Forest Opening in Multipurpose Private Forest – Case Study

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Abstract – Nacrtak

In the past, forest opening with forest roads was planned on the basis of forest wood production. By discovering the importance of other forest roles, gradual integration of individual role into planning processes of forest opening started. The modern approach to the planning of forest opening of multipurpose forests requires a simultaneous consideration of all forest roles. Economic justification for enlarging the existing forest road network is based on the density of forest roads, where the smallest total skidding and transportation costs occur. On this basis, insufficiently opened areas outside the band width of 574 m opened by each road are excluded. Further planning of opening insufficiently opened areas is based on terrain features and technical characteristics of the planned forest roads. The construction of an individually planned forest road is economically feasible when the reduction of wood skidding costs is bigger than the increase of transportation costs. The evaluation of the planned forest road in terms of the multipurpose forest role is done with the suitability map for forest road construction. It is based on the relative importance of each forest role, determined by a multicriteria decision-making method. Selection of the planned forest roads based on the multipurpose forest role represents the quality of the new approach to the planning of forest opening.

Keywords: network enlargement, insufficiently opened areas, multicriteria decision-making

1. Introduction – *Uvod*

In the past, forest opening with forest roads was based on the economic criteria, and namely on the forest production role. The forest opening was planned with the aim to reduce skidding distances as well as skidding costs. During the period of the most intensive forest road construction in the eighties of the last century, the planning of forest opening was liable to the integration of individual farms and hamlets with a valley with the aim to keep the countryside alive.

Planning of forest opening with forest roads is limited by technical elements of forest roads, terrain characteristics, existing forest road network density and multipurpose role of forests. The impact of these elements on the planning of forest opening rises.

When planning the forest opening of a privately owned forest, the final decision on road construction is a matter of the forest owner's individual decision. In the case of small properties, it depends on the agree-ment of all forest owners. A tendency for skidding wood within one's own property is constantly present. It depends on economic indicators and specified technical characteristics of forest roads and is therefore not always possible.

2. Defining the research problem *Definiranje problematike istraživanja*

The optimum density of forest roads represents the basis for the planning of forest opening and is calculated based on the economic criteria. On this basis, excluding the insufficiently opened forest areas, the possibility of further enlargement of forest road network can be perceived. When planning the construction of forest roads in insufficiently opened areas, the required technical elements of forest roads and all forest roles have to be considered.

The basic principles of opening the forest with forest roads are the same for both private and state for-

ests. When planning the forest opening, differences appear due to the size and shape of the forest property. Desiring to manage their property independently, private forest owners try to open their forest in the way to manage wood skidding and transporting independently of the adjoining forest owners. In certain cases the forest opening is also done on account of lower accessibility indicators.

3. Previous researches – *Dosadašnja istraživanja*

Researches in the field of forest opening with forest roads are extensive and they consider forest opening separately in economical, ecological or technological point of view. Some researches of the planning of forest opening with forest roads include several criteria but in no case all forest roles have been taken into account at the same time. Optimal forest road density is important for the planning of the entire forest road network and for determining insufficiently opened forest areas.

The determination of the distances between roads is important for the reduction of skidding costs (Ghaffariyan et al. 2010). It was established in the research area that the average efficiency was 6.70 m^3/h and the average skidding costs 27.60 €/m^3 based on 591 working cycles of wood skidding with the cable yarding. The optimal distance between the roads was then calculated on the basis of the road network and skidding costs at different skidding distances of cable yarding. The minimum total costs of wood skidding in one direction were 42.88 €/m^3 at the road distance of 261 m and optimal road network density was 38.3 m/ha. In the case of wood skidding on the road in both directions, the smallest total costs were 38.48 €/m^3 at the road distance of 400 m and the average road network density was 26.8 m/ha. Research has shown that the optimal distance between roads is reduced by the increase of the total volume skidded and increased by the increase of road network costs.

Optimal forest road density is crucial for an efficient and economical management of forests (Pičman and Pentek 1996). Due to high costs of the forest road construction, maintenance costs and high production costs, forest roads must be properly planned and economically feasible. In each area, it is necessary to justify the opening solutions. The following factors have to be considered: optimum accessibility, skidding conditions and minimum costs of construction, maintenance, transport and wood skidding as well as the value of forest and forest landscape. Matsumoto and Kitagawa (2000) studied the implementation of work in private forests depending on forest accessibility. In the study, they found

that the work efficiency declines with the distance from the road. Forest work is carried out at a distance of 300 m from the road, on average 210 m from the road. Average skidding distances of 275 m confirmed a need for further enlargement of forest road network.

The optimization model of forest road network considering economical, technical, technological, environmental, ecological and sociological factors was designed by Pentek (2002). Each factor was ranked according to the terrain conditions. The suitability of individual forest road location was determined with a total number of points. The survey considered a wide range of influential factors, but not the entire set of forest roles. Samani et al. (2010) developed a model of forest road planning through the use of GIS and AHP (Analytical Hierarchy Process) method at the same time. The study with the use of AHP method considered more influential factors at the same time: the terrain slope, soil type, geology, hydrological conditions, exposition, wood stock, tree species and maps. They excluded the areas that were considered the best, good, medium, worse and the worst according to their suitability for the forest road construction. In the selected areas, forest roads were planned using classical methods. With the help of the program PEGGER and suitability map, the possibility of simultaneous application of both methods in the planning of forest roads was finally shown.

In previous researches, impact factors of the forest road density were examined separately by individual factors or in the mutual interaction of a limited range of factors. Also, optimal densities of forest roads are differently calculated and they represent the basis for further planning of forest opening with forest roads. The complete set of forest roles, defined by the policy (Pravilnik o načrtih... 2010), were not taken into account. Due to the defined multipurpose role of forests, it is important for further forest opening to consider all defined forest roles at the same time.

4. Program and method of work – *Program i metode rada*

In this study, forest roads were investigated in the selected area in the municipality of Črna na Koroškem, on the basis of forest road cadastre, maintained by the Slovenian Forest Service (Kataster gozdnih cest... 2007). The survey area was chosen on the basis of the available database, which consists of a computerized map of forest roles, forest road cadastre, map of wood skidding forms and forest management plans of forest management units. The survey area was selected on the basis of economically feasible band width of 574 m, opened by each road (Hribernik 2013).

The following factors were analyzed on the selected research area:

⇒ existing network of public and forest roads,
⇒ wood skidding costs,
⇒ forest roles,
⇒ terrain characteristics.

In the selected research area, four different forest roads were planned from two standpoints, according to terrain characteristics and specified technical characteristics of forest roads. Forest roads were planned with the help of a terrain model based on points DMV 5 (Digitalni model višin 2010). The longitudinal slope of each planned forest road was verified by the CROSS SECTION tool, showing the vertical position of the road and the slope of the terrain at each leveling point.

Efficiency of forest road planning was checked with an accessibility coefficient (Lünzmann 1968), defined as the ratio between the average theoretical skidding distances on the basis of points DMV and the average theoretical skidding distances, calculated from the average road network density.

$$K_e = \frac{c \cdot t}{2500} \qquad (1)$$

Legend:

K_e – accessibility coefficient,
t – average theoretical skidding distances calculated from points DMV to the road,
c – road density.

The average theoretical skidding distance from the points DMV to the road is calculated as the shortest distance from each point DMV to the nearest road. The calculation was made with the DISTANCE CALCULATOR tool in the MAPINFO program. The entire network of productive and merge roads is considered in the calculation. The theoretical average distance, obtained on the basis of the road network density, is calculated on the basis of the band width opened by each road (Uusitalo 2010).

The economic justification for the forest road construction is based on the difference between the existing and optimum forest road network density in the closed gravitational area. The optimal forest road network density is based on the lowest total skidding and transporting costs (Potočnik 1998). In the case of opening the selected research area, an economical argumentation is made based on skidding and transportation costs. The transportation costs include forest road maintenance costs and costs due to the permanent loss of growing area. The increase of driving costs as a result of the increased transport distance is not taken into account, since these costs are relatively small in

comparison to others (Potočnik 2004). Direct costs of forest road construction are also not calculated. Construction costs are indirectly considered based on individually planned routes of forest roads.

The costs of the permanent loss of the growing area are calculated on the basis of the area of the planned road and average value of the forest increment. It is identified with the help of the cadastral forest income by individual cadastral classes (Lestvice katastrskega dohodka... 2012) and forest areas by cadastral classes (Šegel 2000).

Forest road maintenance costs are calculated based on the planned types of forest roads and the extent of maintenance works, as given in the methodology for the calculation of the average maintenance costs (Uredba o pristojbini... 1994). The type and extent of these works are planned on the assumption that forest roads were properly planned and constructed and that forest road maintenance is carried out regularly. The calculation of maintenance costs includes the planned maintenance of one kilometer of forest roads (Uredba o pristojbini... 1994), and the price list of the selected contactors engaged for forest road maintenance in the research area (Cenik vzdrževalnih del... 2008).

The costs of wood skidding were calculated on the basis of the planned cut in the regulatory period (Gozdno gospodarski načrt gozdno gospodarske... 2007), the price list of the selected concessionaire in the national forests in the research area (Cenik delovnih ur... 2010) and the forest work quotes (Uredba o koncesiji... 2010). The type of wood skidding was determined based on a 50% terrain slope, which delimits skidding with tractor and cable yarding in economic terms (Košir 1990).

We calculated the average marked tree on the basis of planned cut for the period 1994 to 2009 in the broader research area. The average marked tree for conifers was 0.93 m³ and for broad–leaved trees 0.55m³. In the calculation of the average net marked tree, we used the calculation factor between gross and net marked tree, 0.88 for conifers and 0.85 for broad–leaved trees (Uredba o koncesiji... 2010).

The planned forest road is economically feasible when the reduction of wood skidding costs is higher with the increase of the transporting costs. The total reduction of skidding and transportation costs can provide a long-term investment compensation for the planned forest road construction.

The multipurpose forest role was evaluated by using a multicriteria decision-making (Saaty 1994). On this basis, assessments were made of all forest roles on a broader research area (Hribernik 2013). Based on the

calculated assessments and standardized values of forest roles, the suitability map of the regulatory units for forest road construction was designed according to the defined forest roles (Karta vlog gozda... 2007).

According to their suitability for forest road construction, the regulatory units were divided into four groups:

⇒ unsuitable: scoring value under 9.81,

⇒ less suitable: scoring value from 9.81 to 11.70,

⇒ suitable: scoring value from 11.71 to 13.60,

⇒ the most suitable: scoring value 13.61 and more.

The formed thematic map shows the suitability of individual areas for further forest road network enlargement according to the relative importance of the forest roles.

5. Research area – *Područje istraživanja*

The research area represents an insufficiently opened area of private multipurpose forests in the area of the municipality of »Črna na Koroškem«. The area is surrounded by the reef of Kozjapeč, public road »Koprivna – Sleme« and forest roads »Hed« and »Jankovec – Fek« (Fig. 1).

The main characteristics of the research area are:

⇒ multipurpose forest area is 67.20 ha,

⇒ planned cut in the regulatory period is 4.243 m^3,

⇒ average theoretical skidding distance from the existing road network is 529 m,

⇒ average terrain slope is 34%.

6. Research results – *Rezultati istraživanja*

In the planning of forest opening of the selected area, we tried to consider the multipurpose forest role simultaneously with terrain characteristics and limitations due to longitudinal slope of the planned forest roads. We have designed four possible routes of forest roads, which open the selected area in different ways from two different standpoints (Fig. 2).

The planned forest roads A, B and C have a common standpoint within a forest property. They open the insufficiently opened area on different heights. The forest road D is planned from another standpoint and opens up the forest of the adjoining owners.

The planned forest roads A, B and C decline in the direction towards the public road. Critical sections for road construction on the route are at the length of 260 m, where the average terrain slope exceeds 70%. The length of the planned roads varies from 1 500 m to 1 870 m, with an average longitudinal slope of 3.0% up to 6.4%.The planned forest road D in the direction towards the public road first rises with an average incline of 7.3% and for the last 660 meters declines with an average longitudinal slope of 5.2%. The total length of the planned forest road D is 2.492 m.
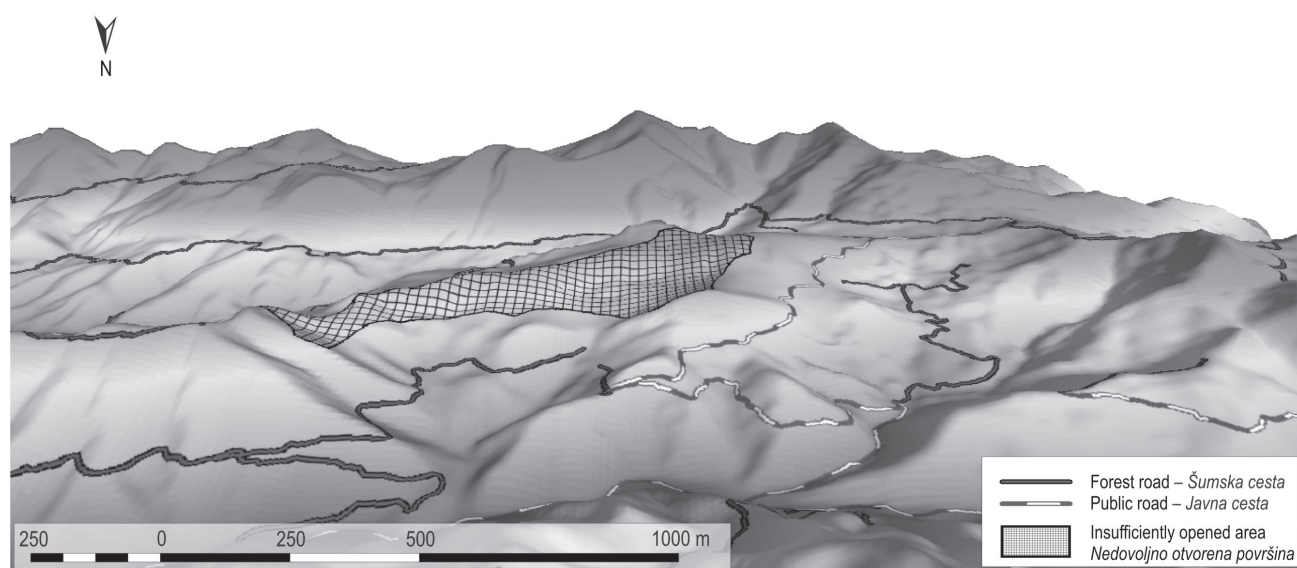

Fig. 1 Relief characteristics of research area
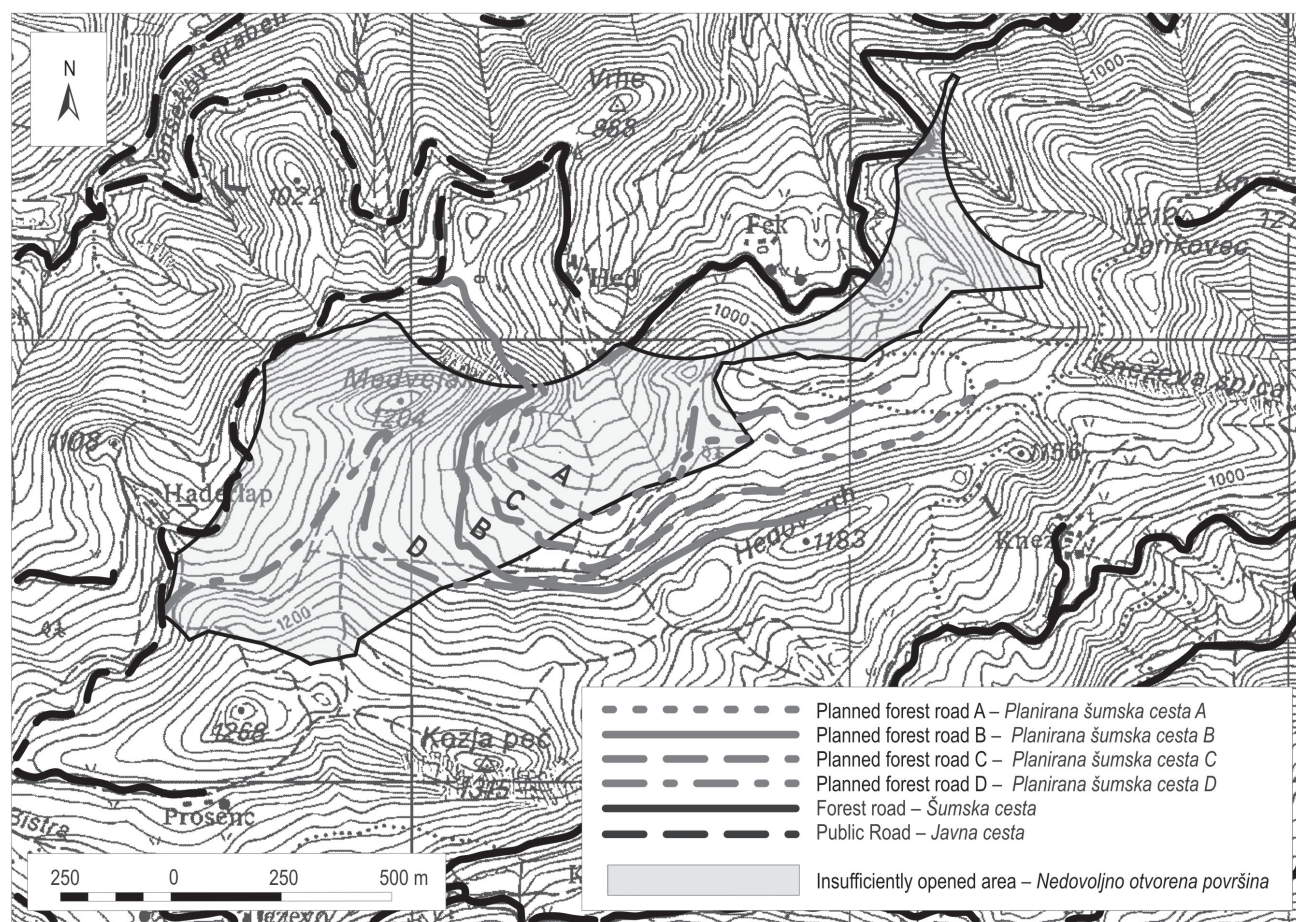***Slika 1.*** *Terenske značajke područja istraživanja*

Fig. 2 Planned routes of forest road
Slika 2. Planirane trase šumskih cesta

6.1 Technical assessment – *Tehnička ocjena*

The success of the planning of forest road opening is based on the calculation of the average theoretical skidding distance and on the accessibility coefficient. Depending on the theoretical skidding distance and accessibility coefficient, the most suitable route of forest road D was planned. It represents the shortest skidding distance of 168 m and the most favorable accessibility coefficient of 1.37. The longest average theoretical skidding distance is reached with 250 m on the planned forest road C. The highest accessibility coefficient is 1.82 on the planned forest road B and is thereby the worst among all four planned forest roads.

On the basis of the slope map, further assessment of the suitability for road construction was made. It depended on the total length of the planned forest road sections by terrain slope gradient (Fig. 3).

A detailed analysis of the planned forest roads points to different suitability of individual routes, be-cause of the terrain slopes, planned excavation and the height of excavated side slopes. The planned forest roads A, B and C are on extremely steep terrain in certain sections. The maximum terrain slope on the planned forest road A reaches up to 120%, and on the planned forest road B and C even up to 140%. From this point of view, the most favorable planned forest road is D, where the highest terrain slope does not exceed 60%.

6.2 Economical assessment – *Ekonomska ocjena*

Assessment of the economic suitability of the planned forest roads was made on the basis of total reduction of skidding and transporting costs. Due to the defined terrain slopes, the research area is suitable for skidding wood with a tractor. The planned forest road construction retains the type of wood skidding, since due to the reduced skidding distances, wood skidding costs are reduced as well. The enlargement of forest road network also increases the transportation costs.
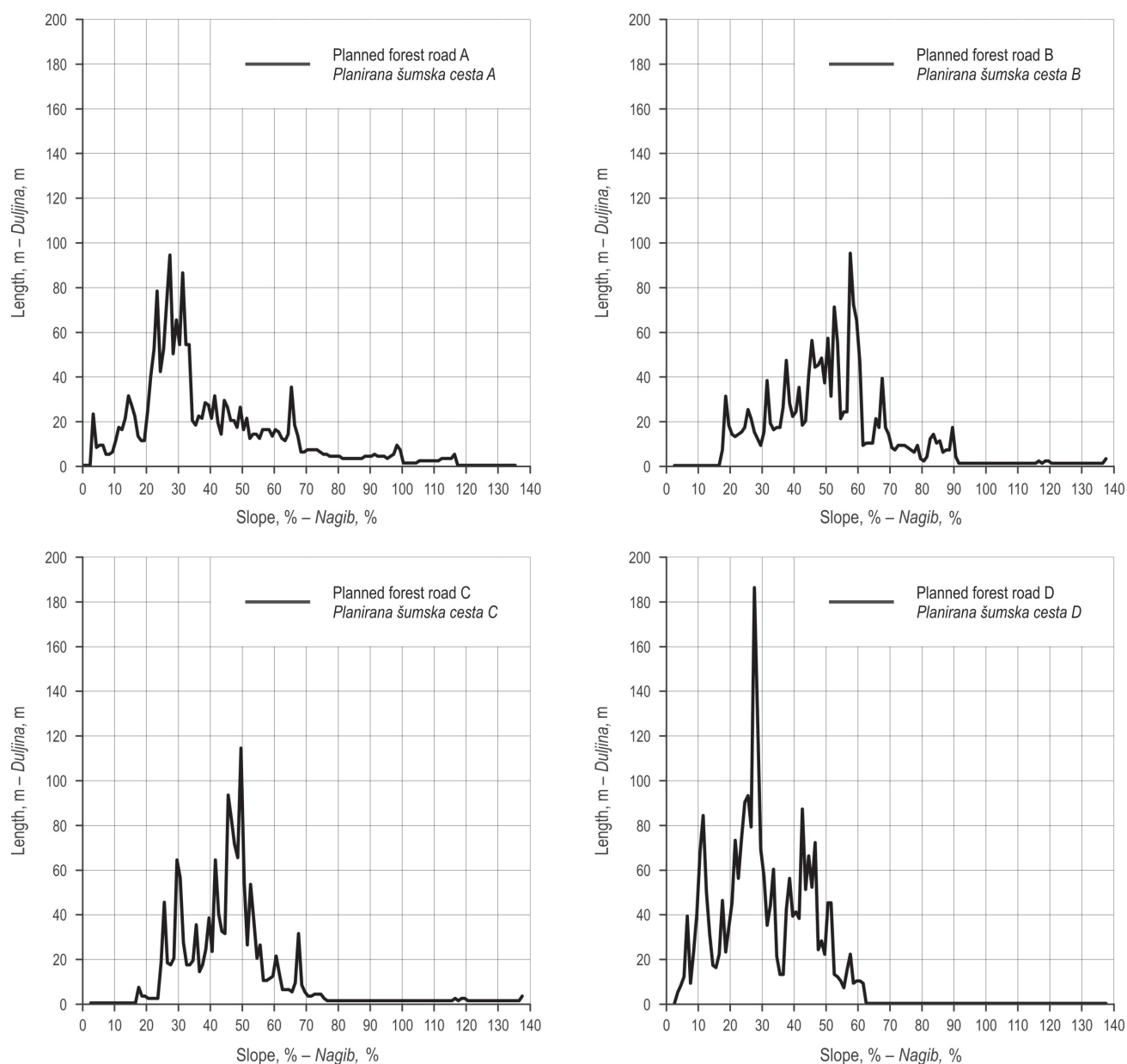
Fig. 3 Section lengths on planned forest roads by different terrain slopes
Slika 3. *Duljine sekcija planiranih šumskih cesta s obzirom na različite nagibe terena*

Reduction of wood skidding costs is higher on all planned forest roads than the increase of transportation costs. Therefore, the construction of each planned route is economically feasible. The highest total cost reduction of 319 € is expected on planned forest road C, while the lowest savings of 69 € are expected on the planned forest road D. When calculating the costs of the planned forest road construction, it is possible to select the economically most favorable planned forest road, with a fast return of construction costs.

6.3 Assessment based on multipurpose forest role – *Ocjena temeljena na multifunkcionalnoj ulozi šume*

The success of laying the planned forest roads was checked with a suitability analysis, based on the multipurpose forest role. The suitability scoring value for each of the planned roads was calculated as the average scoring value of individual road sections, assessed by the length of road sections. Besides the average scoring

value, it is important to determine the lowest scoring value of regulatory units through which the forest road is planned based on the multipurpose forest role.

Regarding the multipurpose forest role, the planned forest road D is the most appropriate. Its average scoring value is 13.52. The least suitable is forest road B with the scoring value of 12.85. In addition, the planned forest road D has the highest average scoring value as well as the highest minimum scoring value of 12.92. This may limit the road construction on individual sections of the planned forest road because of the limitations of individual forest roles.

6.4 Final assessment – *Ukupna ocjena*

The planned forest roads in the research area differ in a number of items. From the technological aspect, the preferred route is the planned forest road D, which provides the lowest accessibility coefficient at a maximum total length. Greater total length also means the increase of total transportation costs and forest road maintenance costs. The construction of the planned forest road D is economically feasible by the annual reduction of skidding costs, which exceed the increase of transportation costs. Based on the economic indicators, the planned route C brings the maximum savings due to the cost reductio.

Direct construction costs were not calculated for any of the planned forest roads. Difficulties in the road construction were assumed on the basis of the total length of the road sections by terrain slope. The estimated construction costs of the planned forest road D are the lowest due to lower terrain slope, despite the maximum total length of the planned route. The main problem of the remaining three planned forest roads is crossing the terrain slopes over 100%. In addition to high construction costs, more problems with the stability of excavated and causeway side slopes arise.

The assessment of the planned forest roads on the basis of the multipurpose forest role also demonstrates greater suitability of the planned forest road D. The planned forest road D has the highest average scoring value and the least critical road sections with the lowest scoring value.

Irrespective of technical and economical assessments and results obtained on the basis of multipurpose forest role, the final decision on the selection of the planned forest road is a matter of agreement between the owner and co-owners and their cooperation.

7. Discussion – *Rasprava*

Forest opening with forest roads was planned in the research area, which represents the selected insuf-

ficiently opened area of multipurpose forests. In the planning of opening of the selected area, we tried to determine the forest road route that would consider the multipurpose forest role as much as possible. At the same time, we also considered the terrain characteristics and limitations of forest road longitudinal slope. Due to specific location of the research area, the planning of the forest opening was made from two different standpoints on the public road and with four planned forest road routes that suit the individual assessment criteria in different ways.

The planned forest roads A, B and C in comparison to forest road D have lower overall length but they cross the area with a larger terrain slope. Due to the more favorable location, the planned forest road D has the shortest average skidding distance and the most favorable accessibility coefficient (K_e = 1.37) and also the largest decrease of skidding costs. The planned forest road C shows the maximum difference between the annual skidding costs reduction and the annual transportation cost increase, but the construction is planned in areas with a higher terrain slope. According to the complexity of the road construction, the road D has the most advantages and the maximum terrain slope does not exceed 60%. In the light of all forest roles, the final assessment shows that the planned forest road D is the most acceptable because it is planned through regulatory units that are the most acceptable for the construction of forest roads.

The final decision on the selection of the planned forest road is not an easy one and remains a matter of forest owner's decision based on advantages and disadvantages of the planned forest roads, depending on the economic and technical criteria and the multipurpose forest role. Regarding general suitability of the research area, all four planned forest roads are acceptable in terms of the multipurpose forest role.

8. Conclusion – *Zaključak*

Planning the opening of multipurpose forests with forest roads is basically the same for national and private forests. First of all, the forest opening must be economically feasible and planned in accordance with the specified technical characteristics of forest roads and terrain features. According to a defined multipurpose forest role, for planning further forest opening it is necessary to consider all forest roles simultaneously and equally.

The final results of the planning of forest opening are different routes of the planned forest roads, which open up the forest successfully in different ways. In

the national forests, the final decision on the selection of the planned forest road route is a matter of technical and economic assessment and assessment of the multipurpose forest role. The final choice in private forest is additionally affected by the owner's desire to open the forest within his property. Final decisions are, therefore, in certain cases made on the account of lower accessibility indicators.

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——————————————————————— **Sažetak** ———————————————————————

Otvaranje višefunkcionalnih privatnih šuma – studija slučaja

Prijašnja otvaranja šumskih područja šumskim prometnicama planirana su na temelju proizvodnje drva iz šuma. Isticanje važnosti ostalih funkcija šuma (zaštitne, turističke i sl.) rezultiralo je postupnom integracijom individualnih uloga u proces planiranja otvaranja šuma. Suvremeni pristup pri planiranju otvaranja višenamjenskih šuma zahtijeva istodobno uzimanje u obzir svih funkcija šumskoga područja. Ekonomski argumenti proširenja postojeće mreže šumskih cesta temelje se na gustoći šumskih cesta na kojoj se ostvare najmanji ukupni troškovi privlačenja i transporta. Temeljem navedenoga isključena su nedovoljno otvorena područja izvan širine pojasa od 574 m koji svaka cesta otvara. Buduće planiranje otvaranja nedostatno otvorenih područja temelji se na terenskim značajkama i tehničkim obilježjima planiranih šumskih cesta. Izgradnja individualno planirane šumske ceste ekonomski je opravdana kada je smanjenje troškova privlačenja veće od povećanja troškova prijevoza. Vrednovanje planirane šumske ceste u smislu višenamjenske uloge šumskoga područja izvedeno je s kartom pogodnom za izgradnju šumske ceste. Istraživanje je temeljeno na važnosti svake funkcije šumskoga područja koje je utvrđeno metodom višekriterijskoga odlučivanja. Odabir planiranih šumskih cesta na osnovi višefunkcionalnih uloga šumskoga područja dodana je vrijednost novomu pristupu planiranja otvaranja šuma.

Ključne riječi: proširenje mreže, nedovoljno otvorena područja, višekriterijsko odlučivanje

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