UDK 630*38:625.711.84
DOI 10.54652/RSF.2024.V54.I2.595

ORIGINAL SCIENTIFIC PAPER

Dimensions of the constructive elements of forest roads

Dimenzije konstruktivnih elemenata šumskih puteva

Vladimir Petković[1,*], Aleksandar Laketa[1], Dragana Gavranić[2], Dane Marčeta[1]

1 Faculty of Forestry, University of Banja Luka; Bulevar Vojvode Petra Bojovića 1a, 78000 Banja Luka
2 PFC "ŠUME REPUBLIKE SRPSKE" a.d. Sokolac; Trg Republike Srpske 8/11, 78000 Banja Luka

ABSTRACT

Forest roads must be maintained in a condition that allows them to handle traffic loads at any given time, which is only achievable if their dimensions remain within the prescribed limits. The dimensions of the elements of the plan, profile, and cross-section of forest roads depend on factors such as soil type in a constructive context, the category of the forest road, and the type of vehicles that will use these roads. In this study, a forest road constructed on soil types IV, V, and VI was examined, and its dimensions were determined. The share of soil type in a constructive sense is 63% of V category, 34% of IV category and 3% of VI category. The average width of the roadway is 6.11 m, with an upgrade of approximately 3% and a downgrade of 6.5%. The cross slope of the roadway is 3.1%, while the slope of the cut areas is 120% (1.2:1), and the slope of the fill areas is 86% (0.86:1). It was concluded that the forest road is in a condition capable of accommodating traffic load. However, attention should be given to the wider roadway width and the lower slopes of the cut-and-fill areas, as these may require adjustments to ensure efficiency and safety.

Keywords: *plan, cross sections, grade of profile, cut and fill slopes*

INTRODUCTION – *Uvod*

Forest roads provide permanent accessibility to forests, leading to long-term or permanent changes to the forest ecosystem. The construction of forest roads represents the largest infrastructure project within a forest and enables sustainable management of this natural resource. Their primary purpose is the long-distance transportation of industrial roundwood. Forest roads are planned, designed, constructed, and maintained structures within the forest, consisting of components such as a plan, profile, cross sections, and data on the volume of earthworks (Jeličić, 1983). The plan of a forest road represents its horizontal alignment, including both horizontal curves and straight segments before and after the curves. The radius (R) is the most critical element of a curve, as it influences driving speed, safety, and the construction cost of the forest road. The width of the roadbed depends on the standard vehicle width used on forest roads, particularly trucks, as well as the width of the safety zone. The safety zone width should range from 0.4 to 0.6 m (Aćimovski, 1997). Forest roads are typically constructed with a single roadbed, having a minimum width of 3 m, with two shoulders width of 0.5 m. According to the IRPC (2002), the average width of the roadway is 4 m. The roadway width should range from 3.5 to 5 m (FAO, 1998) or from 5.5 to 7 m, according to Ryan et al. (2004). The cross slope of the roadbed is

* Corresponding author: Vladimir Petković vladimir.petkovic@sf.unibl.org

a key element in the surface drainage. Its value depends on factors such as the gradient of the forest roadbed, the radius of horizontal curves, the type of material used in roadbed construction, surface roughness, and other conditions. Typically, the cross slope is 3% for straight sections of forest roads and for curves with a radius of up to 70 m. For curves with a radius of up to 70 m, the cross slope ranges from 3% to 6%, depending on the roadbed grade and curve radius (IRPC, 2002). The longitudinal profile represents the vertical aspect of the forest road, featuring vertical curves and straight grade lines that connect these curves. The key element of the forest road longitudinal profile is the grade of the surface, often referred to as roadbed, denoted as i%. This grade is influenced by several factors, including the type of forest road, the type of vehicles used, soil characteristics, traffic load, and rainfall, among others. The maximum longitudinal grade of a roadway generally ranges from 8% to 14% (FAO, 1998; IRPC, 2002; Potočnik, 2004; Ryan et al., 2004).

The cross-section of a forest road is its projection on the vertical plane which is perpendicular to the axis of the forest road. The cross-section of forest roads consists of: clearing width, roadway width, cut and fill slopes, shoulders width, roadbed width and drainage ditch (Figure 1) and cross slope of roadbed.

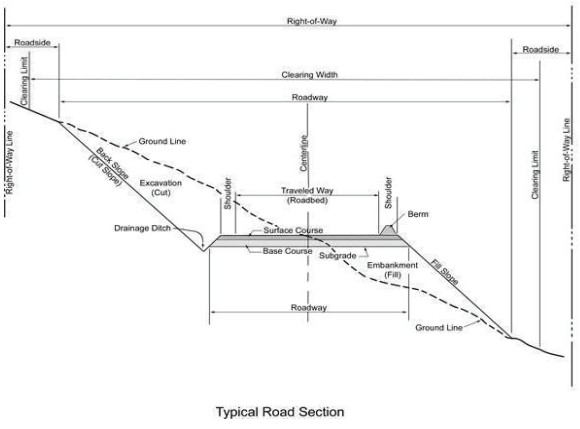

Figure 1. Typical road section (Petković et al., 2014)

Slika 1. Tipični poprečni profil (Petković et al., 2014)

The slope of cut and fill slopes depends on factors such as the type of soil and the height of the slopes. The slope of cut slopes can range from 1:1 (100%) for deep and soft soils (classified as Type III in a construction context) to 2:1 (200%), 3:1 (300%), or even 4:1 (400%) for gravelly and rocky soils (Types IV, V, and VI). For fill slopes, the ratio ranges from 1:1.5 (66%) or 1:2 (50%) for Type III soils to 1:1.25 (80%) in gravelly soils, and 1:1 (100%) in rocky soils (IRPC, 2002; Keller & Sherar, 2003).

The aim of this research is to determine the dimensions of the main constructive elements of forest roads and compare them with the dimensions prescribed by the "Manual for Designing Forest Roads in the Republic of Srpska" (IRPC, 2002) and other relevant references. Forest traffic infrastructure is a prerequisite for modern forest management and utilization (Pentek and Poršinsky, 2012).

MATERIALS AND METHODS – Materijal i metode

The subject of this research is the forest road "Lokva – Compartment 66," which belongs to the Forest Management Area (FMA) "Srednjevrbasko." This FMA is located in the western part of Bosnia and Herzegovina (B&H) and the southwestern part of the Republic of Srpska (RS). It encompasses the vegetation-geographical region of the inner Dinaric Alps, specifically the Western-Bosnian carbonate-dolomite area. This area contains forests of sessile oak and hornbeam (Querco - Carpinetum) (Stefanović et al., 1983). The geological base is composed of limestone and dolomite, on which several soil types are developed, including calcomelanosol, calcocambisol, luvisol, and rendzina.

The total length of roads in the Forest Management Area (FMA) "Srednjevrbasko" is 627.07 km, with forest roads accounting for 617.11 km, resulting in a primary forest accessibility of 11.96 km per 1,000 ha. The forest road "Lokva – Compartment 66" is situated within the Forest Management Unit (FMU) "Gornji Janj." The FMU covers an area of 7,776.77 ha, with a total road length of 133.97 km, of which forest roads constitute 122.72 km. This total length includes both public and forest roads, ensuring forest accessibility. The primary forest accessibility for this FMU is 14.20 km per 1,000 ha (IRPC, 2018). The average primary forest accessibility in the Republic of Srpska (RS) is approximately 10 m/ha (Dražić et al., 2018; Petković et al., 2022).

The total length of the forest road "Lokva – Compartment 66" is 4.015 km. It branches off from the forest road "Bravnice-Natpolje" at a location called "Lokva," passes through compartments 65 and 66, and ends at the boundary between compartments 66 and 67, at a place called "Hrastova kosa" (Figure 2). In this area, forests predominantly consist of beech and fir, with spruce and pine also present.

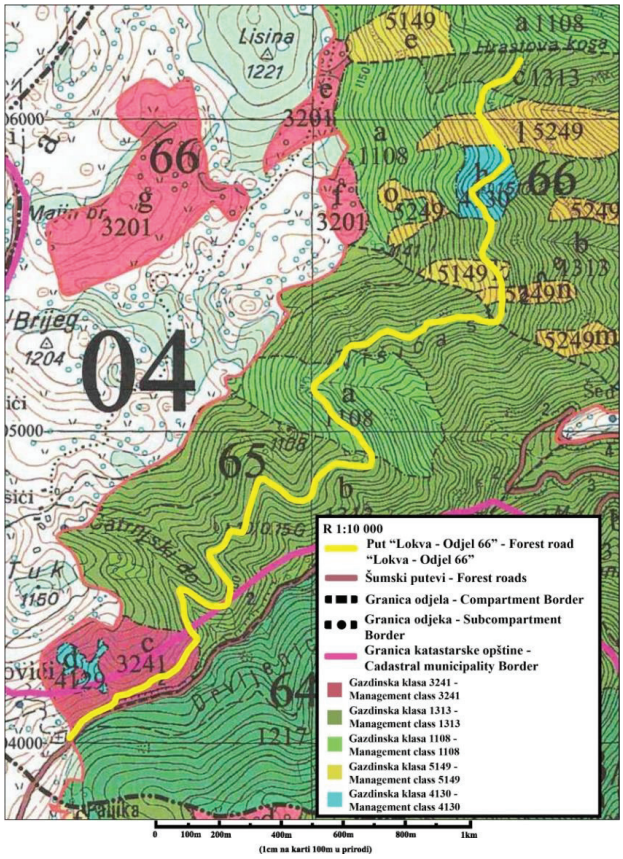

Figure 2. Location of forest road "Lokva-Compartment 66" (IRPC, 2013)

Slika 2. Položaj šumskog puta "Lokva-Odjel 66" (IRPC, 2013)

The terrain through which this road passes is characterized by numerous narrow ridges and ditches, which pose a significant limitation for determining the road alignment. The route is predominantly oriented towards the north. Due to the terrain configuration, 30% of the road consists of curves, while the remainder is composed of straight sections.

The forest road profile is optimally adapted to the terrain conditions, and in areas with a greater cross slope, it is positioned below the ground line to ensure roadway stability and enhance traffic safety. The profile of the forest road resembles a broken line with a general downward slope from start to finish. The maximum gradient encountered in the forest road longitudinal profile is 10.63% over a distance of 70.6 m (IRPC, 2013).

Based on geological conditions, three categories of soil have been identified in a constructive context along the forest road:

- IV category - fractured rock,
- V category - soft rock,
- VI category - solid rock (IRPC, 2013).

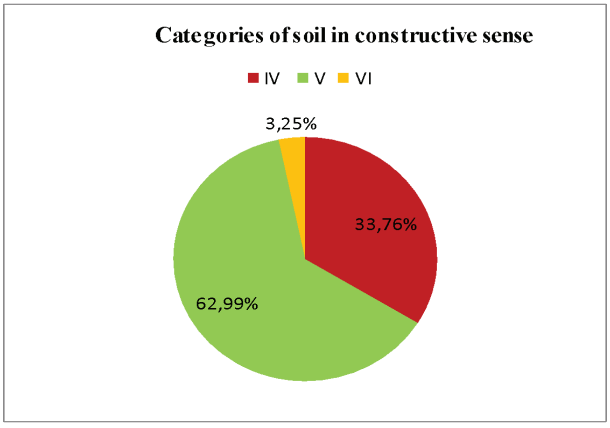

Figure 3. Categories of soil in the constructive sense at the forest road (IRPC, 2013)

Slika 3. Kategorije terena (IRPC, 2013)

Field data collection

The width of the roadway, grade of the roadway, cross slope of the roadway, and the slope of cut and fill slopes were measured at every 10-meter interval along the forest road "Lokva – Compartment 66.

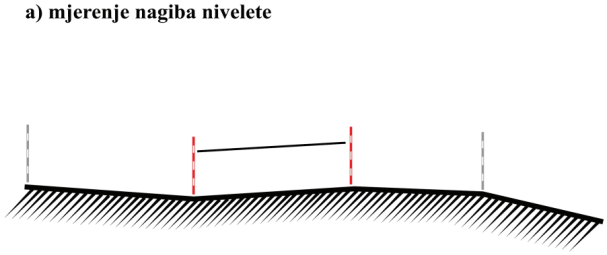

Figure 4. Measurements of the grade of the longitudinal profile of the roadway

Slika 4. Mjerenje nagiba nivelete

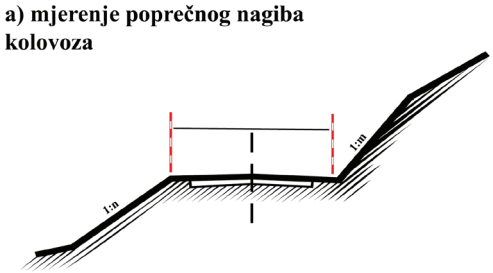

Figure 5. Measurements of the width and cross slope of the roadway

Slike 5. Mjerenje širine i poprečnog nagiba planuma

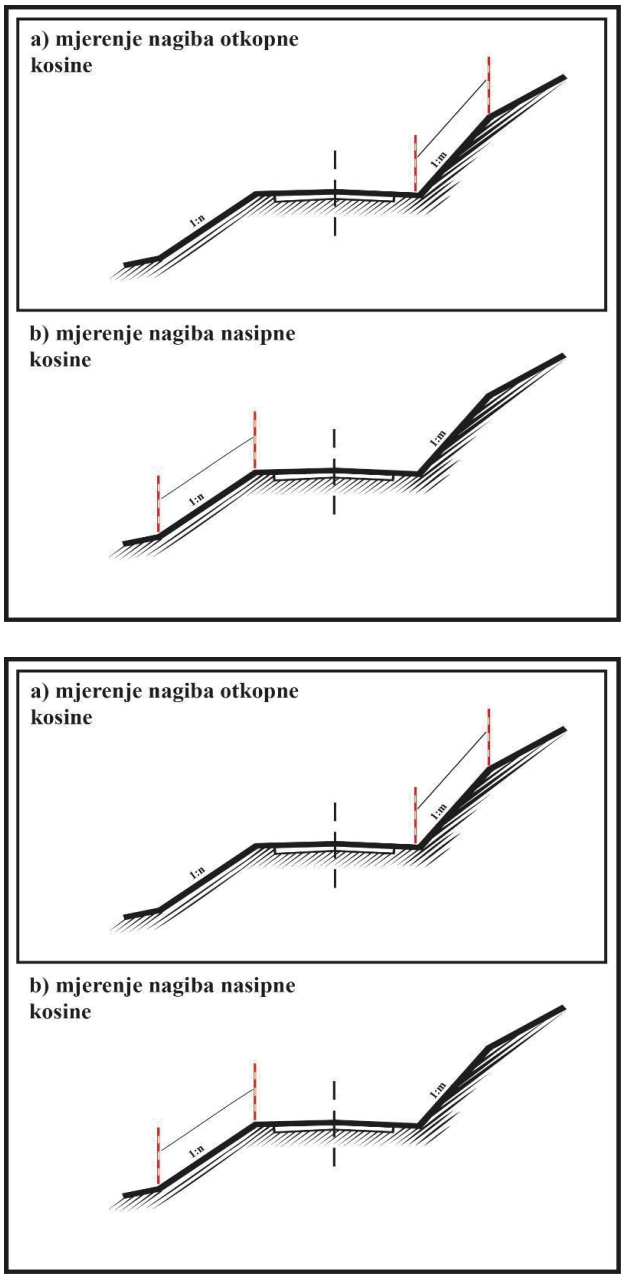

Figure 6. Measurements of the slope of cut and fill slopes

Slika 6. Mjerenje nagiba otkopne i nasipne kosine

The curves were also defined, and the beginning (PK), middle (SK), and end (KK) of each curve were marked. The location of the curve points was estimated on the forest road. The distance between the beginning and the end of the curve was measured, and a point C was established at the midpoint of this distance. Subsequently, the distance from this midpoint (C) to the middle of the curve (SK) was measured. These measurements (half the distance between the beginning and end of the curve, along with the distance from the midpoint to the centre of the curve) are essential for calculating the curve radius R (Petković et al., 2014).

$$R = \frac{x^2}{2y}$$

Where:

R - radius of the curve (m),

x - half the distance between the beginning and the end of the curve (m),

y - distance from the point at the half of the distance between the beginning and the end of the curve and the middle of the curve (m) (Petković et al., 2014).

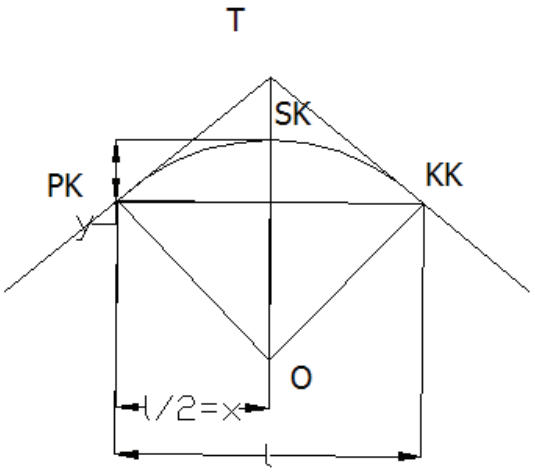

Figure 7. Determination of the radius of horizontal curve (Petković et al., 2014)

Slike 7. Određivanje poluprečnika horizontalnih krivina (Petković et al., 2014)

The width of the roadway and the distances between points were measured using a measuring tape, while the slope of cut and fill areas, the grade of the roadway, and the cross slope of the roadway were measured using a clinometer.

Processing of collected data

Microsoft Excel was used to analyze the collected data, obtaining minimum, maximum, and average values. The results are presented in tables and figures. These findings were then compared with both domestic and international regulations on forest road construction, as well as with results from research conducted on forest roads in various terrain and soil conditions. The outcomes of these comparisons aim to draw conclusions about the current state of the analysed elements of the forest road and recommend measures for its improvement.

RESULTS AND DISCUSSION – *Rezultati i diskusija*

The results of the statistical analysis of the collected data are presented in Table 1. The average roadway width is 6.11 m, and it ranges from around 4 to around 11 m (Table 1).

Table 1. The dimensions of constructive elements of the forest road "Lokva-Compartment 66" (Laketa, 2021)

Tabela 1. Dimenzije konstruktivnih elemenata šumskog puta "Lokva-Odjel 66" (Laketa, 2021)

Statistics	Width of roadway (m)	Cross slope of roadway in the straight lines (%)	Radius of the curves (m)	Cross slope of roadway in the curves (%)
Min	3.83	0	10	0
Max	10.81	9	200	9
Average	5.81	3.3	50	3.4
Prescribed (IRPC, 2002)	4	3	15-20*	3-6**

* minimal radius of the horizontal curves

** depends on the radius of the horizontal curves and grade of the roadway in the longitudinal profile

The average width of the roadway is greater than what is prescribed in the "Manual for Construction of Forest Truck Roads" from 2002, as well as the standards outlined by Jeličić (1983). The reason why the roadway width is greater can be the fact that there is no clear border between road and ditch, the presence of the passing lanes and landings for timber. The dependency of roadway width on the radius of horizontal curves has not been analyzed.

The dimensions of forest roads constructed in the FMU "Potoci-Resanovača" under similar soil conditions are as follows: the average roadway width is 4.5 m, the average grade of the roadway is 2.8%, and the cross slope of the roadway is 3%. The maximum measured grade is 8% (Petković et al., 2014). In comparison, the dimensions of the forest road "Lokva-Compartment 66" are larger, and they also exceed the average dimensions measured on forest roads in FMU "Prosara," which were constructed on Type III soil in a constructive context (Petković et al., 2014).

The allowed maximum upgrade of the roadway is 8%, while the downgrade ranges from 6% to 10%. Although the average values are within these limits, the maximum measured grades of the roadway (12% upgrade and 17% downgrade) exceed the prescribed values. The average upgrade of around 3% and a downgrade of around 6% (Table 2).

Table 2. The grade of the longitudinal profile of roadway (Gavranić, 2022)

Tabela 2. Nagib nivelete (Gavranić, 2022)

	IV category		V category		VI category	
	Average [%]:	Length [m]:	Average [%]:	Length [m]:	Average [%]:	Length [m]:
Down-grade:	6.65	1070	7.21	1620	5	120
Upgrade:	3.75	320	3.95	600	2	10

The slope of cut slope is lower than the prescribed values for the types of soils in the constructive sense, and the average slope of the fill slope is within prescribed boundaries for IV type of soils and lower for V and VI type of soils in the constructive sense (Figure 8).

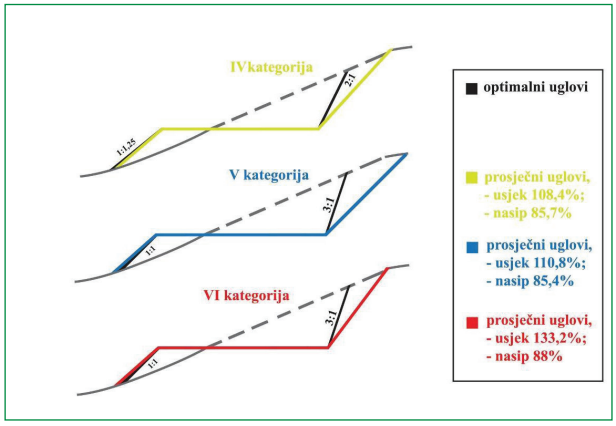

Figure 8. Average slopes of cut and fill slopes depend on the type of soil in a constructive sense (Laketa, 2021)

Slika 8. Prosječni nagibi otkopnih i nasipnih kosina zavisno od kategorije terena (Laketa, 2021)

The cut and fill slopes depend on the type of soil in a constructive context, the height of the slopes, the cross slope of the terrain, and other influencing factors. According to Jeličić (1983), the slope of cut and fill areas for deep soils should range from 1:1 to 1:1.5, while for rocky soils it should be 2:1 or between 1:1.3 and 1:1.5. Aćimovski (1997) suggests that for ordinary and sandy soils, the slope of cut and fill areas should be 1:1 and 1:1.5, respectively. For rocky substrates, cut slopes should range from 1:0, 1:0.2, 1:0.5, to 1:0.75, while fill slopes should be either 1:1 or 1:1.25.

In FMU "Prosara," the average slope of cut areas is 1:1.4 (71%), while the fill areas have an average slope of 1:2.2 (45%) on deep soils. In FMU "Potoci-Resanovača," the average slope of cut areas on shallow soils is 1:1.7 (59%), and the average slope for fill areas is 1:0.9 (111%) (Petković et al., 2014).

There are 99 horizontal curves on the forest road "Lokva-Compartment 66". The radius of these horizontal curves ranges from 10 m to 200 m, with an average radius of 50 m (Table 1). According to IRPC (2002), the minimum radius of curves should be 15 m; however, four curves on this road fall below this prescribed minimum. Sixty-two of the curves have a radius of less than 70 m, which, according to the Manual for Construction of Forest Truck Roads in the Republic of Srpska" (IRPC, 2002), requires calculation for roadway widening. This indicates that the alignment of the forest road "Lokva-Compartment 66" has been adapted to the existing terrain conditions.

The average radius of horizontal curves on forest roads ranges from 110 m to 140 m in FMU "Prosara" and FMU "Potoci-Resanovača". The minimum radius ranges from 15 m in Prosara to 20 m in Potoci-Resanovača. According to Aćimovski (1997), the minimum radius of curves should be 8 m for trucks that are 12 m long and 12 m for trucks that are 18 m long. Butulija (2000) suggests a minimum radius of 20 m for horizontal curves. Potočnik (2004) recommends a minimum radius of 15 m for horizontal curves, depending on the turning capabilities of typical vehicles, such as trucks and trailers.

The average cross slope of the roadway on the forest road "Lokva-Compartment 66" is 3.3%, increasing to 3.4% in curves (Table 1). The cross slope of the roadway in curves depends on the longitudinal profile grade of the roadway and the radius of the curves, ranging from 3% to 6%, while for straight sections it should be 3% (IRPC, 2002). The average cross slope of forest roads in FMUs "Prosara" and "Potoci-Resanovača" is approximately 3%. In curves, the average cross slope is about 3% in FMU "Potoci-Resanovača" and 4% in FMU "Prosara" (Petković et al., 2014). The average cross slope of the roadway on the forest road "Lokva-Odjel 66" aligns with the prescribed standards.

The ditches are filled, preventing them from effectively collecting rainfall runoff from the road. Additionally, there is no distinct boundary between the forest road surface and the ditch, which further complicates water drainage management.

CONCLUSIONS – *Zaključak*

The forest road "Lokva-Compartment 66" was constructed on soil types IV (34%), V (63%), and VI (3%) in a constructive context.

The average width of the roadway is greater than what is prescribed in the "Manual for Construction of Forest Truck Roads in the Republic of Srpska" (IRPC, 2002) and as specified by Jeličić (1983). The average values of the roadway's upgrade and downgrade are within acceptable ranges, but the maximum measured grades exceed the recommended limits.

The average slope of the cut areas along the forest road "Lokva-Compartment 66" is higher compared to the average slope of cut areas on forest roads in FMUs "Potoci-Resanovača" and "Prosara," both of which are also below the prescribed values for cut and fill slopes.

The minimum radius of the curves on the forest road aligns with the recommendations of the authors and the Manual (2002). Similarly, the average cross slope of the roadway for "Lokva-Compartment 66" complies with the prescribed standards.

Based on the results of the study, it can be concluded that, from a cost-efficiency perspective and considering the type of soil in a constructive context, the width of the roadway should be reduced and the maximum longitudinal profile grade of the roadway, while the slopes of cut and fill areas should be increased to optimize road construction costs but this must take into account the driving safety.

REFERENCES – *Literatura*

Aćimovski, R. (1997). Šumska transportna sredstva. Knjiga prva–Šumski putevi, Univerzitet u Beogradu, Šumarski fakultet, Beograd, str, 365.

Butulija, S. (2000). Projektovanje šumskih puteva direktnom metodom (praktikum). Srbijašume-institut za šumarstvo, Beograd.

Dražić, S., Danilović, M., Stojanić, D., Blagojević, V. & Lučić, R. (2018). Openness of forests and forest land in the Bosnia and Herzegovina entity Republic of Srpska. Šumarski list 3-4: 183-195

FAO - Food and Agriculture Organization of the United Nations. (1998). A manual for the planning, design and construction of forest roads in steep terrain. Rome, 130 p

Gavranić, D. (2022). Analiza nagiba nivelete na šumskom putu "Lokva-Odjel 66" [Beachelor's

thesis]. University of Banja Luka, Faculty of Forestry.

IRPC - JPŠ Šume Republike Srpske, Istraživačko razvojni i projektni centar. (2002). Pravilnik o projektovanju šumskih kamionskih puteva. Banja Luka: str. 26

IRPC - JPŠ Šume Republike Srpske, Istraživačko razvojni i projektni centar. (2013). Glavni projekat za šumski kamionski put "Lokva – Odjel 66".

IRPC - JPŠ Šume Republike Srpske, Istraživačko razvojni i projektni centar. (2018). Šumskoprivredna osnova za područje"Srednjevrbasko"(važnost od 01.01.2018. do 31.12.2027.godine), izdavač JPŠ "ŠUME RS" a.d. Sokolac a.d. Sokolac: 1 – 316.

Jeličić, V. (1983) Šumske ceste i putevi, Samoupravna interesna zajednica odgoja i usmjerenog obrazovanja šumarstva i drvne industrije. SR Hrvatska, Zagreb, str. 1–193

Keller, G. & Sherar, J. (2003). Low-volume roads engineering. Best management practices field guide, US Agency for International Development (USA ID): 103 – 114.

Laketa, A. (2021). Analiza nagiba otkopnih i nasipnih kosina na šumskom putu [Beachelor's

thesis]. University of Banja Luka, Faculty of Forestry.

Pentek, T. & Poršinsky, T. (2012). Forest Ecosystems – More Than Just Trees (Šumski ekosustavi – više od samih stabala). Intech web.org, 1–464

Petković, V., Marčeta, D. & Potočnik, I. (2014). Horizontal and Vertical Alignments of Forest Roads. Šumarski fakultet Sveučilište u Zagrebu, Nova Mehanizacija šumarstva 35(2014): 79-87.

Petković, V., Marčeta, D. & Potočnik, I. (2022). Optimization of primary forest accessibility in high forests with natural regeneration. Šumarski list, 9-10: 427-439

Potočnik, I., 2004: Šumske komunikacije-predavanja. Univerzitet u Banjoj Luci, Šumarski fakultet, Banja Luka.

Rayan, T., Phillips, H., Ramsay, J. & Dempsey, J. (2004). Forest Road Manual. Guidelines for thedesign, construction and management of forest roads. CAFORD, Dablin: str. 156.

Stefanović, V., Beus, V., Burlica, Č., Dizdarević, H. & Vukorep, I. (1983). Ekološko-vegetacijska rejonizacija Bosne i Hercegovine, Šumarski fakultet, Univerziteta u Sarajevu, Posebna izdanja No 17., Sarajevo. str. 26.

SAŽETAK

Rad istražuje konstruktivne elemente šumskog puta "Lokva-Odjel 66", smještenog u Šumskom gazdinstvu (ŠG) "Srednjevrbasko", i analizira dimenzije puta u odnosu na postojeće norme i standarde. Glavni cilj istraživanja bio je utvrditi dimenzije osnovnih konstruktivnih elemenata šumskog puta i usporediti ih s propisanim standardima prema "Priručniku za projektovanje šumskih kamionskih puteva u Republici Srpskoj" iz 2002. godine i drugim relevantnim izvorima. Ova studija daje uvid u trenutnu situaciju šumskih puteva, naglašavajući potrebne mjere za poboljšanje efikasnosti i sigurnosti puta.

Ukupna dužina puta "Lokva-Odjel 66" iznosi 4.015 km, a prolazi kroz odjele 65 i 66, završavajući na granici između odjela 66 i 67. Putevi prolaze kroz područja sa šumama bukve i jele, sa smrčom i borom kao dodatnim vrstama. Teritoriju kroz koju prolazi ovaj put karakterišu uski grebeni i jarkovi, što je predstavljalo izazov prilikom određivanja trase puta. Ruta je većinom orijentisana prema sjeveru, a 30% puta čine krivine, dok ostatak čine pravci.

Izmjereni podaci uključuju širinu kolovoza, uzdužni nagib, poprečni nagib, te nagibe otkopnih i nasipnih kosina na svakih 10 metara puta. Prosječna širina kolovoza iznosi 6.11 m, uz prosječan uspon od 3% i pad od 6.5%. Poprečni nagib kolovoza iznosi 3.1%, dok su nagibi otkopnih kosina 120% (1.2:1), a nagibi nasipnih kosina 86% (0.86:1). Rezultati pokazuju da je prosječna širina puta veća od propisane prema Priručniku iz 2002. godine i standardima koje je utvrdio Jeličić (1983). Također, maksimalno izmjereni uzdužni nagibi puta prelaze preporučene vrijednosti, iako su prosječne vrijednosti unutar granica.

Kada se dimenzije puta "Lokva-Odjel 66" usporede sa sličnim putevima u ŠG "Potoci-Resanovača" i "Prosara", ustanovljeno je da su dimenzije šire, a nagibi otkopnih kosina veći. Prosječna širina kolovoza na putevima ŠG "Potoci-Resanovača" iznosi 4.5 m, dok je prosječni uzdužni nagib 2.8%, a poprečni nagib kolovoza 3%. Maksimalni izmjereni uzdužni nagib iznosi 8%. U poređenju s ovim dimenzijama, put "Lokva-Odjel 66" ima veće vrijednosti, što ukazuje na potrebu za usklađivanjem sa standardima.

Nagib otkopnih i nasipnih kosina zavisi od vrste zemljišta, visine kosina, poprečnog nagiba terena i drugih faktora. Prema Jeličiću (1983), nagib otkopnih i nasipnih kosina za duboka tla treba biti u rasponu od 1:1 do 1:1.5, dok za stjenovita tla treba biti 2:1 ili između 1:1.3 i 1:1.5. Prema Aćimovskom (1997), za obična i pjeskovita tla, nagib otkopnih i nasipnih kosina treba biti 1:1 i 1:1.5. U FMU "Prosara" prosječni nagib otkopnih kosina iznosi 1:1.4 (71%), dok prosječni nagib nasipnih kosina na dubokim tlima iznosi 1:2.2 (45%). U FMU "Potoci-Resanovača" prosječni nagib otkopnih kosina na plitkim tlima iznosi 1:1.7 (59%), a prosječni nagib nasipnih kosina iznosi 1:0.9 (111%).

Na šumskom putu "Lokva-Odjel 66" nalazi se 99 krivina, a radijus horizontalnih krivina varira od 10 m do 200 m, s prosječnim radijusom od 50 m. Prema IRPC (2002), minimalni radijus krivina treba biti 15 m, međutim četiri krivine na ovom putu imaju radijus ispod ove propisane minimalne vrijednosti. Šezdeset i dvije krivine imaju radijus manji od 70 m, što prema Priručniku (2002) zahtijeva izračunavanje proširenja kolovoza. Ovo pokazuje da je trasa puta "Lokva-Odjel 66" prilagođena terenskim uvjetima.

Zaključeno je da šumski put "Lokva-Odjel 66" može prihvatiti saobraćajno opterećenje u trenutnom stanju. Međutim, potrebno je obratiti pažnju na veću širinu puta i niže nagibe otkopnih i nasipnih kosina. Prema rezultatima studije, radi optimizacije troškova izgradnje i prilagođavanja uslovima tla, širina kolovoza treba biti smanjena, dok nagibi otkopnih i nasipnih kosina trebaju biti povećani kako bi se smanjili obim i troškovi građevinskih radova, ali treba biti i oprezan zbog sigurnosti vožnje.

Received: October 8, 2024; **Accepted**: November 22, 2024; **Published**: December 21, 2024

Funding: This research received no external funding.

Conflicts of Interest: The authors declare no conflict of interest.