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CONTENTS

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DETERMINATION OF THE OPTIMAL DENSITY OF FOREST ROADS FOR SKIDDING BY METHOD OF MINIMAL COST

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ABSTRACT: This paper presents the methodology for theoretical determination of the optimal density of skidding roads by method of minimal cost skidding of wood assortments. Whit research is developed a model of skidding with a tractor Ford 5600 in real work in mountainous conditions in the Republic of Macedonia. An analysis is made of all the costs that are made in the phase of skidding and the costs of building and maintaining skidding roads. The optimal density of the road network for skidding is calculated using differential estimations from the total costs for skidding. In this research, a connection is made between the density of the skidding roads and the volume of wood to be used when managing the forests. This paper reviews the impact of already built skidding roads on the environment as a factor that must be considered when choosing the optimal density of skidding roads. In a situation where the horse skidding in the forest practice is gradually abandoned, there is a need of displacement with mechanization for skidding. Hence, the determination of the optimal density of skidding roads Gdp and the optimal distance between skidding roads Rdp represents a useful tool in the designing of skidding roads in practice.
Keywords: skidding roads, optimal density, tractor, minimal cost, forest.

1 INTRODUCTION

Secondary transport is an activity by which the wood that had been cut in the forest is transported to the temporary depot.

There is a specific solution for secondary transport when skidding with a tractor or similar skidding devices of transport, for which in order to move on the terrain without performing great violation of the surface, an adequate skidding road network needs to be built.

The cases when great violations and damages in the Macedonian forests have been made because of inadequate analysis of the secondary road network optimization are not rare.

In praxis, the analysis of the optimal building of skid roads should be considered as a whole, with both an economic and ecological solution (Demir M. [8]).

Seen from an ecological viewpoint the optimal density of skidding road network means building as less unproductive roads as possible, by which the usurpation of the forest surface would be reduced. When designing the skidding roads there must be measurements for protection from land erosion of the forest soil and the road foundation. In the end, conservation and protection of the skidding roads from destruction and erosion processes need to be done.

The optimization of the secondary road network viewed from an economic viewpoint means finding a relation between the skidding costs and the skidding roads costs at which there would be minimal costs per unit product.

This means that with a mathematical calculation before the designing of the skidding roads were determine the optimal density of the skidding roads, i.e. the optimal distance of the skidding roads in the area.

There is also an extra analysis of the influence of more parameters which affect the solution: the relief, the wood allowable which is planned for a cutting, the effect of work with a particular skidding means of transport with a specific technology of work.

Input parameters when planning the skidding roads are both the existing road infrastructure, as well as the planned truck road network according to the general plan for forest opening (Pentek T. [26]).

Bearing in mind all these parameters and principles the designer approaches towards designing a secondary plan for forest opening.

The results that are achieved with the mathematical calculations are refer to an ideal model, but at the real planning there will be a deviation from the results.

The minimum cost method have the shortcomings because are not included parameters such as: protective function, social, tourist, recreational, agricultural and others.

2 MATERIALS AND METHODS

In this study the basic methodology is established on differential estimations i.e. determining the minimal costs which are made during the phase of skidding of wood assortments, in order to determine the optimal density of skidding roads in the mountain regions of Republic of Macedonia. The basic theoretical model is taken from the research of (Akimovski R. [1]) as well as scientific research on: (Segebaden G. [33]), (Akimovski R. [2]), (Jeličić V. [13]), (Lovric N., [21]), (Bojan S. [5]), (Krč J. [15]), (Jeličić V. [14]), (Picman, D. [29]), (Chung W. [7]), (Krč J. [16]), (Danilović M. [10]), (Trajanov Z. [22]) and (Lepoglavec K. [20]).

In the field, different models have been researched depending on: the type of assortments which are a subject of skidding (firewood and technical wood), as well as the determination of the influence of the factor ‘gradient of the terrain’ in relation to the optimal density of skidding roads. At the gradient of the terrain there are models of cable winching of wood assortments in increase and in fall, and there is also a model of cable winching of wood on flat terrain with a deviation of $\pm$ 5% of the terrain gradient. The slope of the terrain is determined using the Abney level (clinometer).

During the research, as fixed parameters we considered the following: the costs that are made at the skidding of wood assortments, the training of the staff, the influence of the skidding means of transport, as well as the use of the assortment method as one of the most included technology of work in the forest practice in the Republic of Macedonia. The basic model that was considered at the estimations refers to the average use of the volume of wood of 300 m^3/ha in the period of a

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hundred years where the assortment structure is 50% firewood and 50% logs.

During this research we used the adjusted agricultural tractor Ford 5600, produced in 1985. The tractor is equipped with a warping drum, type Maxwald A516-50, the rope has a length of 100 meters. The skidding with the tractor is performed by four workers. One of them steers with the tractor, another is at the warping drum, and the other two pull the rope from the warping drum to the load, prepare the load and help with the unload.

The input parameters that have been used in these estimations are achieved by direct measurements on the terrain, as well as using an appropriate literature and scientific findings from this area. Comparable research from this problematics has the authors: (Bekar D. [4]), (Samset I. [32]), (Bojanin S. [6]), (Krpan A. [18]), (Krpan A. [19]) and (Pentek T. [25]).

The use of the method of differential estimations is considerably made easier by using the contemporary software tools from the field of mathematics. On this occasion we used the program Wolfram Mathematica 8. Despite the fast estimations it can perform, this program also enables us to create graphic displays which are used in the chapter 'Results'.

The direct costs, on which depends the determination of the skidding roads density, are related to: the costs of building and maintaining the skidding roads and the costs of the wood assortments cable winching to a skidding road. The other skidding costs have no influence on the optimal density of the skidding roads, which is why they are not considered in this analysis.

The costs for skidding roads are estimated with the following equation (1):

$$Tdp = \frac{Cdp\,1 \cdot Gp}{Q} + \frac{codp\,1 \cdot Gp \cdot tod}{Q} \quad (1)$$

In the equation the symbols have the following meaning:
Tdp – total costs for skidding roads
Gp – density of the skidding roads at one hectare
*Cdp*1 – costs for building one metre skidding roads
*Codp*1 – costs for maintaining one metre skidding roads
tod – duration time for maintaining the skidding roads
Q – volume of wood which is used for a period of a hundred years at one hectare.

The costs for the wood assortments cable winching are estimated with the following equations (2):

$$Tpr = \frac{Tden_{pr}}{n_{pr}} \quad (2)$$

In the equation the symbols have the following meaning:
Tpr – The costs for the wood assortments cable winching
$Tden_{pr}$ - direct costs per day when skidding with a tractor
n_{pr} - daily norm for skidding with a tractor

The data about the time needed for cable winching of the wood assortments with a tractor is achieved by terrain research. The achieved data has been mathematically estimated by means of regressive analysis. It is presented as function (3) for driving with the load (going) and function (4) for driving without the load (returning):

$$fode_{pr} = a_{pr} \cdot dd_{pr} + b_{pr} \quad (3)$$

$$fvra_{pr} = c_{pr} \cdot dd_{pr} + d_{pr} \quad (4)$$

A_{pr}, b_{pr}, c_{pr}, d_{pr} - parameters of a linear function for a tractor
dd_{pr} – skidding at a distance

If we replace the analytical form for estimation of the norm, the equation (5) would be acquired:

$$Tpr = \frac{Tden_{pr} \cdot x}{\frac{(T - T_{pz}) \cdot k_{pr}}{fode_{pr} + fvra_{pr} + Tu_{pr} + Tr_{pr}} \cdot qtov_{pr}} \quad (5)$$

In the equation the symbols have the following meaning:
x/(1-x) – coefficient of the area which is being skidded in increase or in fall
T - working hours during the day
Tpz - preparation-finish time
k_{pr} - coefficient for exploitation of the working hours at the skidding with a tractor
Tu_{pr} - time necessary for loading the tractor
Tr_{pr} - time necessary for unloading the tractor
$qtov_{pr}$ – size of the load of the tractor

Considering that at the wood assortments cable winching with a tractor various work effect at different cable winching operations, such as cable winching in increase, cable winching in fall, cable winching of logs and cable winching of firewood, could be achieved, various work norm during the work day could be achieved as well. A need arises for the equation (6) to be completed for different skidding operations depending on the estimations. Such model has been elaborated on in the paper (Trajanov Z. [23]). For the purposes of this research estimations have also been made for cable winching on flat terrain of logs and firewood.

$$Tsum = Tpr + Tdp \quad (6)$$

2.1 Optimization of the skidding road network

The optimal density of the skidding road network is estimated using differential estimations from the total costs for skidding transport, separately for every mode. The equation (7) is used for estimating the optimal density of the skidding road network.

$$\frac{DTsum}{DGdp} = 0 \quad (7)$$

2.2 Input parameters for estimating the optimal density of skidding roads

The maintaining of the skidding roads necessary to be conducted during the whole cycle of forest management. No matter what type of (main) regeneration cutting in the forest we are discussing about: selective cutting or clean cutting. Because in the whole cycle there is a necessity to create previous cultivating (thinning) cuttings as well as to conduct protective measures in the forest. Forest roads with a lower quality are needed for such activities. The quality of the roads at certain parts of the cutting areas would be considerably improved at the performance of the main or the final cuttings.

With these researches the average costs for building the skidding roads are 1,2 Euro/m. The costs for the skidding roads maintaining about the researched period are 4 Euro/m (1 Euro = 61.7 Denars). The average direct costs per day for skidding with a tractor are 79.64 Euro. The estimated working hours during the day are 480 minutes at which the preparation-finish time is 30 minutes. The coefficient of exploitation of the working hours for skidding with a tractor is 0.7.

$$Tpr = \frac{Tden_{pr} \cdot x}{\frac{(T - T_{pz}) \cdot k_{pr}}{fode_{pr} + fvra_{pr} + Tu_{pr} + Tr_{pr}} \cdot qtov_{pr}} \quad (5)$$

Based on terrain research of the time needed for wood assortments cable winching with a tractor, a regressive analysis has been developed according to the equations (3) and (4).

Table I: Index values for cable winching with a tractor in increase and in fall

cable winching	apr	bpr	cpr	dpr	tupr	trpr	qtovpr
op	1,06	31,58	2,52	-7,59	335	72	1,1
ou	1,35	21,42	0,99	7,40	335	72	1,1
tp	1,22	21,88	2,19	26,68	70	57	0,5
tu	1,48	-6,73	1,02	13,65	70	57	0,5
txop	1.25	6.02	0.85	11.02	70	57	0,5

Table I shows the index values of the linear functions for the time needed for cable winching, as well as the average data of the time needed for loading and unloading the wood assortments, and data about the average size of the load. The results are comparable to the research of (Krstevski K. [17]).

The data about the same parameters for cable winching of wood assortments on flat terrain or nearly flat terrain with a deviation of (± 5%) of the horizontal gradient are presented in Table II.

Table II: Index values for cable winching with a tractor on flat terrain

cable winching	apr	bpr	cpr	dpr	tupr	trpr	qtovpr
oxop	0.89	35.87	1.11	27.9	335	72	1,1
txop	1.25	6.02	0.85	11.02	70	57	0,5

Because there weren't any significant differences, the time needed for loading and unloading the wood assortments and the data about the average size of the load are considered as average.

By means of differential estimation, i.e. by estimating the first statement of the total time for skidding of all the wood assortments, we have estimated that the value of *xt* is 0.36. This means that the skidding would be most optimally done if 36% of the wood allowable which gravitates towards the upper road to be skidded in increase, and the rest of 64% to be skidded on the lower road, i.e. in fall. The values are taken from the research of (Trajanov Z. [24]). With horizontal skidding on flat terrain the wood allowable which is placed on 50% of the surface that is the closest is skidded towards one road, and the rest towards another

3 RESULTS AND DISCUSSION

3.1 Estimations of the cable winching costs and skidding roads

The results from this study are in connection to the costs of wood assortments cable winching and the costs for building and maintaining the skidding roads. The model itself, as well as the use of software for calculating mathematical operations enables us to analyze all the input or accounting parameters.

The total costs for cable winching with a tractor are estimated according to the equation (5). The total costs for building and maintaining the skidding roads for the period of research are estimated according to the equation (1). The summary costs from the achieved results are presented in Table 3. Comparable research has the authors: (Robek R. [31]), (Valeria O. [3]), (Sokolovic Dž. [25]), (Enache A. [12]), (Đuka A. [15]), (Pičman D. [30]), (Petković V. [28]) and (Walter W. [35]).

Table III: Cable winching costs and skidding roads in relation to the density of the skidding road network (general model)

Gp [m/ha]	20	40	60	80	100
Tdp [euro/ m³]	0,37	0,73	1,11	1,48	1,84
Tpr [euro/ m³]	3,64	2,54	2,18	1,98	1,89
Tsuma [euro/ m³]	4,00	3,27	3,28	3,46	3,72

Graphic display of the summary costs for cable winching of wood assortments and the costs for skidding roads at the basic model is presented in Figure 1. The optimal density of the skidding roads happens at the point where there are minimal summary costs.

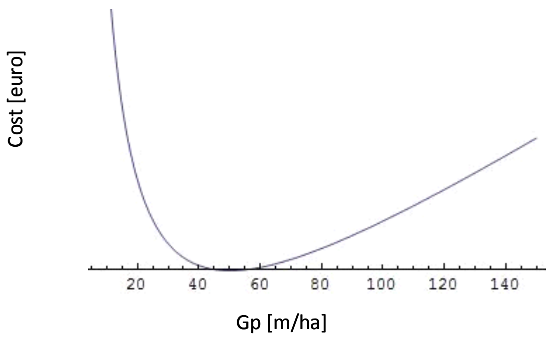

Figure 1: Summary costs for skidding roads and wood cable winching

In Figure 2, with a 3D model, one can see the relation of the costs (axis *z*) to the density of the skidding roads (axis x) and the quantity of the wood allowable which is used in the period of 100 years (axis y). On this graphic display one can notice the tendencies of the optimal density of the skidding roads. The lower fields are the zones with low costs connected to the optimal solution, whereas the upper zones are more inadequate solutions in relation to the density of the skidding roads.

With a small quantity of used wood allowable the zone around the optimal density is sharper, whereas with a greater quantity of used wood allowable the zone around the minimal costs is drastically milder. Thus, one should be more careful in determining the optimal density of the skidding roads with a small quantity of

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used wood allowable i.e. with a small density of the skidding roads. The situation in Austria is similar (Walter W. [35]).

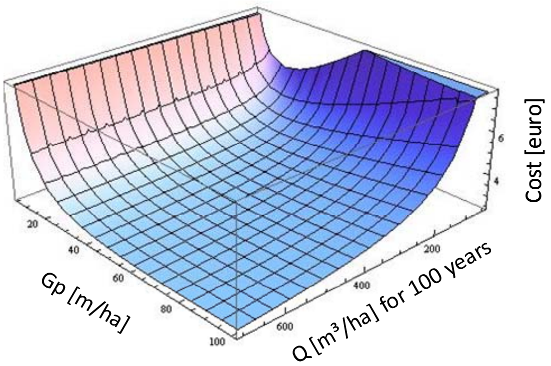

Figure 2: Density of the skidding roads in relation to the used wood allowable and the costs that appear in the phase of skidding

A great display of a certain factor can be presented with a 2D diagram by displaying the zones with a tendency of the summary costs varying.

The influence of the factor x (a fraction of the area which would be skidded in increase) is shown in Figure 3. The least costs are made when the density of roads is from 35 to 55 m/ha when skidding in fall. With increasing the length of the area which is being skidded in increase, as well as with distancing from the optimal density of the skidding roads, the summary costs are also rising.

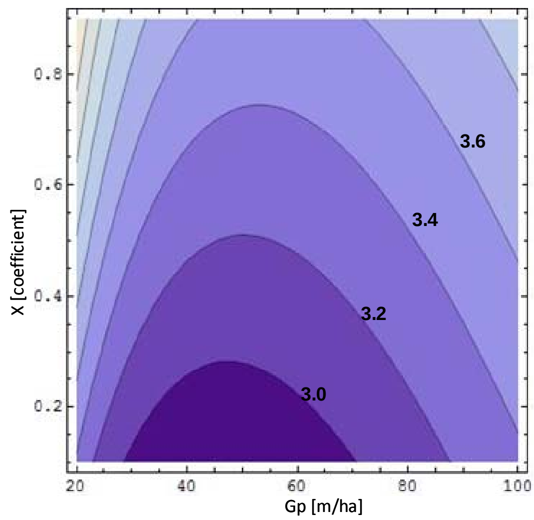

Figure 2: Zones of costs (in euros) in relation to the density of the skidding roads and factor x (a fraction of skidding in increase)

The influence of the portion of firewood in the production structure is presented in Figure 4. The least costs are made when the density of roads is from 25 to 65 m/ha when there is only production of firewood. With increasing the portion of technique wood allowable, as well as with distancing from the optimal density of the skidding roads, the summary costs are also rising.

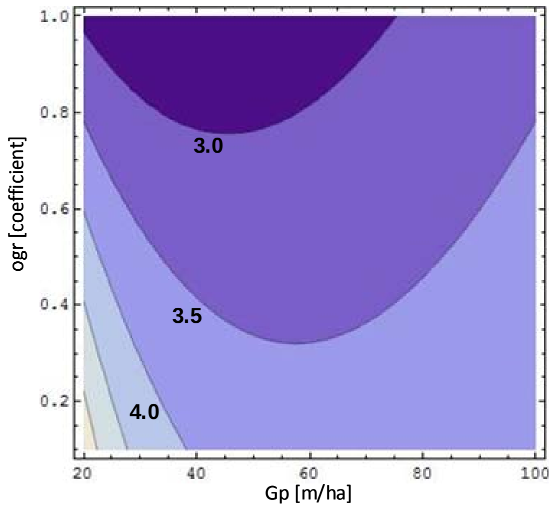

Figure 3: Zones of costs (in euros) in relation to the density of the skidding roads and the quantity of firewood in the wood production

The influence of the used wood allowable for a period of a hundred years is shown in Figure 5. The least costs are made when the density of roads is from 40 to 100 m/ha at the highest use of the wood allowable per unit area. Such results has been elaborated on in the paper (Pičman D. [30]). With reducing the used wood allowable in the period of a hundred years and with distancing from the optimal density of the skidding roads, the summary costs are rising.

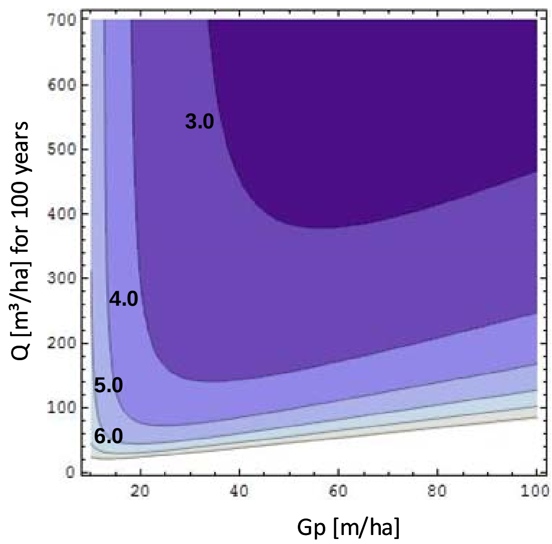

Figure 4: Zones of costs (in euros) in relation to the density of the skidding roads and the quantity of wood that is used in a period of a hundred years

3.2 Differential estimations of the first statement from the sum of costs

Absolute correct results about the optimal density of the skidding roads are acquired by means of differential estimations of the first statement from the sum of costs. Thus according to the equation (7) with an estimation of the first statement from the sum of costs one can acquire density of the skidding roads of 48.82 m/ha. This density refers to the used wood allowable of 300 m^3/ha in a period of a hundred years, with an ideal cable winching of assortments in increase x=0.36 and with an equal portion of firewood and technical wood when skidding wood assortments.

With the change of these parameters the optimal density would change as well. Changes also appear in a situation when the skidding is done on flat terrain or with small deviations of the horizontal line ± 5%.

The influence of the factor x (a fraction of the area which would be skidded in increase and in fall) has been calculated about a situation of cable winching in increase and in fall, and about another situation when the assortments are cable winching horizontally. The results achieved are presented in Figure 6.

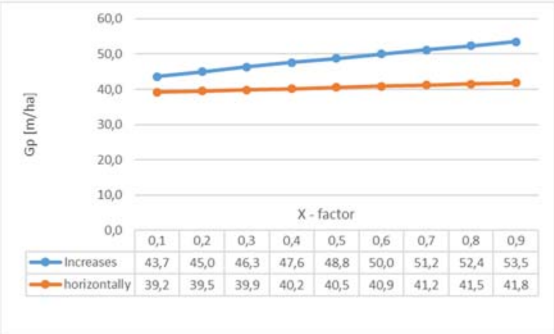

Figure 5: Optimal density of the skidding roads in relation to the factor x (a fraction of skidding in increase)

Figure 6 shows that with the increase of factor x the density of the skidding roads also increases. There is smaller optimal density of skidding roads when cable winching horizontally.

Figure 7 presents the influence of the total costs for building and maintaining the skidding roads in relation to the determining of the skidding roads optimal density. This density refers to the used wood allowable of 300 m^3/ha in a period of a hundred years.

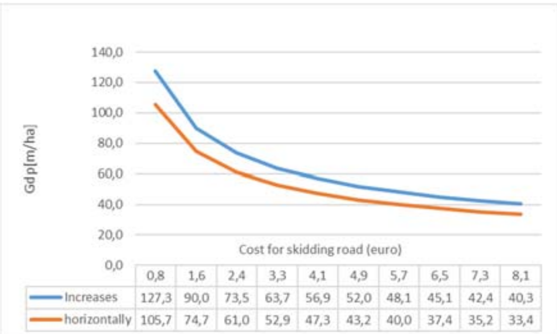

Figure6: Optimal density of the skidding roads in relation different cost for skidding road

From the Figure 7 in diagram one can see that the trends for optimal density remain identical also in the case of skidding on flat terrain, and the values of the optimal density are smaller. Numerical data are given in the table in Figure 7.

Figure 8 presents the influence of the quantity of firewood with various use of the wood allowable in relation to the optimal density of the skidding roads. The calculations refer to cable winching in increase and in fall.

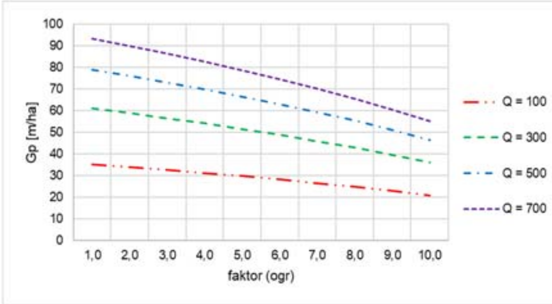

Figure 7: Optimal density of the skidding roads in relation to the portion of firewood in the production with various use for a period of a hundred years (analysis of skidding in increase and in fall)

Figure 8 shows that with increasing the quantity of firewood, as well as with smaller use of wood allowable, the optimal density of the skidding roads is smaller. With increasing the portion of the technical wood allowable, the optimal density of the skidding roads increases, and with increasing the wood allowable which is used for the researched period, the optimal destiny of the skidding roads also increases.

Figure 9 presents the influence of the quantity of firewood with various use of the wood allowable in relation to the optimal density of the skidding roads. The calculations refer to cable winching on flat terrain.

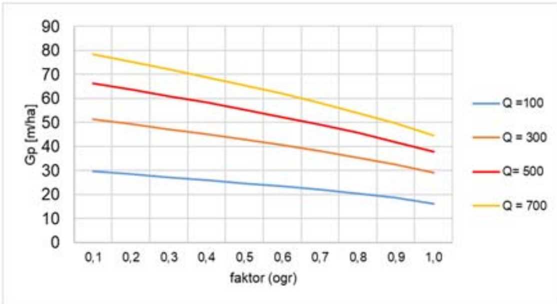

Figure 8: Optimal density of the skidding roads in relation to the portion of firewood in the production with various use for a period of a hundred years - Q (analysis of skidding on a flat terrain)

Figure 9 shows that the trends remain identical also in the case of cable winching on flat terrain, only that on flat terrains in all situations the optimal density of the skidding roads is smaller compared to the cable winching in increase and in fall.

4 CONCLUSIONS

In this study the results are closely connected to: the technical characteristics of the skidding means of transport, the team that works, the natural conditions, as well as the general and legal costs which appeared at the moment of research. With the change of these circumstances there would also be changes in the results.

With the model of displaying the costs that appear in the phase of wood cable winching, as well as the costs for skidding roads, and with the use of zonal graphic displays the trends and tendencies of certain parameters are well presented. Absolute correct solutions about the optimal density are acquired with differential estimations (first

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statement of the summary costs). Thus, at the model that had been researched an optimal density of skidding roads of 48.82 m/ha was determined.

With a small quantity of used wood allowable, the zone around the optimal density is sharper, and with a greater quantity of used wood allowable the zone around the minimal costs is drastically milder. Thus, in practice, one should be more careful in determining the optimal density of skidding roads with small quantity of used wood allowable, i.e. with small density of skidding roads.

In regard to the economic effects, one would make a smaller mistake if in percentage terms a skidding road network with a bigger density is built, compared to the same percentage of smaller density where greater financial losses would happen.

The results achieved about the optimal density of the skidding road network under 50 m/ha with the model of skidding only with the researched tractor would not be taken into consideration because of the technical characteristics of the comber which has a pulling rope of maximum 100 m.

With these analyses it must emphasized that we mathematically estimate an ideal model at which the roads are parallel and regularly placed in the area. Considering the fact that in mountain conditions such model could not be set up, these estimations have the purpose to determine the optimal distance between the skidding roads. That is to say, the expert people who would do the secondary opening of the forests are given a tool that they can use at their work. In reality this estimating density would be stressed with the density of the skidding roads which are unproductive by any reason.

Comparable research and results has the authors: (Sokolovic Dž. [25]), (Krstevski K. [17]), Pičman D. [30] and Walter W. [35].

5 REFFERENCES

[1] Akimovski R, Todorovski S., Angelov S., 1968: Research in skidding of beech tree logs with tractors in Macedonia. Annual collection at the Faculty of Agriculture and Forestry – Skopje: 6-18.

[2] Akimovski R., 1966: Research into the problem of opening the forests in Macedonia. Annual collection at the Faculty of Forestry Skopje: 97-125.

[3] Akimovski R., 1997: Sumski transportni sredstva – sumski putevi, Univerzitet Beograd, Beograd.

[4] Bekar D., Todorovski S., Akimovski S., Kiril A., Angelov S., 1968: Sakupjanje oblog drveta na kratkim distancama sa vitlom na traktorima Ferguson-35, IMT-533 I Zetor-super. Sumarski institute, Skopje.

[5] Bojanin S., 1983: Faktori optimalne otvorenosti šuma kod sekundarnog otvaranja. Mehanizacija šumarstva 11-12 (8): 322-325.

[6] Bojanin S., Krpan A., Beber J., 1988: Komparativno istrazivanje privlacenje drva zglobnim traktorima u jelovim prebornim sastojinama sa sekundarnim otvaranjem i bez sekundarnog otvaranja. Mehanizacija sumarstva 8: 3-13.

[7] 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.

[8] 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.

[9] Đuka A., Poršinsky T., Vusić D., 2015: DTM models to enhance planning of timber harvesting. Glasnik sumarskog fakulteta Beograd (0353-4527): 35-44.

[10] Danilović M., Ljubojević D., 2013: Forest opening with a secondary road network. Bulletin of the Faculty of Forestry Belgrade 108: 25-38.

[11] Danilović M., Stojnić D., 2014: Assessment of the state of a forest road network as a basis for making a program of forest management unit opening. Bulletin of the Faculty of Forestry Belgrade 110: 59-72.

[12] Enache A., Ciobanu V.D., Karl M., Stampfer. 2013: An Integrative Decision Support Tool for Assessing Forest Road Options in a Mountainous Region in Romania, Croation Jurnal of Forest Engineering: 43-60.

[13] Jeličić V., 1979: Otvaranje sječina sekundarnom mrežom šumskih puteva u borovim i hrastovim šumama. Radovi Šumarskog fakulteta i Instituta za šumarstvo u Sarajevu, knjiga 22., sveska 5–6: 91-123.

[14] Jeličić V., 1983: Otvaranje suma primarnom I sekundarnom mrezom sumskih puteva. Mehanizacija sumarstvo 8 (11-12): 1-19.

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

[16] Krč J., Beguš J., 2012: Planning Forest Opening with Forest Roads. Canadian Journal of Forest Research 34(2): 217–228.

[17] Krstevski K., Zudo D., 1987: Research into supply of wood products with a tractor TAF - 654, Forestry review no. 7-12.

[18] Krpan A. P. B., Porsinsky T., Sabo A., 1999: Wood extraction using choker skidders LKT 80 and 81 in selection forests in mountain conditions. IUFRO, Faculty of Forestry of Zagreb University: 121–122.

[19] Krpan A.P.B., Porsinsky T., Susnjar M., 2001: Timber extraction technologies in Croatian mountainous selection forests. Workshop on New Trends in Wood Harvesting with Cable Systems for Sustainable Forest Management in the Mountains, Joint FAO/ECE/ILO & IUFRO, Ossiach (Austria): 18–24.

[20] Lepoglavec K., 2014: Optimizacija primarne i sekundarne šumske prometne infrastrukture nagnutih terena. Disertacija, Šumarski fakultet Sveučilišta u Zagrebu: 1–341.

[21] Lovric N., 1981: Odrezivanje i mogucnost primene srednje daljine centralnog linijskog izvlacenja”.

Institut za sumarstvo i drvna industrija Beograd, Beograd.

[22] Trajanov Z., Nestorovski LJ., Trajkov P., 2014: Transportation costs as an indicator for determination of the optimal road density. Forest review: 20-23.

[23] Trajanov Z., Nestorovski LJ., 2008: Optimal density of the road network in Republic of Macedonia, FAO/ECE/IUFRO seminar on infrastructure and transport in sustainably managed forest, Slovenian forest institute, Portoroz: 54-65.

[24] Trajanov Z., Nestorovski LJ., Trajkov P., 2013: Optimization of skidding distances in mountain conditions with the different skidding device**”,** Nova mehanizacija broj: 21-29.

[25] Sokolovic Dž. et all, 2013: Determination of optimal secondary forest road network layout. Sumarski list 1-2: 7-23.

[26] Pentek T., Nevećerel H., Porsinsky T., Potoćnik I., 2008: Methodology for Development of Secondary Forest Traffic Infrastructure Cadastre. Croation Jurnal of Forest Engineering 29: 75-83.

[27] Pentek T., Picman D., Nevecerel H., 2005: Planning of forest roads – current status, identifying problems and trends of future activities. Nova meh. Sumar. 26: 55–63.

[28] Petković V., Potočnik. I., 2018: Planning Forest Road Network in Natural Forest Areas: a Case Study in Northern Bosnia. Croat. j. for. eng. 39: 45–56.

[29] Picman D., Pentek T., Nevecerel H., 2006: Forest opening by forest roads – choosing the potential locations of the future forest road routes. Glasnik za Sumske pokuse, Specialissue 5: 617–633.

[30] Picman D., Pentek T., Nevecerel H., Papa I., Lepoglavavec K., 2011: Possibilities of application of relative openness in secondary forest opening of slope forests in Croatia, Croatian Journal of Forest Engineering 32(1), Zagreb: 417-427.

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

[32] Samset I., 1988: Some observations on time and performance studies of forest operations. IUFRO, Greece, Department of forest engineering of Forest research institute of Thessaloniki, 171–197.

[33] Segebaden, G., 1964: Studies of Cross-Country Transport Distances and Road Net Extension. Studia Forestalia Suecica, 18: 1–70.

[34] Valeria O., Cea I., Bergeron Y., 2011: A review of skidding distances method under variable retention harvesting considerations. Proceedings of the 34th Council on Forest Engineering 12–15 lipnja, Université Laval, Quebec City, Canada: 1–12.

[35] Walter W., 1998: Assessment of forest road alternatives with special emphasis on environmental protection, FAO.






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