ograničena sredstva za provođenje programa*
Environmental protection – *Zaštita okoliša*	Standards for recognition by program are arbitrary – *Proizvoljni kriteriji za priznavanje izvoditelja*
Compliance with regulations – *Poštivanje zakonskih propisa*	Standards fail to measure ability to conduct safe and effective operations – *Kriteriji ne uspijevaju mjeriti sposobnost sigurnog i učinkovitog obavljanja radova*
Operator safety – *Sigurnost šumskih radnika*	Operating cost to contractors is increased – *Povećani troškovi izvoditelja radova*
Continuing education participation – *Sudjelovanje u kontinuiranoj izobrazbi*	Contractor mobility between states or provinces is constrained – *Ograničena mobilnost izvoditelja radova između država i provincija*
Business management activities – *Aktivnosti poslovnog menadžmenta*	Entry to forest contracting business is restricted – *Ograničen ulaz u posao davanja šumarskih usluga*
Promptness of payment to landowners[a] – *Brzina plaćanja zemljoposjednicima*	Forest contractor numbers are reduced leading to higher consumer costs – *Smanjeni broj izvoditelja vodi višim cijenama usluga*

[a] In cases when forest contractors act as purchasers and timber merchants themselves
U slučajevima kada izvoditelji šumskih radova kupuju drvo na panju i prodaju ga na tržištu

Experience tells us that an individual program of registration, certification and licensing is ruled by several factors. Among others, there are the questions of voluntary or obligatory implementation of institutional enforcement, financial investment levels into the programme, financial resources, etc. In addition, the choice of the programme may depend on the desired influence of the government on the forestry contractors. However, unlike other programmes, the licence guarantees the good quality and the professionalism of the forest jobs, primarily because it is exclusive, i.e. it can be withdrawn if the contractor does not fulfil certain qualification conditions.

Registration and licensing are of primary interest of the forestry contractors, whose target is to establish themselves as professionally capable, while certification comes next. The establishment of a model that would include registration and licensing as obligatory programmes would ensure the reliability between the contractors and investors.

Figure 1 Roles and relations in the process of making a contract on forestry services
Slika 1. Uloge i odnosi u postupku ugovaranja izvođenja šumskih radova



The absence of licensing contributes to the extensive use of *bargaining* – whereby the job is given to the one that will do it at the lowest price, which is undoubtedly a bad option for the forestry of any country. On the other hand, licensing will necessarily result in the increase of the service prices of the contractors in proportion with the skill, technical equipment, safety measures, social standards, etc. However, if the target is to have or develop qualified contractors, licensing becomes the imperative in forestry policy.

The aim of this article is to find models that will – by taking into consideration all characteristics of the present state of forestry operations in Croatia – enable the occurrence of the first formally authorised and qualified forestry contractors. The model should rely on the criteria, bodies, institutions and procedures that would insure objective evaluation and unbiased confirmation of contractor's qualifications, as a guarantee of professional, quality, timely, and economically successful execution of the work. A scientific approach should assess parameters of mandatory conditions, and suggest a certification model that would be acceptable for Croatian forestry.

In relation to the overall forest management, the results of the research should contribute to better quality in making decisions on employing forestry contractors. In view of economics, they would increase the efficiency and lucrativeness of the forest work and its safety as well. A considerable contribution may be expected in the reduction of the forest ecosystem damage.

RESEARCH METHODS
METODE ISTRAŽIVANJA

The research target entailed the following steps:

- Review of the to date research;
- Analysis of the forestry contractors employed by «Hrvatske šume»;
- Review of foreign models and licensing experience;
- Analysis of the criteria for registration and licensing of the contractors as the certification model framework;
- Suggestion of certification model establishment.

Besides investigating the research issue in domestic and foreign specialist literature, the relating offices and organisational units of "Hrvatske šume" were contacted for the necessary data.

The review of foreign models and experience has been made on the basis of the *online* database *Current Contents, ForestScience.info, Cab Abstracts.* The web pages of significant forestry institutions (faculties, research centres, expert associations, etc.) were referred to. The research involved the forestry entrepreneurship of the European countries, the procedure of forestry contractor certification, qualifications and criteria for contractors, certification bodies, etc.

SOME ASPECTS OF THE EUROPEAN FORESTRY ENTREPRENEURSHIP
UVID U NEKE ASPEKTE PODUZETNIŠTVA U ŠUMARSTVU EUROPE

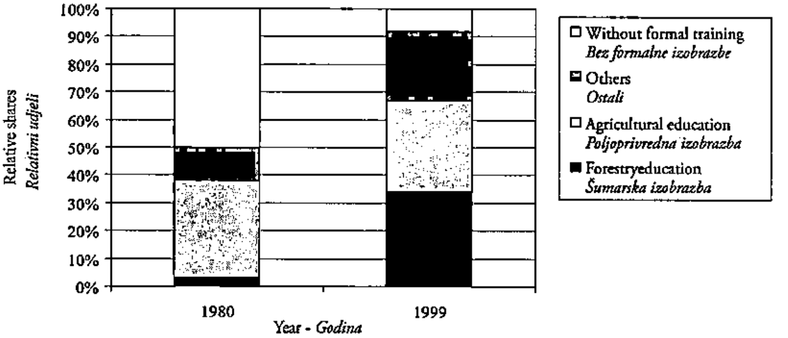
Most enterprises that offer forestry services in Europe are small family firms, which, besides family members, employ one or two additional persons (Kastenholz 2000).

Contractors with a two-figure-staff appear only exceptionally. An average number of staff in a firm ranges between two and five persons. An exception is the Czech Republic, where large wood and paper companies are also included in the calculation. (Table 2).

Table 2 The number of staff in forest service companies (Kastenzolz 2000)
Tablica 2. Broj zaposlenika u poduzećima za pružanje usluga u šumarstvu (Kastenholz 2000)

Country – *Zemlja*	Number of employees – *Broj zaposlenika*			Total employment in all enterprises *Ukupan broj zaposlenih u svim poduzećima*
	min	max	mean – *srednji*	
Bulgaria (BG)	60			240
Switzerland (CH)	1	30	2-3	500
Czech Republic (CZ)	25	800	300	20 000
Germany (D)	1	25-40	3-5	590
Denmark (Dk)	1	15-20	3	150
France (F)	1	30	2-3	2 000
Finland (FIN)	1	50	4	4 500
United Kingdom (GB)	1	40	8	6 000
Ireland (IRL)	1	26	6	600
Lithuania (LT)	3	50	20	700
Luxemburg (L)	3	35	6	-
Latvia (LV)				4 562
Netherlands (NL)	1	25	5	450
Norway (N)	1	65	3-4	500
Sweden (S)	1	25	3-5	3 000

Figure 2 Professional qualifications in forest service companies in Lower Saxony (Geske 2000)
Slika 2. *Profesionalne kvalifikacije u poduzećima za pružanje šumarskih usluga Donje Saske (Geske 2000)*



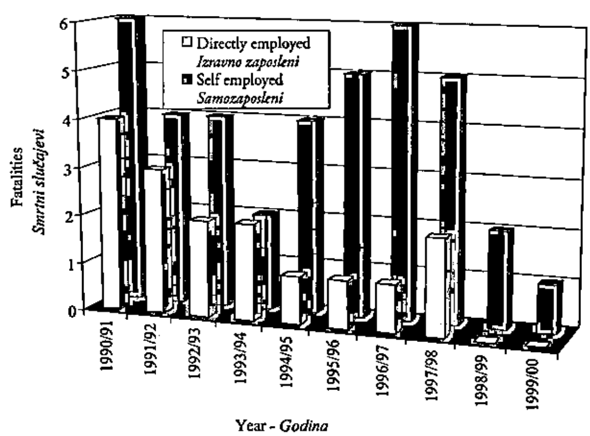
In almost all European countries there are business firms that offer forestry services. They are mainly young associations with low levels of organisation and insufficient financial resources. Most of them were established in the 1980ies and 1990ies, with the basic tasks of representing the interests of their clients vis-à-vis big forest owners, and the protection of the members against unfair competition through low prices.

In European forestry, the demand for basic training is significant (Fig. 2). The improvement of the basic skills may be carried out in short courses, but also in well-developed formal programmes for professional training. North Europe and the countries where German language is spoken offer formal specialist training to forestry workers. However, even in these countries, forestry contractors and their staff do not always possess adequate skills (Kastenholz 2000). Expert associations often play an important role by enabling the contractors' training without long absence from work. Therefore mobile courses are offered, say, in France and Switzerland, where workers can practice during working hours. The aim of such training is rarely the acquisition of formal qualifications, but primarily the one of skills.

The increased numbers of forest contractors are having adverse impacs upon the work safety and health protection in forestry, the areas that have so far been inadequate anyway. The vaguely defined legal obligations of the contractors toward their employees and the inefficiency of the work supervision are the factors responsible for the neglect of the basic safety standards. Small contractors often cannot afford to finance training and development, they are short of qualified workers, and have a high proportion of accidents at work (Fig. 3).

Figure 3 Fatality trends with directly employed and self-employed forest workers in Great Britain (Craig 2000)

Slika 3. Trendovi smrtnih slučajeva među izravno i samo-zaposlenim šumskim radnicima u Velikoj Britaniji (Craig 2000)



According to Kastenholz (2002), the main result of his research on the legal and formal preconditions for forest contract labour is the fact that in most European countries these preconditions do not exceed the routine requirements for any other job. This includes the registration with the authorities for taxing and social security. Only in a few countries there are provisions on necessary qualifications of forestry contractors (France, Great Britain, Netherlands, Sweden, etc.).

DATA AND METHODS FOR THE ANALYSIS OF THE CONTRACTORS EMPLOYED BY «HRVATSKE ŠUME»

PODACI I METODE ZA ANALIZU IZVODITELJA ANGAŽIRANIH OD STRANE "HRVATSKIH ŠUMA"

The data on contractors collected by the Production Service of «Hrvatske šume» have been analysed in order to evaluate the profile and status of the forestry contractors in Croatia. The data were collected from 538 contractors that offered their services at contests between 1998 and 2002. The data on individual contractors include the name and address of the firm, or name, surname and address of the craftsman, number of workers and engineers, number and type of work devices, and (if necessary) a comment on the kind of organisation, staff, or working posts.

The significance of the forest contractors was evaluated according to the work they completed for «Hrvatske šume» in the time period 1998 – 2002. The data on the contracting was used in the process of evaluation, and the following was analysed: tape, volume and value of the contract jobs; organisation and management units where the work was done; terms and the registered and chosen contractors.

The used database contains the required limitations (time period of monitoring, indices contained in the bases, etc.) and other disadvantages. This primarily refers to the irregularity of both the input and updating of the data. Therefore, prior to the data analysis, the necessary adjustments were carried out in order to simplify and accelerate the process of browsing.

Another significant disadvantage is the absence of unified data that would precisely describe the results of the completed work. The presented databases do not tell anything about the quality of the work performed, the damage done, etc., while these data are extremely significant for the evaluation of the contractors' quality and the justification of their employment.

An additional help in the evaluation were "Business reports of «Hrvatske šume»", the reports of the Production Service on the yearly money amounts for the contract work, and the annual reports on production.

The mathematical/statistical processing of the collected data was carried out using a PC with the programme package *Microsoft Excel 97*. The processing was aimed at establishing the basic characteristics of domestic contractors by frequency data analysis, followed by a rough evaluation of the development degree of forestry contractor groups in Croatia. The used data frequencies were absolute and relative, and the results are presented in tables and graphs.

RESEARCH RESULTS
REZULTATI ISTRAŽIVANJA

ANALYSIS OF DOMESTIC FORESTRY CONTRACTORS
ANALIZA DOMAĆIH IZVODITELJA ŠUMSKIH RADOVA

The analysis included the structural characteristics of the contractors (seat, staff number, work means, etc.), market properties of forestry services, and the features of the assigned/completed work.

Some structure indices of the contractors
Neki pokazatelji strukture izvoditelja

Figure 4 Relative proporti-ons of forestry contractors in Croatian constituencies

Slika 4. Relativni udjeli izvoditelja šumskih radova po županijama

The analysis of the territorial distribution of the contractors was carried out according to the firm seat or the place of business registration. The analysis result shows that there is a high concentration of the forestry contractors on the territory of central Croatia, Gorski Kotar and Lika. On the other hand, there are small numbers of contractors in Slavonia and north Croatia, while in Istria and Dalmatia they do not appear at all (Fig. 4).

The most numerous group of contractors (about 64%) is the one without regularly employed workers (Fig. 5). The group with regular employees has the highest proportion of those who employ one or two workers. The contractors with many employees are mainly the firms to which forestry is not the chief field of activity.

The employment of forestry engineers is even less favourable. Only 2%-3% of contractors say that their foresters have high specialist education. These are mainly the firms with one engineer, while only three firms said that they employed more than one forestry engineer (Fig. 6).

Figure 5 Distribution of contractors per number of employed workers

Slika 5. Raspodjela izvoditelja po brojnosti zaposlenih radnika

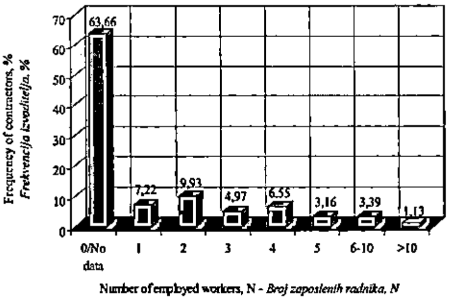
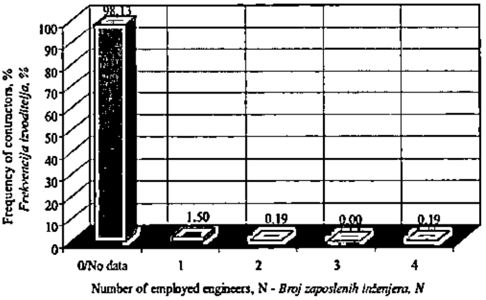


Figure 6 Distribution of contractors per number of employed university graduated forestry engineers

Slika 6. Raspodjela izvoditelja po brojnosti zaposlenih dipl. ing. šumarstva



Forestry contractors' outfit with work devices is presented by the number of machines and tools reported in applications to public contests. The most frequent work device is the chain saw, owned by slightly less than half of the contractors (38.3%). The most numerous are the contractors with only one chain saw (20.4%). Only 49 (9.1%) contractors have three or more saws. Based on experience, we assume that 'Stihl' chain saws are the most frequent trademarks with the contractors, same as with «Hrvatske šume».

Figure 7 Adapted agricultural tractors – common, though not always satisfactory device

Slika 7. Adaptirani poljoprivredni traktori, poznata i ne uvijek zadovoljavajuća radna sredstva

Contractors' outfit for mechanised timber hauling is observed through their distribution in terms of the number and type of adapted agricultural tractors and forwarders (Figure 9). It has been established that more than 75% of the contractors do not possess specialised forestry mechanisation. A firmer orientation in terms of inclusion into forestry is certainly seen with those fifty-three contractors that possess two or more typical items of forestry mechanisation (9.9%). The commonest mechanical devices are the LKT tractors, owned by 44.9% skidder owners.

The situation is better as to the adapted agricultural tractors owned by around 30% of the contractors. These are mainly the IMT tractors, followed by other types (Zetor, Ursus, and Torpedo). The proportion of the contractors with one tractor is the highest (16.2%). Figures 8 and 9 do not contain the contractors that did not report the number of their work devices.

Figure 8 Distribution of contractors per number of chain saws

Slika 8. Raspodjela izvoditelja po brojnosti motornih pila

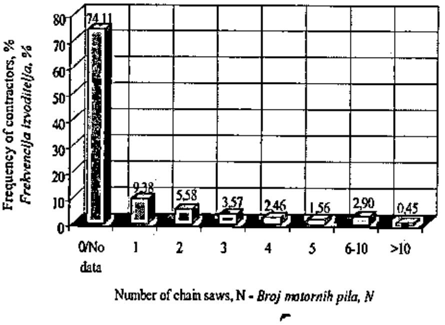
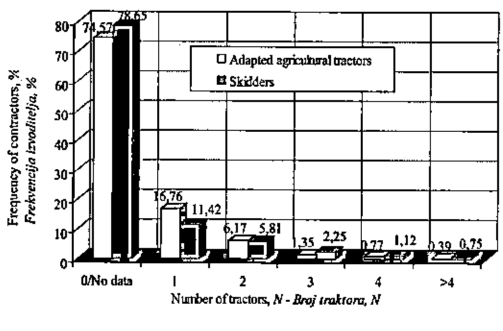


Figure 9 Distribution of contractors per number of forest tractors

Slika 9. Raspodjela izvoditelja prema brojnosti šumskih traktora



The list of forestry work devices shows that the contractors failed to introduce new technological solutions, or the new devices into their work. Only eight contractors use forwarders, while only two of them have cable transporters.

A relatively higher number of horses (Table 3) account for a long tradition of private contractors used to hauling and skidding by horses (named *samaraš*). Among the contractors that use horses, the group with 6 to 10 horses is the commonest (26.6%). The highest number of horses per contractor is sixteen.

Since 1998 the whole wood transport has been subjected to public contests, instead of being dealt with by contractors as before. Accordingly, the analysed databases did not contain any information on the trucks and building mechanisation commonly used by suppliers of services. It also does not contain the data on the age and expiry date of the mechanisation, but it is assumed that this corresponds the ones of "Hrvatske šume". Considering the unsatisfactory condition of the mechani-

Table 3 Forestry contractors according to the number of used horses
Tablica 3. Izvoditelji šumskih radova prema brojnosti konja

Number of horses *Broj konja*	Frequency of contractors *Frekvencija izvoditelja*	
	N	%
0 / no data	444	82.53
Dubious number *Upitan broj*	41	7.62
1	1	0.19
2	6	1.12
3	-	-
4	15	2.79
5	2	0.37
6-10	25	4.65
More than 10 *Više od 10*	4	0.74
Total – *Zajedno*	538	100.00

sation of "Hrvatske šume", as described by Vondra et al. (1997)[1], the question is to what degree such mechanisation contributes to the achievement of positive production, financial and business results.

According to the reported data on work devices and staff, the contractors have been divided into four groups (Table 4). In the Group *No employees and no work devices* there are frequent comments: "workers when required" and "equipment available on requirement", because in Croatian entrepreneurship (not only the forestry one) workers are often employed for occasional jobs.

[1] Vondra et al. (1997) describe the condition and the exploitation of the machines owned by „Hrvatske šume" as follows: „The average age of the main observed groups of working devices (and/or chain saws, tractors, trucks, buses, personal cars) is above eight years. Accordingly, most devices have been used for the time period that is above the limit of an efficient term of exploitation. It is known that the expiry of the term of exploitation means functional and technological obsoleteness and economically unjustified intensive and expensive maintenance. This is connected with numerous difficulties in carrying out the production tasks (delays in bio-technological terms, increased costs, reduced motivation of staff, etc.). The production under such conditions results in abrupt fall of economical efficiency, reduction of production ability, and lower wages. The most significant result is the reduction of the revenue."

Table 4. Basic outfit structure
Tablica 4. Osnovna struktura zbirke

Group – *Grupa*	Frequency of contractors *Frekvencija izvoditelja*	
	N	%
Contractor has staff and work devices *Izvoditelj ima zaposlenike i radna sredstva*	197	36.62
Contractor has staff, but has no/does not report work devices *Izvoditelj ima zaposlenike, nema/ne navodi radna sredstva*	61	11.34
Contractor has no/does not report staff, but has work devices *Izvoditelj nema/ne navodi zaposlenike, ima radna sredstva*	130	24.16
Contractor has no/does not report staff, and has no/does not report work devices *Izvoditelj nema/ne navodi zaposlenike i nema/ne navodi radna sredstva*	150	27.88
Total – *Zajedno*	538	100.00

A little more than one third of the registered contractors (36.6%) have both regularly employed workers and their own work devices. These are mostly small contractors with a staff of one or two and modest equipment. However, they present a healthy base for creating steady and reliable forestry contractors.

Table 5 shows the total number of the employed staff and work devices included in the service sector of the Croatian forestry, with the average values related to all registered contractors (*Average 1)*, and those referring only to the contractors that have staff, i.e. individual work devices (*Average 2)*.

Table 5 Data on the employed staff and work devices of forestry contractors
Tablica 5. Podaci o zaposlenicima i radnim sredstvima izvoditelja šumskih radova

Category - *Kategorija*	Staff/device number, N *Brojnost, N*	Average 1 *Prosjek 1*	Average 2 *Prosjek 2*
Staff – *Zaposlenici*	998	1.86	3.90
Workers – *Radnici*	977	1.82	3.82
Engineers – *Inženjeri*	21	0.04	1.62
Work devices – *Radna sredstva*			
Chain saws – *Motorne pile*	608	1.13	2.95
Stihl	10	0.02	1.67
Husquarna	2	0.004	2.00
Unclassified – *Nerazvrstane*	596	1.11	2.99
Ad. agr. tractors – *Ad. polj. traktori*	230	0.43	1.52

Table 5 continued – *Nastavak tablice 5.*

IMT	42	0.08	2.10
Zetor	9	0.02	1.29
Torpedo	9	0.02	1.50
Steyr	2	0.004	1.00
Universal	2	0.004	1.00
Ursus	2	0.004	2.00
Unclassified - *Nerazvrstani*	164	0.30	1.38
Skidders – *zglobni traktori*	215	0.40	1.82
LKT	91	0.17	1.72
Timberjack	23	0.04	1.53
Unclassified – *Nerazvrstani*	101	0.19	1.77
Forwarders – *Forvarderi*	9	0.02	1.13
Cable transporters - *Žičare*	2	0.004	1.00
Mini forwarders - *Ekipaže*	9	0.02	1.80
Horses - *Konji*	591	1.10	6.29

One fifth of 998 employed are three firms to which forestry work is not the main activity. This means that the average 3.9 employed per one firm/entrepreneur (Average 2) may be somewhat smaller, and could correspond the average number of chain saws (around 3.0). Considering the total number of contractors, this average number could be considerably smaller, i.e. around 1.5, if three mentioned firms are not considered.

Figure 10 Horses are still present in Croatian forestry

Slika 10. Konji još uvijek prisutni u hrvatskom šumarstvu

Adapted agricultural tractors prevail in forest mechanisation with an average of 1.5 (Average 2) and 0.4 (Average 1), as well as forest skidders with an average of 1.8 (Average 2) and 0.4 (Average 1) per contractor. The use of forwarders, cable transporters and other similar devices is very modest. Such status should be related to the beginnings of private entrepreneurship, when there was a risk in employing foreign capital (linked with the insecurity of contracting long-term big-volume jobs), so that service suppliers unwillingly decided on purchasing their own, infrequently expensive, mechanisation.

Relation between service bidders and contractors

Odnos nuditelji – izvršitelji usluga

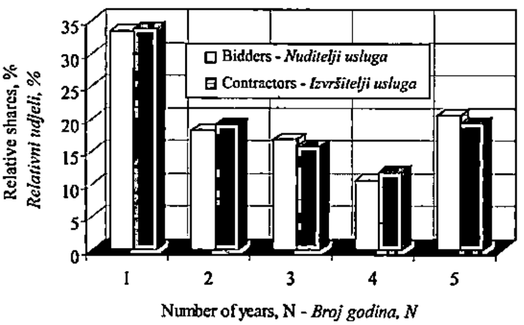
Only thirty-five contractors have never been chosen at «Hrvatske šume « contests among the total number of them that offered their services (Table 6). It looks as if almost all have been regarded as capable of carrying out the given jobs. The question is, what criteria were used at selecting contractors, particularly if their staff and technical/technological insufficiencies are considered. The assumption that there were no firm criteria is justified.

Table 6 Number of bidders and contractors by years
Tablica 6. Broj nuditelja i izvršitelja usluga po godinama

Year - *Godina*	Bidders - *Nuditelji*	Contractors – *Izvoditelji*	
	Number, N – *Brojnost, N*		%
1998	366	351	95.90
1999	324	305	94.14
2000	305	281	92.13
2001	276	251	90.94
2002	254	230	90.55
All 5 years *Svih 5 godina*	573	538	93.89

An average of three hundred contractors contested for job contracts every year. However, their number decreased from 366 in 1998 to 254 in 2002. We assume that those without competitive advantages did not survive. Such selection should lead to increased competition among them, creating a group of high-quality contractors. The future will tell, whether this will really happen. Similar expectations in Europe have so far not been fulfilled.

Figure 11 Contractors by number of years of their practice in providing forest services
Slika 11. Izvoditelji prema broju godina u kojima su prisutni kao nuditelji/izvršitelji usluga



Most contractors display a short-term interest for employment in forestry (Figure 11). One third of the contractors are employed every year, though the number of those that enter is slightly smaller than the number of those that leave.

Contractors are mainly focused on the "central" Forest Office – the one that covers the territory of the contractors' own activities (Tables 7 and 8). One fifth of the contractors exceed such territorial borders and appear as suppliers and/or contractors of services in up to four different forest management offices. However, even in such cases they deal with territorially neighbouring forest managements, so that the contractors of jobs continue to be linked with their seats of business.

Table 7 Contractors by number of forest administrations in which they are present as service bidders

Tablica 7. Raspodjela izvoditelja prema broju uprava u kojima su prisutni kao nuditelji usluga

Year – *Godina*		Number of forest administrations – *Broj uprava šuma*				Together *Zajedno*
		1	2	3	4	
		Frequency of contractors, N – *Frekvencija izvoditelja, N*				
1998		331	30	5	-	366
1999		287	30	7	-	324
2000		271	29	4	1	305
2001		249	24	3	-	276
2002		225	25	3	1	254
Whole period	N	458	83	25	7	573
Cijelo razdoblje	%	79.93	14.49	4.36	1.22	100.00

Table 8 Contractors by number of forest administrations in which they are present as service providers

Tablica 8. Raspodjela izvoditelja prema broju uprava u kojima su prisutni kao izvršitelji usluga

Year – *Godina*		Number of forest administrations – *Broj uprava šuma*				Together *Zajedno*
		1	2	3	4	
		Frequency of contractors, N – *Frekvencija izvoditelja, N*				
1998		317	30	4	-	351
1999		272	26	7	-	305
2000		254	26	1	-	281
2001		226	22	3	-	251
2002		207	21	2	-	230
Whole period	N	433	78	22	5	538
Cijelo razdoblje	%	80.48	14.50	4.09	0.93	100.00

Based on the job types advertised at public contests and the interested (applied) contractors, the following service types have been established:

SBR – simple biological reproduction
radovi jednostavne biološke reprodukcije

EBR – extended biological reproduction
radovi proširene biološke reprodukcije

TH – tractor hauling
izvoženje drva traktorom

HS – horse skidding
vuča drva konjima

F – felling – *sječa*

HH – horse hauling
iznošenje drva samaricom (konjima)

CB – cable hauling
iznošenje drva žičarom

FH – forwarder hauling
izvoženje drva forvarderom

TS – tractor skidding – *vuča drva traktorom*

TT – truck transport
prijevoz drva kamionima

FOE – forest order establishment
uspostava šumskog reda

Other – transport of tractors, students, seedlings etc
prijevoz traktora labudicom, prijevoz učenika na uzgojne radove, doprema sadnica

In the presentation of the number of services, the work on simple and extended biological reproduction was not classified in lower groups of work. Thus established number of services on the Croatian forestry market amounts to 12. When regarded individually, the jobs of both simple and extended biological reproduction, and those under «Other» would amount to 28 service types.

Figure12 Forwarding among the forest contractors' services
Slika 12. Izvoženje drva forvarderima među uslugama koje pružaju izvoditelji šumskih radova

Most contractors (1/4) offer the service of cutting and skidding by tractors (Fig. 13). These are followed by those that offer the service of hauling and/or horse skidding (10%). The possibilities of doing other services are closely connected with the owning of the required machinery. Thus, very few contractors, below 1%, offer hauling by cable transporters and forwarders.

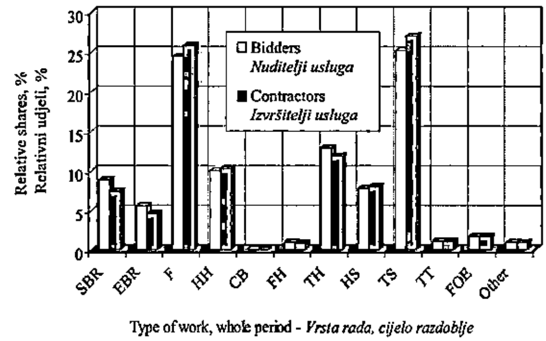


Figure 13 Distribution of contractors by services they provide
Slika 13. Raspodjela izvoditelja prema uslugama koje pružaju

Most contractors (30.2%) offer two services out of twelve defined (Table 9). These are mainly felling and tractor skidding. A considerable part of the offer is given by the contractors that are capable of offering three different service types (23.0%). This service group mainly contains the following: felling, hauling and tractor skidding (38 contractors), and felling, horse skidding, tractor skidding (37 contractors).

Table 9 Contractors by years and number of services they provide
Tablica 9. Izvoditelji radova prema godinama i broju usluga koje nude

Year *Godina*		Number of services – *Broj usluga*								Total
		1	2	3	4	5	6	7	8	*Ukupno*
		Frequency of contractors, N – *Frekvencija izvoditelja, N*								
1998		119	139	75	23	7	3			366
1999		102	135	57	23	5				322
2000		105	120	50	21	6	2			304
2001		61	113	60	27	9	3	3		276
2002		48	98	49	31	17	7	3	1	254
Whole time period	N	124	173	132	82	29	18	13	2	573
Cijelo razdoblje	%	21.64	30.19	23.04	14.31	5.06	3.14	2.27	0.35	100.00

A great number of contractors that offer only one service type (124 or 21.6%) proves that the desired trend of forming universal, all-round contractors is not taking place, or it does not happen fast enough.

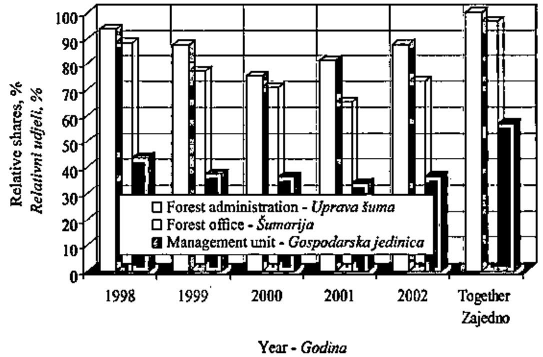
Jobs contracted/carried out through forest service suppliers

Radovi ugovoreni/izvršeni s davateljima šumarskih usluga

The jobs contracted between «Hrvatske šume» and forest contractors are described by the following indices: number of sites, type and volume of work, completion terms, and work value.

The establishment of the number of sites on which contractors are employed is based on the number of organisational units and the units of forest management division. It has been established that in the given time period the contractors carried out work in all of the sixteen forest administrations, in 165 (96.5%) forest offices, and 473 (56.6%) management units. On the average, they yearly carry out work in 128 (75%) forest offices, and all 314 (38%) management units (Figure 14).

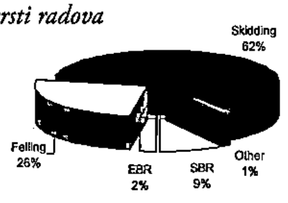
Figure 14 Share of work contracting in all units
Slika 14. Udjeli ugovaranja radova u ukupnom broju jedinica



The number of sites is considered equal to the number of forest sections in which work has been contracted. The differences may be accounted for by the work that took place on several neighbouring sections, all being treated like one work site. Accordingly, in the course of five years, altogether 10,200 sites (determined conditionally by forest sections), on which contractors carried out forest jobs, were reported.

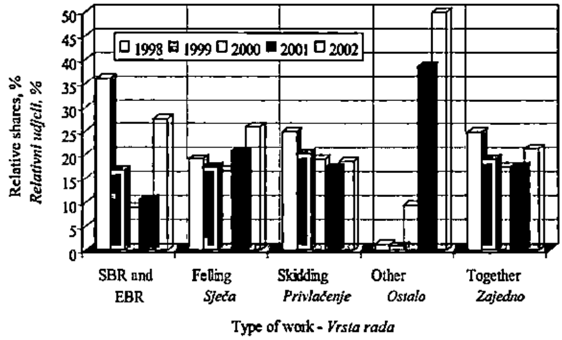
On most sites the services of skidding were used (Figure 15). These are followed by the sites of cutting and processing. In the past silvicultural work (SBR and EBR) was often organised through the establishment of a civil legal relation (CLR) with a high portion of temporary labour. With the absence of this possibility, «Hrvatske šume» must now employ (for a definite time period) workers for carrying out silvicultural work, or engage contractors. In future we may expect an increase in the contracts for this kind of work.

Figure 15 Number of work sites by type of works
Slika 15. Broj radilišta prema vrsti radova



After analysing the contracted jobs, the money to be paid by «Hrvatske šume» for the completed work was calculated. The average amount paid yearly to contractors is KN 77,337,200. The value of all jobs contracted in five years amounts to KN 386,686,000. The proportion of skidding was the highest (KN 277,562, or 71.8%). The increasing trend of other contracted labour is mainly the result of inconsistency in recording timber transport (Figure 16).

Figure 16 The value of contracted jobs per work type and years
Slika 16. Vrijednost ugovorenih radova prema vrsti radova i godinama



After reviewing the values of the contracted jobs, it was interesting to establish the revenues of the forest service suppliers (Table 10). In every year, the highest number of contractors is the one related to the jobs worth KN 100,000. Their proportion ranges between 28.3% (2002) and 39.0% (1998 and 1999). The highest total value of the jobs contracted with individual contractor in one year is up to KN

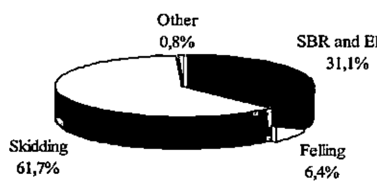
Table 10 Distribution of contractors per year and the value of contracted jobs
Tablica 10. Raspodjela izvoditelja prema vrijednosti ugovorenih radova i godinama

Value of contracted jobs, KN 10^3 *Vrijednost ugovorenih radova, 10^3 kn*	Year - *Godina*					Whole time period *Cijelo razdoblje*	
	1998	1999	2000	2001	2002		
	Number of contractors, N – *Broj izvoditelja, N*						%
0 – 100	137	119	105	86	65	139	25.84
100 – 200	85	67	71	66	59	83	15.43
200 – 300	45	41	38	36	23	58	10.78
300 – 400	24	31	22	22	19	28	5.20
400 – 500	15	12	14	13	16	28	5.20
> 500	45	35	31	28	48	202	37.55
Total, N – *Ukupno, N*	351	305	281	251	230	538	100.00

5,500,000, i.e. up to KN 11,100,000 in a five-year-period. It has already been said that the mentioned values are the contracted prices of the jobs. The real revenue (profit) of the contractors is the difference between the presented revenues and all expenses to be covered by the work contractors.

With the assumption that the initial prices at a public contest present the cost level upon which individual jobs can be carried out individually, the comparison of the contracted prices established the subtracted amounts («savings») realised by «Hrvatske šume». The average annual difference between the initial and contracted prices amounted to around KN 2,156,000. These values ranged in reality between at least KN 1,272,715 (1999, 11.8%) to up to KN 3,034,666 (2001, 28.2%). The total financial effect, realised by «Hrvatske šume» over five years through contractors, amounts to KN 10,779,117 (Figure 17).

Figure 17 Distribution of a five-year financial effect (‚saving') per job type
Slika 17. Raspodjela 5-godišnjeg financijskog efekta ('uštede') po vrstama radova

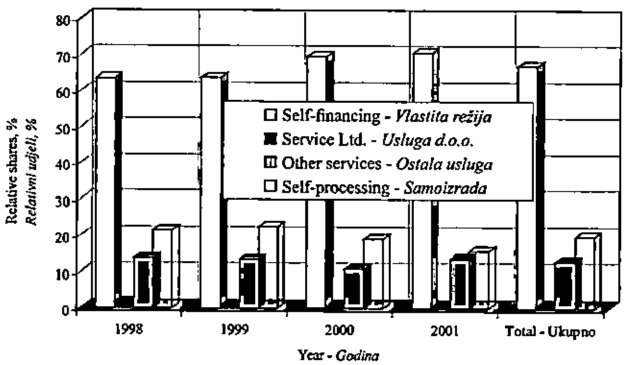


Forestry contracting is made every year on different terms that ranged between one day and one year. However, the short-term ones are the commonest. The average term was 50 days, while 38.8% of contracts were made with terms shorter than 30 days.

A review of the work per individual contractor was made using the Business Reports of «Hrvatske šume» and the Report on Production Realisation by the company's Production Department. Based on this, the proportion of contractors in the total volume of cuts and skidding was established. The said sources do not contain the data on the contractors that carried out work on biological forest reproduction, so that the respective proportion of contractors may be estimated only by assuming that the contracted and completed jobs were of the same size. Furthermore, the Review does not include the year 2002, as at that time reports were not required.

The proportion of contractors in cuts and wood processing («other services» in Fig. 18) ranges between 10.8% in 2000 to 13.7% in 1998. In the analysed four years, they are responsible for 12.8% cuts in the processed 1,698,740 m^3. This is an annual average of 424,685 m^3. The significance of the contractors is even somewhat higher when regarding industrial timber, though a little lower regarding stacked timber. In these two cases, the respective proportions are 13,8% and 11,7%.

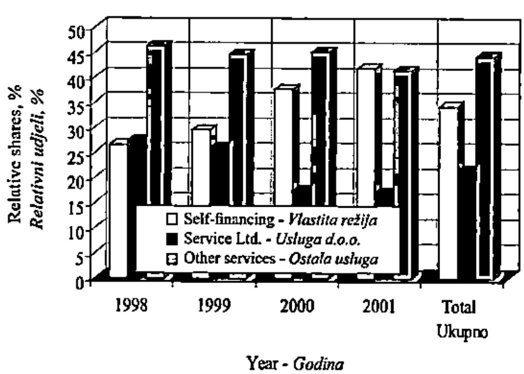
Figure 18 Share of cutters by years
Slika 18. Udjeli izvršitelja sječe po godinama



The proportion of self-processing (cutting and processing done by local population for their own needs) is particularly significant with the processing of stacked wood (40.7%). «Hrvatske šume» carried out 67.0% using their own capacities, or 67.7% if counting the participation of the *Services Ltd.* (former trade companies owned by «Hrvatske šume»).

In timber skidding between 1998 and 2001, contractors carried out for «Hrvatske šume» 44.2% of the total work (Figure 19). The highest proportion in skidding (46.2%) was at the beginning, the lowest (41.3%) at the end of the observed period. In four years, they hauled altogether 4,690,527 m^3, which is an average of 1,172,632 m^3 every year. With a proportion of 57.6%, they hauled more than half the volume of stacked wood, i.e. 38.8% of roundwood.

Figure 19 Share of skidding operators by years
Slika 19. Udjeli izvršitelja privlačenja po godinama



The proportion of foreign contractors in the work on biological forest reproduction in Croatia is estimated according to the volume of contracted work. The proportion of the work on simple biological reproduction contracted with foreign firms in the given period amounts to 10.2%, while the extended biological reproduction amounts to 6.0% of their work.

Estimate of forestry contractors

Ocjena izvoditelja šumskih radova

Forestry contractors in Croatia are small, poorly equipped family firms, often without any regularly employed staff, with no typical, or frequently without any, forestry work devices. Only 36% of the contractors have regularly employed workers and their own work devices. Only 15% of them employ more than three workers, while between 2% and 3% employ forestry engineers. Most firms engage in forestry as a short-term activity. The firms are generally short-lived, and their fluctuation is high. Only 20% of them are active in offering services in forestry for more than five years. Most (30%) may offer services in only two work types (cuts and tractor skidding). Their significance, however, is in the volume of work they perform. Every year they carry out an average of 13% of cuts and 44% of skidding. With a proportion of 10%, they annually participate in the work on biological forest reproduction, and with 60% in wood transport.

Martinić (1998a) considers that *a solid and qualified* contractor is the one that owns at least two typical forest mechanisation devices (forwarder, skidder train) and at least three regularly employed workers. Accordingly, out of 538 analysed contractors, only 1/5 could be regarded as such. The remaining 4/5 contractors (Profile: occasional workers without typical work devices, even without any basic forest work devices) should be taken as temporarily engaged in forestry as occasional, temporary, additional and short-term activity. This means that in the given period, in the field of service entrepreneurship there have been no improvements, and the independent forestry contractors are still not qualified, stable and good-quality components of Croatian forestry.

The biggest supplier of forest work, «Hrvatske šume» has no efficient mechanisms for selecting reliable and responsible forestry contractors, controlling that the work is done timely and properly, and sanctioning the contractors' behaviour that is against the regulations. The absence of an overall system of information on the suppliers of forestry services is a serious shortcoming for both a proper analysis of the situation and the improvement of the issue. Under such condition it is inevitable that the qualifications and business capabilities of contractors are confirmed in order to insure an acceptable quality level of forestry work. A complete certification would secure market priority to the authorised and licensed contractors and also guarantee professional and timely execution of work.

THE PRINCIPLES USED IN THE DEVELOPMENT OF THE CROATIAN CERTIFICATION MODEL
NAČELA RAZVOJA HRVATSKOG MODELA POTVRĐIVANJA

The certification of forestry contractors is a procedure by which the qualifications and capabilities of safe, efficient, and proper forestry work are assessed. At the end of this procedure, contractors acquire a *certification – licence,* which makes them qualified for the contests in Croatian forestry. In order to acquire the attribute «qualified», contractors must meet the requirements of registration, staff qualifications, corresponding obligatory levels of social, safety, organisational/technical, and environmental work aspects. Later priorities for thus qualified contractors should consist of the rights of contesting – which is felt at the moment when unqualified contractors are prevented from contesting for such jobs.

The idea is that by the certification of contractors it is possible and necessary to secure the work in compliance with the regulations of forestry profession. The aims of certification are as follows:

- Insurance of proper and professional forest work as a significant public interest in the management of this important natural resource;
- The guarantee to the supplier that the ordered work will be carried out professionally and timely;
- Contractors' obligation of permanent improvements in all aspects of their activities in accordance with transparent professional criteria.

Contractors' certification is considered a good way of regulating the relations and settling the situation on the market of forestry services. This measure is beneficial both for forest owners/forest job suppliers and contractors. To suppliers, it presents a guarantee for professional, proper, timely and economically efficient forest work, and simplifies the decisions on selecting and engaging contractors. To contractors, the certification is an advantage in terms of limiting the possibilities of unfair competition. Thus, the certification is a filter for excluding those contractors that cannot meet the criteria that are the subjects of licensing (safety, social, technological/organisational, etc.).

The certification of contractors will inevitably result in higher prices of their services. It is, however, unavoidable, if the aim is to increase the quality of forest work – which is impossible with the frequently applied principle of «as cheap as possible». Total forest management effects will certainly exceed the investments into the implementation of the licensing model. Instead of considering it as costs, this should be regarded as a long-term multiply lucrative investment. The expenses of establishing the system should also be participated by the Ministry of Forestry through various programmes, financial support and credit lines, e.g. for the purchase of more adequate and modern mechanisation and other equipment. Among others, «Hrvatske šume» should be a participating party.

The criteria relevant for acquiring the licence

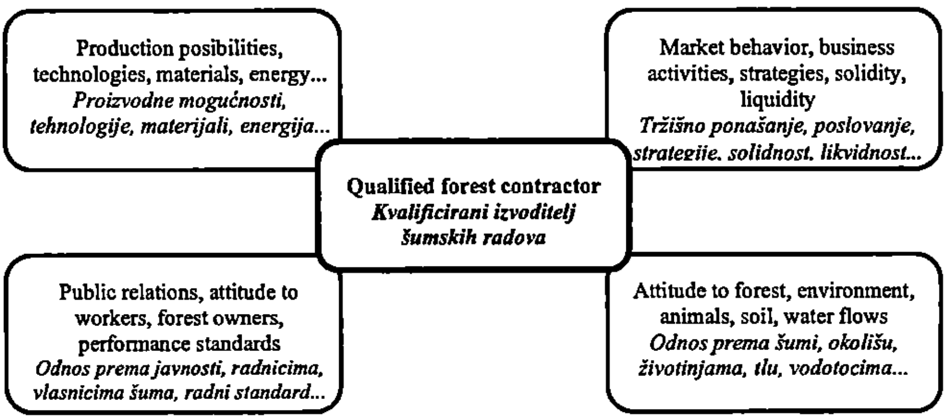
Relevantni kriteriji za dobivanje licence

The following questions should be answered in the process of selecting qualified forestry contractors (primarily the ones for forest exploitation and forest road building), and acquiring the licence in Croatia:

- Which particular unit should be confirmed?
- What should be tested as the qualification condition?
- What and which are the proofs of fulfilled conditions?

In finding the answers to these questions, the current aspects of forest work were considered (environmental consideration, work humanisation, etc.), as well as the protection of the employees' rights, and the development of entrepreneurship as a significant part of today's and future forestry. In doing this, we used numerous domestic and foreign sources of forest services companies and their organisation, environmental suitability, work safety and other aspects significant for evaluating contractors' qualifications.

Figure 20 Areas for assessing the competence of forest contractors
Slika 20. Područja prosuđivanja kvalificiranosti izvoditelja šumskih radova



The suggested contractor certification model is based on the evaluation of qualification in terms of four basic groups of factors. A qualified contractor is the one that fulfils the conditions at the level of all of the four subject fields:

1. Technical/technological field – types, volume and value of the work for which individual contractors are engaged, and their production possibilities. The production possibilities are directly linked with the number and qualification of the staff, and the number and condition of machinery they possess. Accordingly, the technical and technological suitability of the contractor to the basic technologies and categorisation of the terrain includes the testing of the following two aspects:

- Type, number, and technological level of the equipment;
- Age of equipment.

The first task in this phase is to establish the production possibilities of the contractor in terms of particular work types, i.e. which production phases he can accomplish with his own staff and work devices. All is defined by the degree of independence, which is a significant indicator of business capability, and a guarantee of his operating ability.

2. Profession/staff field– undoubtedly deciding in licensing a contractor. With equally good work preparation, the contractor with higher education level of his staff may carry out the job at a higher quality level than the one with lower education. Higher qualification level means higher level of work technique, which results in higher efficiency and lower costs due to injuries or organisation losses. Health and safety of workers cannot be separated from the professional capability of a forest contractor. To every person these factors present a basic value of the working and living standard.

For these reasons, the professional/staff field includes the necessity of satisfying the minimum conditions of formal professional qualification for the following individual work groups:

- Number and professional education of the work manager;
- Number and professional education of the workers;
- Qualification for safe work;
- Outfit with safety means;
- Work standard care;
- Relation towards ecological aspects of work.

3. Economical/organisational field – The following are some aspects the valuation of which is required for establishing the economical/organisational qualification of a forestry contractor:

- Level of company organisation;
- Permanent supervision of work quality – system of responsibility;

- Technical means for acting in case of injury/accident at work;
- Business solidity.

The size of the organisation and the sections that execute the individual business functions is not important. Significant are the presence and the organisation of these functions as integral parts of the management. If the bearer of any production/business function does not work alone but in collaboration with others, or with occasionally engaged workers (subcontractors), this is accepted with a certain reserve, and cannot be valuated as entirely satisfactory. It is necessary to establish, whether the responsibilities and rights of the individual business function bearers have been clearly defined, and whether they have been mutually coordinated. A great attention should be paid to the organisation and implementation of the operative production preparation as a significant guarantee of quality and timely execution of the given tasks.

In order to estimate the business solidity, it is particularly important whether the contractor timely fulfils the contracted tasks. It is also significant to estimate, whether the contractor has been organised so as to secure adequate revenues to the supplier, with simultaneously considering the quality and terms of delivery.

4. Ecological field – Forestry contractors are increasingly faced with the requirements of ecological considerations during their work. A part of their business strategy should also be recognizable, e.g.:

- Strategy of minimum damage to stands and soil;
- Prevention of environmental pollution by oils, etc.;
- Workers' training in practical environmental measures;
- Establishment of stimulation systems for environmental care;
- Establishment of relationships with interest groups (associations, societies that take fight for public interests related to the protection of nature and environment;
- Accessibility and readiness for the application of new, environmentally friendlier technologies, materials and products.

If a forest contractor wishes to acquire the qualification in this licence segment, he must firstly prove that he obeys the legally prescribed measures of environmental protection. The current inefficiency of supervision and sanctioning of ecologically unacceptable behaviour does not mean that this aspect is unimportant.

In the field of ecological protection, the environmental suitability of the technology, the characteristics of the work devices, and the workers' qualifications are evaluated. Particularly interesting are the preventive activities at using the technologies, and the awareness and consistency at removing the caused damage in the environment. Proven events of this are more important than declarative readiness of the contractors to commit such tasks. Some of the preventive activities are the following: use of fast-disintegrating oils; protection of trees from damage (at cuts, upon hauls, at storing wood, etc.); putting up signs or giving additional instructions to workers for the protection of extremely susceptible environments (sources, animal habitats, etc.).

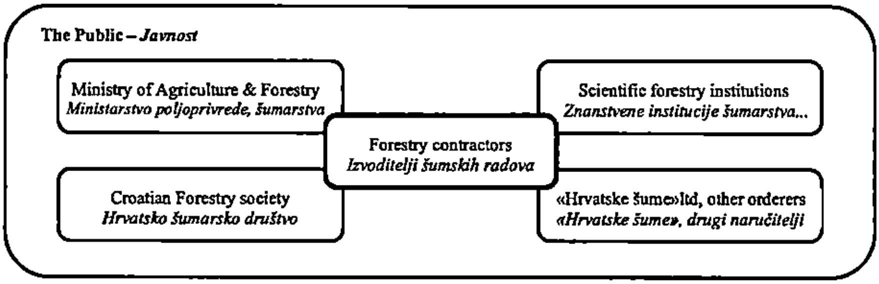
SUGGESTED CERTIFICATION MODEL
PREDLOŽENI MODEL POTVRĐIVANJA

The certification model contained in this study, which will be suggested for the use in the forestry of the Republic of Croatia, includes the following:

- Establishment of the possible bearers of licence;
- Determination of the minimum conditions for the entrance into the licensing procedure;
- Establishment of the protocol and participants in both licensing phases;
- Defining the legal frame and mechanisms (document types, law procedure, etc.), and
- Costs of licensing procedure.

The certification of forestry contractors should not be incidental, and even less should be biased. It therefore cannot be carried out by the forest owner, or work supplier, but by an independent, qualified group of experts/evaluators in an acknowledged specialist organisation or association. It is important that this organisation has no direct business relations with the contractor that is the candidate for licensing. In Croatia there is today no institute for certification of forestry contractors. Likewise, there is no legislative regulation of this issue, nor any authorised institutions, bodies and work groups. All this is yet to be established. Significant discussions on the most acceptable model for Croatian forestry should firstly be expected. For the first time in Croatian forestry science, this study suggests a *draft of the model of forestry contractors' certification.* It includes the choice of the government bodies, institutions and institutes that should be included into the procedure, i.e. that should be the bearers of particular activities and tasks in the authorisation and licensing.

Figure 21 Interested parties in the licensing procedure
Slika 21. Interesne strane licenciranja

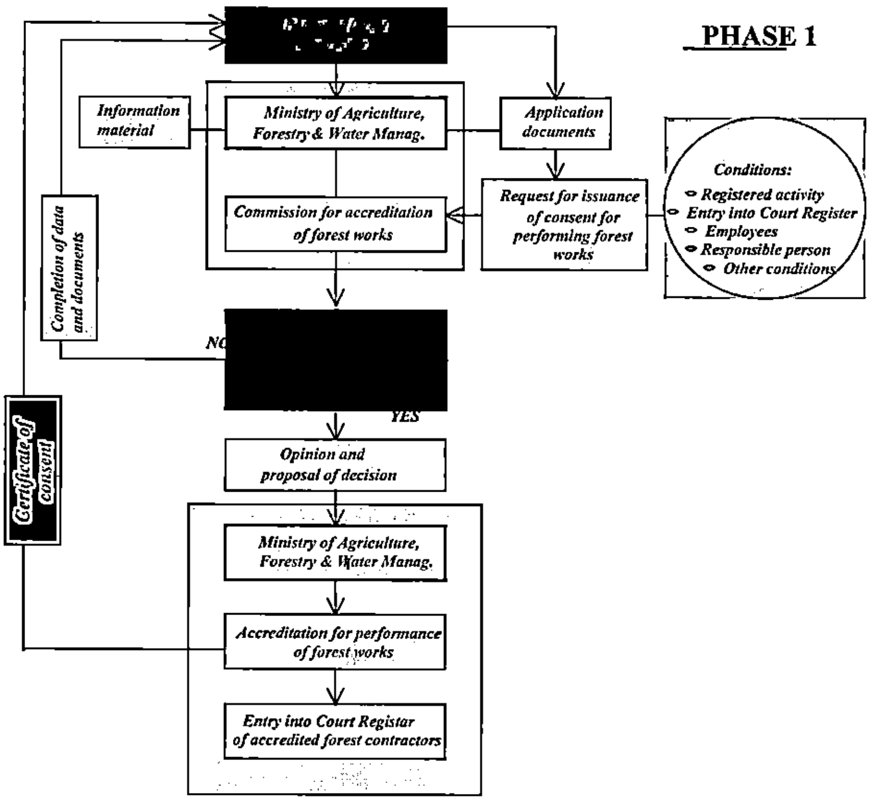


Based on the assessed situation and the profile of a forest contractor, and considering the experience of developed countries, it is suggested that the certification model should be carried out in two phases:

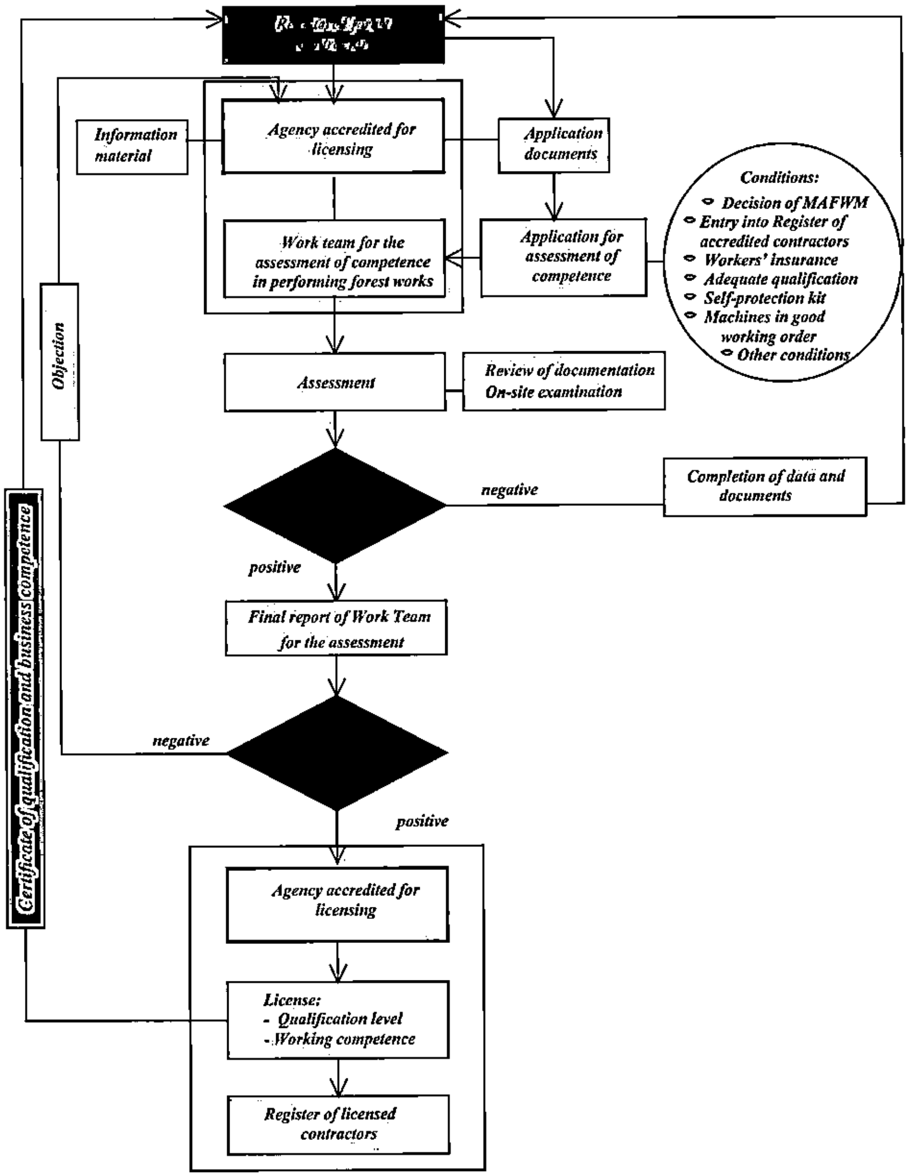
1. Authorisation of forest work;
2. Licensing – evaluation of qualifications and capability for forest work.

Figure 22 shows the model scheme with the certification procedures and bodies. The Croatian licensing system should be established according to the expert criteria and the legally assessed transparent body. The basic normative act for issuing authorisations and licensing is in any case the new *Forest Law.* It is expected that this law will solve the principal issues linked with licensing, and sub law acts should settle them in detail – through the provision of the Croatian government, or by the statutes in accordance with the *Forest Law*. The bearer of this will be the Ministry

Figure 22 Diagram of the proposed model for licensing forest contractors
Slika 22. Shema predloženog modela potvrđivanja izvoditelja šumskih radova



PHASE 2



of Agriculture, Forestry and Water Management. The sub law acts should precisely assign the bearers and ways of licensing, the contents and the form of the relating documents and forms, etc. In the course of carrying out these jobs, the Ministry and the Croatian Forestry Society will form operation bodies for implementing the authorisations and licensing. A special task of the Ministry will be to inform the licensees on all essential issues linked with licensing. By informing its contractors on the new obligation, «Hrvatske šume» can greatly contribute to the success of this part of the task.

Authorisation for forestry contracting

Ovlašćivanje izvođenja šumskih radova

According to the suggested model, the authorised ministry of forestry (MAFW) would carry out forestry contracting. The Commission carries out the procedure of establishing the conformity of the applicant with the prescribed conditions for Authorisation. The Ministry assigns the Commission, which should consist of the representatives of the Ministry, private forest owners, «Hrvatske šume», independent contractors, acknowledged forestry scientists, and non-government associations.

The authorisation of forestry contractors necessarily includes the procedures prior to the submitting and processing of the application, i.e. before the process of confirming the contractor. This entails the advertising and information material, presentations, interviews, and other activities of including the contractors into the process of certification.

The application for authorisation is submitted to the Ministry of Agriculture, Forestry and Water Management. After the inspection, and in case of negative opinion, the Commission returns the documentation to the applicant with explanation and instructions for supplementation; in case of positive opinion, the Commission directs its opinion and suggestion for approval to the MAFW. Based on the opinion and suggestion, the Minister issues the certificate on compliance with the forestry contracting. The applicant is delivered the certificate and he is booked in the Register of authorised contractors.

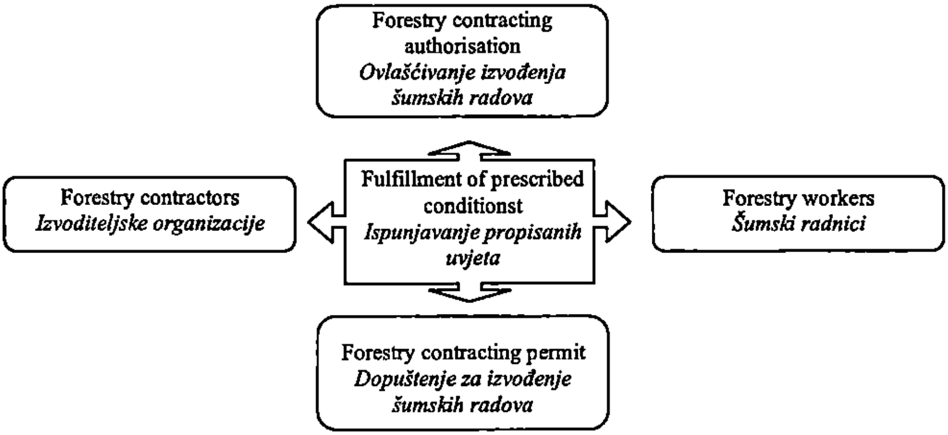
It is very important that Forest Law defines the authorisation for forestry contracting as mandatory, with the provision that only authorised and licensed firms may be forest contractors. This should equally apply to both state and private forests. It is indispensable to allow the possibility that forest owners may carry out certain non-risk and simple jobs on their own.

The authorisation of contractors and their registration into the central Registry will introduce discipline in this field of activity, particularly regarding their obligations toward the employees and the government. Likewise, the government receives the insight into the number and status of forestry contractors, and the possibility of efficient mechanisms for stimulation their work and business.

Subjects, objects and applications for authorisation
Subjekti, predmeti i zahtjevi ovlašćivanja

Authorisation is the allowance of contracting based on the fulfilment of certain prescribed conditions. The subjects of authorisation are legal persons that have registered their field of work together with the jobs that are specific of forestry. Figure 23 shows the objects and subjects of authorisation.

Figure 23 Subjects and objects of forestry contracting authorisation
Slika 23. Subjekti i predmeti ovlašćivanja za izvođenje šumskih radova



A legal person may carry out forestry contracting jobs only on the basis of the certificate issued by MAFW s. The application for the certificate is submitted to the Ministry with the following documents:

- Verified copy of the certificate issued by the Court of Commerce on the registration in the authorised court of commerce, whereby it is evident that the legal person is registered for the work in forestry contracting;
- Name, surname and personal identity number of the person responsible for managing the legal body's affairs;
- Evidence that the person responsible for the authorised legal body has not been sentenced for criminal deed against the Republic of Croatia;
- List of staff;
- Verified copies of staff's health and pension insurance certificates;
- Act of systemising the work posts of the staff with the prescribed specialist qualifications and the description of the tasks with each individual work post;
- Certificate on paid administrative tax.

Another condition included in the suggested model requires that only authorised workers within the authorised legal body may carry out forest work. The application for the authorisation is submitted to the MAFW together with the documents certifying that the applicant

- is a Croatian citizen;
- is 18 year of age;
- has mental, physical and health capabilities;
- has not been sentenced for criminal deeds against the Republic of Croatia, or a criminal deed against life and body, or against other's property, or other criminal deeds with elements of violence, greed, or base instincts;
- is qualified for safe work;
- is qualified for giving first aid;
- is qualified for direct forest work (cutter, tractor driver, etc.).

The fulfilment of each of the listed conditions required from the contracting firm and the persons included in forestry work is proved by documents (certificates) issued by authorised institutions.

The Ministry will issue decisions on withdrawing the authorisation issued to the contracting firm and/or workers employed in such organisations in the following instances:

- if they do not meet the requirements contained in this model of forestry contracting authorisation;
- if the authorisation has been obtained on the basis of false evidence;
- if they carry out forestry work against the regulations established by special prescriptions;
- if there are the reasons that may result in threats to the life and health of humans, and the environment and property.

The authorising institution clearly differentiates the authorised from unauthorised contractors. The advantage of the former becomes thus recognizable and acknowledged on the market. It also removes unfair competition on the market of services, which is beneficial to all, the licensed contractors, suppliers, and the forestry as a whole.

Authorisation is an instrument of achieving the 'first order selection', which puts all contractors to equal position in terms of their legal position, rights and obligations. It presents the first step towards the certification of forestry contractors, and it relates only to the formal and legal premises necessary for carrying out forestry work. A significant part of authorisation is the preparation of the contractors for the second step – licensing.

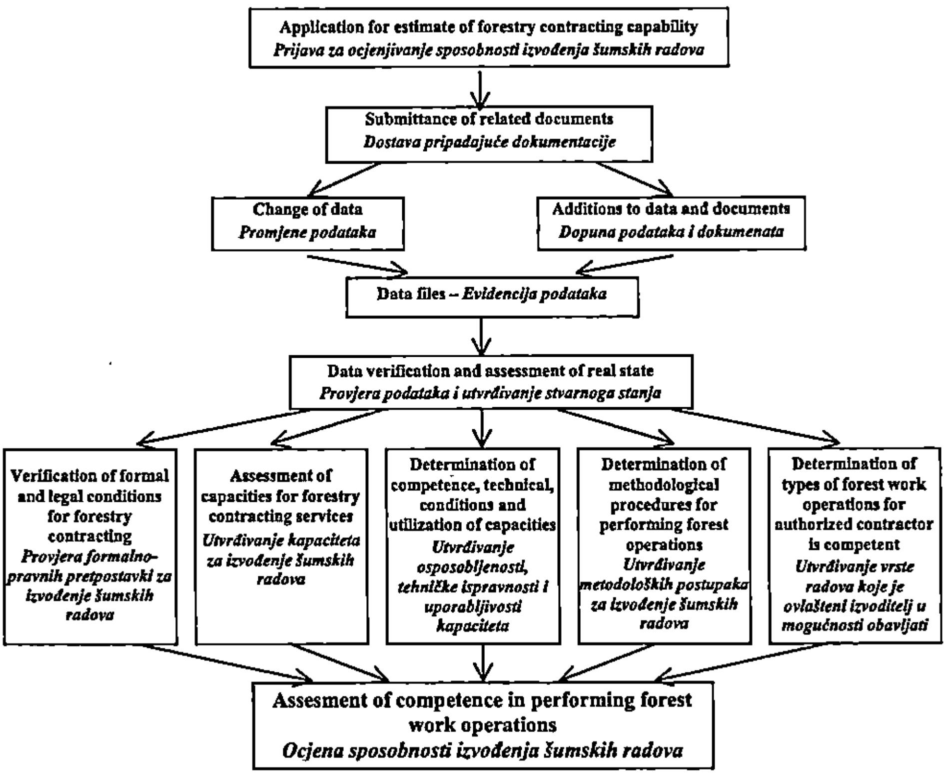
Licensing
Licenciranje

Croatian Forestry Society (or, alternatively, the future Forestry Chamber) has been suggested as the major licensing institution. An independent and acknowledged specialist association would guarantee professional, unbiased and reliable estimates of forestry contracting capabilities. In terms of this, a special work group for licensing consisting of respectable forestry experts and scientists would be formed within the CFS. The licensing procedure can also be organised through several territorially dislocated work groups.

Authorised forestry contractors apply to the licensing procedure upon acquiring the approval from the Ministry, or after the expiry of the previously issued estimate. Figure 24 presents the procedures of capability estimate for forestry contracting.

Figure 24. Procedures of evaluating the capabilities of carrying out forestry contracting services

Slika 24. Postupci ocjenjivanja sposobnosti izvođenja šumskih radova



In order to have their capabilities of carrying out forest services assessed, contractors must submit the related documentation. They must fill in all required data in the prescribed forms, verify them with other documents and submit to the Croatian Forestry Society. Contractors are obliged to report all changes (number of staff, status of work devices, equipment, etc.) that may be relevant for capability of carrying out the work.

Upon inspecting the received data and documents, if needed, the work group invites for their supplementation. By direct insight, the work group assesses the existence of formal and legal presumptions for carrying out forestry work, qualifications, technical correctness and the usability of the capacities. It is particularly important that the members of the Work Group are persuaded whether the contractor is qualified and economically capable for all types of forest work he wishes to carry out.

Based on the findings, the Work Group writes the report and issues the suggestion and evaluation. The opinion and suggestion contained in the decision is delivered to the Presidency (managing body) of the CFS, which makes the conclusion on issuing the certification – the licence on qualification and business capability of the legal body for carrying out forestry services.

In case that the application is refused and the licence not issued, the applicant may file complaint within a prescribed term, enclosing explanations and evidence on which the complaint is based. If the complaint is justified, the evaluation procedure will be repeated.

The licence is issued for a definite time period. The suggested time period in case of the first licence is five years. It is subject to control, and may be withdrawn if the minimum conditions have disappeared. The issued document of licensing (certificate, identity card) must, among others, contain the basic data on the contractor. It is particularly important to list the types of service for which the licence has been issued, i.e. for which the contractor is regarded as capable and qualified.

The changes and additions to the licence is made in cases of significant changes in the capacities of the contractor, the introduction of new equipment, validity expiry of the available outfit, change of staff number, expired date of renting validity, and other changes that have impacts upon the capability of carrying out forest services. The changes should be reported to CFS with the related data and documents required for assessing whether the licence should be supplemented or changed. Likewise, CFS retains the rights of changing a licence whenever it has been established by a single case of inspection of report that the changes in capacities, equipment and other devices are of such nature that may significantly impact the capability of carrying out forest services.

Minimum conditions for issuing the licence
Minimalni uvjeti za izdavanje licence

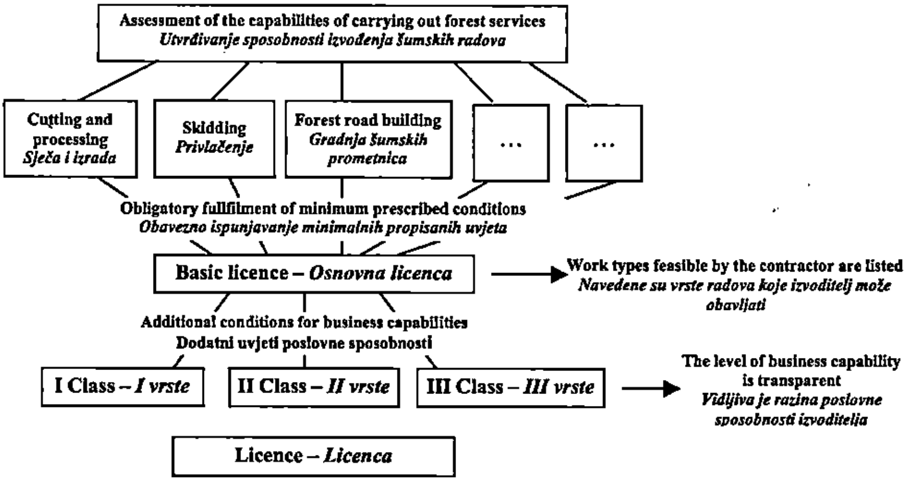
While in the first certification phase formal and legal conditions do not differ essentially from the requirements for any other administrative procedure, licensing is a specialist certification whereby the fulfilment of minimum conditions may suffice for the acquisition of the licence. Taking into consideration all aspects of forest work, the common opinion of the science and profession is that the minimum criteria for every type of forest work should include the following conditions:

- Technical and technological,
- Staff qualification,
- Economical and organisational, and
- Ecological/environmental.

This study is presenting the approach that the basic (elementary) unit of certification should be the wholeness of entrepreneurship consisting of at least one specific work device and one regularly employed worker. There is no reason for refusing the licence to such contractor, if he fulfils all other formal and legal professional criteria and conditions. Such contractor is capable, although his business capability is reduced to small-size forest services.

On the other hand, compared to those with more work devices and bigger staff number, a smaller business capability of such contractors should not be neglected. The same licence to all contractors would lead to their economical equalisation re-

Figure 25 Principle of assessing the capabilities of carrying out forest services
Slika 25. Princip utvrđivanja sposobnosti za izvođenje šumskih radova



gardless of the capacities they possess. It is therefore necessary that, along with the elementary professional qualifications (separating qualified and unqualified contractors), the licensing should be supplemented with another dimension, which would be given to the supplier as the *information on the level of business capability of the contractor*. The presented model of certification suggests that this could be obtained by introducing several levels (categories) of licence.

Mechanised work in forest exploitation as the most significant area of forestry contractors' activity, and the commonest subject of «Hrvatske šume» public contests, should be the first subject of licensing and, as the initial phase of certification, they should present a specific training for further development and application of the model. Accordingly, this article suggests the minimum conditions for making a positive evaluation of the capabilities for carrying out forest services in the case of cutting, processing, and skidding.

• *CUTTING AND PROCESSING/SKIDDING – minimum conditions:*

According to the certification model, a forestry contractor will be regarded as capable for cutting and processing and/or skidding, if he proves that

- he is authorised for forest work;
- he is registered for forestry work;
- he is entered into the Registry of authorised forestry contractors;
- he has at least one employed person that is authorised by MAFW for the work on cutting and processing and/or skidding;
- he insured the staff that is included into the work on cutting and processing/skidding against the case of death or injuries caused while working on these jobs;
- he owns at least one specific work device; chain saw for cutting and processing; adapted agricultural tractor or forwarder for mechanised skidding; one pair of horses for horse skidding;
- his specific work devices used for cutting and wood processing/skidding are technically correct and usable;
- he owns at least one set of specialist equipment, technical devices and tools used for cutting/processing (axe, wedge, gravity cable, turning hook), and skidding (winch, protecting structure, horse ropes, etc.), per person directly included into the operations of cutting and processing/per each specific work device for skidding;
- the specialist equipment, technical devices and tools for cutting and processing/skidding are technically correct and usable;
- he owns at least one set of safety equipment (helmet with protection net, antiphons, gloves, boots, overalls, etc.) per person directly included into cutting and processing and/or skidding;

- the safety equipment is technically correct and usable;
- he has an organised function of safety at work according to regulations;
- he can independently carry out the jobs of cutting and processing/skidding;
- he has the documents/provisions that regulate the ways and procedures of planning, carrying out, and expert supervision of cutting and processing/skidding;
- his previous work did not cause unacceptable stand damage;
- he has not been in frequent and serious conflicts with the organisations that take care of public interests related to environmental protection.

By fulfilling these conditions, the contractor acquires the licence for carrying out cutting and/or timber skidding. The fulfilment of the conditions is proved by required documents issued by authorised institutions and institutes. Among others, these are the following:

- Staff registration with the institute of pension and health scheme, and the authorisations for forestry work issued by MAFW – *number and qualifications of regular workers;*
- Insurance policies in case of death and injury of the workers included directly into the carrying out of forest work – *staff insurance;*
- Certificates on the compliance of the tractors with the conditions prescribed by the Statute on basic requirements for tractors used in agriculture and forestry (NN No. 75/01 of April 2002); the certificates of the authorised institutions for the testing of noise and vibrations of the chain saws, or the certificate that the age of the chain saw is below three years – *technical correctness and usability of specific work devices;*
- The possession of at least half of the registered devices on the basis of ownership, and regular employment of at least half of the registered staff – *capability of independent carrying out of forest services;*
- The certificate issued by the Ministry of Home Affairs on the absence of punishment or processes due to endangering the environment; recommendation of previous suppliers of services, and the certificates of the organisation that care for public interests related to the frequent and serious conflicts – *environmental consideration.*

Types of business capability as a component part of the licence

Vrste poslovne sposobnosti kao sastavni dio licence

The licensing confirms which of the forest services can be carried out independently by the contractor, who, based on the fulfilment of the minimum conditions, acquires the licence. On the other hand, based on the total evaluation results (particularly in the area of staff qualifications and technical/technological relations), the contractor gets additional mark of the level of business capability. Such selection of the licensed contractors enables a specific rating, which is important for the supplier in case that he needs a particular level of qualification and capacity of the contractor. This equally applies to the creators and bearers of the policy of promotion and development of forestry entrepreneurship, as it highlights the business subjects that should be particularly respected. The motivation effect is also significant of this additional classification, as it initiates positive competition on the market of forestry services.

The certification model contains the selection of the licensed contractors into categories with the following grades of business capability:

1) *I Class Licence* – A forestry contractor is given this licence category if he fulfils the prescribed minimum conditions for carrying out a particular type of forest operations at the level of the least number of staff and the least number of work devices.
2) *II Class Licence*– A forestry contractor acquires this licence category if he, besides the minimum conditions, fulfils the following additional ones:
   - He employs regularly at least five workers authorised by MAFW for carrying our forest work;
   - He employs regularly at least one person (specialist job manager) with secondary specialist education in forestry (forestry technician);
   - He owns at least three specific forestry devices (regardless of the job type);
3) *III Class Licence* – A forestry contractor acquires this licence category, if, besides the minimum conditions, he fulfils the following:
   - He employs regularly at least 10 workers authorised by MAFW for carrying out forest work;
   - He employs regularly at least one person (expert work manager) with high specialist education in forestry (graduated forestry engineer);
   - He owns at least 8 specific work devices for the work in forestry (regardless of the type of work).

The level of business capability is assessed cumulatively for the total number of staff and work devices, whereby it is important that each type of work requires the minimum number of staff and work devices.

«HRVATSKE ŠUME» LTD. IN THE PROCESS OF LICENSING
HRVATSKE ŠUME d.o.o. U PROCESU LICENCIRANJA

«Hrvatske šume» Ltd. Zagreb is a trade company with a mandate of managing the national forests and forestlands in the Republic of Croatia. This includes the responsibility for organisation and carrying out of all forest management operations. The maintenance of qualification and work safety, with a staff of over 4,500 directly employed in forestry production, are significant features of the company. This firstly includes the following:

- Standardisation of the work capability and safety at work (statutes, standards);
- Organisation of the work safety system with the central department of work safety;
- System of previous selection of future production staff;
- Internally continuing and/or occasional training of production staff:
- Programme of introducing new workers;
- Supply of ergonomically more suitable work devices (tools, machines and devices);
- Financial support to monitoring and research.

With meeting all legal conditions related to the social and other rights of their staff, in relation to their forestry contractors, «Hrvatske šume» fulfils all prerequisites for correct and professional carrying out the work using its own staff.

Where is the position of the forestry work teams within «Hrvatske šume» in the process of licensing suggested for forestry contractors? The following should be underlined:

- A trade company which runs business on the basis of profit, «Hrvatske šume» as forestry work operator is a participant of market contesting, with permanent need of rational production and economically efficient business transactions;
- All to date evaluations of the company's levels of realising the work organisation functions, working techniques, work efficiency, and safety at work (Vondra, Martinić, Zdjelar, etc.) have shown a very low level of organisation and realisation of all these functions.
- One part of today's forestry contractors once worked in «Hrvatske šume». It is likewise certain, that this process will increasingly continue in near future;
- In everyday production of «Hrvatske šume», many of the quality indices in forestry operations are either not being sufficiently monitored, or they are being entirely ignored.

According to all that was presented above, it is of crucial importance to determine the way in which the suggested licensing model would encompass «Hrvatske šume» with its staff – the bearers of forest work operations. While I studied and developed this paper, I never thought of any kind of privileged position for the employees of «Hrvatske šume». However, the alarming state in the area of supplying forest work to other contractors must be taken into consideration, since almost half of the significant forestry work volume has been carried out without basic professional regulations, principles and criteria. It is clear that «Hrvatske šume» is considered as a more systemised part in the hierarchy of forestry production.

The forest work operators of «Hrvatske šume» should also be submitted to the obligation of licensing, the procedure of which will be simpler, and the formal and professional criteria more organised and easier to obtain. The level of satisfying each of the criteria will be about the same for both sides – anything else would be damaging for the general progress.

Being directly responsible for all aspects of forest management in Croatia in the section of carrying out forestry operations – which is very significant for the public perception of the forest management benefits - «Hrvatske šume» will undoubtedly be extremely interested in such transparent procedure as licensing. It will thus gain a significant confirmation of its correct and responsible work in forestry.

DISCUSSION
RASPRAVA

Forestry service suppliers have become an avoidable factor in the forest management in the whole world. Accordingly, forest service contractors with all attributes that guarantee professional, timely and economically successful work are desirable and needed in Croatian forestry. The expected development of this entrepreneurship area in Croatia has not taken place. Service contractors are characterised by organisational inconsistency, staff shortcomings, and poor technical provision, all of which result in technologically low levels of the work carried out. Lower labour costs offered by service contractors are enabled by omitting many technological, methodological and safety procedures (the costs of which should be included in the service prices), which are tolerated, i.e. not sanctioned. Under the conditions with the highest proportion of temporary staff, contractors often lack workers of satisfactory qualifications and outfit, while the business of many of them is of short life, and the service types they offer are very limited. The proportion of such contractors in accidents at work is extremely high, and the staff most often does not have any safety or health insurance.

In spite of the scepticism in the evaluation of forest contractors, their significance in Croatian forestry is unquestionable and great. Above all this refers to the work volume they carry out. However, the appearance of forest service contractors of many different types is an uncontrolled and chaotic process. In 1995 contracting services reached the proportion of 50% of the volume planned by the year 2000 by the *'Development Programme of «Hrvatske šume» 1991-2025).* If this process remains uncontrolled during the economic re-systematisation of the whole country, forestry included, the result may prove unfavourable for forestry.

The biggest user of services, «Hrvatske šume» should be among the most interested in the achievement of capable and economically acceptable service contractors – partners. As long as their task is the overall management of national forests and the seller of timber, «Hrvatske šume» should stimulate the development of the desired profile of contractors. The basic task of the expert teams of «Hrvatske šume» related to the development of entrepreneurship should encompass the following:

- Middle-term and long-term defining of the contents and volume of the jobs that will be carried out as contracted service;
- Development of contest elaborates encompassing organisational, technical, and technological preparation;
- Development of the methods for control, supervision, and evaluation of the carried out work;
- Development of the tariff system of service prices;
- System of contract clauses and supervisions;
- Designing of the system of stimulating and sanctioning forestry contractors.

In further division of the roles in the development of qualified forestry entrepreneurs at national level, it is important that MAGW suggests and supports government projects for development of entrepreneurship in forestry by way of credit arrangements, subsidies, tax exemptions, etc. Such incentives would be investments into the outfitting and organising/training of forestry contractors.

In near future the forestry institutions of high and secondary education should offer programmes for permanent education and training to service contractors and their staff. It is equally important to achieve stronger inclusion of forestry engineers into this field of forestry, since they are the ones that have specialist knowledge on all parts of forestry work. This should be in compliance with the European trends of profiling those contractors that will be able to offer a wide range of services, such as planning, preparation, carrying out work, supervision, etc. The absence of forestry engineers in the staff structure threatens the realisation of the desired profile of a contractor. The professional level of the work carried out by 'newly recognised' contractors may then also become questionable.

It is possible to overcome this unfavourable situation and to settle the forest service market relations by organising the whole system of forestry contractor's certification. Certification is the measure of establishing the relations of trust on the market of production and services in forestry. It presents an independent and unbiased evaluation of contractors' qualifications by the institutes that carry out measuring, testing, and supervision by acknowledged expert criteria. This is the basic technical infrastructure of the quality of forestry work, ensuring recognition, acceptance and acknowledgment of forestry contractors.

The certification of qualification and business capability of forestry contractors is one of the chief supports in the development of the Croatian market of forestry services. The proving of compatibility of services, equipment and procedures with the regulations, provisions, standards, and contracted technical specifications are the prerequisites of competition capabilities on the demanding domestic (and possibly international) markets. The high requirements related to the quality and warranty of security, reliability and timely delivery mean higher responsibility to the contractors for the products/services they offer on the market. When proving their rating, contractors should also use the services of the professional and technically equipped laboratories/evaluators and certification bodies as the principal institutes of trust in the carried out testing and certification.

The basic normative act that prescribes the obligation of authorisation and licensing should be the *Forest Law*. It is to be expected that this law will define the principle questions related to licensing. The same should be defined in detail by sub-legislative acts – the provisions of the Government of Croatia, or the statutes based on the *Forest Law*. The bearer of this should be MAFW. The sub-legislative acts must precisely define the bearers and the manner of authorisation and licensing, the contents and the form of the related documents, forms, etc. The whole system of certifying forestry contractors in Croatia must be established according to the professionally accepted criteria, and on the basis of transparent, legally determined model.

In view of the presented tasks, the MAFW and CFS should form operation bodies for the implementation of authorisation and licensing. A special task of the Ministry will be to inform the candidates about all essential questions related to authorisation and licensing. «Hrvatske šume» may greatly contribute to the success of this part of the task by informing its forestry service contractors on their obligation. It is also necessary to determine a transitory period before the final implementation of the certification and selection of the contractors.

Furthermore, it is necessary to enable the contractors the following: more suitable and modern mechanisation and equipment obtainable through subsidy credit lines of the Ministry; adequate training courses and programmes for achieving practical business skills; regular payment of completed services, and the supply of other projects and actions for promotion of forestry contracting (credit arrangements, subsidies, tax exemptions, etc.).

The expenses related to the achievement of qualified forestry contractors should be covered by the Ministry of Agriculture, Forestry and Water Management and many other parties, among others «Hrvatske šume» as well.

CONCLUSIONS
ZAKLJUČCI

1. Regardless of their increasing presence and a considerable proportion in the forestry production labour, forestry services contractors are neither organised, nor qualified, and as such are not a stable subject in the production sphere of the forest management in Croatia.
2. The biggest user of the services, «Hrvatske šume» Ltd. have not shown much interest and readiness for the settlement of the situation, and the promotion of entrepreneurship, although this should be among the strategic interests of this company. This relates to the attitude of the company toward the contractors in view of supply of services (type, volume, work locations); payment terms (prices); poor selection of contractors; insufficient records on contractors, etc.
3. By implementing special law acts that regulate the conditions required by independent forestry contractors, the European developed countries have a positive experience related to the registration programme, certification and/or licensing of forestry contractors. These processes have successfully acted as filters, classifying the insufficiently qualified and incapable contractors from the qualified and economically capable ones.
4. As regards the needs for professional regulation of forestry services in Croatia, the registration and licensing are of primary interest. The suggested two-phase model of forestry contractors' professional acknowledgement includes registration and licensing as obligatory programme, i.e.
   - Authorisation for forestry contracting – registration, and
   - Evaluation of qualification and the capability of carrying out forestry work – licensing.
5. The authorisation of forestry contractors brings them all to the equal position in terms of their legal status, rights and obligations. In addition, their work is submitted to financial discipline, particularly regarding their obligations toward their staff and the state.
6. The evaluation of qualifications and capabilities for carrying out forestry work, i.e. the licensing according to the professionally established criteria, are the methods of assessing contractors' capabilities of efficient and proper carrying out forestry work;
7. Considering all aspects of forest work, it is a common opinion that the minimum criteria for authorisation and licensing for every type of forest work should include the following conditions:
   - Technical/technological;
   - Professional;

- Economical/organisational, and
- Ecological.

8. The basic (elementary) unit of certification should be the wholeness of entrepreneurship consisting of at least one specific work device and one regularly employed worker. Besides the fulfilment of other minimum conditions (prescribed/suggested technical/technological, professional, economical/organisational, and ecological conditions), contractors acquire ***a professional certificate – licence***, which makes them qualified in the contests for forestry work in the Croatian forestry.
9. Besides the elementary professional qualification (classification of qualified and unqualified contractors) by certification, it is indispensable to assess the level of contractors' business capability through the following additional licence marks:
   - *I Class Licence* – A contractor fulfils the minimum conditions for carrying out forestry services (1 employed person + 1 typical work device)
   - *II Class Licence* – Besides the minimum conditions, a contractor fulfils some additional ones (5 employed persons + 3 typical work devices + professional work manager: forestry technician)
   - *III Class Licence* – Besides the minimum conditions, a contractor fulfils additional ones (10 employed persons + 8 typical work devices + professional work manager: forestry engineer).
10. The suggested model relies on the criteria, bodies, institutions and procedures that would assure objective evaluation and unbiased affirmation of the operators' qualifications, as a guarantee for expert, good, timely and economically successful carrying out of forest operations.
11. The final form of the model suggested in this paper requires elaboration and testing. It is therefore indispensable to get down to work, everyone in his own area (legislation, legal status, implementation, training programmes, etc), in order realise this model as soon as possible, as a significant step forward in the Croatian forestry practice.

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USPOSTAVA MODELA POTVRĐIVANJA IZVODITELJA ŠUMSKIH RADOVA

SAŽETAK

U radu su istraženi elementi važni za uspostavu modela licenciranja izvoditelja šumskih radova u Hrvatskoj. Postojeće stanje ocijenjeno je na osnovi obuhvatne analize o izvoditeljima i obavljenim radovima u razdoblju od 1998. do 2002. Ocjena je da postojeći uslužni izvoditelji šumskih radova, bez obzira na njihov značajan udio u izvođenju proizvodnih zadaća, nisu ni organizirani, ni kvalificirani, a time ni stabilan partner u proizvodnom dijelu gospodarenja šumama u Hrvatskoj. Na osnovi utvrđenog stanja i profila uslužnih izvoditelja, ali i iskustava zemalja razvijenog šumarstva predložen je model potvrđivanja izvoditelja šumskih radova koji će osigurati nastanak prvih formalno ovlaštenih i kvalificiranih izvoditelja šumskih radova. Predloženim modelom utvrđuju se mogući nositelji licence, minimalni uvjeti za pristup postupku potvrđivanja, protokoli i sudionici u postupku potvrđivanja, pravni okvir i pravni mehanizmi (vrste dokumenata, upravni postupak i dr.), stručne institucije i tijela uključena u licenciranje i dr.

Modelom se predviđa provođenje postupka potvrđivanja u dvije faze:

1. Ovlašćivanje izvođenja šumskih radova
2. Licenciranje tj. ocjenjivanje kvalificiranosti i sposobnosti izvođenja šumskih radova

U obje faze određeni su, osim formalnih i posebni tehničko-tehnološki, stručno-kadrovski, ekonomsko-organizacijski i ekološki uvjeti koje izvoditelji moraju ispunjavati da bi stekli strukovnu potvrdu – licencu koja ih čini kvalificiranim u natjecanju za izvođenje šumskih radova u hrvatskome šumarstvu. Uz licencu izvoditelju se dodaje i oznaka razine poslovne sposobnosti:

- *licenca I vrste* - izvoditelj ispunjava samo minimalne uvjete za izvođenje šumskih radova (1 zaposleni + 1 tipično radno sredstvo)
- *licenca II vrste* - izvoditelj pored minimalnih uvjeta za izvođenje šumskih radova ispunjava i dodatne uvjete (5 zaposlenih + 3 tipična radna sredstva + stručni voditelj posla u zvanju šumarski tehničar)
- *licenca III vrste* - izvoditelj pored minimalnih uvjeta za izvođenje šumskih radova ispunjava i dodatne uvjete (10 zaposlenih + 8 tipičnih radnih sredstava + stručni voditelj posla u zvanju šumarski inženjer)

Predloženi se model oslanja na kriterije, tijela, institucije i postupke koji će jamčiti objektivno vrednovanje i nepristrano potvrđivanje kvalifikacija izvoditelja - kao jamstvo za stručno, kvalitetno, pravodobno i ekonomski uspješno obavljanje radove u šumarstvu.

Ključne riječi: šumarstvo, izvoditelji šumskih radova, poduzetništvo, licenciranje, Hrvatska

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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

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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-length, half-tree, cutt to length 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;

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

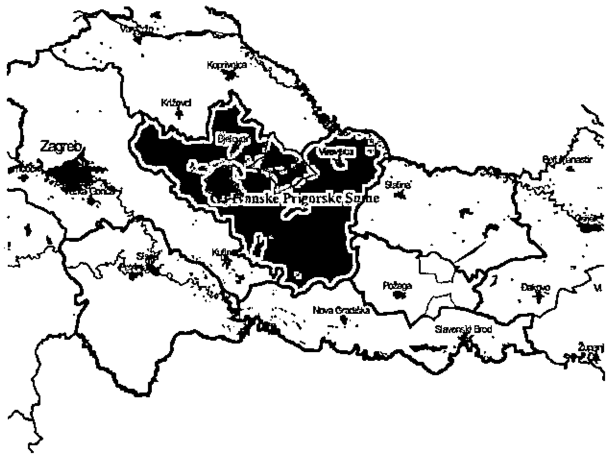


Figure 2 FAA Bjelovar with the Forest Management Unit Ivanske·Prigorske Šume
Slika 2. UŠP Bjelovar s prikazom G. j. Ivanske prigorske šume

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:

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

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

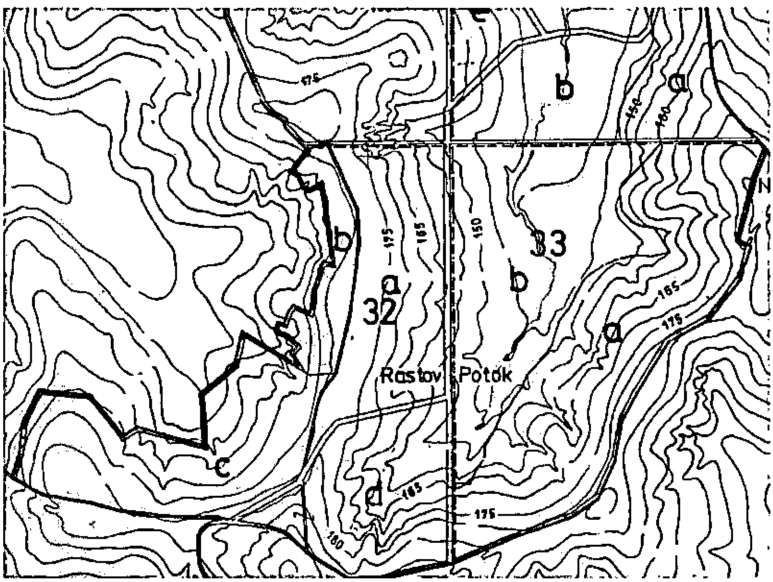


Figure 4 Management map of FMU Ivanska Prigorska Šuma showing Department 32, Map scale: 1:10,000

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 morning 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 (m³); 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 (m³): 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 round-wood *Tehnička oblovina*	Number of pieces *Broj komada*	-	182	-	-	142	-
	Processed volume, m³ *Izrađeni obujam, m³*	-	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, m³ *Obujam komada, m³*	0.114	0.408	0.914	0.113	0.489	1.660
Long stack-wood *Višeme-tarsko drvo*	Number of pieces *Broj komada*	-	508	-	-	596	-
	Processed volume, m³ *Izrađeni obujam, m³*	-	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, m³ *Obujam komada, m³*	0.031	0.217	0.726	0.038	0.239	1.005
Total *Ukupno*	Number of pieces *Broj komada*	-	690	-	-	738	-
	Processed volume, m³ *Izrađeni obujam, m³*	-	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, m³ *Obujam komada, m³*	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 m³, a DBH of 26.4 cm, a mean height of 23.1 m, and a mean volume of 0.739 m³ (Table 4). The second cutter, S2 (with Ecotrac2), felled 289 trees with a total volume of 232.85 m³, a DBH of 27.9 cm, a mean height of 22.5 m, and a mean volume of 0.805 m³. 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 x Total or mean value ** Maximal value
** Najmanja vrijednost x Ukupna ili srednja vrijednost ** 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* per total *prema ukupnom* time / *vremenu*	Time share *Udio vremena* per effective *prema efektivnom* time / *vremenu*	Time share per tree *Udio po stablu*	Time consumption *Utrošak vremena*	Time share *Udio vremena* per total *prema ukupnom* time / *vremenu*	Time share *Udio vremena* per effective *prema efektivnom* time / *vremenu*	Time share per tree *Udio po stablu*
	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 *ukupnom* time / *vremenu*	Percentage per *Postotni udio prema* effective *efektivnom* time / *vremenu*	Total time *Ukupno vrijeme*	Percentage per *Postotni udioprema* total *ukupnom* time / *vremenu*	Percentage per *Postotni udioprema* effective *efektivnom* 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 respective 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 stvarištu 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 m³ wood was processed. Of this, there were 517 pieces medium-volume technical roundwood amounting to 0.249 m³, and 2,132 pieces long medium-volume stackwood of 0.108 m³. The highest use of effective time was 0.67 min/ m³ for the walk to the load, and the same time was used for measuring. The working up of wood assortments required 0.59 min/m³. The average used effective time was 2.11 min/m³, while the average delay times were 10.66 min/m³, which amounted to a total of 12.77 min/m³.

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/m³, while the respective total time is 19.26 min/m³.

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/m^3. The average used effective time of the tractor crane and the crane driver was 5.24 min/m^3. The delay times amounted to 15.63 min/m^3, while the total used time was 20.87 min/m^3. As to the crane work alone, the effective time was 4.28 min/m^3, while the total time was 19.91 min/m^3.

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.

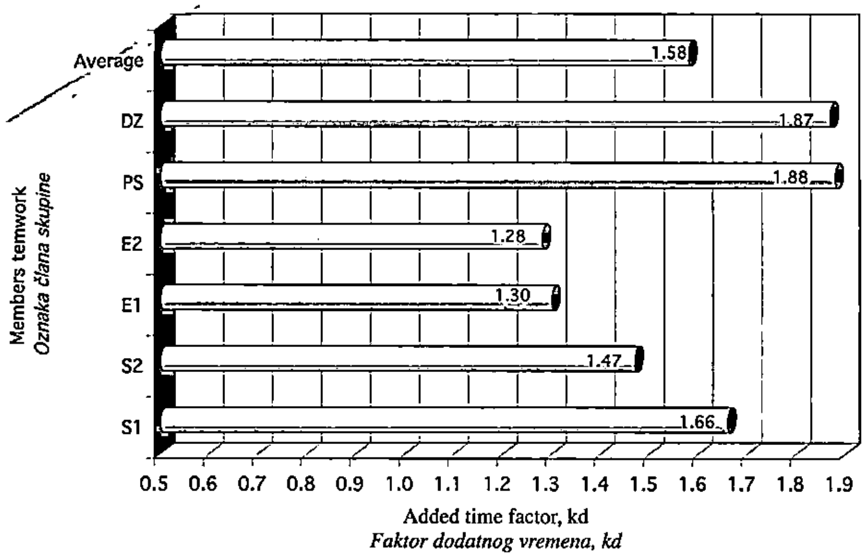


Figure 5 Added time factors of the team members, and the average values of the team
Slika 5. Faktori dodatnog vremena članova skupine i prosječno za skupinu

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 m³, which means 4.99 m³/day per team member. According to the mean tractor skidding distance of 254 m, an output of 32.58 m³/day was realised, which is by 11.57% more than planned. The average realised daily output per team member is 5.43 m³/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 m³, 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/m³	%	min/m³	%	min/m³	%
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/m³ of the delay times, or 82.82 min/m³ of the total time. The second sub team P2 (S2+E2+PS+DZ) spent 34.25 min/m³ of the effective time, i.e. 50.31 min/m³ of the delay times, or a total of 84.56 min/m³.

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

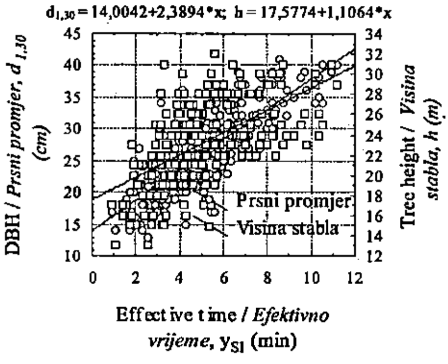
Tablica 16. Opisna statistika temeljnih raspodjela: prsnog promjera, visine stabla te efektivnog vremena sjekača

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.



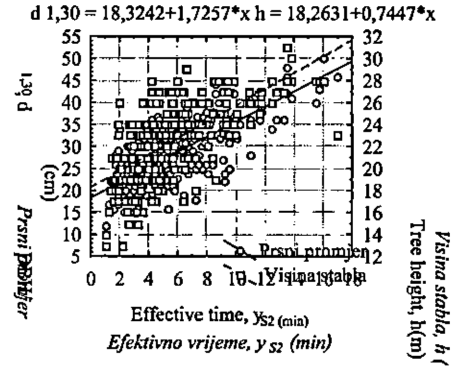


Figure 6 Values scattering of the effective felling/tree processing times depending on the DBH and tree height with cutter S1

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

	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					
N=258	Beta	Std.Err. of Beta	B	Std.Err. of B	t(255)	
Indepedent member/*Nezavisni član*			-1.400591	0.4852197	-2,88651	
BDH/*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:

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

In case of the monitored sample, the average load volume q = 1.328 m^3, while the mean skidding distance 1 = 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

	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				
N=136	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

	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				
N=137	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 1 = 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	;ression Summary for Dependent Variable: Var4 (Spreadsheet2 in I-E1, stov-pun.: R= ,71138245 R2= ,50606499 Adjusted R2= ,49483919 F(3,132)=45,081 p<0,0000 Std.Error of estimate: ,23427				
	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

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

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

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

	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					
N=128	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:

$$y_{E1n} = 0{,}152107 + 0{,}010057 \cdot l \tag{12}$$

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:

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

In 107 tractor cycles, an average load volume is q = 1.485 m^3; mean skidding distance l= 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:

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

With a mean skidding distance of l = 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 1 = 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 1 = 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 èlan*, 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 èlan*, 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_{vE1}) of tractor cycle E1
Tablica 29. Primjer izračuna varijabilnog vremena (T_{vE1}) 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

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

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

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

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

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

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* – Skid trail and felling site *Vlaka i sječina* – Drive/ *Vožnja* – un-loaded *neopterećenog* – Tractor/traktora	Skid trail and felling site *Vlaka i sječina* – Drive/ *Vožnja* – loaded/ *opterećenog* – Tractor/traktora	Landing *Pomoćno stovarište* – Drive/ *Vožnja* – unloaded/ *neopterećenog* – Tractor/traktora	Landing *Pomoćno stovarište* – Drive/ *Vožnja* – loaded/ *opterećenog* – Tractor/traktora	Total time/ *Ukupno vrijeme*	Fixed times *Fiksna vremena* – Work on felling site *Rad na sječini*	Fixed times *Fiksna vremena* – Work on landing *Rad na pom. stov.*	Fixed times *Fiksna vremena* – Total time *Ukupno vrijeme*	Total effective time *Ukupno efektivno vrijeme*	Added time factor/ *Faktor dodatnog vremena*	Total cycle time/ *Ukupno vrijeme turnusa*
	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:

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

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:

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

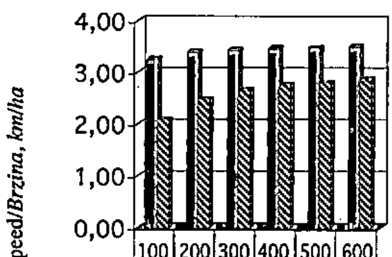
with v_{ov} = loaded tractor drive on skid trail and felling site; l_{ov} = skidding distance of loaded tractor, and t_{ov} = loaded driving time

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

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

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.

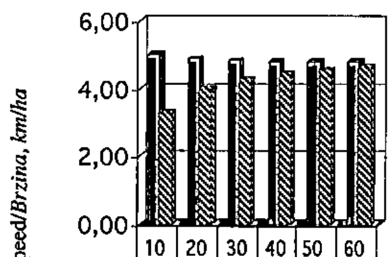


	100	200	300	400	500	600
E1	3,24	3,39	3,44	3,47	3,48	3,49
E2	2,09	2,49	2,65	2,75	2,81	2,85

Distance/Speed-
Udaljenost, m / Brzina, km/ha

Figure 9 Loaded tractor speeds on skid trail and felling site

Slika 9. Brzine opterećenih traktora na vlaci i sječini



	10	20	30	40	50	60
E1	5,00	4,87	4,83	4,81	4,80	4,79
E2	3,27	3,98	4,28	4,45	4,56	4,64

Distance/Speed-
Udaljenost, m / Brzina, km/ha

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*: Effective time *Efektivno vrijeme*		Felling and processing *Sječa i izradba*: Delay times *Opća vremena*		Felling and processing *Sječa i izradba*: Total time *Ukupno vrijeme*		Total time of felling and processing + load binding *Ukupno vrijeme sječe i izradbe + vezanje tovara*	
	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

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

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

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

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

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

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

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

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:

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

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/ m^3 (S1) of the effective time for felling and tree processing and 8.09 min/ m^3 (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_{eu}	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.	m³	min/m³	m³/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/m³ (S1) and 14.26 min/m³ (S2).

The daily output cutter's effect (DU_{s2}) in Variant 2 (Table 33) is 32.93 m³/day (S1) and 33,60 m³/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 (m³) of Variants 1 and 2
Slika 11. Norma vremena sječe, izradbe i vezanja tovara po jedinici proizvoda (m³) za inačicu 1 i 2

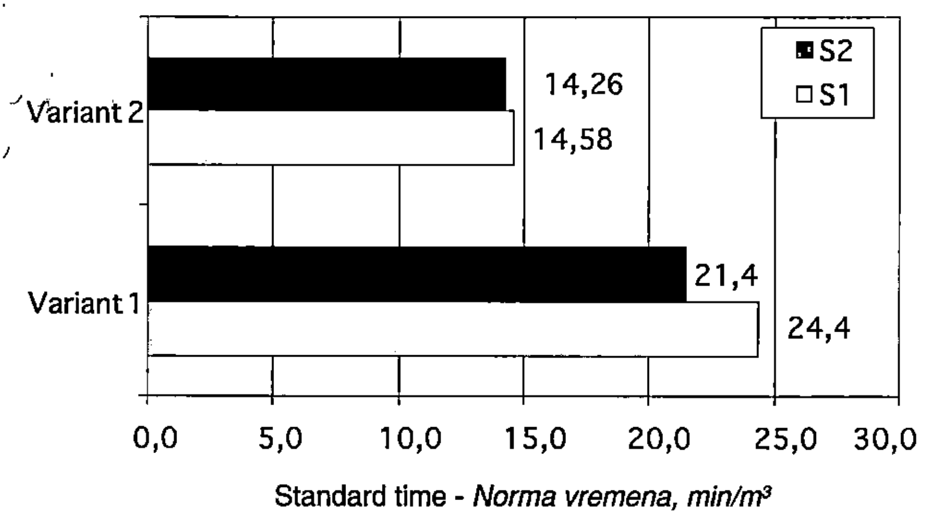


Figure 12 Comparative presentation of cutter's daily output at felling, tree processing and load binding in Variants 1 and 2

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

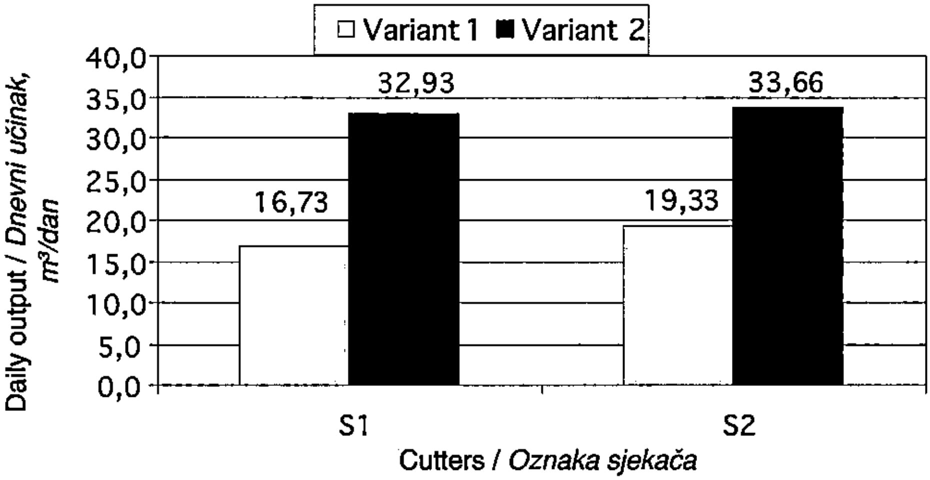


Figure 12 presents the comparative daily output of two variants that best illustrate the behaviour of the cutters in teamwork. Variant 1 presents the realised daily output according to the used work time, while Variant 2 presents the modelled daily output of the corresponding work technology in the prescribed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

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

where NV_t = tractor standard time (min/m^3); T_u = total cycle time (min), and qt = average tractor load volume (m^3),
and the equation:

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

where NV_t = tractor standard time (min/m^3); q_t = average load volume (m^3), 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 (m^3/dan), and NV_t = standard time of the tractor (min/m^3).

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

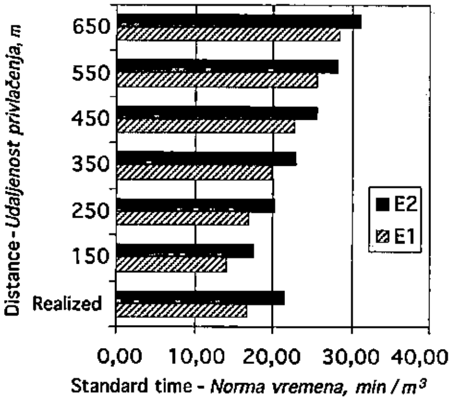
Table 34 Total cycle time, standard time and daily output of Tractors E1 and E2 in the team.
Tablica 34. Ukupno vrijeme turnusa, norme vremena i dnevni učinak traktora E1 i E2 u skupini

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



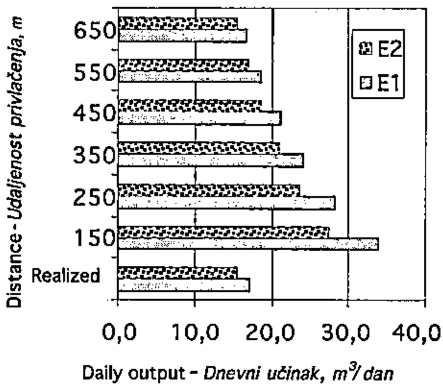


Figure 14 Realised time and standard time of the E1 and E2 team tractors
Slika 14. Ostvareno vrijeme i norma vremena traktora E1 i E2 u skupini

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 m^3/day (E1) and 27,36 m^3/dan (E2); at a skidding distance of 650 m, the respective values may be 16.82 m^3/day and 15,46 m^3/day

STANDARD TIMES AND DAILY OUTPUT OF THE CUTTER-CUSTOMER
NORME VREMENA I DNEVNI UČINAK SJEKAČA-PREUZIMAČA

Standard time (NV_{ps}) of the cutter-customer is expressed as the time used for processing and customizing of tree parts per product unit (m^3). 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/m^3 of effective time and 10.66 min/m^3 of delay time on the landing, or a total of 12.77 min/m^3.

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/m^3	min/piece *min/kom*	min/m^3	min/piece *min/kom*	min/m^3	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

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

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/m^3	m^3/dan	min/m^3		min/m^3	m^3/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 $1.m^3$ 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

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

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 m³/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/m³. 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/m³, and the daily output is 115.68 m³/day. This daily output is by 3.1 times higher than the realised one.

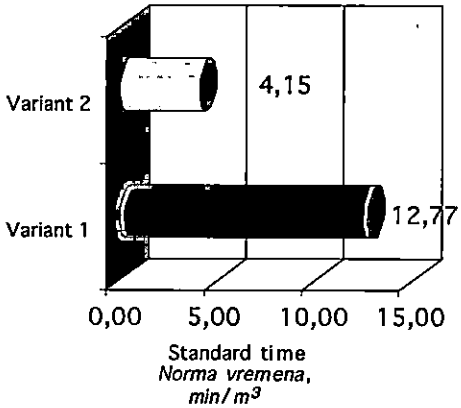


Figure 16 Time used per m³ (Variant 1) and standard time of wood assortment customizing in Variant 2

Slika 16. Utrošeno vrijeme po m³ (inačica 1) i norma vremena preuzimanja drvnih sortimenata za inačicu 2

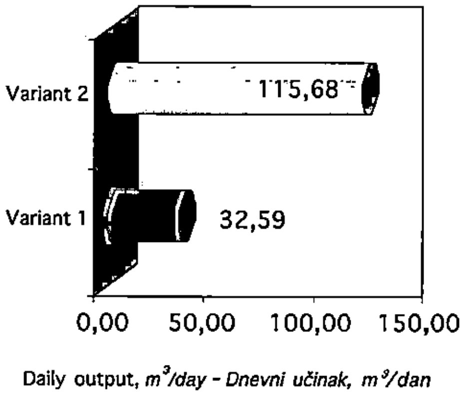


Figure 17 Daily output of cutter customer at processing and wood assortment customizing

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

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

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* I_{eDZ} min/m³	Added time coefficient *Koeficijent dodatnog vremena* k_d	Standard time *Norma vremena* NV_{DZ} min/m³	Daily output *Dnevni učinak* DU_{DZ} 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

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

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.

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

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

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

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

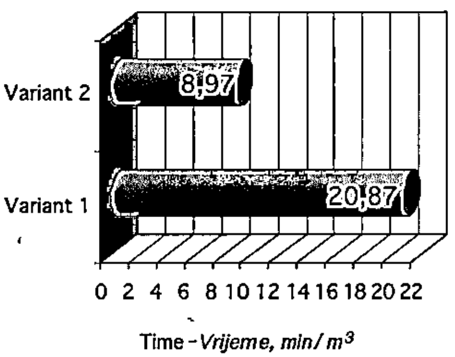


Figure 18 Total used time (Variant 1) and the standard time (Variant 2) of the crane tractor at stacking long timber on the landing

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 m^3/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.

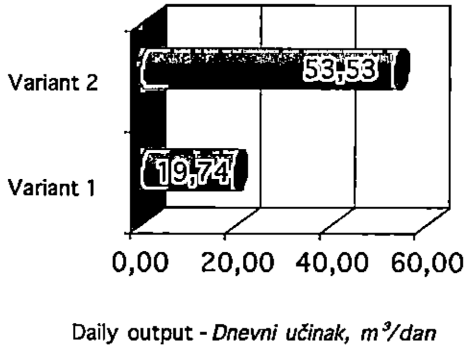


Figure 19 Daily crane output at stacking long timber at landing

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:

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

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:

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

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

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%

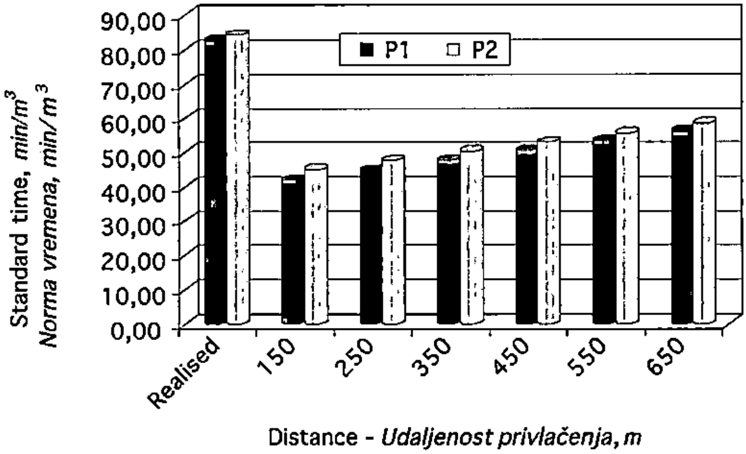
less than the realised time. The respective values at a distance of 650 m were 32.1% and 30.9% less than the realised ones (Table 38).

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/m^3, while the average tractor time norm ranges from 15.83 min/m^3, (150 m) to 29.79 min/m^3 (650 m). The standard time of the cutter-customer on the landing is 4.15 min/m^3 (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/m^3, 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 m^3/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 (m^3/day) of a work team according to the current number of members

Tablica 41. Dnevni učinak (m^3/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, m^3/dan *Dnevni učinak skupine, m^3/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, m^3/dan *Dnevni učinak po članu skupine, m^3/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 m^3/day (150 m) to 5.38 m^3/day (650 m). This is by 88.4% (150 m) – 9.4 % more than the daily output of 4.19 m^3/day per team member. At a distance of 650 m, the calculated daily output is by 0.05 m^3/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).

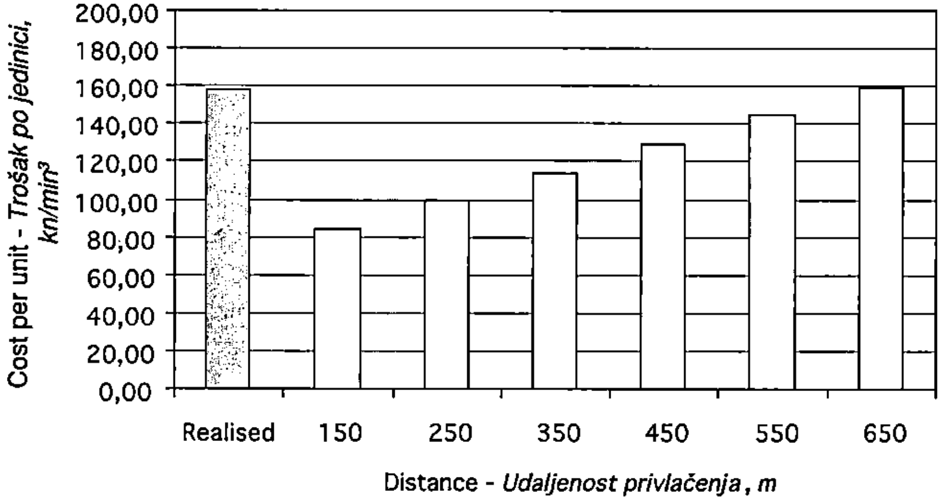
Table 42 Cost calculation of the work team per product unit related to the modelled daily output.
Tablica 42. Prikaz kalkulacija i troškova skupine radnika po jedinici proizvoda prema oblikovanom dnevnom učinku

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/m^3 *Trošak po jedinici proizvoda, kn/m^3*					
(6)	83.91	99.14	114.26	129.40	144.45	159.52

The team costs range between 83.91 kn/m^3 (150 m) and 159.52 kn/m^3 (650 m). Related to the realised costs of 158.07 kn/m^3, 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/m^3 (E1) and 16.41 min/m^3 (E2) of the effective time. The delay times are 11.89 min/m^3 (E1) and 13.00 min/m^3 (E2). The total times per unit are 24.75 min/m^3 (E1) and 29.41 min/m^3 (E2). The effective times of the crane tractor are 25.12 % of the total time and 5.24 min/m^3 respectively.

The realised daily outputs of the cutters are 16.73 m^3/day (S1) and 19.33 m^3/day (S2), while the output of the cutter-customer is 32.59 m^3/day. The realised daily outputs of the tractors in skidding are between 17.11 m^3/day (E1) and 15.47 m^3/day (E2), while the one of the crane tractor on the landing is 19.74 m^3/day. The realised average daily output per team member is 5.43 m^3/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 m^3 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/m^3) was investigated in two variants (1 and 2). The standard times in Variant 2, which best describes the cutters, range from 14.26 min/m^3 (S2) and 14.58 min/m^3 (S1). The modelled daily outputs are 32.93 m^3/day (S1) and 33.66 m^3/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/m^3 (E1) and 17.54 min/m^3 (E2) with a skidding distance of 150 m. The respective values with the distance of 350 m are 19.88 min/m^3 and 22.94 min/m^3. With the distance of 650 m, these values are 28.54 min/m^3 (E1) and

31.04 min/m^3 (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 m^3/day and 27.36 m^3/day; at a skidding distance of 350 m, it is possible to realise outputs of 24.14 m^3/day and 20 93 m^3/day respectively; with the distance of 650 m, the possible daily outputs are 16.82 m^3/day and 15.46 m^3/day.

The standard time of the cutter-customer in Variant 2 is 4.15 min/m^3. The corresponding daily output can be realised in the amount of 115.68 m^3/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/m^3 and a daily output of 56.47 m^3/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/m^3, while the average standard times of the tractor are 15.83 min/m^3 (150 m) and 29.79 min/m^3, (650 m). The standard time of the cutter-customer on the landing is 4.15 min/m^3, 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 m^3/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 m^3/day (150 m) and 5,38 m^3/day (650), which is by 88.4% (150) – 9.4 % (550 m) more than the realised daily output of 4.19 m^3/day per team member.

At a skidding distance of 650 m the calculated daily output was by 0.05 m^3/day lower than the realised one.

The average realised cost per product unit in the team is 158.07 kn/m^3. The modelled costs ranges between 83.91 kn/m^3 (150 m) and 159.52 kn/m^3 (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.

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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

UDK: 630*901

Original scientific paper
Izvorni znanstveni članak

MATHEMATICAL-STATISTICAL APPROXIMATION OF THE DISPERSION OF THE TIME SERIES OF ANNUAL GROSS FELLINGS IN THE NATIONAL FORESTS – THE EXAMPLES OF CROATIA, SWITZERLAND, GERMANY AND FRANCE

MATEMATIČKO-STATISTIČKA APROKSIMACIJA DISPERZIJE VREMENSKIH NIZOVA GODIŠNJIH BRUTO SJEČA U NACIONALNIM ŠUMAMA – PRIMJERI HRVATSKE, ŠVICARSKE, NJEMAČKE I FRANCUSKE

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The possibilities of reliable forecasting of annual felling in the national forests of all types of ownership are being examined in Croatia, Switzerland, Germany and France (in the later the volume felled without fuel wood is being examined – comprising annually about 2-3 million m^3).

Based on time series of annual felling in Croatia (1955-2002), Germany (1984-2001), France (1947-1996, no fuel wood included), and Switzerland (1961-2003), logistic and Gompertz equation the asymptotic values are being calculated.

It is known, assuming the consequent application of sustained yield management, that the volume of annual felling is the function of large number of exogenous and endogenous variables. Just to mention few, such as climatic conditions (the appearance of Vivian and Lothar hurricanes in the nineties years of the 20th century), extreme droughts, and similar, marketing conditions (e.g. economic recession or market recovery) as well as similar factors of forest policy (e.g. when the state starts large scale a forestation or melioration of existing forest stands or numerous other undertakings). The management in the forestry develops and becomes visible only after long periods elapsed; it is thus difficult to say that the volume of timber felled is determined only by management plans, already missing or obsolete for large part of existing forest stands.

Based on time series of annual felling in Croatia (1955-2002), Germany (1984-2001), France (1947-1996, no fuel wood included), and Switzerland (1961-2003), logistic and Gompertz equation the asymptotic values are being calculated.

Practical value of this paper, beside other things, should serve as indicator of actually harvested volume. In case of serious divergences with calculated asymptotic values, the causes leading to it should be investigated (climatic damages, diseases, high or low demand for forest products, their prices, etc.) and eventually eliminated in order to maintain sustainability of the forest management.

Key words: approximation of the dispersion of annual felling in sustained managed forests of some European countries, the application of logistic and Gompertz's curves in calculating of time series functions

INTRODUCTION
UVOD

Forest cover contains about $^1/_3$ of the world's land area.[1] One third of the land area corressponds to the average of the former 15 EU countries (32 %).[2] Notwithstanding large area under forest and tree cover, economic importance and its ratio in the GDP seems of minor importance taking into account only marketable forest products (wood, fruits, etc)and on it based economic activities such as wood and other on forest crop based processsing industries. In Italy and Germany e.g. forestry shares only about 0.1 % of the total national GDP. Even in Sweden, richly endowned

[1] *The total forest area in the world contains about 27% of the land area (inclusive inland water areas and streams). In the developing countries of Africa, Asia, and Latin America, due to poverty, underdevelopment, and overpopulation disappear daily huge areas of forests, the states where it takes place are unable to procure efficient policy to stop such trends, except inapplicable and inefficient restrictive measures. The land obtained by burning or deforestation by clear cutting, in few years, due to erosion and washing of productive humus layers, becomes infertile, what stimulates further clearing and burning of existing forests. The timber, by its greatest part used as fuel, is being burned inefficiently on inadequate fireplaces. By disappearance of forest cover, precipitation waters in raining season, inflict huge damages to people and their property, making their poor and frugal life each day worse. There is little hope for improvements in visible time ahead.*

[2] *The total surface of Europe without states of former USSR comprises 5,649 sq km with about 0.6 billion inhabitants. From the total of this area land surface contains 5,504 sq km, inland waters 174,000 sq km, forests and other wooded land covers 1,950,000 sq km, agricultural land extends over an area of 2,374,000 sq km.*

with high class boreal forests, forestry represent only 1.0 % of the total GDP. The data ilustrating the participation in the national GDP underestimate however the real economic importance of forestry. Without forest cover the agriculture seems hardly possible, since the erosion would fast dissolve latest remnants of fertile soil, forest furthermoree represent ideal space for carbon dioxide strorage, otherwise the greenhouse effect with all consequences would appear sooner, living to men and nature time for the eventual adaptation.

The number of ownership plots in almost all countries is not negligible (about ¼ of land is under forest cover, of which about 70 % is in private ownership consisting of mostly fragmented small plots; in Germany there are total 10.8 million ha of forests, 34 % are in public, 19 % corporative, and about 40 % in private hands. 1.13 million ha of total forest area in Switzerland. 766 thousand ha is publicly, and 364 thousand ha privately owned.

The number of labor employed in forestry in the EU countries is also remarkable. The most important is however that on forest products based national industries are an important part of national income. About 15% of total timber consumption is used as combustible, the largest part is manufactured into wood based boards, sawnwood and paper, the pattern characteristic in all the EU countries.

Nordic countries in the EU are the richest wirh forests. Sweden and Finland, having only little under ½of all forest area of the former 15 states of the EU, are followed by France 14 million ha of forests). The forests do nor extend over north, France, Spain and Italy have an important part of forested area. Greece in fact, with 44% forest cover has the largest ratio of forest coverage.

Nordic boreal forests consist of about 90% conifers, the forests in the mid- and south Europe are by its large part broadleaved or mixed.

Forestry is a multiple industry, delivering to the market and society a multitude of raw materials for further manufacturing, and services consisting of innumerable forest influence functions. Largest part of changes inflicted on forests are anthropogenous, climatic and other changes appear slowly over time, without negative anthropogenous influence, the nature would probably be able to recover or transform into new equilibrium as happens in almost all areas of life of the planet Earth. The demographic growth and conservative methods in food production have reduced the forest area, which was replaced by agricultural land, as well as later abandoned infertile land, until the beginning of the 20th century. After new agro technical methods have been employed, more and more bare land is being transferred into forests.

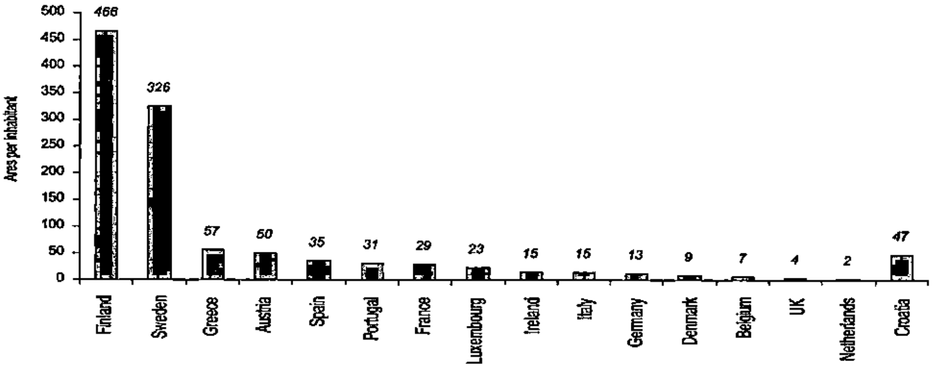


Figure 1. The area per inhabitant ares in the EU (excluding newly joined countries) and Croatia

Slika 1. Površina šume po stanovniku u EU (bez novo priključenih zamalja) i Hrvatskoj

Within the limits dictated by biological and economic necessity, it is natural and desirable that the extent of forest area changes with supply and demand for space. The land use (for agriculture, urban development, transportation facilities, etc.) will proceed to change inevitably in the future, making the decision about fixed forest area an impossible task. A lot of problems in contemporaneous forestry have their source in the conflict between mutually competing social and environmentalistic aims. Optimization of timber production e.g. may stimulate monocultures, which would endanger the habitat of certain animal and plant species.

BACKGROUND
TEMELJNE POSTAVKE

It is known, assuming the consequent application of sustained yield management, that the volume of annual felling is the function of large number of exogenous and endogenous variables. Just to mention few, such as climatic conditions (the appearance of Vivian and Lothar hurricanes in the nineties years of the 20th century), extreme droughts, and similar, marketing conditions (e.g. economic recession or market recovery) as well as similar factors of forest policy (e.g. when the state starts large scale a forestation or melioration of existing forest stands or numerous other undertakings). The management in the forestry develops and becomes visible only after long periods elapsed; it is thus difficult to say that the volume of timber felled is determined only by management plans, already missing or obsolete for large part of existing forest stands.

The population of the planet Earth grows daily. Demographic explosion is possible, if not to eliminate, than at least bring under control only through serious rise of living standard. In the industrially developed countries of Europe, North America, Australia, as well as in some Far East Asian countries (in the first line Japan, than Malaysia, as well as rising superpower China) the land use, thanks to the progress of agro technique, tends by all means towards ¼ of the total land surface. Multitude of countries, alas, by market and intervention failures try to maintain the atavistic concept in agriculture, for which reason is the transfer of present day agricultural land below or at marginal productivity into forests slowed down.

The volume of annual felling does not depend on forest managerial principles only, it is influenced by immense number of factors, impossible embraceable in the planning of specific periods of management plans, such as market conditions, climatic oscillations, forest diseases, etc.

The changes in forestry such as area extension of forests, relief, kind and quality of the soil, species composition, forest cover (growing stock) and other factors, happens very slowly. In case of the sustained yield management in stands for which the management plan is available, the annual allowable cut is in organic connection with all essential factors making forest as close to the natural plant association of the dead and alive nature, which influences positively on ecological condition, over smaller plots as well as over the planet as a whole, ensuring the habitat to the great number of various animals, and supplying men with valuable raw materials required for maintenance of everyday life, supplying the life on the planet Earth with multitude of forest influences services, from life protection, to soil and water protection and regulation, carbon dioxide storage, erosion control, etc.

Prognostic harvesting volume in countries covered by this research made by polynomial trend, in extrapolated forecasts show, as all the trends do, unrealistically high values, since the independent variable is represented only by single one: time. To avoid this mistake, the equation provides as common variable X, comprising beside the time, all other influencing variables without the autocorrelation. In the region of Pre-Alps, and Alps Switzerland and Germany, partly France too, the climatic conditions were strongly influential, producing the exhorted values of polynomial trends, logistic and Gompertz's equations, mainly under valuating the forecasts.

SOME PRINCIPLES OF FOREST POLICY REGARDING FOREST MANAGEMENT

NEKA OD NAČELA ŠUMARSKE POLITKE GLEDE UREĐIVANJA ŠUMA

Forest management in a broad sense denotes the application of the knowledge which has been acquired in all branches of forestry and the allied sciences to the management of forests in the interest of man. Thus, forests are maintained either for their (a) physical effects, or for (b) productive purposes. To the purposes (a) belong forests maintained for the protection of mountain slopes, catchments areas, park lands, game preserves, etc. To the purpose (b) belong forests maintained for the production of minor produce (bark, resin, forest fruits, cork, etc) or of major produce, such as wood.

The role of forest migth be described as pertaining to the following five domains of human life at our planet:

Protective services and influences
- Regulation of climate
- Regulation of atmospheric composition
- Stabilization of slopes, river and streams banks, accumulation of water, sand and sandy dunes.
- Protective belts, moisture retention in the soil
- Water streams regulation, diminuation and control of the flood danger
- Stabilization of soils
- Hindering of disease spreading and calamities
- Storage of nutritients, their distribution and material circulation

Consumption of plants, animals and derivates
- Timber: logs, pulpwood, other industrial and technical wood
- Fulewood and charcoal
- Nutritients such as fish, game, fruits, etc.
- Gras, flowers, medical plants
- Rubber, resins, lacquers, oils, tanning materials, wax, destilates
- Cattle grazing and forrage
- Roof ing, ropes, weawing raw materials, silk
- Non-wood building materials (e.g. bamboo, ratan, etc)
- Animal hides, feathers, animal teeth, bones, horns (antler)
- Domestic plants and pets

Psycho-phyisiological influences
- Recreation, tourism, sport
- The feeling of self-control, peace, and harmony with the nature
- Inspiration for music, art, mythology, relegion and philosophy
- Historical places and values

The source of land and living space
- New arable and grazing land
- Living area for aboriginal population

Educational and scientific services

Ecosystem and organism research

Monitoring of ecological changes

Sample collection for museums, zoos, botanical gardens

Natural Reserves of wild foodstuffs, chemicaly and biologicaly regulative substances

Ecological education

For a very long time in estimation of value of the forest, foresters concentrated their efforts in calculation and mathematical explanation of forest management on the sustained yield basis primarily directed to the wood specific forest might produce, ocasionally mentioning other, non-monetary services of forest.

Forest management uses in the processs of calculation of allovable annual cut various mathematical methods, developed by numerous forest scientists and practicioners, in order to maximize productive capabilities of forests to fulfill a great variety of services required by forest owners, society, or both.

The most frequent forest policy failure seems to lie in the fact that too little of land available is under forests, close to natural ones. The reason lies in intervention and market failures. In most of EU states agricultural surplus is being constantly produced. From the point of cost-benefit valorrisation method, transformation of agricultural land of marginal or below marginal productivity into forest land clearly would increase economic efficiency. The main reason that this does not happen are the government subsidies directed to agricultural production, together with high protectice taxes for agricultural product imports. Subsidies of this type result fundamentally wrong allocation of land use between agriculture and forestry. Subsidies of competing land uses in the end lead to underinvestment in forestry, streghtened by failure in perceiving of non marketable benefits the forestry abundantly produces. Probably the better comprehension of absorption capacity of carbon dioxyde of forest would inevitably lead to mightier investment.

The underinvestment tendency in forestry got difficult due to so called "Market myopia", e.g. insufficient information on negative external effect of forestry on environment, combined with increased risks of long production time, being the significant factors contributing to the soil degradation, a phenomenon met nowadays in numerous south European countries.

Maintenance of sustained yield in production and improvement of forest infuluences always were the concern of forest management specialists, as well as of foresters in other specific occupations, such as sylviculture and other. Only in mid of 20th century this role has increased in importance, growing fast afterwards.

The most important aim of forest management, as it always was, is establishment of forest stands close to natural forest in all the aspects, even in case the distribution of age gradation does not exist and/or will be never reached, i.e. composed of autochthonous tree species specific for location, elevation, climatic and soil condition, and maintained natural phytocenological type. In other words, the aim of forest management is attainment and maintenance of all function of forest at the maximum, or optimum.

Such a standpoint seems acceptable since in it is assumed that natural (nor always necessarily normal) forest is the only able to reach the maximum of values of all products and services, monetary and non monetary. One should always bear in mind that the dry land of the whole planet Earth is almost completely given, and the population is growing close to the Malthusian's prediction. The human race seems not aware that development and marketing policy failures in the development of almost all countries slow down the extension of forests with all the consequences, unnecessarily keeping in agricultural use at and below the marginal of productivity.

The improvement in agricultural technology has made possible, in developed Europe, to feed the present population by using only about $^1/_6$ to $^1/_5$ of the total dry land for agriculture.[3] Believing that the technical, cultural and civilisation progress will gradually reduce the present explosive demographic growth, it seems realistic everywhere possible, slowly to reduce the land use according the proposal given in the Tab. 1.

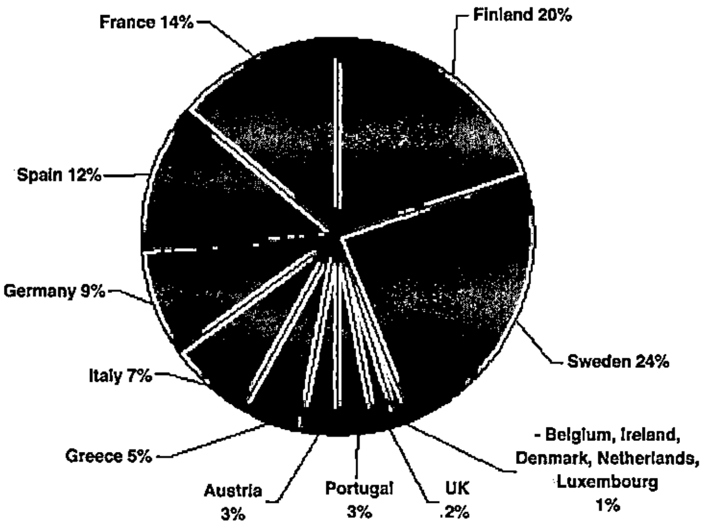


Figure 2. The participation of forests in the European Union
Slika 2. Udio šuma u Europskoj zajednici

[3] Assuming the elimination of damaging chemical substances contained in almost all fertilizers, and other harmful substances.

Table 1. Land use in Europe
Tablica 1. Korištenje zemljišta u Europi

Agriculture – *Poljoprivreda*	About – *oko* 20% to 25%
Forests – *Šume*	About – *oko* 50%
Urbanized land, unfertile land, transportation facilities and surfaces under inland waters – *Urbano zemljište, neplodne površine, prometnice i područja pod kontinentalnim vodama*	About – *oko* 25 – 30%

If above values are set as long term targets, the realisation would be possible only through properly and realistically adapted intervention and market policies.

The above assumptions may at a first glance appear strange, one should bear in mind that each living creature consumes huge quantities of oxygen, emitting atmospherically harmful CO_2. The situation nowadays is completely different when Europe id populated by nearly on billion inhabitants, compared to the population of couple hundred thousand at the beginning of the Middle Age, when deliberate clearing and burning of forests actually started. The erosion and climatic disturbances are as consequence at present days.

Presuming that forest stand is close to virgin one, composed of autochthonous plant species, the aim of forest management is planning and execution of felling of trees predestined to rot anyway in the mutual fight for light, moisture and minerals, required for chlorophyll assimilation. Such felling is acceptable only in case of improvement of specific stand.

Thinning and felling at the end of rotation period facilitate unhindered growth of chosen trees, thus providing valuable raw materials for further manufacturing of final consumption goods, and provide important source for the procurement of growing requirements of energy. In principle, the allowable cut, in case of sustained yield management, should correspond to the annual increment. Such an ideal state of managed forest stand should play the decisive role in optimization of marketable and non marketable yields of forest.

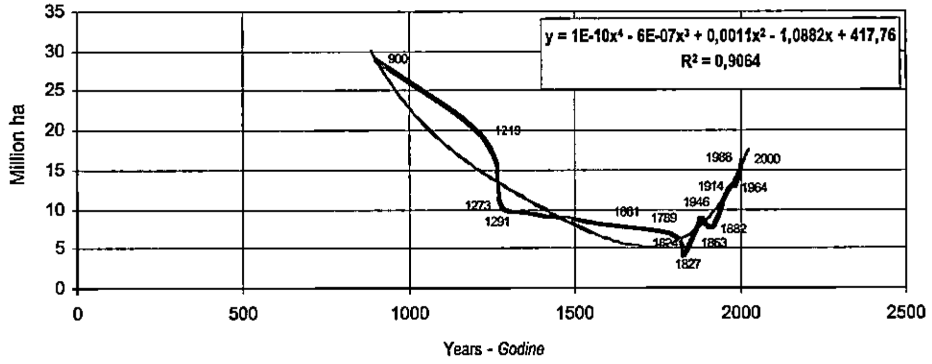
"Normal forest is called when there is an equilibrium of age classes and if the forest is healthy, where ecological circumstances are good, and forest is approachable by sufficient extension network facilities, in which case it may play the role for efficient forest management and which may be named as normal forest."

The former conclusions and data are of course relevant exclusively on industrially developed countries of Europe, better to say on 15 members of the EU before its extension by ten newly arrivals. On other continents with lower level of economic development, the devastation of forests is still progressing at a frightening rate.

Table 2. The development of area under forests in France during 11 centuries
Tablica 2. Razvoj površina pod šumom u Francuskoj tijekom 11 stoljeća

Year *Godina*	Historical event – *Povijesni događaji*	Forest Area million ha *Šumske površine mil. ha*
900	Beginning of the medieval clearing – *početak srednjevjekovnih sječa*	29.0
1219	1st royal ordnance on forests – *prvi kraljevski iskaz o šumama*	19.3
1273	End of medieval forest clearing – *kraj srednjevjekovnih sječa*	10.8
1291	Philippe le Bel appoints Masters for Water and Forests – *Philippe le Bel imenuje Gospodara za vode i šume*	9.9
1661	Colbert's great reformation – *Colbertova velika reforma*	7.7
1789	French Revolution – *Francuska revolucija*	6.8
1824	National School for Water & Forests – *Nacionalna škola za vode I šume*	5.0
1827	Promulgation of Forest Law – *Zakona o šumama*	4.1
1863	Afforestations during the 2nd Empire – *Pošumljavanje tijekom drugog kraljevstva*	7.2
1882	Afforestations in Gascogne – *Pošumljavanje u Gaskonji*	9.0
1914	1914-18 1st WW – *I svjetski rat*	7.74
1946	Establishment of Nat.Fund for Afforestation – *Osnivanje nac. Fonda za pošumljavanje*	11.25
1964	Est. of the l'ONF – *Osnivanje Nacionalne šumarske organizacije*	12.5
1986	1st Directive concerning forests issued by the EEC – *Prva direktiva o šumarskim pitanjima potaknuta od EEC-a*	13.4
2000	Actual stand in 2000 – *Stanje u 2000. godini*	16.2

In the Fig. 3. the development of area under forests in France during 11 centuries illustrates how forests have disappeared from Middle Ages until first half of the 19th century, and how much have been reforested afterwards. The situation is of course different for each country, as the circumstances under which the life was developed, varied.



Source/*Izvor*: Forêts en poche, Min. de l'Agriculture et de la pêche et l'ONF, Oct. 1993; Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand, UN-ECE/FAO0, New York/Génève

Figure 3 French forests during history, polynomial trend and extrapolated forecast -10 and +15 years

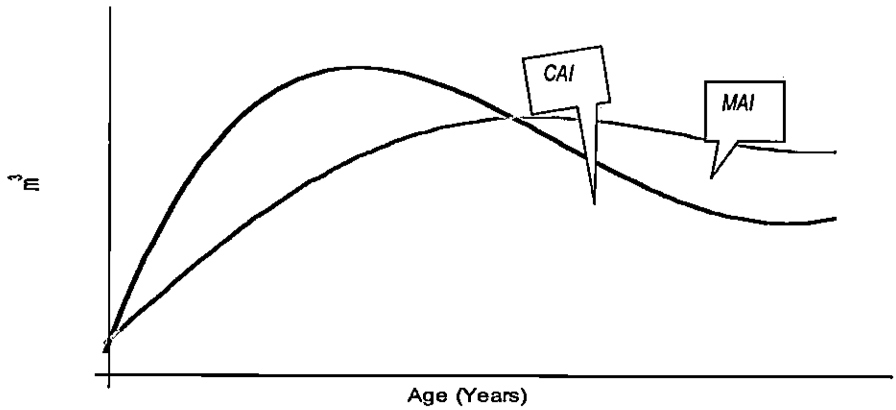
Slika 3. Francuske šume tijekom povijesti, polinomski trend i ekstrapolirano predviđanje za -10 i +15 godina

The volume increment for each year is called Current Annual Increment (C: A:I:). The average increment of wood volume is called Mean Annual Increment (M.A.I.).

The mutual relationship is shown in the Fig. 4.

Systematized by the time flow, the data are called time series. Regression line is the trend curve calculated for the purpose of estimation, foreseeing or forecasting. Assuming that the forest influences servicec are significantly assessed, the maximum of total benefits (monetary and nonmonetary) is the function of the time passed.

The modern standpoint of forest management experts that the total value of CAI (Y) is the function of time (X) On the national level, is not considered the specific forest stand, but the total forest and wooded area, which is constantly changing, not only by surface, growing stock etc. but is under influence of natural changes, economic activities, prices, supply, demand, as well as it is under influence of attained civilization level, and a multitude of other significant factors.



Source/*Izvor*: Jeram, M.R.K., 1945, A Textbook on Forest Management, Chapman & Hall Ltd. London Klepac, D., 1987, Uređivanje šuma, Šumarska enciklopedija, III, pp. 550

Figure 4. Current Annual Increment and Mean Annual Increment of the volume of tree as the function of age

Slika 4. Stvarni godišnji prirast i srednji godišnji prirast obujma drvva kao funkcija starosti

It is easy to apprehend that the mean annual increment is small in the phase of newly sprout forth, enlarging progressivelly until reaching maturity value and death.

According to Klepac, the increment is the function of tine. Considered from the national standpoint level, the total annual fellings are by all means, providing that specific country manages its forests on the sustained yield basis, function of increment. Countring the immense number of dependent and independent variables influencing th growth, the main variables are the forested area, its growing stock, health of stands and theirr reproductive forces. Defined mathematically certain model, it is clear that independent variables are not completely independent, but depend upon other variables, which is known as autocorrealion[4].

The increment musn't and most frequently is not the sole determinant of the volume of annual cut. Besides biological factors (such as e.g. sylvicultural requireements for thinning, etc.), decisive factors come from the market, which dictates the tree species demanded, type of products, the prices, then what kind of customers having certain purchasing power, and what furter products are going to be manufactured.

[4] The correlation between closely lying time intervals of the time series

The above mentioned factors, being endlessly smal portion of the whole, might be in a way expressed mathematically, in which the dependent variable Ya is in closer or looser correllation with a flow of dependent variables x,y,....n. Defining the dependent variable as e.g. value of annual income (or turn over, etc.) its value could be calculated as the sum of values of relative independent variables:

$$z = f(x, y, \ldots n) \qquad (1)$$

which is much closer to the reality in economic activities, since the real life is composed of inumerable multi variable functions. Such function enable the calculation the effect of variables considered, or summarized variables of moderate influence. Derivate of such function illustrates the changes of (z), leaving other variables (e.g. x, y,...n) constant (The principle "ceteris paribus").

The present study, being the part taking the biological and other influential conditions in which a forest grows as granted, adds a row of other influential variables which make the overalll value of forests for inhabitants populating our planet. It was thus necessary to extend the physicall and biological aspects, otherwise basically different to econometrics and other sociall sciences.

Econometrics is the integration of economic theory, mathematics, and statistical techniques for the purpose of testing hypotheses about economic phenomena estimating coefficients of economic relationship, and forecasting or predicting future values of economic variables or phenomena. The tool in econometrc study is the regression analysis which studies the causal relationship between one economic variable to be explained (dependent variable) and one or more independent or explanatory variables. In other words, the present study on annual cut in some European countries, tries to explain the annual felling volume by explanatory variables such as bioclimatical condition of national forest stands, health of trees, growing stock, increment, demand for timber, supply of timber, other forest products, as well as multitude of forest influence services the forest provides in a time flow where all the independent variables are subject to changes.

There are three interrelated functions in econometrics:

(a) Testing of economic theories or hypotheses.
(b) To provide numerical estimates of the coefficients of economic relationship.
(c) Forecasting of economic events

The inclusion of a random disturbance or error term (with well defined probabilistic properties) is required in regression analysis for three important reasons. (1) Since the purpose of theory is to generalize and simplify, economic relationships usually include only the most important forces at work. This means that numerous other variables with slight and irregular effects are not included. The error term can be viewed as representing the net effect of this large number of small and irregular forces at work. (2) The inclusion of the error term can be justified in order to take into consideration the net effect of possible errors in measuring the dependent variable or variable being explained. Finally, (3) Since human behaviour usually differs in a random way under identical circumstances, the disturbance or error term can be used to capture this inherently random human behaviour. This error terem thus allows for individual random deviations from the exact deterministic relationship postulated by economic theory and mathematical economics.[5]

Econometrics presupposes the existence of a body of economic theories or hypotheses requiring testing. If the variables suggested by economic theory do not provide a satisfactory explanation, the researcher may experiment with alternative formulationns and variables suggested by previous tests orm opposing theories. In this way, econometric research can lead to the acceptance, rejection, and reformulation of economic theories.

Mathematics is used to express the verbal statements of economic theories in mathematical form, expressing an exact or deterministic functional relationship between the dependent and one or more independent or explanatory variables.[6]

Statistical analysis applies appropriate techniques to estimate the inexact and nonexperimental relationship among economic variables by utlizing relevant economic data and evaluating the results.

THE POSSIBILILTY OF APPROXIMATION OF TIME SERIES OF GROSS FELLINGS IN FORESTS AT THE NATIONAL LEVEL
MOGUĆNOST APROKSIMACIJE VREMENSKIH NIZOVA BRUTO SJEČA U ŠUMAMA NA NACIONALNOJ RAZINI

Recording the annual fellings the time series is obtained, which dispersion is poossible to approximatre functionally, by a mathematical equation, following the rules of mathematical statistics.

[5] Stochastic variable expresses random behaviour which can't be completely explained by pure deterministic model, i.e. by model in which all the changes are the consequence of previous causes.

[6] The another variable depending upon independent variable, when meaning and cause might be but not necessarily included.

Table 3. Equations of approximating curves
Tablica 3. Jednadžbe krivulja aproksimacija

$Y = a_0 - a_1X$	*Straight line*
$Y = a_0 + a_1X + a_2X^2$	*Parabolic or Quadrate curve*
$Y = a_0 + a_1X + a_2X^2 + a_3X^3$	*Cubic curve*
$Y = a_0 + a_1X + a_2X^2 + \ldots\ldots\ldots a_nX^n$	*n^th^ degree curve*
$Y = 1/(a_0+a_1X)$ or $1/Y = a_0 + a_1X$	*Hyperbolic*
$Y = ab^X$ ili $\log Y = \log a + (\log b) X$	*Exponential curve*
$Y = aX^b$ ili $\log Y = \log a + b \log X$	*Geometric curve*
$Y = ab^X + g$	*Modified exponential curve*
$Y = aX^b + g$	*Modified geometric curve*
$Y = pq^{bX}$ ili $\log Y = p + b^X \log q$	*Gompertz curve*
$Y = 1/pq^{bX} + h$	*Modified Gompertz curve*
$Y_t = \dfrac{k}{1 + be^{-at}}$ ili: $\log a_0 + a_1(\log X) + a_2(\log X)^2$	*Logistic or Pearl-Reed curve*

THE APPLICATION OF PEARL-REED (LOGISTIC) AND GOMPERTZ'S FUNCTION IN CALCULATION OF THE HARVESTING VOLUME

PRIMJENA PEARL-REED-OVE (LOGISTIČKE) I GOMPERTZOVE FUNKCIJE U RAČUNANJU VOLUME NA SJEČA ETATA

The statistical methods, as it is known, are not suitable if there exist autocorrelation between some elements. By other words, if these elements are mutually not independent in the sense of the probability theory. Thus, relatively new methods have been developed with the aim of avoiding infinite time trend, but obtaining the data approaching asymptotically to a certain finite value.

FOREST RESOURCES AND DEVELOPMENT OF ANNUAL FELLING IN CROATIA, SWITZERLANDD, GERMANY AND FRANCE
ŠUMSKI IZVORI I KRETANJE GODIŠNJIH SJEČA U HRVATSKOJ, ŠVICARSKOJ, NJEMAČKOJ I FRANCUSKOJ

Table 4. Forest area, growing stock, annual increment and annual allowable cut in forests in Croatia, Switzerland, Germany and France

Tablica 4. Šumske površine, drvna zaliha, godišnji prirast i godišnja sječiva masa u Hrvatskoj, Švicarskoj, Njemačkoj i Francuskoj

	Croatia	Switzerland	Germany	France
Total land area, km^2 – *Ukupna površina*	56 610	41 284	357 000	543 250
Population (census year) – *Stanovništvo*	4 437 460 (2001)	7 299 000	83 500 000	56 440 000
Total forest area, ha – *Ukupna površina šuma*	2 078	1 173	10 800 000	16 181 000
Total growing stock, m^3 – *Ukupna drvna zaliha*	326 256 137	422 453 000	2 820 000 000	2 015 309 000
Current annual increment, m^3 – *Godišnji prirast*	9 643 117	10 107 000	89 000 000	87 402 000
Annual fellings, 000 m^3 – *Godišnje sječe*	4 105 000 (2001)	4 845 000 (1998)	39 060 000(1998)	35 527 000(1998)

Source/*Izvor*: *Forest Resources of Europe, CIS, North America, Australia, Japan and New Zealand*, UN-ECE/FAO0, New York/Génève, 2000; *Statistical Yearbook* 1992-2003, Public Statistical Bureau of Croatia, Zagreb; Croatian Forests Public Corp., 1998, The *Development Plan for Forestry of the Republic Croatia*, Zagreb

Table 5. Stocked forest area in Croatia by its classification
Tablica 5. Obrasle šumske površine u Hrvatskoj prema namjeni

Classification of forests *Namjena šuma*	High forests *Sjemenjače*	Coppice *Panjače*	Maquis *Makije*	Ga-rigue *Garig*	Scrub *Šikare*	Bush *Šibljaci*	Planta-tions *-Plantaže i kulture*	Total *Ukupno*
	ha							
Total – *Ukupno*								
Exploitable forests *Gospodarske šume*	1161095	484969	28818	12918	270657	6863	15714	1981034
F. under spec. manag. *Šume posebne namjene*	43125	4581	1568	59	116	37	183	49633
Protective forests *Zaštitne šume*	46150	15351	438	226	8246	6900	4	47624
Total *Ukupno*	1250370	504901	30824	13203	279019		15901	2078291

Table 6. Fundamental data on forestry in Croatia
Tablica 6. Osnovni podaci o šumarstvu u Hrvatskoj

Hardwood broadleaved growing stock – *Tvrde listače drvna zaliha* = 266 164 278 m^3

Softwood broadleaved growing stock – *Meke listače drvna zaliha* = 12 006 530 m^3

Hardwood broadleaved annual increment – *Tvrde listače godišnji prirast* = 7 902 285 m^3

Softwood broadleaved annual increment – *Meke listače godišnji prirast* = 482 229 m^3

Broadleaved growing stock total – *Ukupno listače drvna zaliha* = 278 170 808 m^3

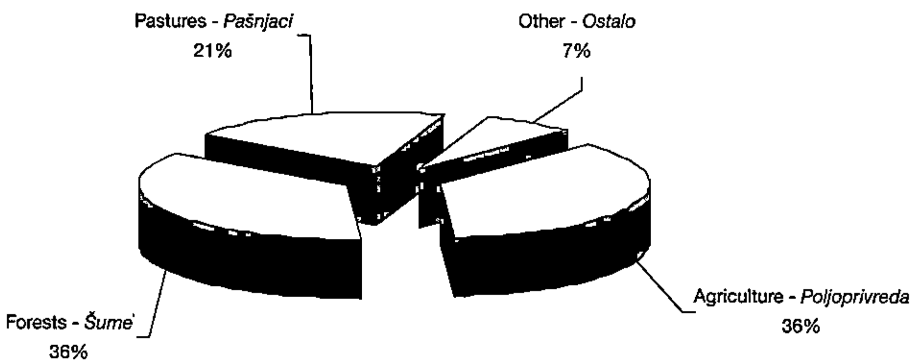
Broadleaved annual increment – *Ukupno listače godišnji prirast* = 8 384 514 m^3

Conifers growing stock – *Četinjače drvna zaliha* = 48 082 818 m^3

Conifers annual increment – *Četinjače godišnji prirast* = 125 8524 m^3

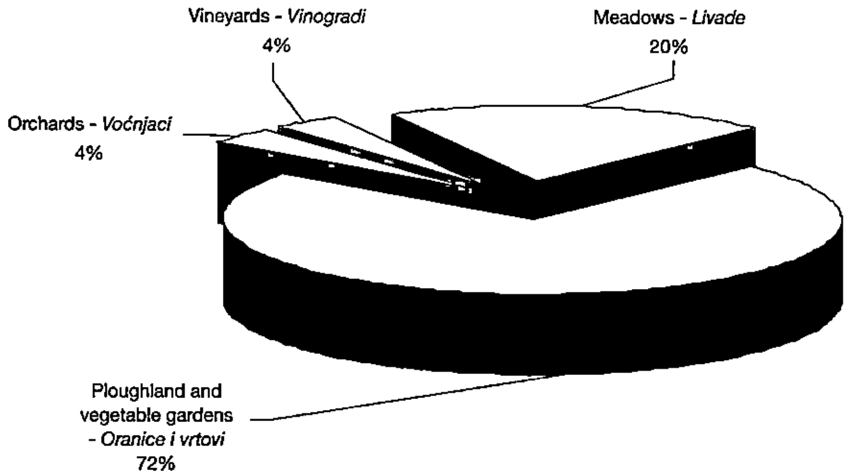
Nastavak tablice 6.

Other, growing stock – *Ostalo, drvna zaliha* = 2 511 m^3
Other, annual increment – *Ostalo,godišnji prirast* = 79 m^3
Growing stock total – *Ukupno drvna zaliha* = 326 256 137 m^3
Annual increment total – *Ukupno godišnji prirast* = 9 643 117 m^3
Rate of growth of the growing stock – *Postotak prirasta drvne zalihe* = 2,95 %
Total land surface of the Republic of Croatia – *Ukupna površina Republike Hrvatske* = 56610 km^2
There of – *od toga* – agricultural land – *poljoprivredno zemljište* = 20340 km^2 – forests and wooded land – *šume (šumom obraslo tlo)* = 20782.3 km^2 – pastures – *pašnjaci* = 11510 km^2 – other – *ostalo* = 3977.7 km^2 (inland areas, built up sites, transportation facilities, swamps, reed, fish-ponds, bare land and other – *unutrašnje vodene površine, izgrađeno zemljište, komunikacije, bare, trščaci, ribnjaci, goleti i ostalo*)



Source – *Izvor*: Statistical Yearbook 1990-2003, The State Statistical Agency, Zagreb. *Statistički godišnjak 1990-2003, Državni statistički zavod, Zagreb.*

Figure 5. Croatia, land use (56 610 km^2)
Slika 5. Hrvatska, uporaba zemljišta (56 610 km^2)



Source – *Izvor*: Statistical Yearbook 1990-2003, The State Statistical Agency, Zagreb.
Statistički godišnjak 1990-2003, Državni statistički zavod, Zagreb.

Figure 6. Croatia, agricultural land (20 340 km²)
Slika 6. Hrvatska, poljoprivredne površine (20 340 km²)

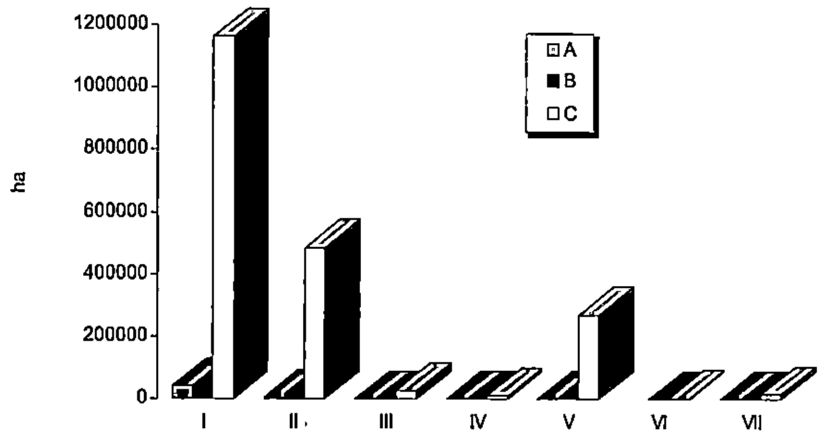


Figure 7. Croatia, stocked forests (20 782.9 km²)
Slika 7. Hrvatska, obrasle šumske površine (20 782.9 km²)

Legend – *Legenda*

	A Forest with restrictions *Šume posebne namjene*	B Protection forests *Zaštitne šume*	C Exploitable forests *Gospodarske šume*	Total – *Ukupno*
	Hectares - *Hektara*			
High forests – *Sjemenjače*	43125	23322	1161095	1227542
Coppice – *Panjače*	4581	15351	484969	504901
Brushland (Maquis) *Makija*	1568	438	28818	30824
Bushes (Garigue) *Garig*	59	226	12918	13203
Scrub *Šikare*	116	8246	270657	279019
Osier *Šibljak*		37	6862	6899
Plantations *Plantaže i kulture*	183	4	15714	15901
Total – *Ukupno*	49632	47624	1981033	2078289

Source – *Izvor:* Longterm and midterm development plans for forestry in Croatia, Croatian forests, 1988, *Dugoročni i srednjeročni plan razvoja šumarstva R. Hrvatske,* Hrvatske šume, 1998.

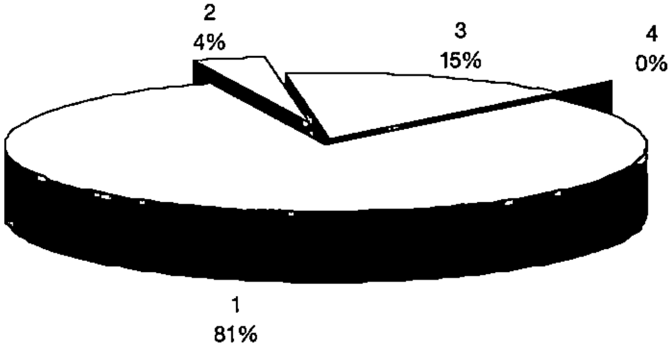


Figure 8. Growing stock of wooded land in the republic of Croatia
Slika 8. Drvna zaliha šumom obraslih površina u republici Hrvatskoj

Legend – *Legenda*

	1 Broadleaved hardwood - *Tvrde listače*	2 Broadleaved softwood - *Meke listače*	3 Conifers - *Četinjače*	4 Other - *Ostalo*	Total – *Ukupno*
	m³				
Total *Ukupno*	266 164 278	12 006 530	48 082 818	2 511	326 256 137

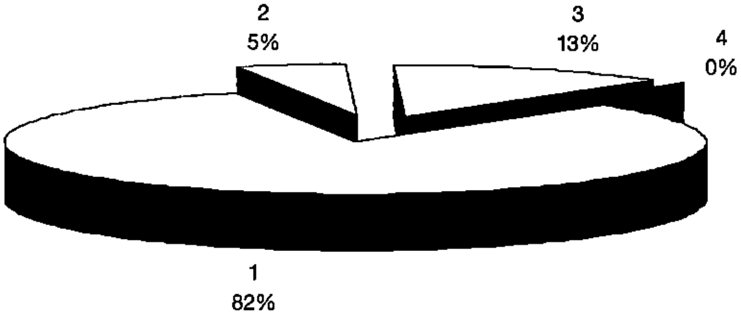


Figure 9. Annual growth of wooded land in the republic of Croatia
Slika 9. Godišnji prirast šumom obraslih površina u republici Hrvatskoj

Legend - *Legenda*

	1 Broadleaved hardwood *Tvrde listače*	2 Broadleaved softwood *Meke listače*	3 Conifers *Četinjače*	4 Other *Ostalo*	Total – *Ukupno*
	m³				
Total *Ukupno*	7 902 285	482 229	1 258 524	79	9 643 117

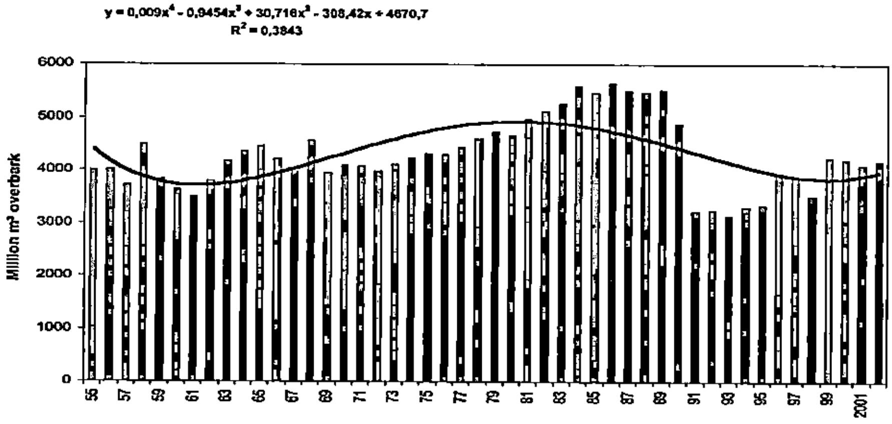


Figure 10. The development of annual gross timber cut in Croatia 1955 – 2002
Slika 10. Razvoj godišnjih bruto sječa u Hrvatskoj 1955 – 2002.

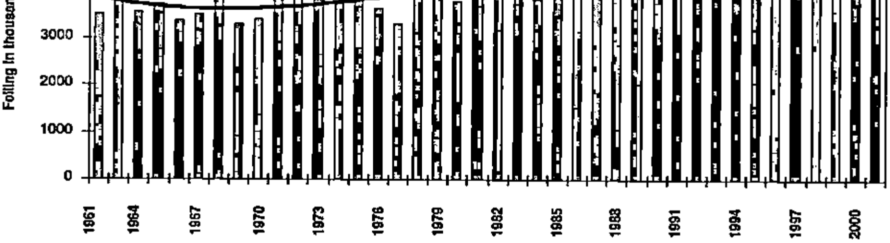


Figure 11. The development of annual gross felling in Switzerland 1961 – 2001
Slika 11. Razvoj godišnjih bruto sječa u Švicarskoj 1961 – 2001.

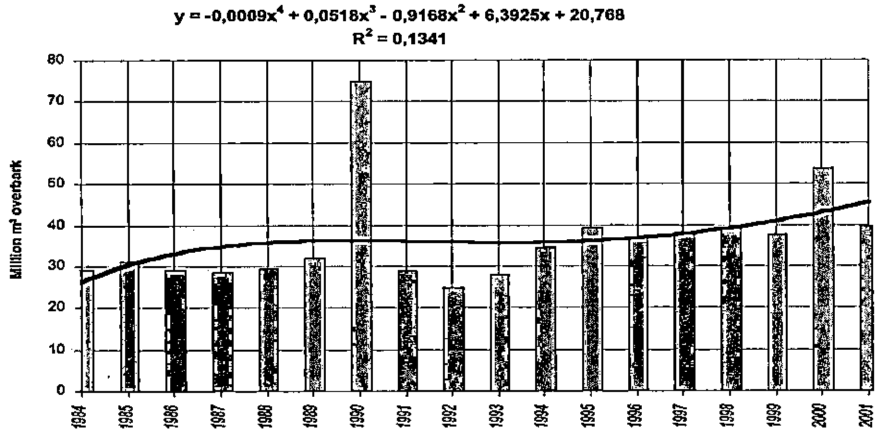


Figure 12. The development of annual felling in Germany 1987 – 2001
Slika 12. Razvoj godišnjih sječa u Njemačkoj 1987 – 2001.

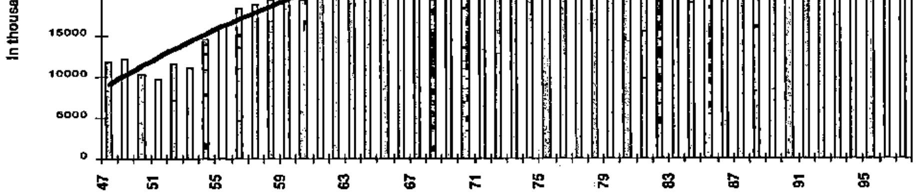


Figure 13. The timber production in France, (without fuel wood) 1947 – 1997
Slika 13. Proizvodnja drva u Francuskoj (bez ogrjevnog drva) 1947 – 1997.

LOGISTIC FUNCTION APPLICATION IN ASSESSING HARVESTING VOLUME IN SOME EUROPEAN COUNTRIES
PRIMJENA LOGISTIČKE FUNKCIJE U PROCJENI VOLUMENA ETATA U NEKIM EUROPSKIM ZEMLJAMA

In cases of long time series these functions might be used if trend is to be avoided. The logistic function is most frequently used in forescasting of population number. In the econometrics it is generally possible to handle mutually dependent economic series by logistic function.

By mid of 20th century comes to great progress in statistical calculation of stationary stochastic processes. Un econometrics almost all empirical series contain a certain trend, thus making them not stationary, which makes the elimination of trend is necessary, by application of statistical methods on trend residues.

Easiest way would be to apply trend, consisting time exponent as a variable. Such a trend would show alas, unpleasant characteristics, growing with time indefinite. Such a trend is thus useful for intrapolation, and unsuitable for extrapolation, when economic time series are being handled.

The logistic trend has a property to tend with time towards a certain asymptotic value. The definition of the logistic function y_t is

$$y_t = \frac{k}{1 + be^{-at}} \qquad (2)$$

In the formula (2) t is time, k, a and b being constants generally unknown. Constant k is the upper asymptote of the logistic function. It is evident that:

$$\lim_{t \to \infty} y_t = k \qquad (3)$$

It is perfectly clear that the assessment of felling volume by the logistic curve has a multitude of reproaches. But let us try to explain the assesssment itself and what kind of prognostic values could be expected from this functioin. In the long time period, even if about Croatian forestry is concerned (not necessarily to mention the forestry of Switzerland, Germany, and France), nowadays since the modern forest management has been practised for already 150 years, the principle of forest management is the sylvicultural treatment oriented towards to the nature close forest stands, corresponding by species composition and other biocenological characteristics to natural autochtoneous forests. During long periods of timehere and there, comes to changes, due to anthropogenic and other influences, mostly independent from biology of forest.

Technical and biotechnical progress, particularly in agriculture, change constantly the requirements for land used for agriculture, tending towards diminuation in industrially developed countries, rregardless of demographic situation in these countries. The consequence is that agriculktural land below and at marginal productivity is abandoned and in countries with progressive forest policy turned to forrestry, thus meliorating the ecological overall situation. The example of France given in the Fig. 3 and Tab.2. witness as a proof, how consistently and rationally designed forest policy might improve the own country turning it, step by step, into ecological sanctuary.

The reasons for deforestation differ from one to another country. The deforestation in the northern part of Croatia wasn't so dramatic thanks to low population number, absence of communications, and low demand for timber. This is not the case with the littoral part of the country, which has been deforested from the anthropogenous as well as climatic reasons. Large clearings were characteristic particularly in the Middle Ages in France and Germany, at the time relatively densely populated.

Common to all mentioned is that all the changes relative to starting forest areas and their state are granted, the changes expressed by volume of cut result from observing or neglecting the quantities set as allowable cut in management plan, changes in areas, changes in growing stock, changes in age structure, health of stands etc. Obviously, as the case always is, the annual fellings in a way flow asymptotically towards certain limit, which is being the result of changes taking place now or will happen in the future. In the nineties years of the 20th century two typhoons (Vivian and Lothar) have devastated huge areas of forests in the Alpine region of Europe, thus increasing logging volume beyond all by managerial plans envisaged quantities.

In all cases it should be mentioned, in describing the sources of data and their reliability, that e.g. for Croatia the volume of annual felling in the public sector of forestry is acceptable, what is not the case with fellings in the private sector. Private forest sector in Croatia extends over an area of 0.454 million ha, which is nearly ¼ of all foresst area with about 38 million m^3 of growing stock and about 1.35 million m^3 of annual increment. Due to confusing forest policy, each private forst owner should apply cutting permit which, before obtaining it , obliges the owner to pay taxes in advance. Regardless to the low increase in recorded cutting permits, almost half a century the felling in private forests doesn't exceed 400 thousand m^3 (in the period 1982-90), after which only in 1993 (203,000 m3) and 1994 (224,000 m^3)

exceeded 200,000 m^3 annually.[7] If this would happen to be true, in fifty years the growing stock in private forestss would be multiplied several times, which is not the case. According to free estimates, in private forests in Croatian about 1 million m^3 of timber is cut, which estimate, lacking reliability musn't be taken true. In present calculations, only the official dana will be considered, which does not make any difference on obtained trends, as long as the present forest policy is maintained.

The area under forest cover asymptotically tend towards a limit, determined by distribution of land use, which is the consequence of population growth (which is also a logistic function), improvemeents due totechnical and technologgical ddevelopment, climatic changes, changes in the state of forest stands, etc. Practically is hardly possible to specify all these variables and their influence onforests and resulting felling volume. Taken together all them, in sufficieently long and reliable time series, assessment of annual fellings made by logistic function may prove acceptable and relativelly reliable tool in a row of operations of valuation of forests in their totality, monetary and non monetary.

The difficulties arising by the estimates of this kind, i.e. estimation of the logistic function (unknown parameters) are generally known. The pure numerical methods must be applied, since the normal equation obtained by the application of least squares method or Maximum Likwlihood method are not always linear in unknown parameters. For assessment of these parameters Hotelliing has developed the method starting from the differential equation of the logistic function:

$$\frac{(\partial y_t / \partial t)}{y_t} = a - (a/k) y_t \qquad (4)$$

Now is possible to apply the method of least squares or Maximum Likelihood method directly on above (4) differential equation. The estimates for a and a/k parameters, enable calculation of original constants a and k. The missing parameter b is possible to obtain by the well known Rhodes's method:

$$\ln b = a\,(N + 1)/2 + \{ \sum_{t=1}^{N} \ln [\,(k/y_t) - 1\,] \} / N \qquad (5)$$

There are N number of observations in constant distribution flow (e.g. anually). In the above formula the Napier's or natural logarithm with the base e is applied..

[7] Izvor, Source: Državni zavod za statistiku, Zagreb

In the practical use, the idea of Hotelling comes to a difficulty: the rate of growth $(\partial y/\partial t)/ y_t$ is required, for which, as in all ecconomic series no continual observations are available, just e.g. annual (or mensual or similar). For this reason it is necessary to draw close the rate of growth by differences. This is rather complicated and results are not reliable, particularly if there an error available in observations of the original data flow.

There is a simple way to overcome this shortage. Looking for the moment at the logistic function as a law of development of certain phenomenon (population, forest area, growinf stock, increment, allowable cut, etc.) in which case the recirpocal value of the phenomenon is proportional. In this case one comes to the simple transformation:

$$z_t = 1/y_t = \frac{1 + be^{-at}}{k} \qquad (6)$$

The function z_t has the linear differential first grade function:

$$z_{t+1} = (1 - e^{-a}) / k + e^{-a} z_t \qquad (7)$$

It may prove useful to explain the estimate, and what prognostic values could be expected from this function.

In the very long time series, particularly when speaking of Croatian forestry, almost 1 and ½ centuries since the principle of sustained yield management is strictly applied on to the nature close forest stands, composed of appropriate autochtoneous tree species and phytocenological associations, with close to optimal growing stock , regular annual increment, and appropriate allowable cut serving as sylvicultural tending of forest stands. During time elapsed the changes occur, certain stands were being degraded, some improved, coppice and coppice with standard were being turned into high forests, and vice versa. Some forests dissapear due to forest fies, another land use and similar, elswhere appear new stands through afforestation.

Technical and biotechnical progress, particularly in agriculture, stirs up permanently changes in laqnd use, tending generally towards reduction of areas in agricultural use, most frequently in industrially developed countries, regardless of population growth, the later being slowed down too. Macro- and microeconomic factors in the complex of these circumstances maintain the pressure on agriculture to abandon the areas at the margin of productivity or below it, which offers to the forestry the possibility to expand. All European countries are, more or less a proof for the development of this kind, which process might be accelerated if the government follows the adequate development policy.

Table 8. Parameters of the logistic curve of annual gross felling in the national forests of Croatia, Switzerland, France (without fuelwood) and Germany

Tablica 8. Parametri logističke funkcije godišnjih bruto sječa u nacionalnim šumama Hrvatske, Švicarske, Francuske (bez ogrjevnog drva), i Njemačke

Croatia – *Hrvatska* (r = 0,850412543)

$z_t = A + Bz_{t-1}$	a	k	b	$y_{t=15\,(1969)}$	$y_{t=25(1979)}$	$y_{t=35\,(1989)}$
z_t = 0,02644183+0,875461 z_{t-1}	0,133	4,71	2,3762	4,146	4,339	4,606

Germany – *Njemačka* (r = 0,3025)

$z_t = A + Bz_{t-1}$	a	k	b	$y_{t=10\,(1993)}$	$y_{t=20\,(2003)}$
0.020251851+0,3024872 z_{t-1}	1,19572	34,44193	122,964	34,41	34,44

France – *Francuska* (r = 0,909)

$z_t = A + Bz_{t-1}$	a	k	b	$y_{t=30\,(1976)}$	$y_{t=40(1986)}$	$y_{t=50\,(1996)}$
z_t = 3,0824x10^{-3} +0,9086 z_{t-1}	0,0958	29,64	3,052	25,28	27,80	28,91

Switzerland – *Švicarska* (r = 0,482513873)

$z_t = A + Bz_{t-1}$	a	k	b	$y_{t=10\,(1970)}$	$y_{t=20\,(1980)}$	$y_{t=30\,(1990)}$
0,122956965+0,4877531 z_{t-1}	0,717946	4,1661	2,81x10^5	4,162	4,166	4,166

The calculated value of timber felled by logistic (and Gompertz's as well) function, one got to know that its value expressed in money is, by momentarystandards, hardly $^1/_{20}$ of the total value of all benefits the forest represent in maintenance of sustainable development.

Now is possible at the differential equation (6) apply directly the method of least squared or Maximum Likelihood. Following the path the estimates of parameters $(1 - e^{-a}) / k$ i e^{-a} are obtained, enabling the calculation of constants a and k of the logistic function. The remaining constant b has to be calculated using the Rhodes formula (5).

THE APPLICATION OF GOMPERTZ'S FUNCTION IN APPROXIMATION OF THE NATIONAL ANNUAL FELLINGS

PRIMJENA GOMPERTZOVE FUNKCIJE PRI APROKSIMACIJI NACIONALNIH GODIŠNJIH BRUTO SJEČA

Gompertz's[8] function is most frequently used as the curve for approximation of best fit of mutually related set of observations. Its formula is:

$$Y_{calc} = ka^{bX} \quad (8)$$

Depending upon values of parameters *k*, *a* and *b* (or their logarithms) it might take any of the variety of shapes shown in Fig. 14-17. Form (1) is of special interest in that it has an upper asymptote which, in a biological, business etc. context, means market or any other saturation.

In the practice frequently comes to situation that there is relation between two or more variables. E.g. the gross felling volume cut in national forests of specific country depends on weather, practised sustained yield management, area under forests, growing stock, allowable cut etc change in mutually depending relations. From this reason is desirable this mutually dependent relation express mathematically, by determination of equations which connect the most different variables, together with non identified random variables.

The parameters *k, a* and *b* are obtained as follows:

1) The number of observations must be divisible by 3, i.e. there are 3*n* periods of the base data.
2) Convert the Y's to logs
3) Add the first *n* log-Y's to obtain $\Sigma_1 \log Y$; then the second n dana points to obtain $\Sigma_2 \log Y$; i and the last *n* points to obtain $\Sigma_3 \log Y$.
4) Note that X = 0 for the first year.
5) Substitute in the following formulas::

$$b^n = \frac{\Sigma_3 \log Y - \Sigma_2 \log Y}{\Sigma_2 \log Y - \Sigma_1 \log Y} \quad (9)$$

[8] Gompertzova teoretska distribucija predložena je po statističaru Benjaminu Gompertzu (1825) za tvorbu tablica dužine života pri osiguranju utemeljena je na pretpostavci da je "prosječno slabljenje čovjekove snage da izbjegne smrti je krajem svakog beskrajno malenog intervala jednaka intenzitetom kao i na početku tog intervala. ".

Rezultirajuća slučajna funkcija je: f(x) = Bcx za x≤ 0; B > 0; c ≤ 1

$$\log a = (\Sigma_2 \log Y - \Sigma_1 \log Y)\ \frac{b - 1}{(b^n - 1)^2} \qquad (10)$$

$$\log k = 1/n\ [\Sigma_1 \log Y - \frac{b^n - 1}{b - 1} \log a] \qquad (11)$$

6) A formula for obtaining the asymptote k directly is

$$\log k = 1/n\ [\frac{(\Sigma_1 \log Y)(\Sigma_3 \log Y) - (\Sigma_2 \log Y)^2}{\Sigma_1 \log Y + \Sigma_3 \log Y - 2\,\Sigma_2 \log Y}] \qquad (12)$$

Figure 14 – 17. The possible shapes of Gompertz curve
Slike 14 – 17. Mogući oblici Gompertzove krivulje

Fig. 14

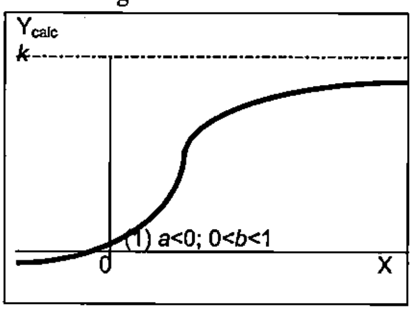


Fig. 15

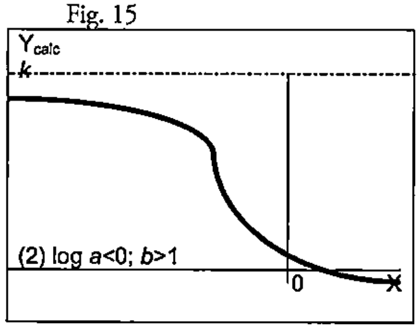


Fig. 16

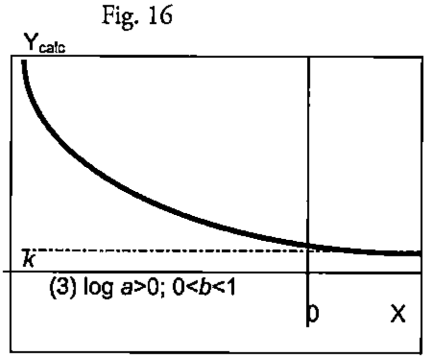


Fig. 17

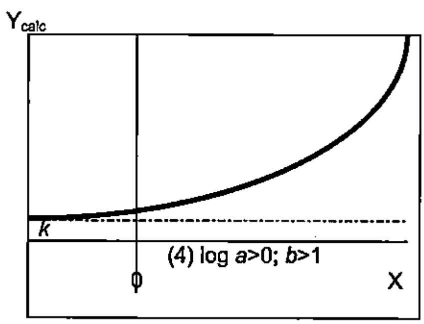


Table 9. Calculated parameters of the Gompertz functions for annual gross fellings in Croatia, Switzerland, Germany and France

Tablica 9. Izračunati parametri Gompertzove funkcije za godišnje sječe u Hrvatskoj, Švicarskoj, Njemačkoj i Francuskoj

Parameters *Parametri*	Croatia	Switzerland	FR Germany	France (without fuelwood) *Francuska (bez ogrjeva)*
b	1,12941	1,04533	0.95006304	0,93107
b^n	4,30747	1,86014	0,735384615	0,31895
log a	0,0030860921	0,03867	-0,324491497	-0,4592162
a	1,0007131297	1,093115951	0.473705582	0,3473633
log k	3,596343922	3,52346643	4,762346123	4,512377
k	3 947 700 m³ ob*	3 337 850 m³ ob	57 855 700 m³ ob	32,536.965 m³ o.b.
Curve's shape -*Oblik krivulje*	(4)	(4)	(1)	(1)
N° of observations n – *broj ponavljanja*	12	14	6	16

* o.b. = over bark – *mjereno s korom*

CONCLUSION
ZAKLJUČAK

The countries' statistics of Croatia, Germany, Switzerland and France in annual fellings show great differences. Coefficieents of correlation of annual fellings approximated by polynomial trends is high only in case of Croatia for the period 1955-1990, i.e. until the beginning of the war Serbia waged against Croatia (R^2 = 0,8614), and France (without fuelwood cut) in the period 1947-1996 (R^2 = 0,9368). Extrapolated forecasting values of trenda are difficcult to accept even in case of mighty enlargement of forest area, for which one knows grow relatively slowly, and that affoeerestation of new land comes to be very expensive.

It is a hard fact that the overall public opinion is not yet at the level to understand that the condition of their existence lies in extension of forest surface of the planet because of the air, water, as well as to maintain the fertility of land in agricultural use.

Even if the working of prices has not yet expressed itself, to let the price mechanism in the undeisturbed supply and demand to start solving the problems of ecology, incessantly growing problem of the human life and its existence at the planet Earth, one should admit that some results, nevertheless how small, are visible. Notwithstanding to the nostalgic yearning for preservation of the national soul of the vilages and rural life, relentless reality declares such villages ans its way of life, particularly its economic side based on fragmented agriculture, already dead atavism for a long time, and the measures for return it futile, hindering overall economic development. In the industrially developed Europe e.g. the productivity in the agriculture, together with the agro-biotechnical progress, regardless to the growing population, the need for agricultural surface diminishes steadily, contrary to frequent policy failures (unreasonable protection of national, non competitive agricultural products, or futile efforts of subsidizing it, etc.) asymptotically leading to a certain limit of $^1/_5$ land area of the European temperate zone (see Tab. 1.). The number of personel employed in agriculture has diminished in the last century several times, closing the rate of employment in the USA's agriculture (less than 2% of total). Even in the least developed European countries there is hard to find pure agricultural families, at least one or more find permanent or temporary job outside agriculture. The process embraces slowly even some Far Southeast Asian countries , China, and South America.

In Fig. 18.-23. the actual valume cut in reference countries, the logistic and Gompertz's equation fitting are shown. In case of Croatia and Switzerland the Gompertz curve fitting does'nt show reliable results, thus the logistic curve fitting

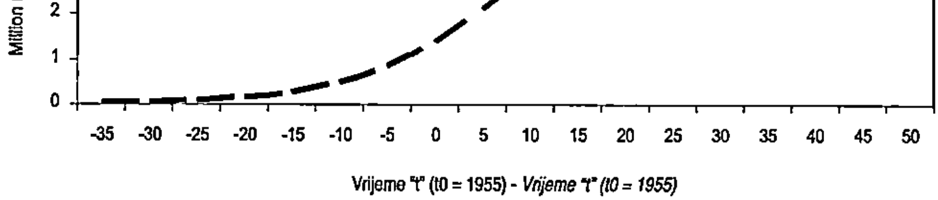


Figure 18. Actual, logistic and Gompertz's function of gross harvested timber in forests of Croatia

Slika 18. Stvarne sječe, logistička i Gompertzova krivulja bruto sječa u šumama u Hrvatskoj seems more reliable, in spite that almost all volumes cut up to the period of Patriotic War 1990> lie above logistic curve, the reason lies outside variables considered in the econometric model (in case of Croatia there was certain pressure and partly greed as well for earning the much money as possible, in case of Switzerland on the other side, dominated by restraint not to cut too much, but the weather frequently spoiled up such an attitude.

The calculated harvested volume by these two functions for the period 1989-2002 (War and consequences) shows in the Fig. 20. how much Croatia suffered economically due to the war, which damage is presented as the difference between logistic curve line, and actual volume harvested not to mention all other damages made to the potential of forests to produce countless goods and services, monetary and non monetary.

The calculated harvested volume by these two functions for the period 1989-2002 (War and consequences) shows in the Fig. 21. how much Croatia suffered economically due to the war, which damage is presented as the difference between logistic curve line, and actual volume harvested not to mention all other damages made to the potential of forests to produce countless goods and services, monetary and non monetary.

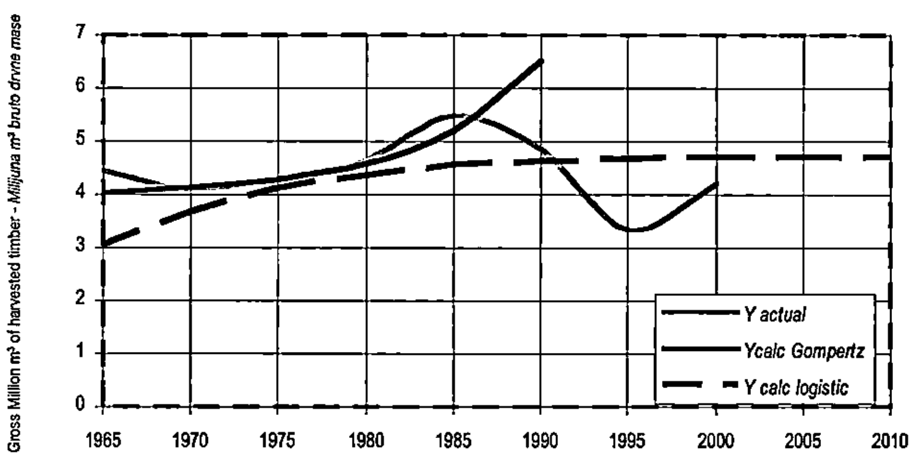


Figure 19. The development of annual felling in Croatia – actual dispersion and fitting by logistic and Gompertz's equation

Slika 19. Kretanje godišnjih sječa u Hrvatskoj – stvarna disperzija i prilagodba logističkom i Gompertzovom funkcijom

Table 10. Losses in the volume of timber logged caused by the war
Tablica 10. Gubitak u obujmu drva uzrokovan ratom

Year – *Godina*	y_t	Σ_t	Loss – *Gubitak*
1989	5.528	4.606	0.922
1990	4.877	4.618	0.259
1991	3.228	4.631	-1.403
1992	3.244	4.640	-1.396
1993	3.136	4.648	-1.512
1994	3.303	4.656	-1.353
1995	3.337	4.663	-1.326
1996	3.945	4.668	-0.723
1997	3.878	4.674	-0.796
1998	3.502	4.678	-1.176
1999	4.228	4.682	-0.454
2000	4.201	4.685	-0.484
2001	4.105	4.689	-0.584
2002	4.168	4.691	-0.523
1989 – 2002 Σ			-10.549
1991 – 2002 Σ			-11.73

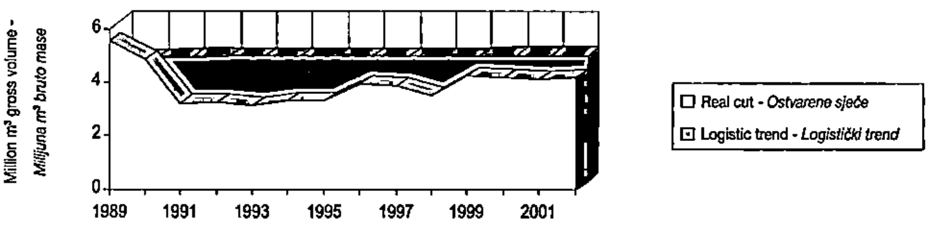


Figure 20. The loss in timber harvesting due to the war in Croatia
Slika 20. Gubitak sječa uslijed rata u Hrvatskoj

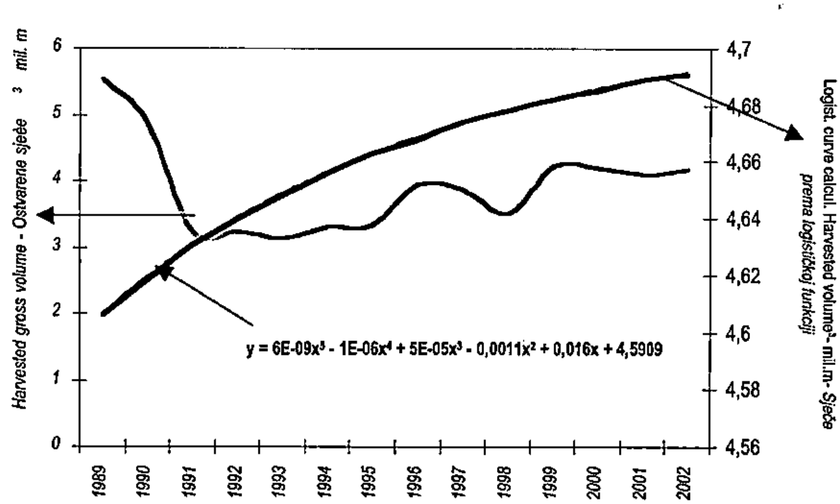


Figure 21. Annual felling in Croatia during and after patriotic war (1989 – 2002)
Slika 21. Sječe etata u Hrvatskoj za vrijeme i poslije domovinskog rata (1989 – 2002)

Fig. 22. shows the case of gross allowable cut in Switzerland in the period 1961-2000, and fitting the observations by logistic and Gompertz equation. As it might be seen, the Gompertz curve, being of the type log $a > 0$, $b > 1$ (Fig. 17), proves not suitable for reliable approximation, and forecasting, since it follows the shape of nonlinear trend.

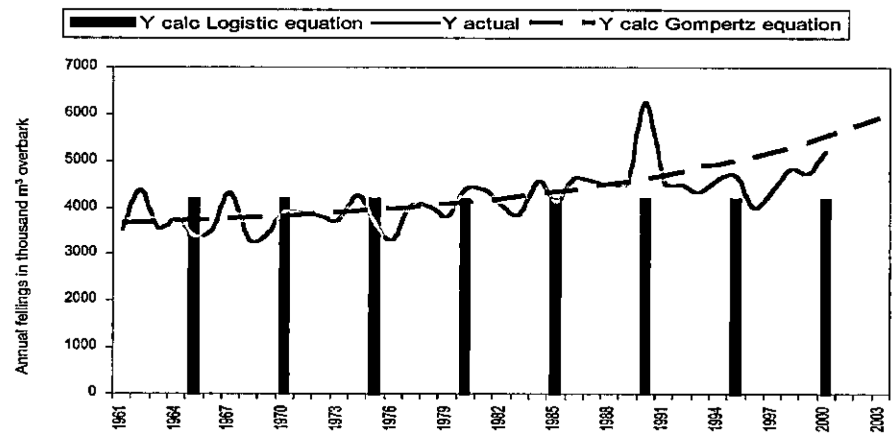


Figure 22. The development of actual annual felling in Switzerland, logistic and Gompertz's equations
Slika 22. Razvoj stvarnih godišnjih sječa u Švicarskoj, logistička i Gompertzova jednadžba

The situation is different in case of Germany, where Gompertz curve has the proper shape as shown in Fig. 14. The problem however is, that the sample is too small, with incorporated consequences of two destructive hurricanes, thus the Gompertz curve follows the pattern too high for asymptotic value of harvested timber. Elimination of said two disturbances could probably produce more realistic assessment of annual gross cut. Since such operation probably might be not more reliable, the authors have renounced the idea to make additional calculations of this kind.

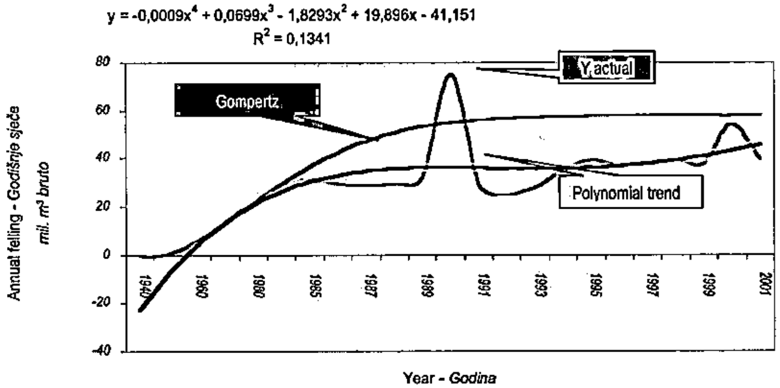


Figure 23. Annual gross felling in Germany obtained by Gompertz's equation from the time series 1984 – 2001 and polynomial trend fitting

Slika 23. Godišnje bruto sječe u Njemačkoj dobivene ekstrapolacijom modela izvedenog iz podataka 1984 – 2001 Gompertzovom krivuljom i aproksimacija polinomskim trendom

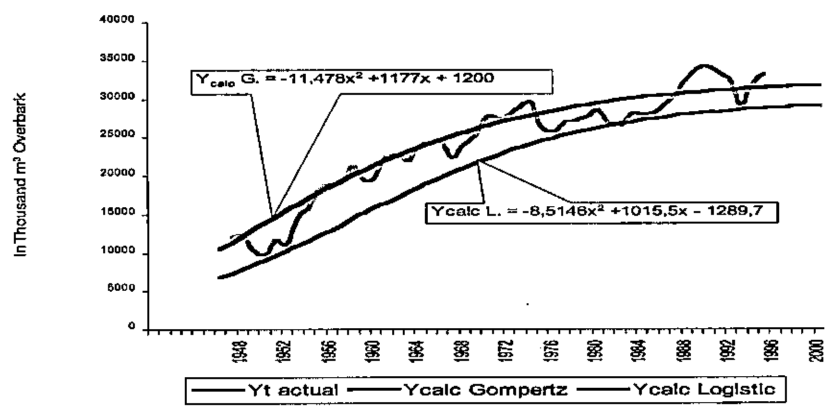


Figure 24. Annual fellings in france, actual data, logistic and Gompertz's functions approximation

Slike 24. Godišnje bruto sječe u Francuskoj (bez ogrjevnog drva), stvarni podaci, aproksimacije logističkom i Gomperttzovom funkcijom

The standpoint towards the land use obviously should be changed in order to facilitate transformation of agricultural land of marginal or below productivity to forests, in the same time rigorously protecting newly afforested surfaces. Such ecological investment is at the same time productive investment, since the forest by its influence function can ensure greater land productivity in the agricultural use.

Due to energy shortages, proposals come from various sides to replace fossil fuel by plant oil. One should bear in mind that the 3rd Reich Germany has waged war for six years based almost on synthetic petrol, having developed sophisticated processes, all of which disappeared immediately after its defeat. Except synthetic gasoline, on the other side, the population turned for energy to the wood, and numerous primitive units producing mobile absorption gas facilities were developed for driving of tracks, tractors, etc. It is believable that if present monopoly of international petrol cartels' ban on serious research for alternative energy is eliminated or at least moderated, new technologies for using wood as energy could be developed within shortest time, in which case it would mean new impulse for unseen progress everywhere, particularly in forestry. On the other side, the idea for search energy substitutes in production plant oil doesn't seem plausible. One got to know that agriculture, through increasing use of fertilizers, and other damaging chemicals causes deterioration of soil condition, not to speak about scenery ugliness.

It should not forget that wood coming from on sustained yield based forests, produces, besides oxygen, numerous influence functions, stores CO_2 etc. represents God's present as energy as well.

In the normal forest, healthy and managed on sustained basis, with optimal growing stock, could normally produce, in temperate zone, average even 5 m^3/ha. One stacked m contains about 0.6 m^3 which has the heating capacity 0.147 TOE. If annual average gross cut is reduced by 20% provided for losses, the net volume harvested annually could reach about 4 m^3/ha. About 20% of this volume contains fuel wood, which is about 0.12 TOE/ha[9].

Adding about 0,32 m^3/ha of technical timber for further reproductive processing, from at least $^1/_3$ would be used as fuel, the rest , being turned to products and partly exported, contributes enormously to the benefit of national economy, the idea of cultivation oil plants for fuel becomes questionable.

Gompertz equation of the type shown on Fig. 14 in case of France and Germany. Logistic curve asymptotic value of annual felling *k* attains 29.64 million m^3/y (F), and 34.44 million m^3/y (D) gross volume of timber. In case of Germany the value k attains 57.86 million m3, which is an enormous difference of 60%. It could be ascribed to too small data population and to the inclusion of the consequences of

[9] TOE = Ton-oil equivalent = tona jednakih mazutu

two hurricane years. Other differences between two equations applied in the research are negligible.

Despite of differences in the gross felling volume, the calculated approximations by two equations, logistic and Gomperttz's, seems acceptable, particularly if larger data populations could be provided.

The practical value of above presented approximations lies in the facts that a reliable indicator for GDP and employment in forestry and depending industries could bve provided, which may prove valuable in national policy decisions.

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MATEMATIČKO-STATISTIČKA APROKSIMACIJA DISPERZIJE VREMENSKIH NIZOVA GODIŠNJIH BRUTO SJEČA U NACIONALNIM ŠUMAMA – PRIMJERI HRVATSKE, ŠVICARSKE, NJEMAČKE I FRANCUSKE

SAŽETAK

U radu se istražuju mogućnosti pouzdanog predviđanja godišnjeg volumena sječa u nacionalnim šumama svih vlasničkih oblika u Hrvatskoj, Švicarskoj, Njemačkoj i Francuskoj (u potonjoj se razmatra sječa bez ogrjevnog drva kojega je godišnja količina oko 2 – 3 milijuna m^3 bruto mase). Na temelju godišnjih podataka o obujmu bruto sječa u Hrvatskoj (1955 – 2002), Njemačkoj (1984 – 2001), Francuskoj (1947 – 1996., bez ogrjevnog drva) i Švicarskoj (1961 – 2003), primjenom logističke i Gompertzove funkcije, izračunate su asimptotičke vrijednosti sječa. Poznato je da je pod pretpostavkom potrajnoga gospodarenja šumama volumen godišnjih sječa funkcija velikoga broja egzogenih i endogenih varijabli. Da spomenemo samo neke: klimatske prilike (primjerice pojava orkana Vivian i Lothar devedestih godina 20. stoljeća), ekstremne suše, tržišne prilike (na primjer gospodarska recesija ili gospodarski uzlet), čimbenici šumarske politike (na primjer kada država pokrene velike radove pošumljavanja ili melioracije postojećih sastojina) i drugo. Gospodarenje šumama se odvija u dugim vremenskim rasponima, pa je djelovanje šumarske politike i drugih nezavisnih i zavisnih varijabli kasno uočljivo. Stoga je teško reći je li volumen sječa isključivo i samo određen gospodarskim osnovama kojih čak u brojnim slučajevima niti nema. Broj stanovnika na Zemlji se neprestano povećava. Izgleda da demografsku eksploziju može, ako ne ukloniti ono barem svesti u razumne granice, samo ozbiljan porast standarda življenja ljudi. U industrijski razvijenim zemljama Europe, u Sjevernoj Americi, Australiji te nekim zemljama istočne Azije (u prvom redu Japan, Malezija, dolazeća Kina) uporaba zemljišta zahvaljujući napretku agrotehnike po svemu sudeći teži u poljodjelstvu ka ¼ ukupne suhozemne površine. Međutim, mnogobrojne zemlje neekonomskim promašajima nastoje održati atavistički koncipirano poljodjelstvo. Stoga je prijelaz sadašnjih poljodjelskih površina ispod i na graničnoj stopi proizvodnosti u šumske površine usporen. Obujam sječa ne zavisi samo o uređivačkim načelima trajnog održavanja normalne šume, već na njega imaju utjecaj bezbroj drugih činitelja, koje je nemoguće uzeti u obzir pri planiranju u specifičnim razdobljima u gospodarskim osnovama, kao što su, primjerice, tržišne prilike, klimatski poremećaji, bolesti šuma, itd. Promjene u šumarstvu kao što su površina pod šumom, reljef, vrsta i kakvoća tala, sastav vrsta, obrast, drvna zaliha i drugi činitelji, događaju se vrlo sporo. U slučaju potrajnog gospodarenja sastojinama za koje postoje gospodarske osnove godišnji je etat u vezi sa svim bitnim činiteljima koji čine prirodni šumski ekosustav. Prognostički volumen sječa u zemljama koje pokrivaju ova istraživanja daje nerealne visoke vrijednosti, jer se u računu zavisne varijable nalazi samo jedna nezavisna varijabla X, a to je vrijeme. Da bi se to izbjeglo izračunate su jednadžbe u kojima nezavisna varijabla X sadrži, osim vremena, i druge varijable. Njihov izračun proveden je tako da se izbjegne autokorelacija. Sve jednadžbe izračunate su na temelju vremenskih nizova vremena datog za svaku od promatranih zemalja. Asimptotičke vrijednosti izračunate logističkom funkcijom kojima teže nacionalna šumarstva u pravilu su bliska stvarnim kretanjima. Praktična vrijednost ovih istraživanja, pored ostalog, trebala bi poslužiti kao indikator obujma sječa u nacionalnim šumama. Ukoliko dođe do ozbiljnijih prekoračenja izračunatih asimptotičkih vrijednosti sječa, potrebno je ispitati koji su uzroci do tog doveli. Primjerice, osim vremenskih nepogoda i kalamiteta to mogu biti i povoljna tražnja za šumskim sortimentima te njihova cijena.

Ključne riječi: aproksimacija disperzija godišnjih sječa pri potrajnom gospodarenju šumama nekih europskih zemalja, primjena logističke i Gompertzove krivulje pri izračunu funkcija vremenskih nizova

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PRIMJERI NAVOĐENJA LITERATURE:

Članak iz časopisa

Arrouays, D., & P. Pelissier, 1994: Modeling carbon storage profiles in temperate forest humic loamy soils of France. Soil Sci. 157(3): 185–192.

Matić, S., 1993: Unapređenje proizvodnje biomase šumskih ekosistema Hrvatske. Glas. šum. pokuse, pos. izd., 4: 1–6.

Matić, S., 1972: Prirodno pomlađivanje u zaraženim jelovim sastojinama. Šum. list 11–12(96): 432–441.

Članak iz zbornika

Hampson, A. M., & G. F. Peterken, 1995: A Network of woodland habitats for Scotland. In: Korpilahti, E., T. Salonen & O. Seppo (eds.), Caring for the Forest: Research in a Changing World, International union of forestry research organizations, Tampere, pp. 16–17.

Matić, S., I. Anić, M. & Oršanić, 1996: Prilog poznavanju nekih šumsko-uzgojnih svojstava pionirskih listopadnih vrsta drveća. In: B. Mayer (ed.), Unapređenje proizvodnje biomase šumskih ekosustava, Šumarski fakultet Sveučilišta u Zagrebu & Šumarski institut, Jastrebarsko, Zagreb, pp. 181–187.

Knjiga

Burschel, P., & J. Huss, 1997: Grundriss des Waldbaus (2nd ed). Parey Buchverlag, Belin, 487 pp.

Rauš, Đ., 1987: Šumarska fitocenologija. Sveučilišna naklada Liber, Zagreb, 313 pp.

Poglavlje iz knjige, monografije, enciklopedije

Lammi, J. O., 1994: Professional ethics in forestry. In: L. C. Irland (ed.), Ethics in forestry, Timber press, Portland, pp. 49–58.

Mayer, B., 1996: Hidrološka problematika osobito s gledišta površinskog dijela krovine. In: D. Klepac (ed.), Hrast lužnjak (*Quercus robur* L.) u Hrvatskoj, Hrvatska akademija znanosti i umjetnosti & "Hrvatske šume", p. o. Zagreb, Zagreb, pp. 55–71.

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EXAMPLES OF REFERENCES:

For periodicals

Arrouays, D., & Pelissier, P., 1994: Modeling carbon storage profiles in temperate forest humic loamy soils of France. Soil Sci. 157(3): 185–192.

Matić, S., 1993: Unapređenje proizvodnje biomase šumskih ekosistema Hrvatske. Glas. šum. pokuse, pos. izd., 4:1–6.

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For edited symposia, proceedings, special issues, etc.

Hampson, A. M., & Peterken, G. F., 1995: A Network of woodland habitats for Scotland. In: Korpilahti, E., Salonen, T., & Seppo, O. (eds.), Caring for the Forest: Research in a Changing World, International union of forestry research organizations, Tampere, pp. 16–17.

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Rauš, Đ., 1987: Šumarska fitocenologija. Sveučilišna naklada Liber, Zagreb, 313 pp.

For multi-author books

Lammi, J. O., 1994: Professional ethics in forestry. In: Irland L. C. (ed.), Ethics in forestry, Timber press, Portland, pp. 49–58.

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CONTENTS
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9 770352 386008