Preliminary note

Technological and Environmental Parameters of Helicopter Timber Extraction in Slovakia

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Abstract – Nacrtak

This paper summarises the results of the research whose aim was to evaluate technical, technological, ergonometric and environmental parameters of timber air extraction. Ground based extraction technologies are localised to land routes where the possibilities of development are partially exhausted. Searching the way to eliminate the consequences of extraction technologies on the environment was carried out by use of three dimensional technologies. The aim of this work was to elaborate a design of technological procedures for timber transportation by helicopters depending on the type of felling, terrain configuration, technical aids, assessment of performance characteristics, design of work safety and assessment of noise level in the forest environment.

Keywords: *timber extraction, helicopter, mountain forest*

1. Introduction – *Uvod*

The idea of the use of air transportation was born in 1911 by the Prussian forester Alfred Zimmermann (Dykstra 1976). The first experiments on timber extraction by helicopters were carried out in Caucasus in 1954 (Gordijenko 1987), and a few years later in Scotland, in 1956. In late 60s and early 70s experiments with air timber extraction were carried out in North America (Heinimann 1995). Other experiments were carried out in Norway, Canada, the former USSR, and the USA. The first experiments in former Czechoslovakia were performed by Kostroň (1972).

At present the technology of timber extraction by helicopter is used in many forestry-developed European countries, e.g. Switzerland, France, Austria, and Germany. In the USA and Canada the share of this technology in overall capacity of the extracted timber is even more significant. In economically and ecologically developed countries the air transportation is being shifted from the position of emergency measures to common operation technology.

In the mountain forests of Switzerland, the use of helicopter accounts for up to 20% of timber extraction. Interest was also shown by the Forestry Commission from Great Britain, which visited Switzerland in 1995 and they are now researching the possibility of its use in Britain. The work is carried out by private companies. In Austria and Germany the latest helicopter K-Max is being used and it is owned by AHT Company in Innsbruck. The researches of French authors focus their interest on the use of helicopters for home production. In the USA a Helicopter Logging Committee has been established just for the purpose of supporting the use of helicopters in aerial logging.

As in Slovakia there is a high rate of forest acreage in mountain areas, this topic is interesting and shows the possibilities of decreasing the damage to forest ecosystems. In Slovakia the contribution for the support of such an environmentally friendly technology in mountain areas is well recognized, especially in the forests with a high-level of legislative protection. The objective was to elaborate the review of effectiveness, norms and directives related to the stated technology and lay good theoretical basis for technologies of timber air transportation as well as other activities in forestry that use helicopters e.g. protection of forests and support to all tasks that provide good prospects for timber extraction by helicopters and elaboration of technological procedures, work safety rules and environmental conditions.

2. Research methods – *Metode istraživanja*

Methodology was elaborated in several areas:

A) Assessment of technical possibilities and properties of various types of helicopters used for timber extraction

Based on studied literary resources, a review was prepared of helicopters used in timber extraction, and a list of technical parameters was prepared for better orientation focusing on the most important parameters such as performance, useful load, speed, and other design characteristics of individual helicopters during timber extraction. For clarifying the technical scope, the basic helicopter flight operation was elaborated and lifting capacity of Mil Mi-8 helicopter used in Slovakian conditions was determined.

B) Designing a technological procedure according to the type of felling

Based on the results gained from the use of helicopter in timber extraction at several sites in the forests of the Slovak Republic and especially based on results and experience in organising helicopter timber extraction in the intended regeneration felling, a technological procedure was designed with the emphasis on improving overall efficiency while observing and adhering to safety at work regulations. The technological procedure was designed for the preparation and organisation of work in key stages of the working cycle (stand, landing, air operations).

C) Assessment of efficiency characteristics of Mil Mi-8 helicopter

The efficiency of helicopter timber extraction was evaluated by chronometric measurements of Mill Mi-8 helicopter used in the mountain areas of the Slovak Republic. During processing of the salvage timber (Belianske Tatry mountains, Javorina mountain range, Srdiečko mountain area of Ružomberok), time consumption was evaluated for a working cycle and for individual work operations, as well as shift efficiency, size of load, number of logs in a load and the same parameters indicating efficiency of Mil Mi-8 helicopter during regeneration felling in the protected area of Poľana.

D) Helicopter noise stress of forest and work environment

In particular conditions at several sites (Belianske Tatry, Poľana, Muráň), measurements were carried out of noise affecting workers and the surrounding nature. The methodology of processing by DTM has not been used in any known literature so far nor has the noise spreading model in the nature during helicopter timber extraction.

3. Results – *Rezultati*

3.1 Evaluation of technical possibilities and properties of various helicopters used in timber extraction – *Procjena tehničkih mogućnosti i značajki različitih helikoptera korištenih za iznošenje drva*

Regarding the properties of helicopters they present a practical and irreplaceable means of transportation. The possibility of vertical flight and flight down without dependence on long take-off and flight down runway gives incredibly wide operational space to helicopters, because flight down and taking-off do not need large and especially designed area. Another important quality – »hanging« – (possibility to remain in the air at one place for a necessary time) enables the transportation of a load in the areas with low bearing capacity or at places which are not accessible by other means of land transportation. Untraditional manoeuvring properties enable helicopters to fly at a distance very close to land. Lower speed, compared to other means of air transport, is an advantage in case of timber extraction. Due to these properties, their use is the most common technology in air extraction. Table 1 shows some selected types and selected technical characteristics of helicopters used in timber extraction.

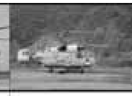
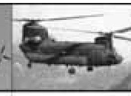
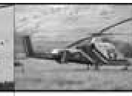
3.2 The design of technological procedures in accordance with the type of felling – *Oblikovanje tehnoloških postupaka prema vrsti sječe*

The choice of technological procedure should be adapted to technical equipment, terrain and climatic conditions, type of felling, volume of extracted logs. It is possible to extract whole trees, logs, or assortments by helicopter. The transportation of logs is the most profitable; if the weight is exceeded, they must be shortened to assortments. Trees are extracted in case of e.g. bark-beetle salvages when stand sanitation is required.

Highly effective technology of helicopter timber extraction requires thorough technological preparation of a workplace and perfect team work of all involved partners.

Technological procedure can be divided into several work stages which can be prepared individually and however they must be compiled into one harmonious corpus.

Table 1 The review of parameters of selected helicopters used in wood extraction
Tablica 1. *Pregled značajki odabranih helikoptera za iznošenje drva*

										
Builder and Type *Proizvođač i tip*	Mil Mi-8 Hip	Mil Mi-10 Harke	Kamov KA-32 Helix	Kamov KA-60 Kasatka	Sikorsky S-64 Skycrane	Boeing-Vertol CH-47 Chinook	Bell 205 Huey	Kaman K-1200 K-MAX	Aerospatiale SA 330 Puma	Aerospatiale SA 332 S.Puma
Country of Origin *Zemlja podrijetla*	Russia *Rusija*	Russia *Rusija*	Russia *Rusija*	Russia *Rusija*	USA *SAD*	USA *SAD*	USA *SAD*	USA *SAD*	France *Francuska*	France *Francuska*
Type of engine *Tip motora*	TV2-117A	D-25V	TV3-117V	RD-600V	T73-700	T55-L-11A	T53-L-13	T53-17A-1	TURMO IVC	MAKILA 1A
No. of engines and power, kW *Broj i snaga motora*, kW	2 x 1250	2 x 4101	2 x 1645	2 x 956	2 x 3579	2 x 2796	1 x 1044	1 x 1125	2 x 1174	2 x 1380
Length (fuselage), m *Duljina (trupa)*, m	18.2	32.9	11.3	13.5	21.4	15.5	12.8	12.7	15.1	15.5
Length with rotors, m *Ukupna duljina (sa rotorima)*, m	25.2	41.9	15.8	15.6	27.0	30.2	17.6	15.8	18.2	18.7
Height, m *Visina*, m	5.6	9.9	5.4	4.2	7.8	5.7	4.4	4.2	5.1	4.9
No. of rotor blades (main / tail) *Broj lopatica rotora (glavni / repni)*	5 / 3	5 / 3	3 / 3	4 / 2	6 / 4	3 / 3	2 / 2	4 / -	4 / 4	4 / 4
Rotor diameter (main / tail), m *Promjer rotora (glavni / repni)*, m	21.3 / 3.9	35.0 / 6.3	15.9 each	13.5 / 1.2	22.0 / 4.9	18.3 each	14.6 / 2.6	14.7 / -	15.0 / 3.1	16.5 / 3.1
Empty weight, t *Masa praznoga helikoptera*, t	7.2	27.1	6.5	4.5	8.9	10.4	2.4	2.2	3.6	4.5
Maximum (take-off) weight, t *Najveća poletna masa*, t	12.0	43.5	12.6	6.8	21.3	22.7	4.3	5.2	7.4	9.0
Payload (on sling), t *Nosivost (vanjska)*, t	4.0	15.0	5.0	2.8	9.0	10.0	1.8	2.7	3.2	4.3
Speed (maximal / cruise), km/h *Brzina (najveća / putna)*, km/h	260 / 225	235 / 220	250 / 230	300 / 270	205 / 170	290 / 260	205 / 180	185 / 150	270 / 250	280 / 260
Service ceiling, m Najveća visina leta, m	4500	3000	5000	5150	6100	4400	3800	3850	4100	4600
Hover ceiling in ground effect, m *Visina lebdjenja s utjecajem podloge*, m	1900			2900	3900	2000	3100	2400	2800	3100
Hover ceiling out of ground effect, m *Visina lebdjenja bez utjecaja podloge*, m	800		3800	2100	1970	950	1500		1650	2100
Vertical Climb Rate, m/s *Brzina uzdizanja*, m/s	9.0		9.1	10.4	11.6	10.0	11.6	12.7	7.0	8.8
Flight radijus, km *Radijus leta*, km	480	430	430	610	400	510	500	460	620	640

From the viewpoint of work management it is necessary to plan in detail as follows:

⇒ preparation and work in a stand,

⇒ establishment of sufficient number and suitable position of landings,

⇒ meeting technical requirements of helicopter operation.

The efficiency of helicopter technology for timber extraction is significantly influenced by quality and extent of preparation work in a stand. Due attention must be given to this stage as this might be the stage to decide on the result of the whole operation and namely on economic parameters and occupational safety. Different approach to preparation work is influenced by the type of felling.

Work in a stand during salvage cutting requires preparation according to the type of salvage (storm, insect) and if required initial work shall include debranching and bucking of tree trunks from the root system.

Processing of salvage proceeds from the upper part of a hill slope and preparation work should be carried out before the beginning of timber extraction. Small sized logs should be piled at the sites meeting the requirements of safe log fastening and take-off of a helicopter. Referring to a strewed salvage mass in a standing stand, this means that a helicopter can easily manage to lift the logs even in this stand.

Technological work progress in the stand will significantly influence the technology of helicopter transportation of cut timber (intended regeneration cutting).

When directional felling is provided, it is possible to achieve an optimal load weight for a helicopter according to useful load. Compared to processing of salvage timber, in most cases it is not necessary to pile logs in a stand. For logs of higher volume, it is necessary to shorten them because of allowed loading of a helicopter. The length of assortment is influenced by timber species, volume weight of timber, moisture contents and type of assortments.

The preparation of loads for a helicopter during felling influences the time consumption needed for fastening the load as well as the time of the whole working cycle. Compiling the load and fastening the burdens as well as unfastening the loads at the landing is carried out by workers (fasteners), who are trained specifically for working with loads under a helicopter.

The efficiency of a helicopter depends on the time of a return, on the size of a load per cycle and on compulsory idle time. The time of a working cycle depends on the efficiency of fasteners working in a stand, who if they manage to assess the load weight correctly and fasten logs quickly can avoid repeated unfastening for overweight. To check the correct load weight, every helicopter is equipped with a weighting gauge for measuring the weight. A helicopter can extract timber from any place. It is better if timber is in an open area, e.g. at the edge of a stand, but it can also easily manage to lift a load above a stand from among the trees.

From the technological point of view the most demanding part is fastening loads in a stand. This operation must be carried out quickly and at the same time safely. The conditions of fastening are demanding especially in processing salvage timber. It is advisable to have at least two workplaces with two fasteners at the stand being processed, thus creating conditions for the preparation of further loads.

The load size depends mainly on the carrying capacity of a helicopter, season of the year, and time of the day in dependence on temperature conditions. It is more profitable if the load consists of fewer logs as this shortens the time of fastening up. The load is fastened to a helicopter either by a winch rope or more often by a helicopter fixed rope because lifting the load by winch is slower than by lifting via fixed rope.

Work procedures and technical devices common in industry dealing with load transportation are applied. Coordination of the whole working team is managed by using transmitters.

The form of forest management is not a limiting factor for using this technology. From the point of view of technical and technological managing it is possible to take into account the use of this method not only in clear cutting and partial felling but in selective cutting shelterwood system if the economic conditions are acceptable for both contractual parties.

Regarding time consumption per cycle, a larger freely accessible area or a kettle-shaped area is better than a selective cutting method. The best option is if the area has been prepared and branches cut off, but if necessary it is possible to extract the trees. The hill slope enables the pilot better orientation in hanging against a hill. If the crew has a possibility to fly over the area from the bottom part, the pilot has a perfect picture of the prepared timber. Lowering down of underslung equipment hooks is done quickly, the fasteners are in an visual contact with the crew, so as to move off at a safe distance from the timber. Lifting the timber and its taking off can be performed without avoiding obstacles and the departure can be made without rising which is made possible by the hill slope. The departure is possible in every azimuth from a slope. When applying a selection method, all

Table 2 Time consumption per working components and basic data about timber extracted by helicopter in Belianske Tatry for an average extraction distance of 700 m (Messingerová 1994)

Tablica 2. *Utrošak vremena sastavnica rada i osnovni podaci o iznešenom drvu helikopterom u Belianskim Tatrama pri srednjoj udaljenosti privlačenja drva od 700 m (Messingerová 1994)*

No. *Br.*	Working components *Radne sastavnice*	Arithmetic mean, min *Aritmetička sredina, min*	Mean error, min *Srednja pogreška, min*	No. of observations *Broj opažanja*
1	Flight without load into stand *Let bez tereta u sastojinu*	1.53 ± 1.66	0.24	49
2	Flying down into stand *Let prema dolje u sastojinu*	0.56 ± 0.35	0.05	60
3	Load fastening *Vezanje tereta*	0.69 ± 0.42	0.06	58
4	Lifting of load in stand *Podizanje tereta u sastojini*	0.74 ± 0.62	0.08	63
5	Flight with load *Let s teretom*	2.10 ± 0.72	0.10	55
6	Flying down into landing *Let prema dolje do stovarišta*	0.26 ± 0.21	0.03	57
7	Load unfastening *Odvezivanje tereta*	0.34 ± 0.19	0.03	57
8	Flying up the landing Uzdizanje sa stovarišta	0.24 ± 0.13	0.02	57
9	Cycle time *Trajanje radnoga ciklusa*	5.92 ± 1.24	0.19	49
Average volume of load, m^3 *Prosječan obujam tovara,* m^3		2.87 ± 0.71	0.09	69
Average number of logs per load, pcs *Prosječan broj trupaca u tovaru, kom.*		5.3 ± 2.4	0.3	69
Average volume of extracted logs, m^3 *Prosječan obujam privučenih trupaca,* m^3		0.54 ± 0.38	0.05	69

these positive circumstances do not appear because it is necessary to push hooks into a stand. The most demanding situation is at the flat surface, where there is no advantage of a contra-hill and it is necessary to look for fasteners in a stand. Yet, an advantage of this method is that a helicopter can work effectively also in selection felling although the time consumption for the working cycle of this method is a bit higher.

In the technological preparation of the workplace, the selection of sufficient time and accessibility of landings play an important role. Unfastening a load can be done at roadside landing manually, mechanically, automatically. Manual unfastening increases time requirements because workers can approach the load after its stabilisation on the ground. Automatic unfastening shortens the length of the whole cycle.

The place of unfastening, landing, must be chosen so that the load can be put down without time and space limitations. The size of landing depends on the amount of timber and the requirement of timber sorting, e.g. according to timber species or assortments. The storage area must provide the conditions for a continuous work operation in terms of its size and position. Inappropriate landings are those which are small and have uneven surface, large obstacles or »untouchable« obstacles at the edge.

During processing salvage timber, it is difficult to carry out the requirement for sorting timber, and however, when the work of timber extraction from the intended felling is well organised, it is possible to sort out the timber into piles by requirements.

Regarding the fact that in Slovakia there are no generally applicable safety laws for the technology of helicopter timber extraction compared to ground

Table 3 Quantity of timber extracted by helicopter in the Pol'ana protected area

Tablica 3. *Količina iznesenoga drva helikopterom u zaštićenom području Polana*

Date *Datum*	Conifers *Četinjače*	Broadleaves *Listače*	Total *Ukupno*
	m^3		
8. IX	43.20	136.10	179.30
9. IX	149.14	76.74	225.88
10. IX	36.43	156.89	193.32
11. IX	30.17	150.27	180.44
12. IX	33.97	96.18	130.15
13. IX	114.33	45.09	159.42
Total – *Ukupno*	407.24	661.27	1068.51

Table 4 Time consumption per working components in timber extraction by helicopter in Pol'ana protected area for an average extraction distance of 800 m

Tablica 4. *Utrošak vremena sastavnica rada pri iznošenju drva helikopterom u zaštićenom području Polana pri srednjoj udaljenosti privlačenja drva od 800 m*

No. *Br.*	Working components *Radne sastavnice*	Time consumption *Utrošak vremena*	Percentage *Postotni udio*
		min	%
1	Flight without load into stand *Let bez tereta u sastojinu*	1.16	23
2	Flying down into stand *Let prema dolje u sastojinu*	0.29	6
3	Load fastening *Vezanje tereta*	0.62	13
4	Lifting of load in stand *Podizanje tereta u sastojini*	0.38	8
5	Flight with load *Let s teretom*	1.61	33
6	Flying down into landing *Let prema dolje do stovarišta*	0,33	7
7	Load unfastening *Odvezivanje tereta*	0.29	6
8	Flying up the landing Uzdizanje sa stovarišta	0.18	4
9	Cycle time *Trajanje radnoga ciklusa*	4.83	100
Number of flights per day *Broj letova dnevno*		72	
Time consumption per fuelling *Utrošak vremena pri točenju goriva*		11.23	
Time consumption per daily maintenance of helicopter *Utrošak vremena dnevnoga održavanja helikoptera*		45.20	

based timber extraction technologies and the requirements in this area are higher, a design of safety principles has been drawn. The design is based on safety in flight operations and considers specific conditions of helicopter use in forestry.

3.3 Performance characteristics for helicopter Mil Mi-8 – *Radne značajke helikoptera Mil Mi-8*

The most important parameters in timber extraction at various sites in the mountain forests in Slovakia are shown in Tables 2, 3, 4 and 5.

3.4 Effects of helicopter noise stress on forest and working environment – *Opterećenje šumskoga i radnoga okoliša bukom helikoptera*

The intensity of outer noise was not only measured directly at the workplace but also in the surrounding area in a hectare network at a 2 km distance. The measuring equipment of the firm Bruel and Kjaer was used with a built-in A weight filter. The noise level was measured at a different distance from the helicopter during hanging and during the flight.

The level of the machine noise is assessed in accordance with the relative directives from two viewpoints. For people directly involved in the work with the machine, the noise at the workplace is relevant and for the others the outside noise is relevant. In the first case, the highest possible level accounts for L_P = 80 dB(A), and as the work of fasteners can be considered physically demanding in terms of accuracy and concentration, the correction of the basic level –5dB will be applied. In the second case the value of 55 dB(A) is applied as the highest accepted value for the air operation noise (Konrád 1973, Kon-

Table 5 Indicators of efficiency in timber extraction by helicopter

Tablica 5. *Pokazatelji djelotvornosti pri iznošenju drva helikopterom*

Efficiency indicator *Pokazatelj djelotvornosti*	Average value *Srednje vrijednosti*
Average daily volume of extracted timber, m^3 *Prosječan dnevni obujam privučenoga drva*, m^3	178.08
Average number of logs per load, pcs *Prosječan broj trupaca u tovaru, kom.*	1.61
Average volume of load, m^3 *Prosječan obujam tovara*, m^3	2.10
Average volume of extracted logs, m^3 *Prosječan obujam privučenih trupaca*, m^3	1.38
Time consumption per 1 m^3 of timber, min *Utrošak vremena po 1 m^3 drva*, min	2.48

Table 6 Noisy and silent intervals during helicopter's operation
Tablica 6. *Bučni i tihi intervali rada helikoptera*

Working components *Radne sastavnice*	%	Cycle *Ciklus*		Shift *Smjena intervala*	
		Noise *Buka*	Silence *Tišina*	Noise *Buka*	Silence *Tišina*
		min			
Helicopter operation: *Rad helikoptera:*	100	5.92	-	300.0	-
Above a fastening place *Iznad mjesta vezanja tereta*	32.2	1.91	4.01	96.6	203.4
Above an unfastening place *Iznad mjesta odvezivanja tereta*	14.4	0.85	5.07	43.2	256.8

rád 1993, Konrád et al. 1993, Messingerová et al. 2000).

The measurements were processed into noise maps. In this paper, the results are presented from the High Tatra – The TANAP report, LS Javorina, Pod Muráňom locality. The model of noise propagation was developed from 180 values measured at 35 spots. For comparison, the results of measurements in Pol'ana, prepared in the environment of a digital terrain model, are also presented.

The helicopter timber extraction is 8–10 times more effective than ground based skidding technologies and as much as 20 times more efficient than cable yarding. This is the result of the fact that the forest environment and workers are exposed to the noise produced by helicopter for a much shorter time, which is particularly important in protected areas. During the research the noise was measured in the most severe conditions, at minimum distance from the helicopter (under the helicopter, or at the helicopter's level on the slope). During a routine operation the noise values at the ground are usually lower.

The analysis was carried out of time consumption of individual operations and time of exposure to direct noise of the workers on the ground (Konrád and Messingerová 1993), and noisy and silent intervals were calculated for the staff working on the ground (Table 6). The load fasteners and unfasteners are exposed to an excessive noise only during a short part of a working cycle. During a shift a fastener is exposed in total to the noise for 97 minutes and an un-fastener for only for 43 minutes.

The measurements were evaluated by a topographic programme ATLAS. On the noise map (Fig. 1 – one square represents dimensions: 100 × 100 m) the three significant peaks stand out:

⇒ A – the place of fastening logs in a stand,
⇒ B – the place of fastening logs in free space (salvage place),
⇒ C – the landing where the load was unfastened.

The map was produced by synthesis of noise fields and it is not real, because a helicopter cannot appear at three different places at the same time. This procedure was established to identify the area where the highest noise values at the workplace are exceeded.

The results show that the noise shortly exceeds the allowed limits, but they are likewise exceeded by tractors used for skidding timber. The excess is less significant, the changes of the level are not so rapid and the mentioned noise was only found in the vicinity of the tractor. However, it is present during the whole time of the tractor's operation. At the distance of 2 m from the tractor the noise is 90–95 dB(A), at the distance of 20 m it is approximately 75 dB(A) (Konrád 1973)

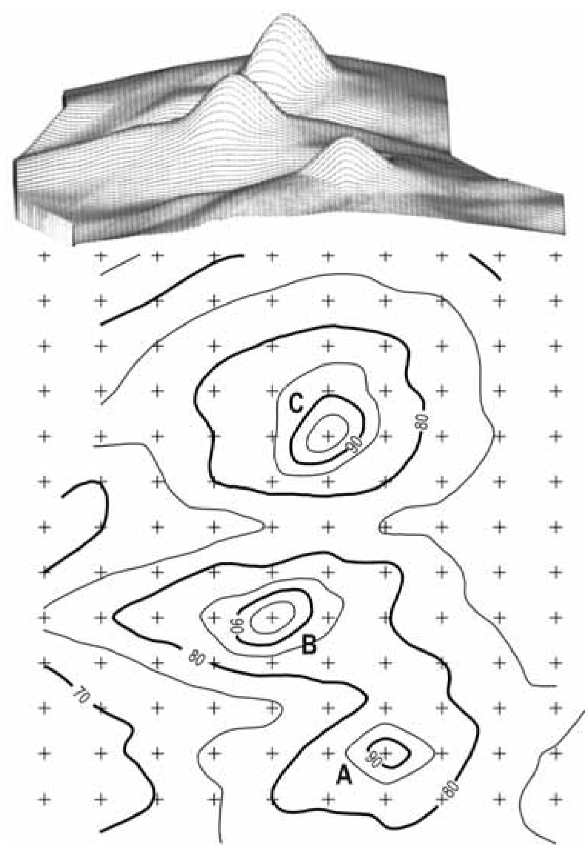


Fig. 1 The map of noise intesity in the immediate helicopter's surrounding in dB(A)
Slika 1. *Karta intenziteta buke u neposrednoj okolici helikoptera u* dB(A)

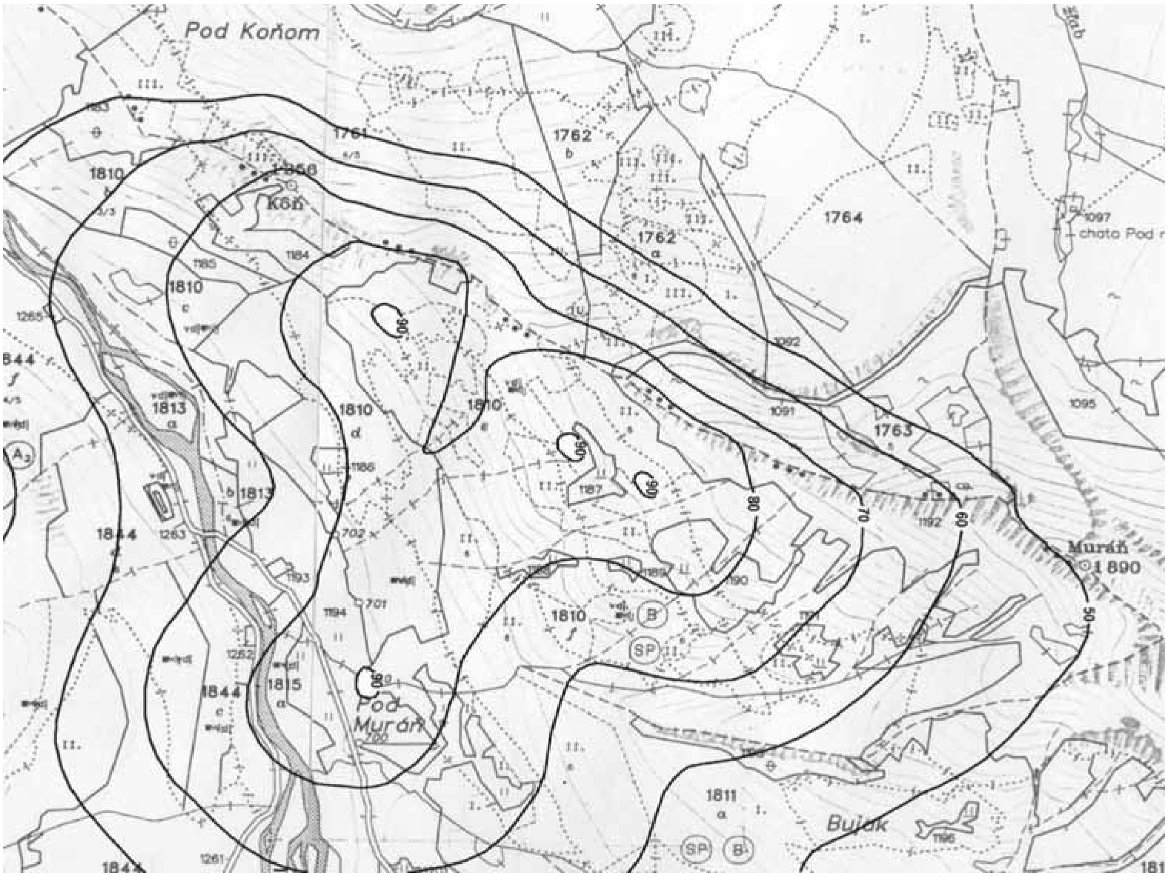


Fig. 2 The map of helicopter's noise intensity isolines
Slika 2. *Karta izolinija intenziteta buke helikoptera u* dB(A)

If the helicopter is »hanging« above a working place (rope length: 30–50 m) the noise below it is 93–100 dB(A). The acceptable level of 80 dB(A) is at the distance ranging between 100 and 200 m depending on the terrain configuration. This is why the workers must use hearing protectors. The noise layout in a broken terrain has better spreading than in an open area due to the formation of noise traps (behind the ridge, in thick vegetation). In Figure 2 it can be seen that the noise is spreading over a wider area around Kežmarský štít – a peak, Muráň – a mountain area, and in the Belianske Tatry – a mountain range.

The last measurements were carried out in the High Tatra, locality Javorina – Muráň. They were used to determine the noise model depending on the distance and elevation of helicopter's flight.

The results of regression analysis in the following gradients of decreasing noise intensity are shown in Figures 3 and 4.

The significance of distance, flight height and terrain configuration was analyzed by the method of

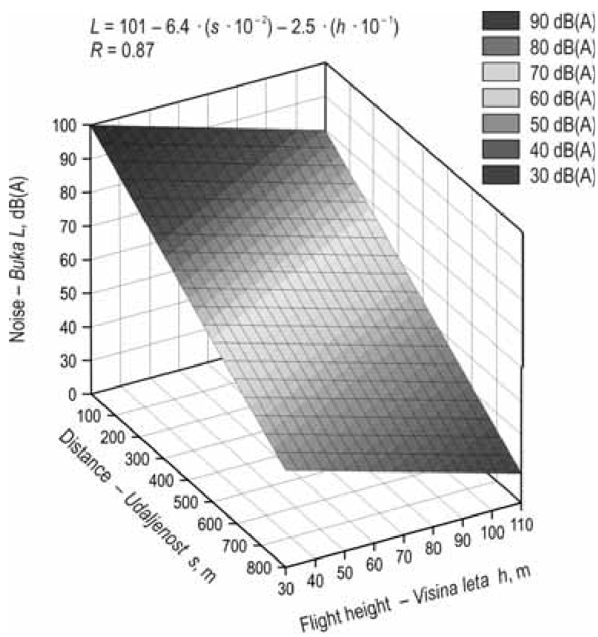


Fig. 3 Linear model of helicopter's noise intensity
Slika 3. *Linearni model intenziteta buke helikoptera*

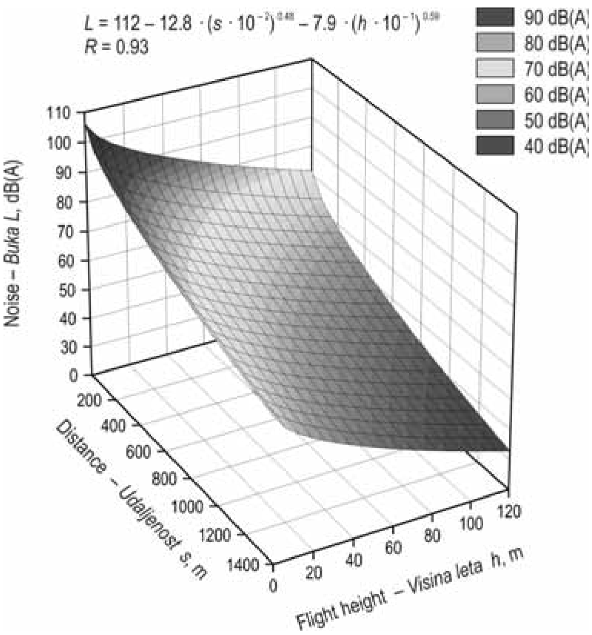


Fig. 4 Power model of helicopter's noise intensity

Slika 4. *Eksponencijalni model intenziteta buke helikoptera*

Table 7 Factors significance

Tablica 7. *Značajnost razlika čimbenika*

Factor – *Čimbenik*	*F*	*a*	P_{1-a}	*b*
Distance – *Udaljenost*	66.812	0.000 00	1.000 00	-0.64
Flight height – *Visina leta*	11.866	0.000 00	1.000 00	-0.41
Terrain configuration – *Konfiguracija terena*	5.9585	0.003 38	0.996 62	-0.12
Total – *Ukupno*	20.581	0.000 00	1.000 00	*R* = 0.87

one- and multi-factor analysis. The following classification was used for a terrain:

⇒ 1 – open terrain, plain

⇒ 2 – broken terrain in a slope

⇒ 3 – a valley off the flight route.

Table 7 shows that the distance influence and flight height are significant practically with a 100% probability and the influence of terrain brokenness has likewise a 99.62% probability.

Where: *F* – calculated value of *F*–division,
a – significance level,
P_{1-a} – reliability degree,
ß – partial coefficients of correlation (calculated by the method of multiple regressions),
R – coefficient of multiple correlation.

(For the number of measurements $n = 122$, $F_{tab,0,05} \approx 3.08$)

Table 8 Average values of intensity noise at different factor levels

Tablica 8. *Srednje vrijednosti intenziteta buke pri različitim razinama čimbenika*

Factor – *Čimbenik*					
Distance – *Udaljenost*		Flight height – *Visina leta*		Terrain configuration – *Konfiguracija terena*	
m	dB(A)	m	dB(A)	Class – *Razred*	dB(A)
0	95	0	112	1	80
100	81	35	83	2	74
200	74	40	80	3	70
300	69	45	78		
400	65	50	77		
1200	50	60	71		

The values of β coefficients can be interpreted as the intensity of impact of individual factors within their synergic effect. Table 8 presents the average values of noise intensity at various factor levels. The average noise intensity during measuring was 77 dB(A).

To get a general perception of noise, several criteria must be taken into consideration, similarly to other physiological perception, resulting from physiology of perception organs. Various subjective noise perceptions depending on sound frequency of oscillation are processed into standardized curves of identical loudness levels – Fletcher-Munson curves (Smetana 1987).

4. Conclusion – *Zaključci*

The air transportation of timber is the most environmentally friendly technology of all current extraction technologies. The advantages of helicopter technology can be summarized as follows:

⇒ possibility to decrease requirements for making access into complicated terrain conditions of mountain stands,

⇒ possibility to improve the structure of mountainous forests,

⇒ fast processing of salvage felling requiring an immediate solution,

⇒ prevention of salvages in stands which are not considered accessible by traditional technologies,

⇒ minimum damage to soil by minimisation of the contact between the load and soil,

⇒ inhibition of consequential rainfall erosion,

⇒ no soil disturbances compared to ground based technologies,

⇒ as a result of avoiding ground based technologies, better hydrological conditions in mountain terrains,

⇒ minimised damage to remaining trees,

Assuming that good planning and work organization are provided, taking into consideration safety and noise impact on the environment, it is possible to obtain good results in spite of the fact that compared to traditional technologies helicopter logging is the most risky one.

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Sažetak

Tehnološki i okolišni parametri iznošenja drva helikopterima u Slovačkoj

Rad prikazuje rezultate istraživanja tehničkih, tehnoloških, ergonomskih i okolišnih značajki primjene helikoptera na iznošenju drva iz brdsko-planinskih šuma u Slovačkoj. Pregled najvažnijih tehničkih značajki helikoptera koji se upotrebljavaju za iznošenje drva dan je u tablici 1.

Cilj je rada utvrditi tehnološke postupke, pravila sigurnosti rada te okolišne uvjete koji će osigurati pravilnu primjenu i učinkovitost postupaka iznošenja drva helikopterom. Stručno izvođenje iznošenja zahtijeva visoku kakvoću tehnološke pripreme radnoga mjesta i savršenu organizaciju rada. Tehnološke postupke valja prilagoditi tehničkim sredstvima, terenskim i klimatskim uvjetima, vrsti sječe i obujmu drva za iznošenje. Čitava stabla, debla ili trupci mogu se iznositi helikopterima. Dulji se trupci moraju skratiti kako bi bili sukladni dopuštenomu opterećenju helikoptera. Duljina je trupaca uvjetovana vrstom i specifičnom težinom drva, sadržajem vlage u drvu i vrstom sortimenta.

Priprema tovara u sastojini utječe na smanjenje utroška vremena za vezanje tovara i time na trajanje cijeloga radnoga turnusa. Uvjeti za vezivanje osobito su zahtjevni i teški pri izvlačenju drva dobivenoga sanitarnim sječama. Racionalnije je na određenoj čestici postaviti dva radilišta (s po dva radnika koji vežu teret na svakom *radilištu). Time se uštedi vrijeme za pripremu sljedećega tereta. Koordinacija čitavoga tima obavlja se uz pomoć prijenosnika. Pripremu tovara u sastojini, njegovo vezanje na vučno uže helikoptera te odvezivanje tovara na stovarištu obavljaju radnici kopčaši posebno pripremljeni za siguran rad u blizini helikoptera.*

Trajanje radnoga ciklusa ovisi o spretnosti radnika koji vežu tovar, njihovoj sposobnosti da odrede težinu tovara, da brzo vežu trupce i spriječe odvezivanje u slučaju prevelikoga opterećenja. Svaki je helikopter opremljen dinamometrom, uređajem za mjerenje težine tereta. Teret se može odvezivati ručno, mehanički ili automatski. Veličina tereta ovisi o kapacitetu nosivosti helikoptera, godišnjem dobu i dobu dana s obzirom na vremenske uvjete. Teret je uz helikopter privezan užetom preko vitla ili češće pričvršćenim užetom jer je podizanje tereta vitlom sporije nego fiksiranim užetom. Štoviše, vitlo smanjuje korisnu nosivost helikoptera. Fiksirano je uže dugačko 30 – 50 m.

Izbor dovoljno prostranoga stovarišta i njegov smještaj igra važnu ulogu u tehnološkoj pripremi radilišta. Lokacija stovarišta mora omogućiti spuštanje tereta bez poteškoća. Veličina stovarišta ovisi o količini drva i zahtjevima razvrstavanja, npr. po vrstama ili sortimentima.

U slovačkom se šumarstvu za privlačenje drva koristi helikopter Mill MI-8 te su u tablicama 2, 3, 4 i 5 prikazni utrošci vremena sastavnica rada i osnovni podaci o iznesenom drvu na dva mjesta istraživanja.

Iznošenje je drva helikopterima učinkovitije 8 – 10 puta od privlačenja drva traktorima i do 20 puta od iznošenja drva žičarama. Iz toga slijedi da je šumski ekosustav izložen buci za vrijeme rada helikoptera znatno kraće vrijeme. Ta je činjenica posebno značajna u zaštićenim područjima.

Mjerenja razine buke koja djeluje na radnike i okoliš provedena su izravno na radilištu te okolnom području u krugu 2 km. Buka je mjerena Bruelovom i Kjaerovom opremom s filterom »A« pri različitim udaljenostima od helikoptera pri njegovu letu i lebdenju. Promatran je utjecaj buke na radnike (buka na radnom mjestu) i na ostale (buka izvan radnoga mjesta). U prvom je slučaju najviša dopuštena razina buke L_p = 80 dB(A) s ispravkom temeljne razine 5 dB jer je rad koji obavljaju radnici vežući tovar naporan i zahtijeva visoku koncentraciju. U drugom slučaju možemo govoriti o vrijednosti od 55 dB(A) kao najvišoj dopuštenoj razini buke (Konrad i Messingerová 1993).

Raščlanjen je utrošak vremena za pojedine radne zahvate i izračunati su intervali buke i tišine kojima su izloženi radnici na tlu. Rezultati prikazani u tablici 6 pokazuju kako su radnici samo kratko vrijeme radnoga ciklusa, dok vežu i odvezuju teret, izloženi prekomjernoj buci.

Na karti intenziteta buke (slika 1) naznačena su mjesta vezanja tovara u sastojini (A), na otvorenoj površini (B) i odvezivanja tovara na stovarištu (C) te je vidljivo da buka samo kratkotrajno prekoračuje dopušteno ograničenje.

Buka na radnom mjestu iznad kojega je helikopter iznosi 93 – 100 dB(A). Dopuštena razina od 80 dB(A) na udaljenosti je od 100 do 200 m u skladu s konfiguracijom terena. Raspodjela buke na razvedenom terenu sa zvučnim preprekama (iza brda, u gustoj sastojini) drugačija je nego na otvorenom prostoru (slika 2). Stoga u tom prostoru radnici moraju nositi štitnike za uši.

Linearni i eksponencijalni model razine buke, dobiven iz rezultata u ovisnosti o udaljenosti i visini helikoptera, određen je regresijskom analizom (slika 3 i 4). U tablici 8 prikazane su srednje vrijednosti intenziteta buke pri različitim radnim čimbenicima: udaljenost od helikoptera, visina leta i konfiguracija terena. Konfiguracija je terena razdijeljena na ravni otvoreni teren (1), brdoviti teren (2) i doline izvan linije leta helikoptera (3).

Prednosti iznošenja drva helikopterima vidljive su u mogućnosti rada na teško pristupnim terenima, u visokoj učinkovitosti na sanitarnim sječama, smanjenju oštećenja tla, dubećih stabala, onečišćenja vodotokova i opasnosti od erozija tla.

Ključne riječi: *iznošenje drva, helikopter, planinske šume*

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