Traffic load of forest roads as a criterion for their categorization – GIS analysis

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Abstract – Nacrtak

The categorisation of forest roads can be based on several different criteria. In this paper, the outlines of the primary forest traffic infrastructure were divided according to the traffic load typical of long-distance transportation of timber. The survey was conducted in the management unit of Veprinačke šume, forest office of Opatija, forest administration of Buzet. This paper defines the methodology of forest roads categorisation using the GIS analysis, which should become a mandatory tool in development of forest roads network in Croatia.

Traffic load of forest roads as a criterion for their categorisation can be used for the rationalisation of construction and maintenance expenses of the primary forest traffic infrastructure, while additional researches should define the standards for construction and maintenance of each category of forest roads.

Keywords: forest road, traffic load, categorisation, relative openness, further timber transportation

1. Introduction – *Uvod*

The total quantity of forest roads, their spatial distribution and prescribed technical characteristics must be sufficient to enable a high-quality management of forest ecosystems with minimum starting and additional financial investments. Construction and maintenance of the primary forest road infrastructure network, as well as the construction and repairs of the secondary forest road network (skid roads) make a very important element of the overall expense structure related to forest management.

The aim is to construct a spatially well-positioned network of forest roads whose technical characteristics will enable the fulfilment of all the tasks set forth by the Management Plan for a specific forest area. While achieving this goal, we are also trying to reach the satisfactory quality level with the least possible financial investments.

The Geographical Information System (GIS) is today used in almost all segments of society, so forestry could not have stayed aside. When it comes to forest roads, the GIS was used so far in planning of the primary and secondary forest road network, i.e. in drafting of the primary and secondary studies of forest opening (Pentek 2002).

The basic aim of this paper is to show how successfully the GIS may be used in combination with the appropriate software applications, for the rationalisation of the expenses of construction and maintenance of forest communications, with particular regard to forest roads.

Potočnik et al. (2005a) state that the development of good studies of the primary opening of forests could significantly rationalise and control the expenses for construction and maintenance of the primary forest road infrastructure.

Pentek et al. (2006) believe that during its amortisation period, the quality of a constructed primary forest road infrastructure can only be retained by regular maintenance interventions whose frequency and intensity depend on the category of the specific forest road.

The establishment of the GIS of the surveyed area, together with the analysis of the secondary forest openness and simulation of timber assortments' transportation from the felling site to the asphalt public roads network is used as a basis for planning and rationalisation of construction and maintenance expenses.

2. Research issues – *Problematika istraživanja*

2.1 Categorisation of forest roads – *Kategorizacija šumskih prometnica*

In relation to the traffic density, Šikić et al. (1989) divided forest roads into primary and secondary forest communications.

The primary forest communicatons include forest roads. These are permanent constructions, which enable continuous traffic of motor vehicles for the purpose of fulfilment of all tasks set forth by the Management Plan. These roads consist of the lower and upper layer and have all the technical characteristics of roads, thus permanently bereaving the forest of its productive area (proportionally to the road's width, i.e. the road's body).

The secondary forest communications include skid roads and skid trails. The secondary forest communications are constructions occasionally used for the fulfilment of tasks set forth by the Management Plan. Their primary purpose is timber skidding and forwarding.

Šikić et. all (1989) distinguish four forest road categories with five road body widths. If a road has two lanes, its body width varies between 6.0 and 7.5 metres; in case of a single-lane road, the width varies between 5.0 and 5.5 metres. According to the same source, the following technical characteristics of forest communications in Croatia were prescribed: (1) the minimum radiuses of horizontal curves, (2) the necessary broadening of roads in curves, (3) transversal slopes of forest roads, (4) maximum longitudinal slopes of forest roads and (5) minimum allowed radiuses of transversal curves. Regarding the frequency of use and considering the maintenance requirements, Pičman and Pentek (1996) divide forest roads as follows:

⇒ primary forest roads, used throughout the year with permanent maintenance needs,

⇒ secondary forest roads, used only occasionally when needed; their maintenance is periodical.

Potočnik (1996) states that forest roads exist in a multifunctional forest, and accordingly they also become multifunctional. Furthermore, he divides forest roads' functions as follows: roads with forestry function and roads with a non-forestry function. It is very important to analyse the trend of change of structure and intensity of forest roads traffic, which certainly increases their maintenance expenses, but also the expenses of construction, due to high traffic security requirements and technical equipment demands. The intensity of non-forestry functions of forest roads, which generate additional expenses, is quite variable and depends on the spatial position of the forest road as well as on the surrounding environment and its prospects.

According to the FAO guidelines (FAO 1998), the classification was made of forest communications on sloping areas:

⇒ access roads,

⇒ main roads,

⇒ secondary roads (feeder roads),

⇒ skid road,

⇒ skid trails.

Based on frequency of use and importance, Potočnik et al. (2005b) divide forest roads into three main categories: main forest roads, secondary forest roads and access forest roads, whereby the technical characteristics are prescribed, and construction standards are the same for all three categories, while the difference is noticeable in their basic purpose, frequency and intensity of traffic and, finally, construction and maintenance expenses in the amortisation period.

According to Potočnik et al. (2005a), assuming constant habitat conditions, cumulative traffic load and intensity are mostly affected by the position and distance of an individual forest road section from the public road, then by the secondary forest roads and finally by turnaround location on the forest road. Again, the closer the sections of a forest road are to the conjunction of the forest road with a public road, the better they have to be constructed in compliance with higher construction standards and regular maintenance in shorter intervals, which accordingly justifies the categorisation of not only forest roads, but also of specific sections of forest roads as well.

The first step that has to be taken before the beginning of opening up of a specific forest area is the analysis of the existing network of primary and secondary forest communications. In order to do this, it is necessary to have a cadastral plan of primary and secondary forest communications in a digital form.

According to Pentek et al. (2003), the cadastral plan of primary and secondary forest road infrastructure provides as follows:

⇒ precise and detailed overview of the existing resources of a specific forest area,

⇒ the analysis of the existing state of primary and secondary forest communications development,

⇒ observing of contingent needs, deficiencies and faults regarding forest road infrastructure,

⇒ planning and control of expenses of forest roads maintenance and expenses for repairs of skid roads,

⇒ development of a detailed building site survey when harvesting is carried out in a specific forest area.

3. Research area – *Područje istraživanja*

The researches were performed within the selective forests area of the management unit of Vepri-

načke šume, forest office of Opatija, forest administration of Buzet. The total surface of the management unit is 1,950.87 ha, whereof 1,899.23 ha is forest covered, 43.36 ha is non-forest covered, 3.12 ha is a non-forest covered unproductive soil and 5.16 ha is unfertile soil. The Veprinačke šume management unit (Fig. 1) is a part of the Ćićarija massif, situated between 45°20′ and 45°24′ of Northern latitude and 14°11′ and 14°16′ of Eastern longitude. The highest peak is at an altitude of 1144 metres, while the lowest point is at the altitude of 760 metres.

A half-tree-length method is used in felling and processing. Timber is extracted by skidders equipped with cable winches. This method of primary timber transportation requires a well-developed secondary openness. Due to the terrain configuration and orographic development, skid roads have to be constructed. The scaling of roundwood is performed within the felling site.

The basic characteristics of forest opening-up and timber harvesting are steep, orographically diverse mountainous terrain, richness of the karst relief phenomena, shallow soils and rocky bedrock, as well as heavy construction material categories. The average slope inclination of the terrain ranges between 5 and 30°. Further to the above, the necessity for providing a good primary and secondary openness is obvious. The 10-year harvesting volume (81,131.75 m^3) is of a high quality; the main commercial tree species is beech.

The primary forest openness amounts to 8.58 m/ha and 16.78 m/ha, respectively, if an old Italian macadam public road is taken into account. The secondary forest openness is 101.94 m/ha.

Fig. 1 Position of the management unit of Veprinačke šume
Slika 1. *Položaj GJ Veprinačke šume*

4. Objective and methodology – *Cilj i metode rada*

4.1 Objective – *Cilj rada*

The objective of this paper is to calculate the traffic load of each component of the primary forest road infrastructure by use of the GIS analysis. The traffic load will be calculated assuming that timber transportation is carried out by truck.

The following working phases are planned:

⇒ establishment of GIS of the researched area,

⇒ defining positions of landings,

⇒ analysis of the secondary openness of the management unit of Veprinačke šume,

⇒ defining of gravitation zones,

⇒ defining of traffic load of the primary forest road infrastructure,

⇒ categorisation of the primary forest road infrastructure.

4.2 Working methodology – *Metode rada*

4.2.1 Positioning of forest roads with GPS – *Snimanje šumskih prometnica GPS uređajem*

Positioning of forest roads was carried out by the Trimble Geoexplorer 3 GPS. The recording interval was 5 seconds. For the positioning of forest roads, we used an external antenna attached to the terrain vehicle, while skid roads were passed on foot.

The primary and secondary forest communications were positioned by the so-called snap-back method during the period of vegetation dormancy, in accordance with the previously defined almanac.

The data obtained were downloaded with the GPS Pathfinder Office 2.80 application package and entered into the ArcView 3.1 application package, and afterwards integrated into previously prepared digital maps.

4.2.2 Data analysis – *Obrada podataka*

4.2.2.1 Defining of opened areas for the chosen length of the skidder's winch cable – *Određivanje otvorenih površina za odabranu duljinu užeta vitla zglobnoga traktora*

The length of the skidder's winch cable, used within the researched habitat and stand conditions, is 60 metres. Due to the terrain's slope and surface obstacles, timber assortments cannot be winched from a 60-metres distance from both sides of forest roads. The »useful« length of a winch cable is 45 metres (Nevečerel 2004).

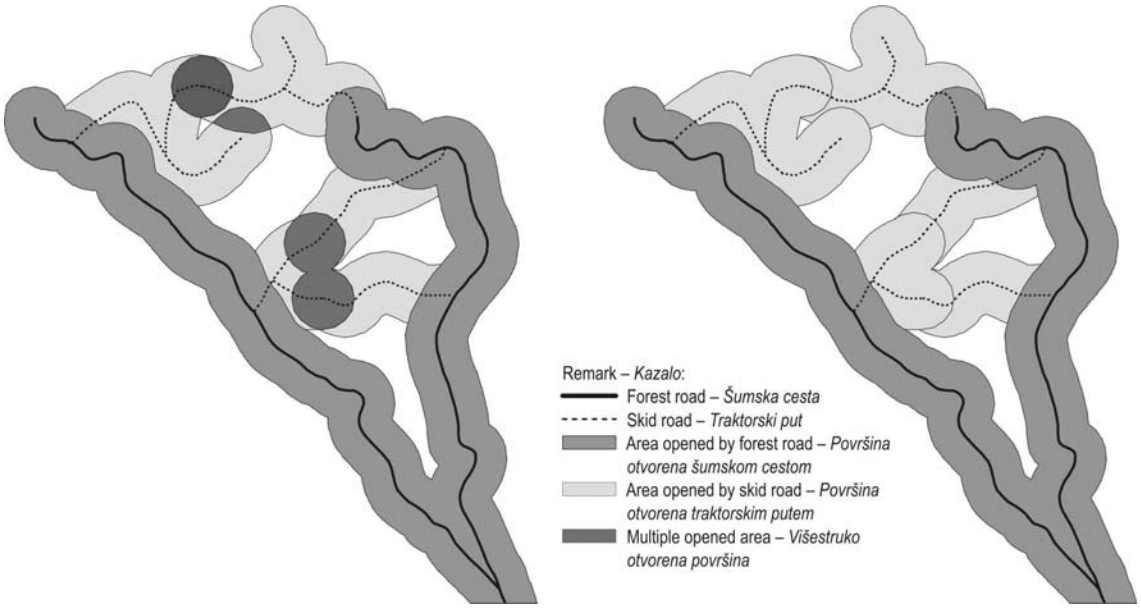

Fig. 2 Defining priorities with the secondary forest roads due to the exclusion of the »multiple opened areas«
Slika 2. *Određivanje prioriteta kod sekundarnih šumskih prometnica zbog isključivanja »višestruko otvorenih površina«*

In digital maps, the 45-metre buffers were laid on both sides of the primary and secondary forest roads. The marked area, i.e. the area within the buffered zone, is opened for the chosen length of the skidder's winch cable, meaning that the timber assortments within the buffered zone can be winched without a skidder's descent from the forest roads. This can also apply for the reverse situation.

4.2.2.2 The analysis of the secondary openness – *Raščlamba sekundarne relativne otvorenosti*

The analysis is conducted for each forest road, for each category of the forest roads (primary and secondary), for each subcompartment and finally for the entire management unit. When analysing relative secondary openness, priority is given to the forest roads, whose ranking starts with those of higher classes and proceeds to lower class roads. When it comes to the roads of the same rank, priority is given in accordance with the constructing sequence.

If we assume a homogenous structure of all stand and habitat factors within one subcompartment, the results of the analysis of the secondary relative openness can be used for defining harvesting volume, which is prescribed by the Management Plan at a subcompartment level gravitating towards an individual forest road. The harvesting volume, which is situated outside the buffered zones, is distributed to forest roads proportionally to their participation in the distribution of a 10-year harvesting volume within the buffered zones.

Each junction of the secondary and primary forest rorad presents a landing (of higher or lower capacity). Each of the primary forest roads is divided into sections (segments between the two landings) as the smallest unit for which a traffic load is calculated. The processed timber assortments, except on landings, are stored along public and forest roads.

5. Research results – *Rezultati istraživanja*

5.1 The analysis of the relative secondary openness – *Raščlamba sekundarne relativne otvorenosti*

Regarding the total opened area in comparison to the total area, the average relative openness of the management unit of Veprinačke šume is derived. It amounts to 72.34%, of which 14.65% accounts for roads and 57.69% for skid roads. The unopened area covers 27.66% of the management unit area.

5.2 Defining of traffic load of the primary forest road infrastructure – *Određivanje prometnoga opterećenja primarne šumske prometne infrastrukture*

Figure 3 shows the total traffic load of public roads with marked gravitational areas in the horizontal alignment of junctions with forest roads.

There are two versions of load calculations for the primary forest road infrastructure. The first version

Table 1 Relative openness and harvesting volume distribution
Tablica 1. *Relativna otvorenost i raspodjela etata*

Compartment *Odsjek*	Area, ha *Površina, ha*	Removal, m^3 *Etat, m^3*	Openness, % *Otvorenost, %*			Unopenned areas, % *Neotvorena područja, %*	Timber that gravitates towards, m^3 *Drvo koje gravitira, m^3*	
			Skid roads *Traktorski putovi*	Public and Forest roads *Javne i šumske ceste*	Total *Ukupno*		Skid roads *Traktorski putovi*	Public and Forest roads *Javne i šumske ceste*
1a	30.56	895.00	59.20	0.00	59.20	40.80	895.00	0.00
2a	64.35	1,521.50	56.62	9.79	66.41	33.59	1,372.52	148.98
3a	40.35	2,237.50	50.69	21.29	71.98	28.02	1,761.22	476.28
4a	30.56	1,190.35	68.76	8.00	76.76	23.24	1,095.17	95.18
5a	13.18	751.80	56.38	21.44	77.82	22.18	590.64	161.16
5b	19.73	67.13	27.62	0.00	27.62	72.38	67.13	0.00
6a	32.57	1,512.55	47.13	37.41	84.54	15.46	946.68	565.87
6b	13.80	0.00	5.42	66.46	71.88	28.12	0.00	0.00
7a	47.58	537.00	9.51	0.26	9.78	90.22	535.58	1.42
7b	13.64	0.00	16.32	4.10	20.42	79.58	0.00	0.00
8a	61.63	2,640.25	39.33	0.53	39.86	60.14	2,626.17	14.08
9a	35.52	1,320.13	70.48	3.89	74.38	25.62	1,268.72	51.40
10a	24.83	895.00	53.30	31.84	85.14	14.86	610.03	284.97
11a	35.73	1,136.65	64.02	17.65	81.67	18.33	936.00	200.65
12a	37.48	1,700.50	63.03	8.75	71.77	28.23	1,551.76	148.74
13a	47.47	1,807.90	58.11	17.88	75.99	24.01	1,484.71	323.19
14a	56.85	2,622.35	57.31	5.91	63.22	36.78	2,467.36	154.99
15a	25.97	1,118.75	63.59	22.99	86.58	13.42	861.54	257.21
16a	38.89	2,022.70	64.82	10.85	75.67	24.33	1,803.19	219.51
17a	54.30	2,452.30	70.86	15.13	85.99	14.01	2,081.28	371.02
18a	26.51	671.25	43.82	27.77	71.60	28.40	484.82	186.43
19a	16.83	554.90	81.53	1.02	82.55	17.45	549.25	5.65
19b	25.82	223.75	22.53	0.00	22.53	77.47	223.75	0.00
20a	46.61	1,342.50	64.77	16.42	81.20	18.80	1,122.01	220.49
20b	3.97	35.80	65.06	0.00	65.06	34.94	35.80	0.00
21a	41.43	1,548.35	65.97	17.71	83.67	16.33	1,274.20	274.15
22a	23.12	1,163.50	66.46	24.61	91.07	8.93	877.20	286.30
23a	27.96	1,163.50	58.26	22.49	80.75	19.25	901.83	261.67
24a	25.57	1,342.50	62.04	26.28	88.32	11.68	989.68	352.82
25a	47.81	895.00	58.02	22.48	80.50	19.50	693.79	201.21
26a	48.48	2,595.50	85.20	7.01	92.21	7.79	2,413.59	181.91
27a	34.21	1,360.40	68.60	23.80	92.41	7.59	1,036.57	323.83
28a	48.26	2,461.25	84.48	10.25	94.74	5.26	2,208.86	252.39
29a	25.58	1,476.75	78.59	13.19	91.77	8.23	1,282.00	194.75
30a	44.99	2,774.50	72.91	16.80	89.70	10.30	2,308.51	465.99
31a	26.84	0.00	19.03	5.08	24.11	75.89	0.00	0.00
32a	36.39	1,378.30	71.38	6.07	77.45	22.55	1,294.63	83.67
33a	28.69	1,432.00	52.40	33.05	85.45	14.55	958.78	473.22
33b	5.76	268.50	16.52	0.00	16.52	83.48	268.50	0.00
34a	46.23	1,745.25	80.62	9.83	90.45	9.55	1,573.65	171.60
35a	28.10	1,118.75	70.94	25.76	96.70	3.30	830.58	288.17
36a	48.31	2,640.25	80.03	10.02	90.05	9.95	2,375.79	264.46
37a	34.65	2,971.40	86.35	9.55	95.90	4.10	2,687.58	283.82
38a	37.16	1,611.00	11.38	7.22	18.60	81.40	1,494.71	116.29
39a	20.86	1,745.25	61.38	22.62	84.00	16.00	1,350.48	394.77
40a	30.35	1,969.00	74.75	12.86	87.62	12.38	1,715.70	253.30

Compartment *Odsjek*	Area, ha *Površina, ha*	Removal, m^3 *Etat*, m^3	Openness, % *Otvorenost, %*			Unopenned areas, % *Neotvorena područja, %*	Timber that gravitates towards, m^3 *Drvo koje gravitira*, m^3	
			Skid roads *Traktorski putovi*	Public and Forest roads *Javne i šumske ceste*	Total *Ukupno*		Skid roads *Traktorski putovi*	Public and Forest roads *Javne i šumske ceste*
41a	41.41	1,790.00	73.21	17.82	91.03	8.97	1,471.06	318.94
42a	37.46	1,637.85	74.28	20.27	94.55	5.45	1,305.88	331.97
42b	2.13	0.00	55.93	0.00	55.93	44.07	0.00	0.00
43a	62.41	2,774.50	61.43	32.55	93.98	6.02	1,871.51	902.99
44a	39.36	2,103.25	79.05	9.64	88.69	11.31	1,900.47	202.78
45a	37.22	1,700.50	42.11	0.00	42.11	57.89	1,700.50	0.00
46a	40.12	2,685.00	84.62	4.89	89.50	10.50	2,553.79	131.21
47a	54.58	2,908.75	36.78	29.05	65.83	34.17	2,063.75	845.00
48a	26.90	912.90	50.91	11.79	62.70	37.30	805.23	107.67
49a	41.87	1,700.50	66.80	18.16	84.96	15.04	1,391.64	308.86
Total – *Ukupno*, m^3		81,131.75					68,970.79	12,160.96
Average – *Prosječno*, %			57.69	14.65	72.34	27.66		

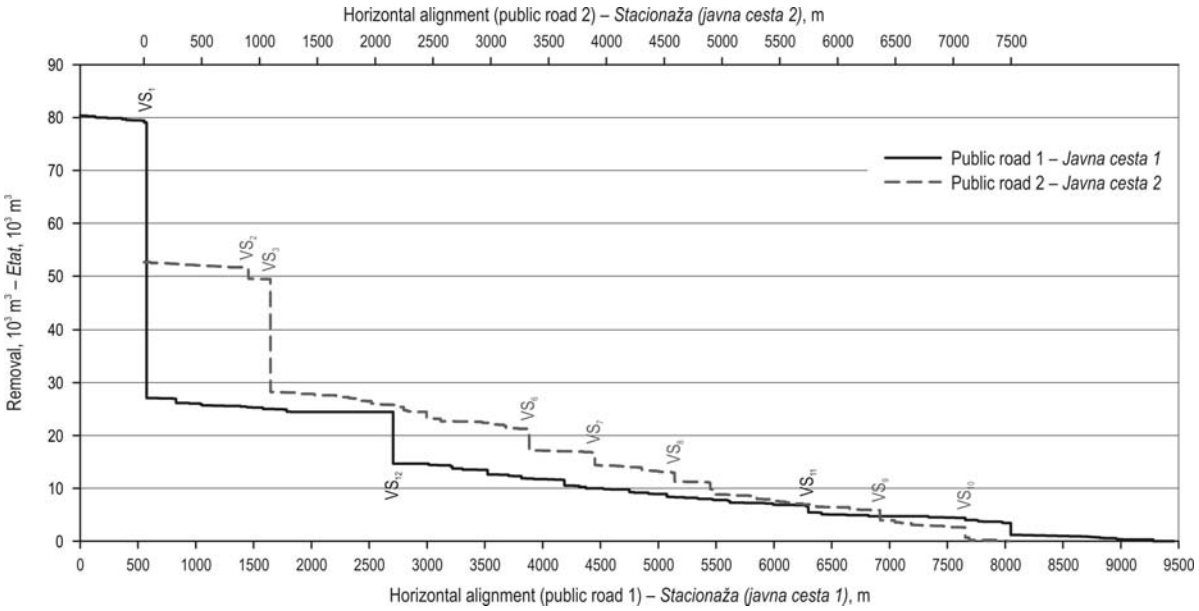

Fig. 3 Traffic load of public roads
Slika 3. *Prometno opterećenje javnih cesta*

assumes a truck as a mean for long-distance transportation of timber, while in the second version it is a truck with trailer (Fig. 4).

The net mass values of transported timber were calculated in comparison to the 10-year harvesting volume that was transported on each of the roads at the beginning of its horizontal alignment, where the average volume mass of beech timber (1.07 t/m^3) was used for scaling (Anon. 1966). The number of truck cycles (n) presents the total number of passes of the chosen means of long-distance transportation of timber required to transport the entire harvesting volume (assuming a truck or truck with trailer is fully loaded at departure and empty at arrival). The following equation was used:

$$n = \frac{m_{net}}{(m_{\max} - m_{ts})} \cdot 2 \qquad (1)$$

m_{net} – 10-year timber mass, t
$m_{\max}$ – maximum mass allowed, t
$m_{\max}$ – mass of a chosen means of long-distance transportation of timber, t

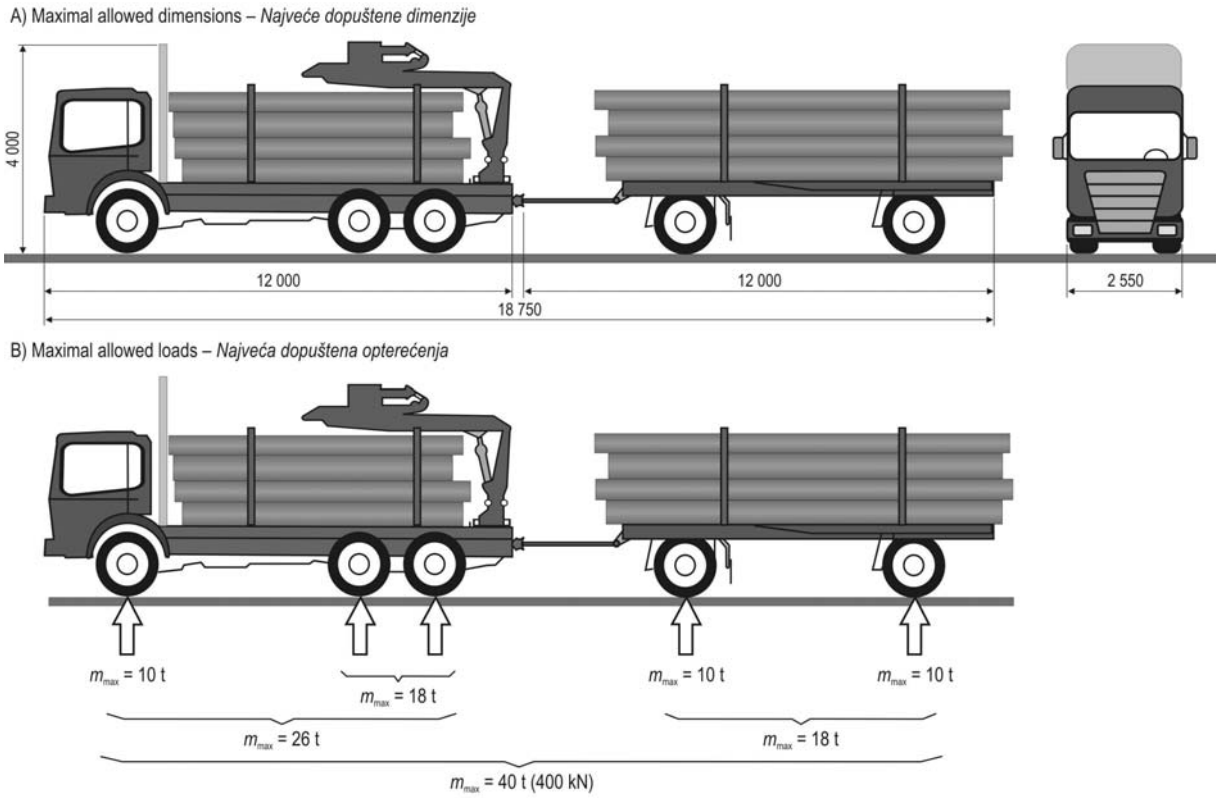

Fig. 4 Maximum dimensions and loads allowed for trucks with trailer
Slika 4. *Najveće dopuštene dimenzije i opterećenja kamiona s prikolicom*

The maximum mass allowed of a truck is 26 t, 40 t for a truck with trailer (Anon. 2005). The mass of the chosen means of transportation in the first case is 14.138 t; 18.723 t in the second case (Krpan et al 2002). The gross mass was calculated as a sum of net mass and the total mass of turns of the chosen means of transportation. The loads of the primary forest road infrastructure regarding trucks and trucks with trailers are shown in Table 2.

The elements of the primary forest road infrastructure, in accordance to the traffic load presented as gross tons per year, are divided into five categories:

⇒ I. class (>80.000 t)
⇒ II. class (60.000 – 80.000 t)
⇒ III. class (40.000 – 60.000 t)
⇒ IV. class (20.000 – 40.000 t)
⇒ V. class (<20.000 t)

Categorisation was made based on the analysis of traffic load for the primary forest road infrastructure of the management unit of Veprinačke šume (one road is class IV, while all the others are class V). The results are shown in Figure 5.

6. Conclusions – *Zaključci*

End finally, based on the results obtained, the following conclusions are derived:

⇒ Determination of forest roads by use of GPS and snap-back method presents a very fast and sufficiently accurate technique, which enables integration of the recorded forest roads and skid roads into maps of a 1:5000 scale.
⇒ Once established, the cadastral plans of forest roads enable accurate and detailed overview of the existing resources of a specific forest area, analysis of the existing state of primary and secondary forest openness as well as insight into possible needs, deficiencies and faults. It also enables planning and control of expenses of maintenance of forest roads and repairs of skid roads, development of detailed studies of harvesting operations, etc.
⇒ The method of buffered zones, combined with relative openness, is a very good indicator of efficiency of a high-quality spatial distribution of the primary and secondary forest communications.

Table 2 The load of public and forest roads at the horizontal alignment 0+00,00 hm
Tablica 2. *Opterećenje javnih i šumskih cesta na stacionaži 0 + 00,00 hm*

Road mark *Oznaka ceste*	10-years removal *10-godišnji etat*	10-years nett mass *10-godišnja neto masa*	Truck – *Kamion*		Track and trailer – *Kamion s prikolicom*	
			No. of cycles *Broj turnusa*	10-years gross mass *10-godišnja bruto masa*	No. of cycles *Broj turnusa*	10-years gross mass *10-godišnja bruto masa*
	m^3	t		t		t
Public road 1 *Javna cesta 1*	81,131.75	86,811	14,636	293,735	8,160	239,591
Public road 2 *Javna cesta 2*	51,880.44	55,512	9,360	187,844	5,218	153,209
Forest road VS_1 *Šumska cesta* VS_1	460.32	493	84	1,680	46	1,354
Forest road VS_2 *Šumska cesta* VS_2	1,821.63	1,949	328	6,586	184	5,394
Forest road VS_3 *Šumska cesta* VS_3	21,226.85	22,713	3,830	76,861	2,134	62,668
Forest road VS_4 *Šumska cesta* VS_4	3,348.02	3,582	604	12,122	336	9,873
Forest road VS_5 *Šumska cesta* VS_5	2,242.89	2,400	404	8,112	226	6,631
Forest road VS_6 *Šumska cesta* VS_6	4,074.09	4,359	734	14,737	410	12,036
Forest road VS_7 *Šumska cesta* VS_7	2,374.73	2,541	428	8,592	238	6,997
Forest road VS_8 *Šumska cesta* VS_8	1,200.44	1,284	216	4,338	120	3,531
Forest road VS_9 *Šumska cesta* VS_9	1,837.57	1,966	332	6,660	184	5,411
Forest road VS_{10} *Šumska cesta* VS_{10}	1,957.48	2,095	354	7,099	196	5,764
Forest road VS_{11} *Šumska cesta* VS_{11}	1,190.10	1,273	214	4,299	120	3,520
Forest road VS_{12} *Šumska cesta* VS_{12}	9,774.46	10,459	1,764	35,398	984	28,882
Forest road VS_{13} *Šumska cesta* VS_{13}	4,932.36	5,278	890	17,860	496	14,564

⇒ The survey of the opened area for the chosen skidder's winch cable length, as opposed to non-opened area, clearly illustrates which forest areas need further intervention in terms of additional secondary opening-up. Also, the presence of the so-called »multiply opened areas«, not defined as necessary, illustrates the non-productive lengths of the secondary forest roads.

⇒ The analysis of the secondary relative openness indicates that the significant amount of the forest area is opened through public and forest roads, meaning that a great portion of net harvesting volume can be winched from public or forest road. This information was also taken into account when it came to defining traffic load where, except for the landings at skid road junctions, the roadside landings were taken into consideration as concentration spots of winched net harvesting volume.

⇒ The results of the conducted survey of traffic load indicate that specific forest roads, even

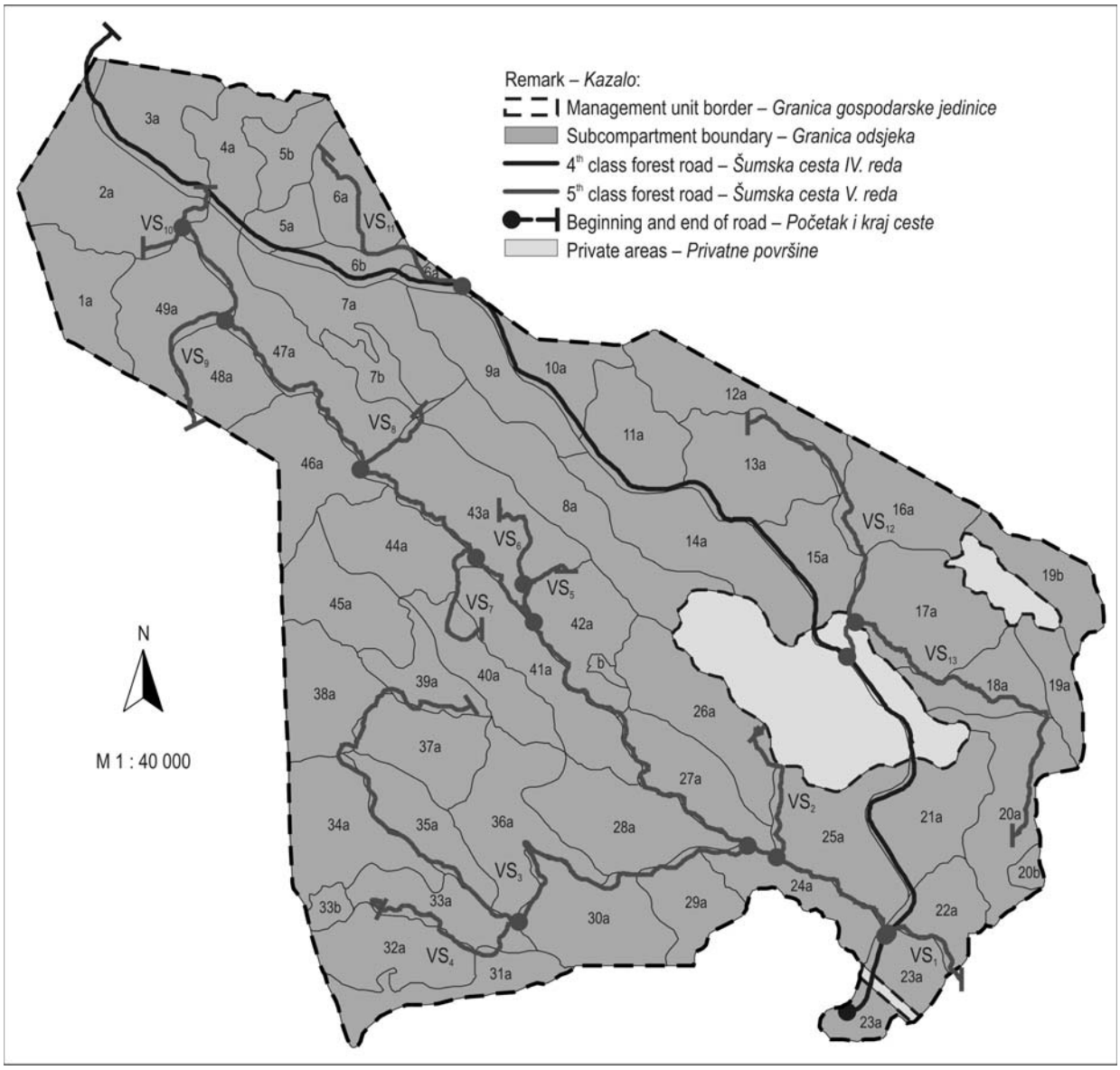

Fig. 5 The overview of the categorisation of traffic load
Slika 5. *Prikaz kategorizacije prometnoga opterećenja*

the individual sections of the same forest road, should be constructed taking into consideration different construction standards, i.e. applying different technical conditions. This would enable the rationalisation of construction expenses and consequently enable the use of the saved financial funds for the investment into further opening-up of still non-opened forest areas.

⇒ Forest roads with higher traffic frequency require regular periodical maintenance of a higher quality and in shorter intervals.

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Sažetak

Prometno opterećenje šumskih cesta kao kriterij njihove kategorizacije – GIS analiza

Izgradnja i održavanje primarne mreže šumske prometne infrastrukture te izgradnja i popravci sekundarne mreže šumskih prometnica (traktorskih putova) čine značajnu sastavnicu unutar ukupne strukture troškova povezanih s gospodarenjem šumom. Potrebno je izgraditi prostorno dobro položenu mrežu šumskih prometnica koja će svojim tehničkim značajkama omogućavati izvršavanje svih zadataka predviđenih programom gospodarenja određenim šumskim područjem. Pri dosezanju toga cilja nastoji se postići zadovoljavajuća razina kakvoće uza što manja financijska ulaganja.

Istraživanja su provedena u prebornim šumama GJ Veprinačke šume Šumarije Opatija, UŠP Buzet. Ukupna je površina gospodarske jedinice 1950,87 ha, od čega je obraslo 1899,23 ha, neobraslo proizvodno 43,36 ha, neobraslo neproizvodno 3,12 ha te neplodno 5,16 ha. Gospodarska jedinica Veprinačke šume (slika 1) dio je planinskoga masiva Ćićarije. Nalazi se između 45°20' i 45°24' sjeverne zemljopisne širine te 14°11' i 14°16' istočne zemljopisne dužine. Najviša je točka na 1144 m n. v., dok se najniža točka nalazi na 760 m n. v. Primarna otvorenost GJ Veprinačke šume iznosi 8,58 m/ha, odnosno 16,78 m/ha, ako se u obračun uzme stara talijanska javna cesta s gornjim strojem izgrađenim od tucanika. Sekundarna otvorenost iznosi 101,94 m/ha.

Cilj je ovoga rada bio izračun prometnoga opterećenja svake od sastavnica primarne šumske prometne infrastrukture primjenom GIS-a u raščlambi. Uspostavom se GIS-a istraživanoga područja, raščlambom sekundarne otvorenosti te simulacijom transporta drvnih sortimenata od sječine do sustava asfaltiranih javnih cesta određuje prometna opterećenost primarne šumske prometne infrastrukture kao podloga za planiranje i racionalizaciju troškova izgradnje i održavanja. Prometno će se opterećenje izračunati za kamionski transport drva.

Planirani su ovi radni koraci: uspostava GIS-a istraživanoga područja, određivanje položaja pomoćnih stovarišta, raščlamba sekundarne otvorenosti GJ Veprinačke šume, utvrđivanje gravitacijskih područja, određivanje prometnoga opterećenja primarne šumske prometne infrastrukture i kategorizacija sastavnica primarne šumske prometne infrastrukture.

Primarne i sekundarne šumske prometnice snimljene su GPS uređajem TrimbleGeoExplore 3 tzv. povratnom metodom u vrijeme mirovanja vegetacije prema prethodno određenomu kalendaru.

Raščlamba se sekundarne relativne otvorenosti provodi za svaku šumsku prometnicu, za pojedinu kategoriju šumskih prometnica (primarne i sekundarne), za svaki odsjek i konačno za čitavu gospodarsku jedinicu. Pri raščlambi prioritet imaju primarne šumske prometnice idući od onih višega reda k onima nižega reda. Kod šumskih prometnica istoga reda prioritet se određuje sukladno redoslijedu izgradnje. Srednja sekundarna relativna otvorenost gospodarske jedinice Veprinačke šume iznosi 72,34 %, od čega na ceste otpada 14,65 %, a na traktorske putove/vlake 57,69 %. Neotvoreno se područje proteže na 27,66 % površine gospodarske jedinice.

Pretpostavi li se homogena struktura svih sastojinskih i stanišnih čimbenika unutar odsjeka, tada se rezultati raščlambe sekundarne relativne otvorenosti mogu iskoristiti za određivanje etata, propisanoga programom gospodarenja na razini odsjeka, koji gravitira pojedinoj šumskoj prometnici. Etat koji se nalazi izvan omeđenih površina raspoređuje se na šumske prometnice sukladno njihovu udjelu u raspodjeli etata unutar omeđenih površina. Raščlamba je sekundarne relativne otvorenosti i raspodjela etata prikazana u tablici 1.

Opterećenje primarne šumske prometne infrastrukture izračunato je za dvije inačice. U prvoj je inačici kao sredstvo daljinskoga transporta drva korišten kamion, dok je u drugoj inačici sredstvo daljinskoga transporta drva kamion s prikolicom (slika 4). Vrijednosti su neto mase izvezenoga drvnoga obujma izračunate prema izvezenomu etatu svake od cesta na njezinoj početnoj stacionaži, pri čemu je za preračun mase iz obujma korištena prosječna obujamna težina bukve u sirovom stanju od 1,07 t/m^3 (Anon. 1966).

Broj je kamionskih tura ukupan broj prolazaka odabranoga sredstva daljinskoga transporta drva potreban za izvoženje ukupnoga etata (punoga transportnoga sredstva u odlasku i praznoga transportnoga sredstva u dolasku). Bruto je masa dobivena kao zbroj neto mase i ukupne mase broja kamionskih tura odabranoga transportnoga sredstva. Opterećenja su primarne šumske prometne infrastrukture pri upotrebi kamiona i kamiona s prikolicom prikazana u tablici 2.

Sastavnice primarne šumske prometne infrastrukture, prema prometnomu opterećenju iskazanom u bruto tonama/godišnje, podijeljene su u 5 kategorija:

- ⇒ *I. reda (>80 000 t)*
- ⇒ *II. reda (60 000 – 80 000 t)*
- ⇒ *III. reda (40 000 – 60 000 t)*
- ⇒ *IV. reda (20 000 – 40 000 t)*
- ⇒ *IV. reda (<20 000 t).*

Temeljem raščlambe prometnoga opterećenja za primarnu šumsku prometnu infrastrukturu gospodarske jedinice Veprinačke šume izrađena je kategorizacija (jedna je cesta IV. reda, a ostale V. reda), koja je prikazana na slici 5.

Temeljem dobivenih rezultata istraživanja mogu se izvesti ovi zaključci:

- ⇒ *Jednom uspostavljen katastar šumskih prometnica omogućuje točan i detaljan uvid u postojeće resurse određenoga šumskoga područja, analizu postojećega stanja primarne i sekundarne otvorenosti šuma te uočavanje eventualnih potreba, nedostataka i manjkavosti, planiranje i kontrolu troškova održavanja šumskih cesta i popravaka traktorskih putova, izradu elaborata radilišta pri sječi i dr.*
- ⇒ *Metoda omeđenih površina u kombinaciji s relativnom otvorenošću vrlo je dobar pokazatelj uspješnosti kvalitetnoga prostornoga rasporeda primarnih i sekundarnih šumskih prometnica.*
- ⇒ *Prikaz otvorenoga područja za odabranu duljinu užeta vitla, za razliku od neotvorenenoga, zorno prikazuje na kojim je šumskim površinama potrebna daljnja intervencija radi provedbe sekundarnoga otvaranja. Također prisutnost tzv. »višestruko otvorenih površina«, koje nisu definirane kao nužne, prikazuje neproduktivne duljine sekundarnih šumskih prometnica.*
- ⇒ *Raščlamba sekundarne relativne otvorenosti pokazala je kako je značajna količina šumske površine otvorena javnim i šumskim cestama, odnosno kako se velika količina neto etata može privući s javne, odnosno šumske ceste. Takav je podatak uzet u obzir pri određivanju prometnoga opterećenja gdje su, osim pomoćnih stovarišta, na spojevima grana trakorskih putova, kao mjesta koncentracije privučenoga neto etata, u obzir uzeta i »stovarišta« uz cestu.*

⇒ *Rezultati provedene raščlambe prometne opterećenosti pokazuju kako određene šumske ceste, pa čak i pojedine dionice iste šumske ceste, treba graditi poštujući različite standarde gradnje, odnosno primjenjujući drugačije tehničke uvjete. Time je moguće racionalizirati troškove izgradnje te tako sačuvana financijska sredstva investirati u daljnje otvaranje još neotvorenih šumskih područja.*

⇒ *Na šumskim cestama s većom frekvencijom prometa potrebno je provoditi češće periodično i kvalitetnije tekuće održavanje.*

Ključne riječi: šumska prometnica, prometno opterećenje, kategorizacija, relativna otvorenost, daljinski transport drva

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