Planning Forest Opening with Forest Roads

Janez Krč, Jurij Beguš

Abstract – Nacrtak

The article presents the model for determining inaccessible forest areas by density of forest roads. The model is based on the GIS analysis of the distances between the existing network of public and forest roads and inaccessible forest areas, sizes of excluded forest areas, and forest site potentials. In order to increase forest road density, the following must be done: (1) construct connecting roads to the inaccessible forest areas and (2) construct new forest roads with different density in the excluded inaccessible forest areas. The model provides the minimum size of the inaccessible area located at least 300 m away from the existing forest and public road. The selected inaccessible forest areas are first analyzed according to their size – plot size of at least 30 ha is used as a model default size suitable for economically justified construction of the access road that connects the existing road network to the inaccessible forest area. The analysis showed that there are still 210,385 ha of inaccessible forests in Slovenia according to the model criteria. According to the research of regional units conducted by forest experts and based on the determination of priorities for the next ten-year forest management plan, the construction of 758 km of new forest roads is planned at the national level.

Keywords: forest road, density, forest operation, model, forest management plan

1. Introduction – *Uvod*

The construction of forest road network is considered as the key element for successful forest management. It has the biggest impact on the forest production function, since it enables and also technologically defines the forest operations in the majority of cases. The importance of forest roads or forest road network can also be considered in terms of comparison, i.e. asset values that occur in forest operations. The simplified model can be of assistance where the forest, as a piece of land, is considered as fixed asset, whereas the forest stand, road network and working means represent the current assets – all used in forest operations. In view of the above mentioned factors, the forest management should provide the sustainability of these factors. The current asset values (forest stand, road network and working means) are in the approximate value interrelation of 100:10:1. The relation is calculated for the model example covering 2667 ha taking into account the following assumptions:

⇒ Stand: value 45,142,000 € (timber value 60 EUR/m^3, volume 282 m^3/ha) (SURS: Gozd in gozdarstvo 2013), (Poročilo o gozdovih za leto 2011, 2012);

⇒ Forest roads: value 4,300,000 € (construction costs 65 EUR/m, road density 24,8 m/ha) (Robek et al. 2007), (Gozdnogospodarski in lovsko upravljalski načrti območij za obdobje 2011–2020, 2012);

⇒ Working means: value 500,000 € (efficiency 80 m^3/day, utilization 200 days/year).

The calculation was made for the projected model of forest operations with the capacity of modern working means serving as a referential value (harvester and forwarder). The average annual volumes of allowable cut of 6m^3/ha/year were applied for the calculation of the necessary utilization of the available capacity of modern working means. On the basis of the above model assumptions, the necessary forest cutting area for forest operations is well congruent with the size of the average forest district in Slovenia and volumes of allowable cuts defined in the forest management plans (Poročilo o gozdovih za leto 2011, 2012).

The relations show the great importance of systematic approach to the issue of forest opening conducted on a strategic and detailed level. The strategic or general level is implemented at various levels of forest management planning. This should replace the current approach of integrated planning of opening the forests

with forest roads that called for the preparation of »Perspective programs for integrated opening of forests« (Program odpiranja gozdov z gozdnimi prometnicami, 1990), studies that have not been successfully implemented anywhere in Slovenia. Today, these studies can be of a great assistance and are widely used as reference points to conduct the tests of methodology presented in this article. In the forest management plans prepared by Slovenia Forest Service (SFS), the priority areas of opening are determined within the strategic planning of forest road construction. These areas represent the surfaces where the forest roads should be constructed. Due to legal procedures of adopting forest management plans, they do not include detailed routes of forest roads. At a higher level of forest management planning, i.e. at the level of regional forest management plans, the priority opening areas are not determined. However, the strategic evaluation should include the volume of new forest road construction that would provide the necessary forest road network from the point of view of timber harvesting.

1.1 Previous research – *Dosadašnja istraživanja*

Expert and scientific literature have been dealing with the issue of estimation of forest opening together with the evaluation of the density of the existing forest road network for a relatively long time (Matthews 1942, quoting Chung et al. 2008).

The research of forest opening frequently includes the relations between skidding costs and the costs of forest road construction and maintenance. Frequently, these estimations apply the assumption about the equal distribution of logging operations in a certain area. As a result, the optimum density and position of a forest road network are determined. These are calculated according to the differential ratios of timber skidding costs. Skidding costs are primarily dependant on the applied skidding method and skidding distances (Krč 1999, Košir 2000). Some studies deal with the optimum forest road network layout on the basis of the shortest path between the appropriately distributed timber sources (timber stacks at forest road) in a certain area – i.e. from the point of view of further timber transport (Anderson et al. 2004, Dean 1997).

An attempt of Preliminary Planning of Forest Road Systems Using Digital Terrain Models was conducted by Liu and Sessions (Liu et al. 1993). They set the optimal road alignment using a three step method (The first step includes the identification of possible road segments, the second step deals with the minimization of the sum of construction, maintenance and transport costs, while the third displays the results to provide the verification of result by operation planner).

The ecosystem approach to road issues was comprehensively treated by Lugo and Gucinski (2000). They proposed the unified ecosystem approach to road management using an environmental gradient analysis based on three main parameters (ecological, socioeconomic and physical).

Similar to our problem, Demir (2007) tried to find a systematic solution for the remaining portion of forest road network in Turkey. He used specific functional planning criteria for different forest road network systems (production forest, reforestation forest and national parks). The determination of road density in the production forest was differentiated by growing stock (20 m/ha for stands over 250 m^3/ha and 10 m^3/ha under 250 m^3/ha, respectively).

Previous studies also state different definitions of primary forest openness. In Croatia there are different levels of primary openness determined according to the planning level (global : local) and definition purpose (planning, research work). The openness has also been determined according to the relief regions (lowlands, hilly, highlands, Karst). The planned openness (from minimal to the target) according to relief region and projected plan is determined in the interval between 7 and 30 m/ha (Pentek et al. 2007).

The issue of including the road sections (public and forest roads) into the selection of productive values in terms of timber harvesting is dealt with by Pentek et al. (2011). Also the position of forest road plays an important role when estimating the level of forest openness. Thus, the length of productive and connecting roads is differentiated. According to Dobre (1995), the productive forest road length is considered when:

- ⇒ Road runs through the forest;
- ⇒ Road runs along the forest;
- ⇒ Forest is located less than 200 m from the road – there are no obstacles for skidding operations;
- ⇒ Non-forest zone is longer than 200 m, but shorter than 200 m along the road.

The data from recent studies were applied and partly adjusted for the preparation and verification of the following model for planning the necessary forest opening with forest roads.

1.2 Purpose and aims of planning the necessary forest opening with forest roads – *Svrha i ciljevi planiranja potrebne otvorenosti šumskim prometnicama*

At a strategic level, in forestry management planning of opening the forest with forest roads, the main question is related to the target density and consequently the total length of forest roads. This means

that the answer should include the quantity of new forest roads that will reach the goals set at different levels of planning. Basically, two questions are relevant: where the new forest roads need to be constructed, and how many kilometers of forest roads are still necessary. It is estimated that these two answers suffice at the strategic level, i.e. regional level.

In Slovenia, the contents related to the planning of forest opening with forest roads are legally defined. Thus, the Article 3 of the Regulation on Forest Infrastructure (Pravilnik o gozdnih prometnicah, 2009) differentiates the strategic and detailed level of opening. The strategic level, i.e. the level of forest management planning defines the priority areas for forest opening with forest roads, whereas the detailed level includes making the elaborate of nought line definition. Furthermore, the Article 10 of the Forest Act (Zakon o gozdovih, 1993 and following) states that the concept of forest infrastructure is shown in the spatial part of forest management plan of regional unit. At a lower level of forestry management planning – forest management plan for forest management unit provides the concept and overview for forest infrastructure. The detailed scope for planning, construction, and maintenance of forest roads is regulated by the Regulation on Forest Infrastructure.

Despite some previous attempts, the strategic and integrated planning of providing forest opening with forest roads on the basis of special programs/studies has never been truly successful and never really implemented on the national level. Current regulations try to solve the actual situation by implementing the regulations on the strategic/general planning of forest opening with forest roads to the forest management plans of forest management units with the determination of preferential areas for forest road construction. Due to formal reasons[1], the routes of future forest roads are not defined in the forest management plans, and it is, therefore, hard to make an objective evaluation of how many forest roads should still be constructed to provide the optimum operation of forest production simply by applying the currently known approaches. The plans include certain actual and target forest road densities that show the level of forest opening with forest roads, but still this data insufficiently indicates further actions. Preferential opening areas show the locations where new forest roads should be necessary, but this still does not mean that the new forest road construction would not be possible elsewhere. However, the strategic decision-making should not overlook the data of how many forest roads are still needed, i.e. not just the mere location but also the quantity that would provide the realization of the set goals. This requires a unified approach to the planning that would provide the decision-making based on the objective evaluation of needs for the increasing forest road density.

According to the legal provisions and relevant issue, the accessory tool was developed that provides a quick, unified, and consistent evaluation of all forests from the point of view of forest accessibility necessary for performing forest operations. This tool consequently enables the exclusion of inaccessible areas and hence the sequence of opening, i.e. increasing forest road density, is determined in gradual steps.

It is estimated that the present model tool is a step forward, since its consistent procedure helps to define the location of inaccessible forests with the quantification of needs for opening.

2. Materials and methodology – *Materijal i metodologija*

Slovenia is located between 45°25′–46°52′ N latitudes and 13°35′–16°35′ E longitudes. Slovenia is surrounded by neighboring countries (Italy, Austria, Hungary and Croatia) and the Adriatic Sea. It covers an area of 2,027,300 hectares and has a 43 km long coastline. It belongs to the group of the smallest EU countries (the longest width of 257 km is in the East–West direction, while the smallest range of 78 km is between the North-South direction). Slovenia has four geographical regions (Pannonian on the East, Mediterranean on the South-West, Alpine on the North, and Dinaric on the South part of the country). The total forest area in Slovenia is 1,184,369 hectares. This figure represents 58.4% of the total area. High quality forests prevail, while the coppice forests spread only over 39,432 hectares and account for 3.3% of the total forest area. According to 2011 figures, the share of coniferous forest in the total growing stock is 46.2%, whereas the deciduous forest covers 53.8 %. The total annual increment amounts to 8,265,936 m^3, whereas the annual allowable cut equals 5,498,733 m^3 (Poročilo o gozdovih za leto 2011, 2012). According to the data of the current forest management plans for regional units (Gozdnogospodarski in lovsko upravljalski načrti območij za obdobje 2011–2020, 2012), forests in Slovenia are accessible by forest roads (12,023 km) and primary prevention fire roads (489 km), which means 12,512 km or 10.6 m/ha of roads density in total. The forest area is

[1] The routes of individually planned forest roads should not be drawn in the forest management plans, since then each plan would require the environmental impact assessment.

additionally also accessible by public roads, which could be suitable for forestry operations and wood transport. In total, the Slovenian forests are accessible by 29,244 km of roads, with a road density of 24.8 m/ha.

2.1 Data selection and analysis – *Odabir podataka i analiza*

The model was developed according to the results of previous studies and new technological trends that have influenced the needs for additional forest roads. The model performed the geographical analysis of three main influential factors: (1) distance from the forest to the existing productive forest road or public road that provides forest accessibility, (2) forest site potentials (Košir 1975), and (3) surfaces of potentially inaccessible forests. The areas for further forest construction of forest roads were determined by applying the skidding distance and site potential factors. Then the priority of opening was determined for individually selected inaccessible areas that met the criterion of minimum size.

The criteria for area selection, suitable for road construction according to the values of influential factors, were somewhat adjusted in terms of previous research results, regulations, and practice (Dobre 1995):

(1) distance between the forest and the road has been increased, i.e. to 300 m,
(2) minimum inaccessible area size (30 ha) has been determined,
(3) also the public roads that can be used as productive roads for forest production have been included.

The following general data of forestry information system were applied:

⇒ Forest and public roads suitable for forest production and primary forest fire prevention roads with the status of a forest road (hereinafter referred to as »forest road«). Public roads suitable for forest production have been determined with the intersection of public road linear layer and border of the forest area. Herein, the condition has been included that the section includes 200 meter of influential buffer zone around the public roads. The final classification of public roads has been determined with the in-situ examination and confirmation of Slovenia Forest Service specialists.
⇒ Forest-stand map with the map of forest border.
⇒ Map of protective forests and forests with special purpose.
⇒ Geo-encoded data on forest sections.
⇒ Map of forest plant associations, acquired from the digital data on forest sections (spatial and attributive part).

2.2 Procedure of model preparation and application – *Postupak pripreme i primjene modela*

The preparation and basic processing of the selected data from the forestry information system is conducted first. The data preparation provides the necessary information for the determination of the position and scope of inaccessible forests in a specific area. The tools for raster processing of spatial data and DBMS modules (Database Management System) are applied for the data analysis. The attributive data are processed with DBMS modules – in terms of input data preparation as well as in terms of determination of the selected areas that are smaller than minimum projected surface for additional increasing the forest road density. The combination of basic as well as derived spatial vector and raster data of forestry informational system are applied for map preparation. Maps of model-wise inaccessible forests acquired from data processing of forest information system then serve as the basis for in-situ evaluation of the suitability of computerized model results, executed by foresters at the SFS local unit level.

The process can be divided into the following steps (Fig. 1):

1. Determination of all areas with inadequate forest road network – low access areas.
2. Exclusion of inaccessible areas that are smaller than 30 ha (model-default as the minimum size of inaccessible forest area that needs further increasing of the forest road density).
3. Determination of the necessary road density per hectare. The road density is defined by site potentials (Table 1). Each surface was given the additional 300 meters of forest road for the connection to the existing road network.
4. Preparation of the numbered list of the low access areas with inadequate forest road network in the attributive form, simultaneously shown on the map (identification key is the serial number of the low access area).
5. The examination of suitability of the low access areas and the determination/selection of reasonable low access areas (i.e. the exclusion of low access areas that cannot be considered suitable for further increasing of forest road density on the basis of computerized model and input data quality).
6. Determination of low access areas where roads should be constructed with priority in the ten-year period while the forest management plan for the regional unit is in force, in order to achieve the set goals. The determination is defined by forest management goals and by the total length

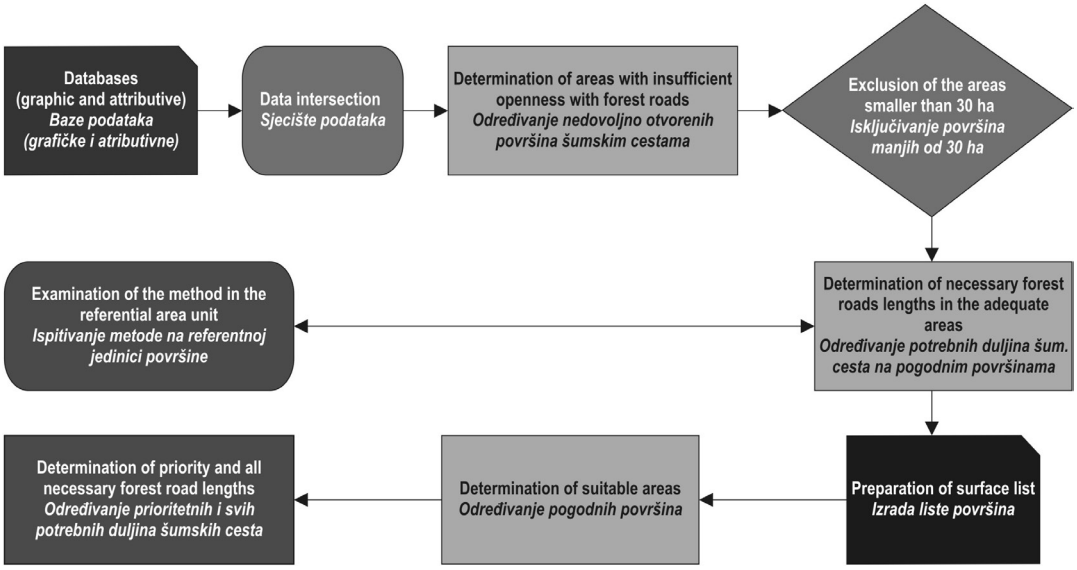

Fig. 1 Main steps of the model for determining the necessary forest road density
Slika 1. *Glavni koraci modela za određivanje potrebne šumske otvorenosti šumskim prometnicama*

of forest roads that should be constructed for this purpose (determination of priority low access areas during the validity of the forest management plan).

2.3 Definition of conditions for determining low access areas – *Definiranje uvjeta za utvrđivanje nedovoljno otvorenih površina*

Further in the text, the main characteristics are given of the model preparation and of the process for acquiring influential data used for the evaluation of the areas requiring higher forest road density. All forest and public roads (suitable for forest production) and primary forest fire prevention roads were assigned an influential buffer zone of 300 meters according to the relief conditions, thus determining an area suitable for providing good forest accessibility. It was estimated that skidding method (tractor or cable skidder) does not play a crucial role and does not influence the width of the influential buffer zone. Thus, the cable skidding operation over the distance of 400 m and tractor skidding over the distance of 600 m was encompassed (distance from the standing tree to the road). The areas outside this zone are poorly accessible by roads.

The map of low access areas was made on the basis of road intersection and 300 meter buffer zone. It determines the necessary locations of forest road construction (areas outside 300 meter buffer zone along the forest roads). Since the information layer intersections offered areas of different sizes, also with very small areas included, the size limit area had to be determined to get a reasonable idea of forest road construction. The estimation showed that the smallest low access area where the construction of forest roads would be reasonable was 30 ha. It would be unreasonable to construct forest roads on smaller areas or in other words it would be more reasonable to provide their opening with skid trails.

During the development of this method, the result of suitability had to be checked with a referential study. The Study of Integrated Forest Opening with Forest Roads, i.e. »Program of Forest Opening with Forest Roads« (hereinafter referred to as »Program«), developed by the Regional Unit Kočevje in 1990 (Pro-

Table 1 Target forest road densities (TFR) according to the level of the forest site potentials

Tablica 1. *Ciljana gustoća šumskih prometnica (CGŠP) prema razinama potencijala šumskoga područja*

Site potentials *Potencijal područja*	Target forest road density, m/ha *Ciljana gustoća šumskih cesta,* m/ha
< 5*	0
5–8	15
9–11	20
>12	25

*The exception is the Karst region where the opening was planned also for the areas with the lowest level of site potentials (fire protection function).
** Iznimka je krško područje gdje je otvaranje planirano kao za područja s najnižom razinom potencijala područja (protupožarna funkcija).*

gram odpiranja gozdov z gozdnimi prometnicami, 1990), was used as the referential study. The study map was compared with the model map of areas that needed opening. The method was also presented to the forest road specialists and field foresters at the Regional Unit Kočevje and thus the independent opinion on the applied methodology had been acquired already in the process of model development. The comparison of the study and the map of 300 m zone showed a high degree of accordance of inaccessible areas in terms of both location and shape. Also the length of necessary forest roads established by the Program was examined and a relatively high degree of agreement was confirmed – the Program foresaw the construction of 331 km of forest roads, whereas the model offered the result of 376 km.

To establish the final result, i.e. the required length of forest roads to be constructed, it was necessary to determine the required forest road length for each selected area of 30 ha or larger. The assumption was accepted that the management of better forest sites was more intensive, thus justifying the higher forest road

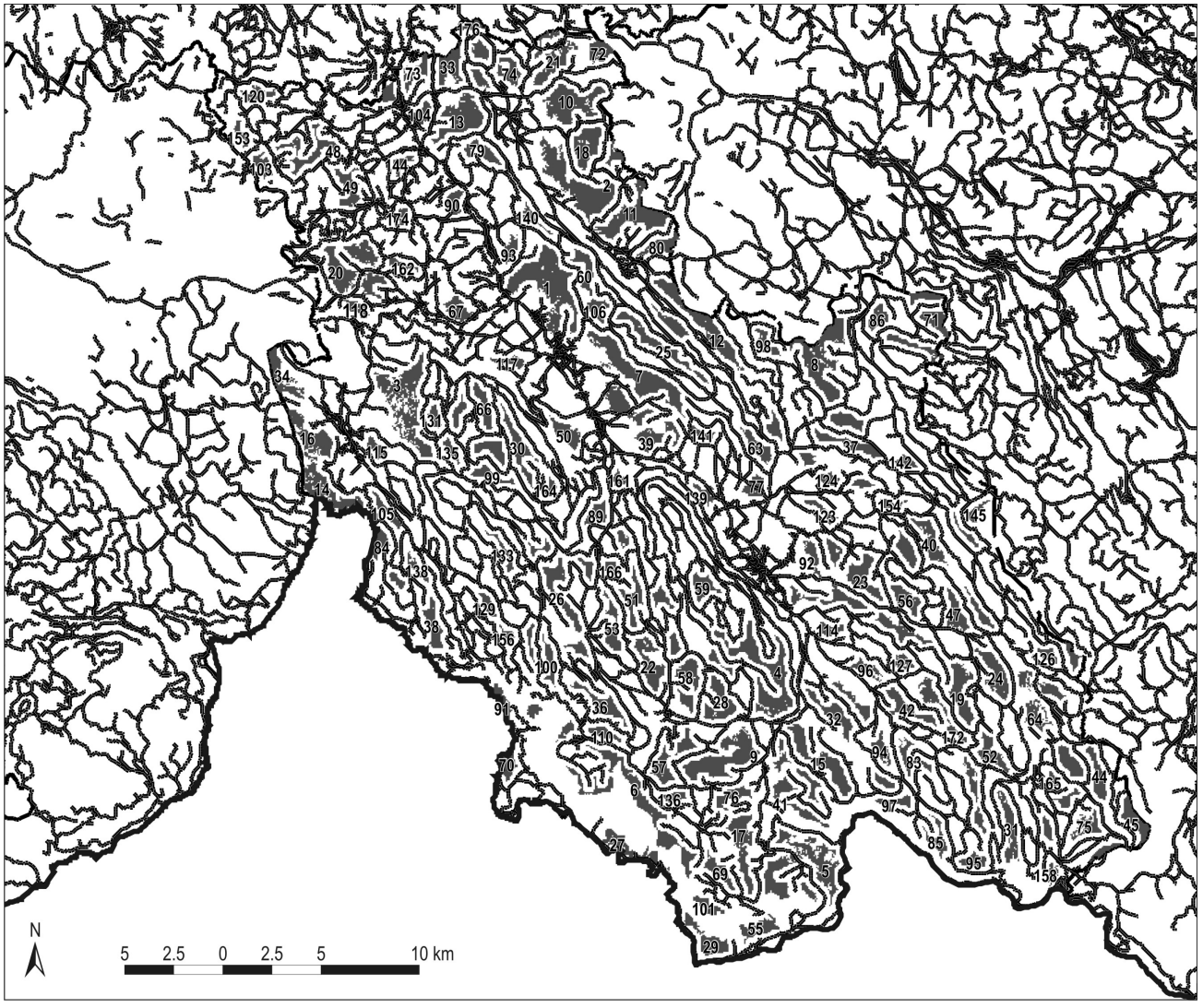

Fig. 2 Example of the map with the numbered selected areas in the Regional Unit Kočevje with road network at the regional level
Slika 2. *Primjer karte s obrojčanim odabranim područjima u Upravi šuma Kočevje s cestovnom mrežom na razini Uprave*

Table 2 Example of the selected areas list in the Regional Unit Kočevje according to the level of site potentials with the planned length of new roads

Tablica 2. *Primjer popisa odabranih područja u Upravi šuma Kočevje prema razinama potencijala područja s planiranim duljinama novih cesta*

	Level of site potentials, selected areas, ha *Razina potencijala područja, odabrana područja,* ha								New Forest Roads, km *Nove šumske prometnice,* km		
No. *Br.*	1	3	5	7	9	11	15	17	New *Nove*	Access *Pristup*	Total *Ukupno*
1	0	0	0	0	143	448.75	0	0	11.84	0.3	12.14
2	0	0	0	0	116.5	355.25	0	0	9.44	0.3	9.74
3	0	0	0	88.5	164	207.25	0	0	8.75	0.3	9.05
4	0	0	0	0	255.5	190.75	0	0	8.93	0.3	9.23
5	0	0	34.25	26.5	169	43.75	0	169.5	9.40	0.3	9.70
...											
174	0	0	0	0	15.5	14.75	0.75	0	0.62	0.3	0.92
175	0	0	0	0	0	31	0	0	0.62	0.3	0.92
176	0	0	0	0	30.5	0.25	0	0	0.62	0.3	0.92
177	0	0	1	0	25.75	4	0	0	0.61	0.3	0.91
178	0	0	5.5	0	24.5	0	0	0	0.57	0.3	0.87

densities (Table 1). The level of the forest site potentials was acquired from the forestry information system defined on the basis of forest vegetation associations (Košir 1975). The value of forest site potential is a rank that represents the relative ratio of forest vegetation associations based on forest site production potential. The ranks are scaled from 1 to 17. The most productive rank is 17, while the least productive one is 1. The value is assumed as a long-term management goal, determined by the composition of tree species which is close to the potential natural state of forest stand (Košir et al. 2006).

When each area was adjusted with the necessary forest road length, the numbered list of these areas needed to be prepared. As the attributive basis, this list was connected to the graphic information layer (Table 2, and Fig. 2) with all areas appropriately numbered.

The attributive list of the selected areas includes the data on the site potentials and data on forest road lengths. The list is necessary to provide clear and precise positioning of the areas in the region.

In the next phase of the method, it is necessary to assess the suitability of the selected areas. Not all forest areas that are more than 300 m away from forest roads are appropriate for opening. Apart from the minimum area size factor (30 ha), the shape of the selected areas must also be taken into account. The typical example are the areas between two roads that can be very narrow and long; this is especially obvious for forest roads that run along both sides of long ridges – Number 34 in Fig. 3.

This is the stage where the estimation with the application of computer tools does not suffice, and the estimation of the in-situ experts is required. They decide which areas are actually suitable for opening. All the selected areas the experts find unsuitable for opening, mainly due to their shape, are excluded from the list and map.

The final, adjusted model product is represented in the form of thematic map and table, which offer spatial and quantitative recapitulation of the data on the structure of the excluded inaccessible forests according to the site conditions and calculated new forest road lengths for every selected area. Additionally, the access roads are included connecting the inaccessible sections with the existing forest road network.

3. Results – *Rezultati*

Table 3 shows the results of the described model at the national level (Slovenia). It presents the quantities of model-wise excluded inaccessible areas by regional units of Slovenia Forest Service and site potentials (Košir 1975). Then the necessary scope of new forest road construction is calculated for regional units to achieve the target road density according to the site potentials of the excluded surfaces and in the extent shown in Table 1. The scope of construction in the model is divided into the access roads and the road network that provides the forest opening. The length is determined according to the forest operations on the basis of target forest road density.

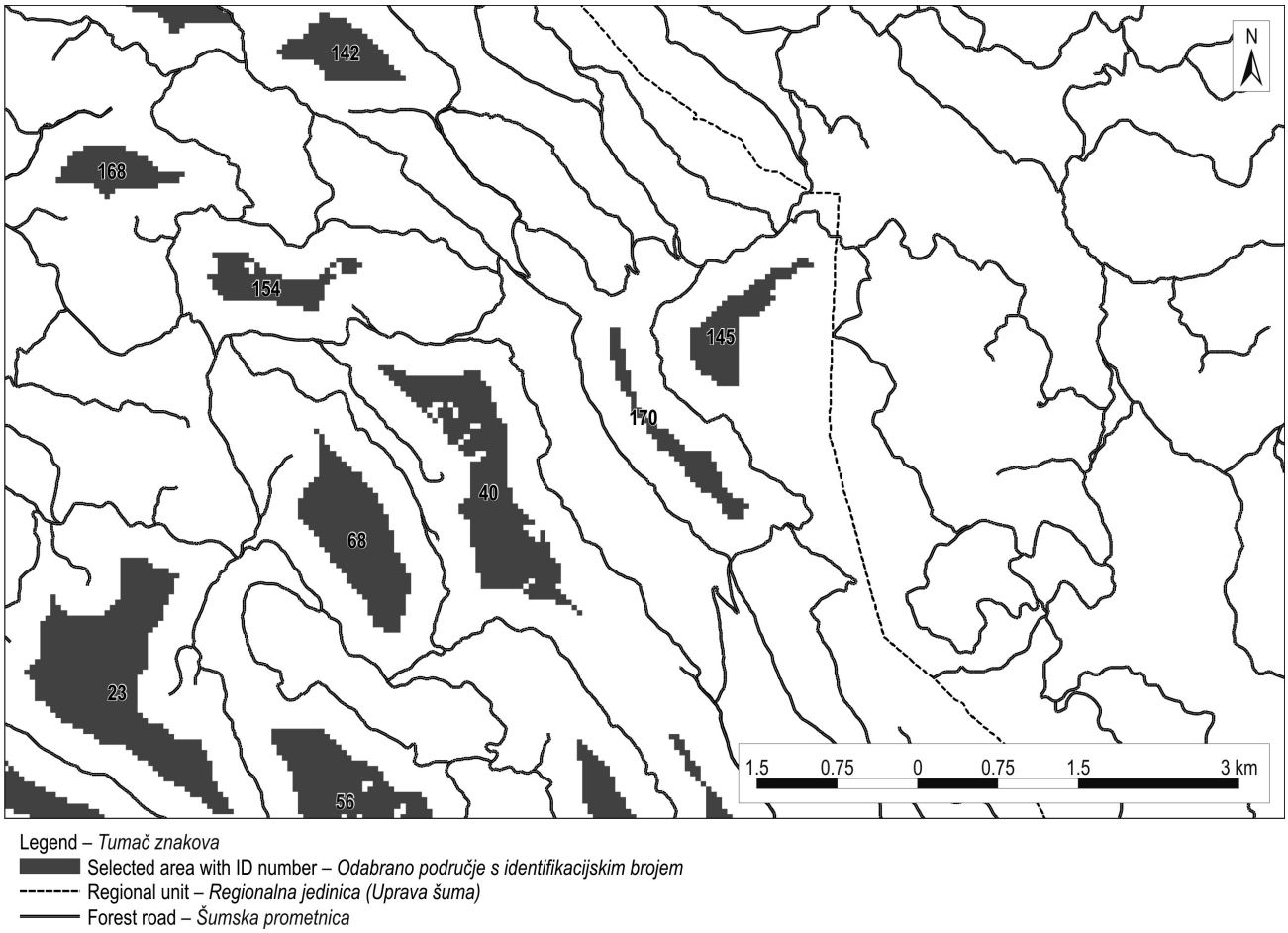

Fig. 3 Example of the area section numbered 170 unsuitable for additional opening
Slika 3. *Primjer izdvojenoga područja s brojem 170 koji je neprikladan za daljnje otvaranje*

The analysis in the Karst area additionally included the forests with lower site potentials, where the construction of primary fire-prevention roads is planned.

The majority of inaccessible areas were excluded on the sites with lower site potentials, while only a good third of the total length was excluded on the sites with the site potential level higher than 10. This only confirms the established fact that the forests located at better sites had the priority for the construction of forest roads in the past. Nowadays, more attention has to be paid to the medium potential sites.

All the necessary forest roads cannot be constructed in the following management period, since the evaluation is a long-term one and in terms of the present timber harvesting technology it represents the final solution of the forest roads density. Thus, the final product determines the areas that must be made accessible to reach the management goals, set in the current plan. That is why the priority areas for increasing forest road densities are defined together with the necessary length of new forest roads. After the final examination of the specialists of SFS in the regional units and after the determination of priorities, the final result is shown in Table 4.

In general, less than a fifth (17 %) of forest roads has to be constructed in Slovenia to ensure optimal forest accessibility. Here the area of Regional Unit Sežana stands out, i.e. the area of Slovenian Istra, Brkini and Kras, as it was neglected in terms of forest road construction. However, the forest roads and primary fire prevention roads are very important in this area, representing the key element of fire protection safety. That is why the sites with lower site conditions were also included in the calculation of forest road construction in this area.

4. Discussion – *Rasprava*

The model for planning the necessary forest opening with forest roads provides a consistent and com-

prehensive evaluation of the locations and necessary lengths of new-built forest roads for strategic and tactical forest management planning at the regional as well as the national level. Further in the text, certain characteristics are presented together with recommendations for further model development and research work in the field of forest opening with forest roads.

The basis for differentiation of target forest road densities is the potential situation and forest site potentials, i.e. the projected potential of forest sites based on plant associations – and not the current situation of forest stands wood volumes. That is why some deviations can occur from the established guidelines, which presume higher forest road network density in better stands (evaluated according to the growing stock). Thus, the model serves to adjust the forest road density to the site conditions – regardless of the current level of potential forest site exploitation.

The problem of access, connecting roads leading into the selected inaccessible areas is dealt with in a unified and simplified way. It is an approximation that will be definitively longer (minimum distance for the access road is included) in the majority of cases, since this method variant failed to include the coefficient of road winding factor, whereas in larger excluded areas the possibility was also foreseen of a greater number of connecting (access) roads to the selected inaccessible forest area.

The adjusted criteria for the selection of inaccessible forest areas were used with the purpose to determine the priorities for locations with relatively long distance from forest to roads in terms of skidding operations. Thus, the smallest area, entitled to further investments in road network from forest funds, was provided. The additional motive for criteria adjustment is due to the fact that the consequences of technological progress have also been taken into consideration. The development of logging and skidding technology also generates larger quantities of timber to be transported (on wheels) in the skidding operations. The share of ecologically and economically disadvantageous ground skidding is thus decreasing compared to the transport on wheels, causing the increase of the acceptable distance of timber skidding. In comparison with ground skidding, timber transport is a more ecological, faster, and more efficient method of timber skidding. It is expected that the longer distance between forest and road is also justified because the model does not include public cart tracks and all types of skid trails with road elements.

The gap between the current construction scope and the need for new forest road construction on the

Table 3 Results of model calculation for increasing forest road density at the national level and its structure according to the regional units
Tablica 3. *Rezultati izračuna modela za povećanje gustoće šumskih cesta na nacionalnoj razini i njihova struktura po upravama šuma*

Area, Regional Unit *Područje, uprava šuma*	Site potentials, excluded surfaces, ha *Potencijal područja, isključene površine,* ha							New Forest Roads, km *Nove šumske prometnice,* km		
	5	7	9	11	13	15	17	New *Nove*	Access *Pristup*	Total *Ukupno*
Total (Slovenia) *Ukupno (Slovenija)*	24197	36784	68126	76570	830	832	3046	3926.35	540.90	4467.25
Tolmin	4106	13997	9328	1794	0	2	37	494.95	57.90	552.85
Bled	1056	4216	1067	1575	0	0	1	131.96	26.70	158.66
Kranj	2639	3750	4690	2122	0	226	542	251.29	37.50	288.79
Ljubljana	5779	2296	16204	6428	3	241	470	591.60	84.00	675.60
Postojna	1576	2392	7057	6463	813	0	179	354.70	36.00	390.70
Kočevje	595	810	5563	11193	0	166	220	365.84	53.40	419.24
Novo Mesto	518	339	6374	24453	0	0	474	641.21	63.30	704.51
Brežice	385	336	3720	6540	0	0	15	216.38	34.20	250.58
Celje	1575	1129	2153	223	0	0	84	90.18	23.40	113.58
Nazarje	632	876	1218	1300	0	129	149	79.94	14.70	94.64
Slovenj Gradec	137	222	994	181	2	41	58	31.40	8.70	40.10
Maribor	825	2062	1607	2502	11	28	819	146.91	30.30	177.21
Murska Sobota	4376	786	1838	11797	0	0	0	350.13	18.30	368.43
Kras	0	3573	6314	1	0	0	0	179.89	52.50	232.39

Table 4 Presentation of the necessary and priority construction of forest roads and primary fire-prevention roads – regional forest management plans 2011–2020

Tablica 4. *Prikaz otvaranja potrebnim i prioritetnim šumskim cestama i primarnim protupožarnim cestama – planovi uprava za gospodarenje šumama 2011–2020.*

Regional Unit *Uprava šuma*	Forest roads – *Šumske ceste*		Primary fire prevention roads *Primarne protupožarne ceste*	
	Necessary for optimum opening *Potrebno za optimalnu otvorenost*	Priority lengths of opening in the next decade – priority areas *Prioritetne duljine otvaranja u sljedećem desetljeću – prioritetna područja*	Necessary for optimum opening *Potrebno za optimalnu otvorenost*	Priority lengths of opening in the next decade – priority areas *Prioritetne duljine otvaranja u sljedećem desetljeću – prioritetna područja*
	km			
Tolmin	370	205	–	–
Bled	96	25	–	–
Kranj	240	80	–	–
Ljubljana	125	22	–	–
Postojna	149	21	120	50
Kočevje	376	58	–	–
Novo Mesto	365	50	–	–
Brežice	197	30	–	–
Celje	91	9	–	–
Nazarje	35	17	–	–
Slovenj Gradec	41	16	–	–
Maribor	101	45	–	–
Murska Sobota	117	40	–	–
Sežana	450	140	440	325
Total – Ukupno	2,753	758	560	375
Total forest and fire roads *Ukupno šumskih i protupožarnih cesta*	3,313	1,133	–	–

basis of the present model is wide and obvious (Robek et al. 2007). Slovenia Forestry Service keeps the database on forest roads, i.e. Records of Forest Roads (RFR) that is also legally defined in the Forest Act and the Regulation on Forest Infrastructure. The user interface has also been developed to enable the maintenance of the database, designed as relation base (Beguš 2002). The data on the new constructions or increasing of forest road density are systematically acquired through RFR. The scope of new constructions is relatively small, since 2011 witnessed only 2.5 km of new forest roads (Poročilo o gozdovih za leto 2011, 2012). Therefore, the recapitulation of the model calculation has been prepared on the level of larger spatial units (forest management units), which provides the evaluation of the necessary road construction scope to meet the target density, defined in the model. According to the existing forest road construction dynamics in Slovenia, it is reasonable to include in the model a procedure, which will enable experts to define priorities for opening up inaccessible forests that can be realistically achieved during the validity of forest management plans.

Apart from the included influential factors (forest sites and skidding distances), further model development should also include additional factors related to the decision-making, planning and maintainance of road network. Some of these factors are: forest road construction and maintenance costs, forest operation technology, timber skidding methods, current stand structures, relief characteristics, skidding trail construction and maintenance costs as well as restrictions and needs depending ecologic and social forest functions. Also the forest ownership or socio-economic and size category of forest ownership definitely plays an important part.

5. Conclusions – *Zaključci*

The present model is a tool giving satisfactory results at the strategic (national) level and is also applicable at lower forest management planning levels. The model provides the possibility to determine the need for construction of new forest roads on specific areas – not only the target density. In our opinion, the most prominent added value of the model application (in view of the existing planning process) lies in its spatial determination of the needs for the additional forest opening (by forest roads).

We also assume that the model can be used in different circumstances and also at the international level. Its practical applicability was proven on the national level elaborating Regional Forest Management Plans in Slovenia (Gozdnogospodarski in lovsko upravljalski načrti območij za obdobje 2011–2020, 2012).

The contemporary perspective offers the following development possibilities of the present model:

- ⇒ Inclusion of relief characteristics (e.g. recognition of ridge points),
- ⇒ Exclusion of protected sections (differentiating the length of forest roads according to different levels of protection),
- ⇒ Differential model evaluation of road construction on different mostly rock surfaces,
- ⇒ Inclusion of timber skidding direction (shorter under; longer above the road with exception of cable skidding),
- ⇒ Differentiation of the smallest size of low access areas according to site potentials,
- ⇒ Estimation of forest functions according to forest road density,
- ⇒ Determination of priorities according to the actual accessibility (public cart tracks),
- ⇒ Preparation of the module for forest road density optimization (e.g. logging and skidding costs according to construction and maintenance costs of forest roads).

From the point of view of the model development, there are still many possibilities for improvement of the presented tool that would also facilitate the preparation of regional forest management plans. The development result will be a more complex model that would show a more reliable and detailed first version of low access areas and calculation of the necessary forest road densities and length of new road construction.

6. References – *Literatura*

Anderson, A. E., Nelson, J., 2004: Projecting vector-based road networks with a shortest path algorithm. Canadian Journal of Forest Research 34(7): 1444–1457.

Beguš J., 2002: Razvoj informacijskega sistema in podatkovnih zbirk za spremljavo stanja gozdnih cest. Master thesis. Univerza v Ljubljani, Biotehniška fakulteta, Oddelek za gozdarstvo in obnovljive vire, 130 p.

Liu K., Sessions J., 1993: Preliminary Planning of Road Systems Using Digital Terrain Models. Journal of Forest Engieenering 4(2): 27–32.

Demir, M., 2007: Impacts, management and functional planning criterion of forest road network system in Turkey. Transportation Research Part A: Policy and Practice 42(1): 56–68.

Chung, W., Stückelberger, J., Aruga, K., Cundy, T., 2008: Forest road network design using a trade-off analysis between skidding and road construction costs. Canadian Journal of Forest Research 38(3): 439–448.

Dean, D. J., 1997: Finding optimal routes for networks of harvest site access roads using GIS-based techniques. Canadian Journal of Forest Research 27(1): 11–22.

Dobre, A., 1995: Gozdne prometnice. Študijsko gradivo. Oddelek za gozdarstvo Biotehniške fakultete. 71 p.

Gozdnogospodarski in lovsko upravljalski načrti območij za obdobje 2011 – 2020, Zavod za gozdove Slovenija, Ljubljana 2012.

Košir, Ž., 1975: Vrednotenje gozdnega prostora po varovalnem in lesnoproizvodnem pomenu na osnovi naravnih razmer. Zasnova uporabe prostora – gozdarstvo. Zavod SRS za družbeno planiranje in Inštituta za gozdno in lesno gospodarstvo pri Biotehniški fakulteti, Ljubljana, 145 p.

Košir, B., Krč, J., 2000: Where to Place and Built Forest Roads – Experience From the Model. Journal of Forest Engineering 11(1): 7–19.

Košir, B., Košir, Ž., Krč, J., 2006: Natural composition of tree species as a basis for model development of stumpage price. Croatian Journal for Forest Engineering 27(2): 71–80.

Krč, J., 1999: Modelni izračun vpliva ceste na povečanje vrednosti donosa gozda, Zbornik gozdarstva in lesarstva 59, Ljubljana, 121–139.

Lugo, A. E., Gucinski, H., 2000: Function, effects, and management of forest roads. Forest Ecology and Management 133(3): 249–262.

Matthews, D., 1942: Cost control in the logging industry. McGraw-Hill Book Company, New York, 374 p.

Pentek, T., Nevečerel, H., Pičman, D., Poršinsky, T., 2007: Forest road network in the Republic of Croatia – Status and perspectives. Croatian Journal for Forest Engineering 28(1): 93–106.

Pentek, T., Pičman, D., Nevečerel, H., Lepoglavec, K., Papa, I., Potočnik, I., 2011: Primary forest opening of different relief areas in the Republic of Croatia. Croatian Journal for Forest Engineering 32(1): 401–416.

Poročilo o gozdovih za leto 2011, Zavod za gozdove Slovenije (Slovenia Forest Service) (http://www.zgs.gov.si/slo/zavod/informacije-javnega-znacaja/letna-porocila/index.html) (Accessed: 1 August 2012).

Robek, R., Klun, J., 2007: Recent developments in forest traffic way construction in Slovenia. Croatian Journal for Forest Engineering 28(1): 83–89.

Program odpiranja gozdov z gozdnimi prometnicami, 1990, Gozdno gospodarstvo Kočevje, Kočevje 1990

Pravilnik o gozdnih prometnicah, 2009, Uradni list RS št. 4, Ljubljana 2009.

SURS: Gozd in gozdarstvo (http://www.gozd-les.com/vsebina/odkupne-cene-hlodovine) (Accessed 1. January 2013).

Zakon o gozdovih, 1993, Uradni list RS no. 30.

Sažetak

Planiranje potrebne šumske otvorenosti šumskim prometnicama

U radu je predstavljen model koji određuje neotvorene šumske površine temeljeći se na analizama postojeće mreže javnih i šumskih cesta provedenima pomoću GIS-a te analizama potencijalnih bonitetnih staništa u neotvorenim šumama.

Unaprjeđenje gustoće cesta ostvaruje se preko dva oblika nadgradnje cestovne mreže: (1) izrada spojnih cesta do neotvorenih šumskih područja i (2) izgradnja novih šumskih cesta različite gustoće na izdvojenim područjima neotvorenih šuma. Dakle, model daje minimalnu veličinu neotvorene površine, koja se nalazi najmanje 300 metara od postojeće ceste. Izdvojena se područja neotvorenih šuma najprije analiziraju iz aspekta njihove veličine – površina od minimalno 30 ha uzeta je kao primjerena za izgradnju pristupnih cesta koje povezuju postojeću cestovnu mrežu s neotvorenom šumskom površinom. Povećanje gustoće cesta, gradnjom novih šumskih cesta, ovisi o šumskom ekosustavu pri čemu uzimamo u obzir njegov RK kao pokazatelj bonitetnog potencijala neotvorene šumske površine. S obzirom na bonitet staništa definirane su različite gustoće cestovnih mreža na izdvojenim neotvorenim šumskim područjima.

Model je testiran na primjeru Uprave šuma Kočevje gdje je već bio izrađen »Program otvaranja šuma šumskim prometnicama«, koji je pri testiranju rezultata analize poslužio kao referencija. Podrobnije je model analiziran na području gospodarske jedinice Kočevska reka gdje smo rezultate modela predstavili stručnom osoblju Zavoda za šume Slovenija, Uprava šuma Kočevje, i napravili procjenu usklađenosti između rezultata modela i ocjene stručnjaka, koja je prethodno dobivena terenskom procjenom položaja šumskih cesta u analiziranoj gospodarskoj jedinici Kočevska reka.

Sukladno važećim podacima šumskogospodarske osnove (šumskogospodarske i lovnogospodarske osnove za razdoblje od 2011. do 2020. godine) Slovenija ima 12 023 km šumskih cesta i 489 km protupožarnih cesta. Gustoća šumskih i protupožarnih cesta iznosi 10,6 m/ha. Šume su dodatno otvorene javnim cestama, koje u pojedinim odsjecima služe za šumarske radove, pa je tako šumska površina u Sloveniji otvorena s ukupno 29 244 km cesta, što znači da je gustoća cesta 24,8 m/ha.

Predstavljena analiza pokazala je da je u Sloveniji, prema kriterijima modela, još 210 385 ha neotvorenih šumskih površina. Stručnjaci u upravama šuma Zavoda za šume u daljnjem su postupku odabrali prioritetne površine na kojima je u idućih 10 godina gospodarenja potrebno izgraditi 758 km novih šumskih cesta.

Ključne riječi: šumske prometnice, gustoća cesta, šumske operacije, model, plan gospodarenja šumama

Authors' address – *Adresa autorâ*:

Assoc. Prof. Janez Krč, PhD.*
e-mail: janez.krc@bf.uni-lj.si
Biotechnical Faculty
Department of Forestry and Renewable Forest Resources
Večna pot 83
1000 Ljubljana
Jurij Beguš, MSc.
e-mail: jurij.begus@zgs.gov.si
Slovenia Forest Service
Večna pot 2
1000 Ljubljana
SLOVENIA
* Corresponding author – *Glavni autor*

Received (*Primljeno*): August 16, 2012
Accepted (*Prihvaćeno*): December 30, 2012