Where to Place and Build Forest Roads -- Experience From the Model

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ABSTRACT

The paper presents the conditions in which forest production as well as forest road design and construction in Slovenia are going on. The most important influential factors and the limitations in the production process have been given special emphasis, among which there are also potential environmental disturbances and forest functions. A brief description of a method based on multi-criteria decision making, a model form of which was applied in the analysis of technologies and forest road network in the Jezersko forest region, is presented as well. The results indicate the suitability of terrain for the design and construction of forest roads and skidding tracks. An analysis of the present forest road and skidding track network as well as a comparison of terrain suitability with the suitability of all terrain have been made as well. It has been established that especially in the construction of forest roads and skidding tracks difficulties regarding construction have strongly been taken into consideration, because the existing network is situated on terrain which is easier than the average. Finally, the possibilities as to the further developments of the model have been indicated.

Keywords: *models, forest technology, forest roads, skidding tracks, GIS.*

INTRODUCTION

Slovenia is a country rich in forests. Due to its position it links the northern Adriatic coast, the southern part of the Alps and the western part of the Pannonian lowland. It is characteristic of this region that relief forms are highly diverse - from a completely plain part in the East to alpine regions in the north-west of the country. From the strategic point of view, forests extending over such a vast area and with great timber supply represent extraordinary riches, a huge capital, which can be maintained and multiplied if being properly employed, thus providing income to a great part of the population or representing important life quality improvement to others.

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One of the most important tasks of forestry is to keep forests vital, stepping-up the significance of the latter while focusing on different uses thereof. Under the new legislation on forests (1993) the planning of forest road network has been taken over by the Public Forest Service of Slovenia. Despite the fact that a rhythm of intensive construction of forest roads and skidding tracks, which could be established for a long period in the past, has been interrupted, there still remains a challenge for the forestry branch to set the foundations to ecologically more appropriate method of forest opening - the designing and construction of new roads and skidding tracks which are to be built in the future. The purpose of this article is to show appropriate methods which could be useful thereby and the modes in the evaluation of terrains suitable for the designing and construction of forest roads and skidding tracks. The criteria are still to be studied by experts and defined in the form of guidelines and limitations [8]. Here the topic has been restricted to forest roads and skidding tracks, leaving out of the discussion on cable crane lines. The task was performed by modelling, a means which has becoming more and more popular in the solving of complex problems [2,5]

CONDITIONS IN WHICH WOOD PRODUCTION AND FOREST ROAD AND SKIDDING TRACK CONSTRUCTION IS PERFORMED IN SLOVENIA

The conditions which are important in wood production and the construction of forest roads and skidding tracks are the following: natural conditions and management methods, forestry and other infrastructure and economic-political factors.

Under natural conditions and management methods we understand: stand conditions (growing stock, permitted cut, limitations) general terrain conditions (terrain slope, altitude, relief), special terrain conditions (rockiness, stoniness, soil depth and bearing capacity etc.) as well as climatic conditions (the quantity and type of precipitation, their distribution, temperature). Forestry and other infrastructure comprise: forest accessibility (type and density of roads and skidding tracks, their location, productivity of roads and skidding tracks etc.) and the location of forests as to management centers and timber consumption (the distance to and the distribution of working sites, the distance to timber consumers, the position of wood processing companies). Economic-political factors like forestry organization, stability and character of the market (links to foreign countries), a pressure on prices (Trade Unions, home and foreign competition), the role of the state and forest owners are of great significance as well. We are only going to deal with those factors which are in direct connection with timber production technologies and the forest opening related thereto, leaving aside those having only indirect influence - through economic pressures, public opinion, etc.

The share of forests and forest area increases with the altitude. The distribution of the areas of the entire Slovenia and the forest areas by altitude zones gives a similar picture: there are no forests in the highest altitudinal zones (tree-line). Stand conditions are also an important factor which especially exerts influence on forest openning. These conditions are: forest area, growing stock and increment, thus including the developmental phase as well. Stand conditions have been presented in this article by the anual stand's increment.

General terrain conditions refer to the form of relief, its slope, altitude and similar. Almost all the stated indices change with the altitude [1]. With lower altitudes, flat terrain to that of slight slope, hill and hollow terrain prevail. The terrain characterized by funnel-shaped holes mostly occurs between 500 and 1,100m above sea level (in the High Karst region), its share even increasing with the altitude. Terrain full of ditches can mostly be found at an altitude of 500m above sea level; afterwards its share slightly decreases only to increase again at higher altitudes. Terrain shape is related to terrain slope, which is one of the most important terrain indices and at the same time a factor having its role in the selection of technologies and wood skidding means. It has also important effect on forest road and skidding track construction. Flat terrain (to 10%) can be found to about 300m above sea level, after that its share strongly decreases. Similar also holds true of gently sloping terrain (10-20%) and moderately sloping terrain (to 35%). These three terrain slope classes are also the most suitable for tractor skidding. Steep terrain (to 70%) and extremely steep terrain (over 70%) most frequently occur at higher altitudes yet they do not exceed 50% of the areas in the altitudinal zones where forests prevail.

Among the important indices influencing the entire process of wood production there is also forest accessibility through forest roads and permanent skidding tracks (in 1992 there were 16.32m/ha of forest roads and about 42m/ha of skidding tracks). Accessibility increases with altitude to approximately 1,100m above sea level; further up it quickly decreases. The highest density of forests can be established at altitudes between 800 and 1,200 m above sea level, after that they rapidly decrease due to the upper timber-line and protection mountain forests. It is also of great importance that great forest estates prevail at higher altitudes (state forests, farms of large estate), the situation being quite different in lowland forests where there are many small estates. Terrain slope has no direct influence on the accessibility itself yet it does influence the position and the construction of forest roads as well as their maintenance.

Special terrain conditions affect those production phases which are carried out in the forest itself, i.e. cutting and wood skidding, forest road and skidding tracks construction - first of all skidding tracks and cable crane lines. They have smaller effect on timber transport, work in auxiliary storage places and other jobs which are not directly depedent on wayless ground. The micro-relief of terrain - partly already covered by the above stated indices - and surface, which can be rocky or stony, soil type (of low bearing capacity and deep or shallow and of high bearing capacity) are classified as special terrain conditions. Bearing capacity is an important factor because it often inhibits mechanization work in the forest; it also changes with moisture, which depends on the quantity and distribution of precipitation. On the soil of poor bearing capacity, which is quite frequent in the forest, the use of mechanization is limited. Only special machines with small pressure against the ground or cable cranes can be used. In such cases careful planning regarding the moving of machines on wayless ground is required.

Climatic conditions - temperature and precipitation - are important from the aspect of work organization and working time utilization as well as work's difficulty degree. They have, however, indirect effect on the working site and mechanization or technology type which is to be used. Climatic factors in connection with soil conditions also represent important limitations since they may inhibit work and the construction of forest roads and skidding tracks in sensitive sites. Precipitation height is also in close relation with erosion danger, which can occur as a consequence of forest road and skidding track construction; this especially holds good of skidding tracks which are steeper and less supervised once having been used than forest roads are. The height and form of precipitation, their distribution during the year have important influence on the dynamics of forest work course in timber production and forest opening. Climatic conditions have not been taken into consideration in the present article since they have been taken into account in technical elements of existing forest roads and skidding tracks (longitudinal slope of a road and skidding track, drainage width and method, etc.).

LIMITATIONS IN TIMBER PRODUCTION AND IN FOREST ROAD AND SKIDDING TRACK CONSTRUCTION

Forest management in Slovenia is based on the principles of sustainability, co-natural approach and multiple use of forests. The goals of forest management are implemented in the management of each stand with adapted silvicultural goals; they also determine the necessary measures and indirectly the scope and type of forest work. All forest work is in one or another way related to transport infrastructure which enables the access to forest and work therein. Thereby, secondary forest opening is closely related to timber skidding technology and is thus in direct relation to forest work costs and negative effects of the construction and use of forest roads and skidding tracks in forest. Apart from forest's condition, the functions that could potentially be exercised by a forest and man's needs to cherish or employ them through the use of forest, have influence on management goals as well.

It is proved by data that no function of general benefit has separately been defined for 77% of all Slovenian forests, which, however, does not mean, that multiple management has not been practiced in these forests [3,4]. The estimate claiming that 25% of Slovenian forests have permanent or all-round emphasized protection role, an 28% are situated on unstable ground and only 23% of forests have been ranked among stable ecological complexes is still valid. The major part of timber production forests - 88% in all - still have at least the protection role; yet there are no limitations in the performing of work in these forests or the former already represent a component part of the principles regulating forest managing in Slovenia. Among timber production forests there are 18% of them where one or more functions of general benefit have been emphasized. It can be expected that these are the forests where limitations in the performing of work should be more distinguishable and ranked as to the demands of additionally emphasized functions.

From the country's point of view there are more forests of emphasized functions of general benefit - 23%, yet these also comprise those socio-economic forest categories which already determine emphasized non-timber uses of these forests by themselves, various environmetal ones being the most frequent among them. Most of the forests of emphasized functions of general benefit are in the category of permanent protection forests and in the forests of limited timber production significance (90% or 24% respectively).

The limitations in forest management are primarily reflected in the selection of management goals and the selection of the type and intensity of measures; the limitations in the performing of forest work, however, refer to definite forest work, the mode of its performing, working conditions etc. [4]. The limitations can be classified into the following classes: limitations as to measure types, measure intensity, economic expectations, measure application frequency and the effect of working conditions on production implementation.

In the present analysis the functions of general benefit, which were determined in timber production forests during forest inventory, have been taken into account as a factor diminishing the suitability of an individual part of a stand for the designing and construction of forest roads and skidding tracks [3,4]

THE METHOD AND SELECTION OF AN OBJECT

The suitability of the location of forest roads and skidding tracks which are primarily used for forest production is in close relationship with forest work economy and the negative effects of forest roads and skidding tracks on forest and forest space. Thereby the microlocation of a road and skidding track is of extreme importance, which is in fact the possibility to adapt to the environment as economically as possible and ecologically suitable. The width of a road or a skidding track is only one of the factors which on steep slopes clearly shows the extent of the wound cut into the slope. The present construction technology does not enable that the width of individual categories of roads and skidding tracks would entirely be adapted to the necessary width of a skidding means, but it is always considerably greater; therefore negative effects caused in the forests are greater on steep slopes and frequently there are no considerable differences between the influences caused by the construction of forest roads and skidding tracks if only the width of a road and a skidding track are taken into consideration. Differences could be very important due to the longitudinal slope of a road or skidding track, where many critical situations might occur primarily with steeper skidding tracks.

Tractor skidding tracks are areas between trees, without larger obstacles and with such technical elements and position which correspond to a timber skidding technology. Tractor skidding tracks are not built on easy terrain; it is sufficient if their location is marked. In more difficult terrain (rockiness and terrain slope) construction is necessary, thus interfering with the environment. It has been proved by monitoring that tractor drivers do not observe the marked skidding directions in wood skidding on easy terrain and frequently enter into stands in order to shorten the distances in the timber bunching. Thus the affected area is enlarged and unnecessary damage is caused to trees. The issue regarding the width and quality of roads and skidding tracks along which wood transport from the forest is carried out has therefore been linked to designing suitability (i.e. the location of a road and skidding track in a stand) and construction suitability (expediency of construction and potential effects on the environment). The issue regarding the optimal density has been excluded from the model at this stage of the research; it thus represents a means for the analysis of the existing road and skidding track network.

In the describing of working conditions which determine terrain suitability for a certain wood skidding method and the designing and construction of forest roads and skidding tracks spatial, quantitative and qualitative aspects are distinguished. Even most severe working conditions do not represent a problem on condition the area they prevail, if the area is small enough. The quantitative aspect comprises the features of influential factors as to the skidding method and suitability for designing and construction of forest roads and skidding tracks. Among these factors difficult working conditions are best defined by terrain slope, passability (rockiness, soil bearing capacity) and stand characteristics.

The analysis regarding suitability of terrains for the construction of forest roads and skidding tracks (roads and skidding tracks) has been done on the example of the Jezersko forest region, comprising 5,000ha of forests in typical alpine terrains. A model was applied which had been developed for the elaboration of a technological map [6], using also - apart from separately developed programs - the IDRISI program package. The technological map was employed as one of the influential factors in the establishing of the suitability of terrains for the construction of forest skidding tracks.

Table 1. Some characteristics of the Jezersko forest region.

Altitude	m	660 - 1,800
Average terrain slope	%	27
Total area	ha	6,840
Forest area	ha	5,100
Area under forest	%	75
Growing stock	m^3/ha	318
Increment	m^3/ha/y	7.4
Conifers' share	%	82
Road density	m/ha	11.2

In the model the procedure of multi-criteria decision making was applied, in which three data sources were used: forest inventory data base, a digital relief model and a digitalized network of forest roads and skidding tracks. All the information referred to the basic cell of a raster of 50x50m. The final result highly depends on the establishing of the significance of influential factors, which was made by means of the pairwise comparison method in an expert way.

Table 2. The continuous rating scale.

Extremely strong	9
Very strong	7
Strong	5
Moderately strong	3
Equal	1
Moderately weak	1/3
Weak	1/5
Very weak	1/7
Extremely weak	1/9

For the present needs, four such suitability matrixes were determined, while the scale of proportional evaluation of suitability from Table 2 was taken into consideration as well. In the suitability matrixes individual factors were compared to each other and assessments as to their importance rate were made. A higher value in a matrix means that the factor is more influential in a pair comparison which is in the first column.

Suitability matrix for wood skidding selection (Appendix 1) had been used before for the elaboration of a technological map and is only resumed in this place; other matrixes, however, (Appendices 2-5) were used for the analysis of terrain suitability for the designing and construction of forest roads and skidding tracks. The suitability matrix for the selection of timber skidding takes into account the distance to a truck road, as the second most important factor (with a weight of 28.54%), and soil depth (weight 2.77%), which does not occur in the matrixes regarding stand opening. In these matrixes gross yield and forest function factors, which have been disregarded in the establishing of wood skidding methods, have been taken into consideration.

From Appendices 2-5 weighed influence of an individual factor for each of the dealt with activities was calculated for each basic cell (50x50m) (Appendix 6). The significance of terrain slope is smaller in the designing of roads and skidding tracks, the former, however, being greater in the construction itself. The situation is vice versa with annual cut from forest, whose influence on the construction is very low. A certain forest function of general benefit or the limitation of a timber production function has similar influence, only that the total influence on decisions is lower. Firmness of the ground, rockiness and stoniness together have fairly high influence on a final decision; the latter, however, is lower in designing than in the construction of forest roads and skidding tracks.

Thereupon the dependence of terrain suitability (within the range from 0 to 20) with regard to the range of values in which a factor occurs has also been worked out for each of the stated factors. Thereby a point value of 20 stood for the maximum and value 0 for the minimum suitability. The point value of a basic terrain cell (50x50m) thus established was then multiplied by a weight of an individual factor and afterwards they were added up. Thus a file of terrain suitability for the designing and construction of roads and skidding tracks was created, followed up by a graphical presentation.

RESULTS AND DISCUSSION

By means of the method described five different pieces of spatial information were gained for each basic cell (50x50m) in the Jezersko region, on the basis of which corresponding maps were elaborated and comparisons carried out. A technologic map (Figure 1) can in these comparisons be understood as a consequence of the existing road and skidding track network and as a starting point for the future forest opening. By all means there must be relations between the estimates regarding terrain suitability for the designing and construction of roads and skidding tracks and the present figure of technologies.

The analysis of timber skidding methods has evidenced [6] that at present 71.8% of skidding in the forest region is performed by tractors, 1.2% manually and 26.8% by cable cranes (Figure 1). The model's results have proved that terrains and road locations are primarily suitable for tractor skidding downhill (69.1%) and only few (2.7%) for tractor skidding uphill. With cable crane skidding the model has shown that 13.5% of skidding is carried out downhill and approximately the same percentage (13.3%) of terrains are suitable for cable crane skidding uphill. Such timber skidding structure is the consequence of the present location of forest roads and the present stage of technological development. In the future modifications in technology applications can be expected, which are going to be the consequence of new constructions in the regions most suitable therefore.

By means of the model described, the maps of suitability for the designing and the construction of forest roads and skidding tracks have been elaborated (Figure 2). While observing a map, one can establish that many existing roads are situated in the positions that have been designated as appropriate by the model, too. In mountain region these are often valleys or passes and smaller ledges on larger slopes. It can also be established that in the terrains which have been marked as appropriate for cable crane skidding by the model there are quite a few tractor

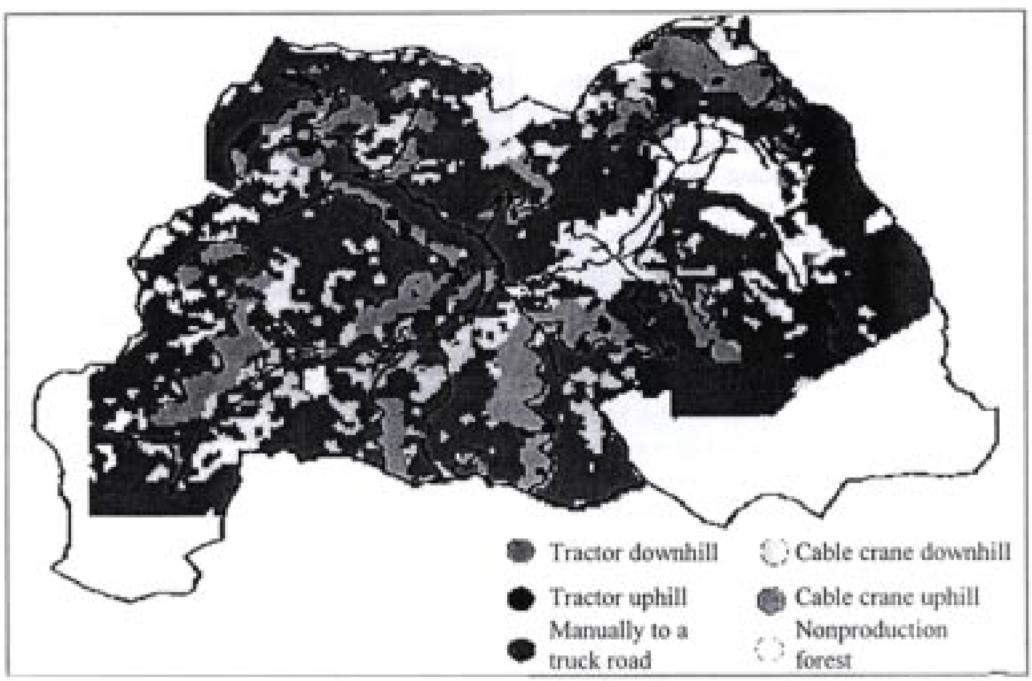

Figure 1. Wood skidding types (KRČ, 1995).

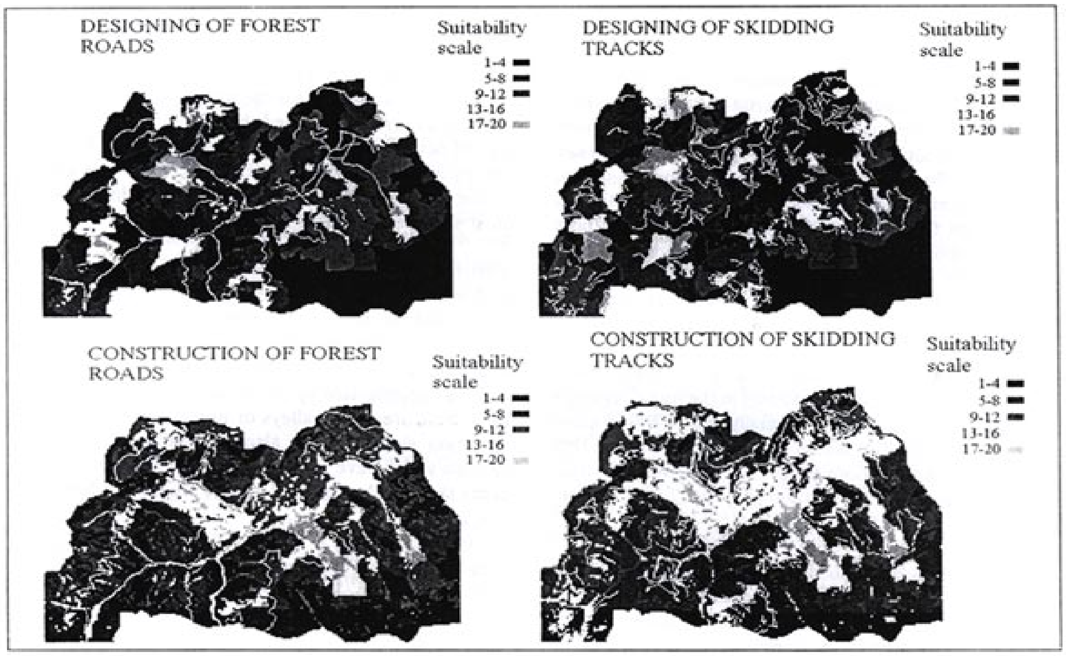

Figure 2. Suitability maps of basic terrain cells for the designing and construction of forest roads and skidding tracks.

haulage tracks whose course is also partly identical to the lines of the former skidding by horses.

Figures 3 and 4 show frequency distribution of individual basic cells as to the suitability of terrains for the construction of skidding tracks according to individual types and directions of timber skidding. Skidding direction is defined by terrain slope and road position because of which there are significant differences between frequency distributions for individual types and directions of skidding. Tractor haulage has advantage in slight inclinations to moderate terrains downhill; this is also indicated by the distribution and differs from the frequency distribution for tractor skidding uphill, which is asymmetrical and evidences higher densities in easier terrains. Manual and cable crane skidding downhill also exhibit asymmetrical frequency distributions with higher densities in the region of less suitable terrains. Cable crane skidding uphill, compared with tractor skidding, is relatively more appropriate, which is also shown by the characteristics of the terrains which are more appropriate for skidding track construction yet less suitable than in tractor skidding uphill.

As to the findings stated above we could be satisfied with the results of the model since it enables fairly good and logical conclusions. Consequently tractor skidding uphill is nowhere performed in extremely difficult terrains (suitability 5 and less points). The analysis regarding suitability for the designing of forest skidding tracks indicates similar though less explicit relations between various types and directions of timber skidding. The reason is the fact that forest annual cut has strong influence on skidding track designing, yet it does not have much influence on the construction itself; terrain slope, however, has less influence on designing suitability but on the other hand it is a strong factor in the construction of skidding tracks. Besides, in the establishing of terrain for skidding track construction terrain slope is by its weight pretty close to the influence of terrain slope in the deciding on potential types and directions of timber skidding.

Frequency distributions of the suitability of basic cells for the construction of roads in tractor terrains offer a different image since they are much more equal and without explicit peaks. This finding is even more expressive in frequency distribution regarding the suitability of basic cells for the designing of roads where the equalization rate of distributions is even higher. In fact it is only characteristic of both distributions that the classes close to both boundaries of the interval for tractor skidding are

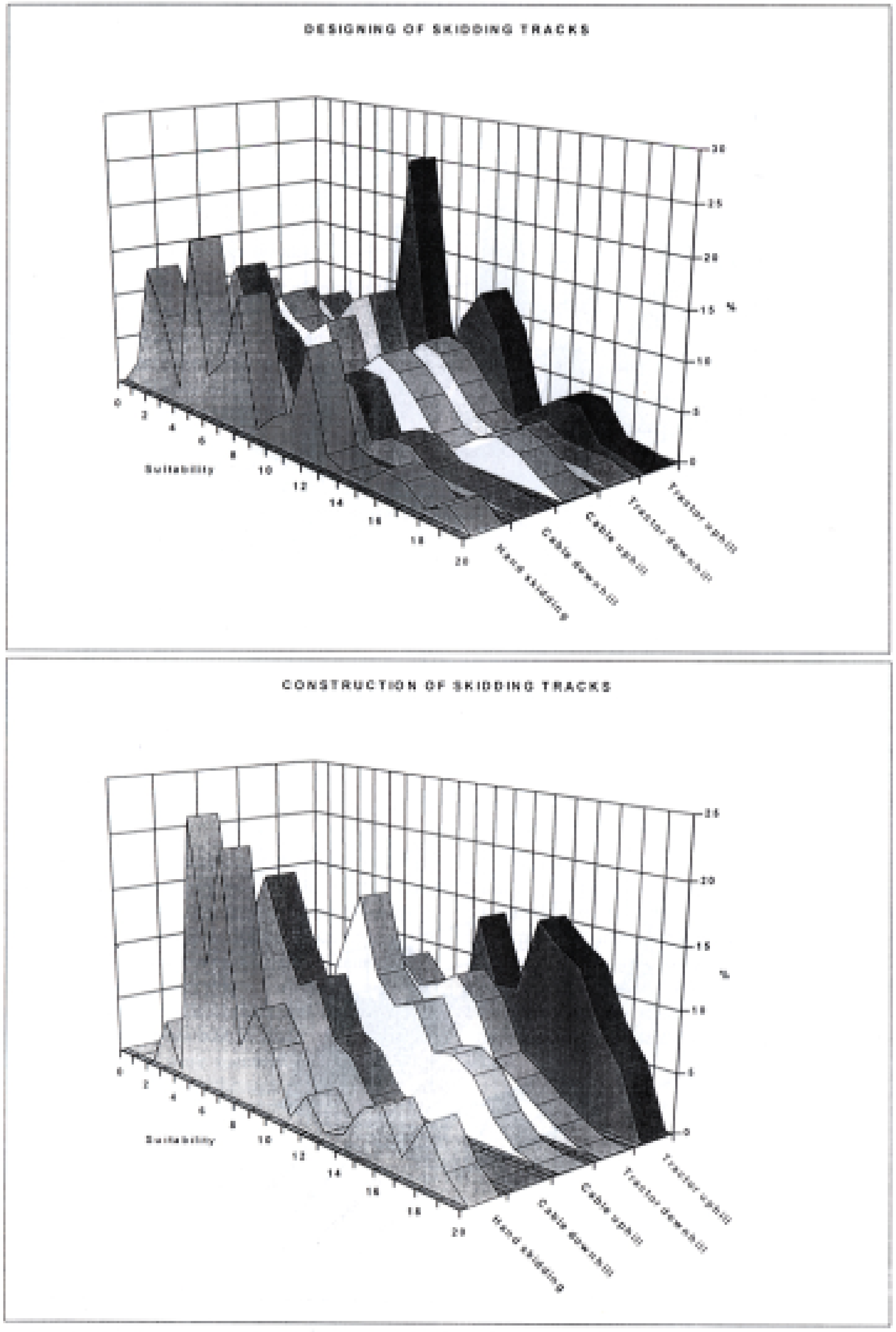

Figure 3. Relative frequency distributions of the suitability of basic terrain cells as to the direction and type of skidding for the designing and construction of skidding tracks.

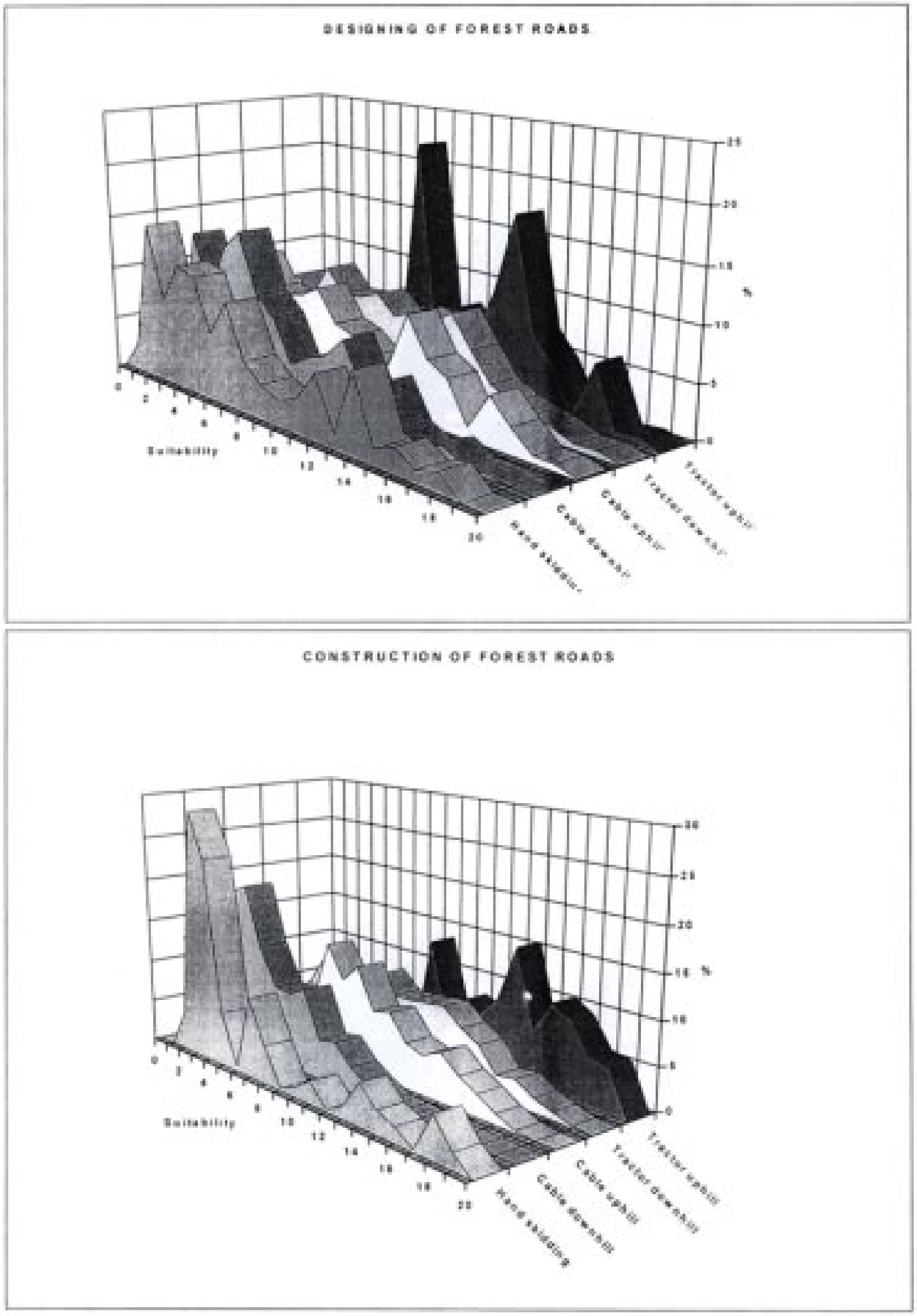

Figure 4. Relative frequency distributions of the suitability of basic terrain cells as to the direction and type of skidding for the designing and construction of forest roads.

more empty or that there are less extremely difficult and extremely easy terrains; there are, however, no significant differences established between the classes in the middle of the interval. The suitability for construction is lower in cable crane terrains—these being more difficult terrains from the road construction's point of view as well. The purpose of road construction is more than merely to meet the momentary needs regarding timber skidding since they are under strong influence of forest annual cut and forest functions - the factors which do not influence the decision on the technology of timber skidding.

The analysis regarding the suitability of terrains for road construction has evidenced great differences regarding the potential technologies of timber skidding (Figure 4) and confirmed the anticipated relations between working conditions in which tractor skidding and other skidding types are performed. These relations would also reflect the extent of potential negative influences on the environment and forest management if roads were actually built in such terrains. From this point of view, an analysis of the existing network of forest roads and skidding tracks is necessary. A comparison has been made between relative frequences of all basic terrain cells and those basic cells through which the existing roads and skidding tracks lead.

A comparison of terrains and the existing network of forest skidding tracks for the designing (Figures 5 and 6) indicating the suitability of the location itself and the direction of skidding tracks as regards the selected criteria evidences a high similarity of both frequency distributions.

CONCLUSIONS

A conclusion can be drawn that the designers of skidding tracks have taken into consideration all the factors which are decisive in the establishing of the necessity of the stand opening by skidding tracks. A comparison of both frequency distributions regarding the suitability for skidding track construction yields, however, a quite different result (Figure 5). It is obvious that on the average skidding tracks have been buit in easier terrains, which proves that designers were successful in selecting the most suitable microlocations through which the network of skidding tracks actually leads.

Similar conclusions can also be drawn on the basis of relative frequency distributions of suitability rates of all terrains and the terrains with the present road network (Figure 6). Designing suitability distributions indicate similarity yet the distribution of the existing network is only shifted towards more suitable terrains, athough less than shown by the comparison of the suitability for forest road construction. Due to the fact that in the least favourable terrains primarily mannual and cable crane skidding prevail, it is evident that first of all easier terrains, where tractor skidding prevails, have been made accessible by designers so far.

Integral analyses require the application of models, which can illuminate a certain problem and are at the same time flexible enough to record the consequences of various influential factors. Thereby the analysis of terrain characteristics and their effects on different production phases is of extreme importance, not only for overall studies of a certain forest region regarding potential forestry technology but primarily for those regarding the properties of the existing network and for the planning of forest road and skidding track network complementing.

The paper gives a description of the use of a model for the establishing of the suitability of terrains for the designing and construction of forest roads and skidding tracks from the aspects of economy and ecological suitability. The model which had been developed to establish the technologies of timber skidding in alpine region [6], was slightly complemented for this purpose. The results resume the technologic map, which is at this stage of model's development appropriate for a comparison regarding the suitability of terrains for the construction of roads and skidding tracks - especially the latter - yet not for the comparison of the suitability of terrains for the designing of new forest roads. If we wished to analyse terrains from the point of view of network's complementing as well, the algorithm would have to be complemented for the future opening of stands, taking also into account the distance of the basic cell from the existing roads and skidding tracks. In such a case it would be wise to work out an algorithm which would search for the best possibility of a road location between two starting points.

During the phase of the developing of the model a datum on the protection rate of forest associations for each terrain cell was included as a supplementary factor yet the incorporating of this variable did not bring the anticipated results due to inadequate method of the establishing of forest associations' sensibility. Thus, the vulnerability of forest associations still remains the criterion which will have to be incorporated into the future model's development.

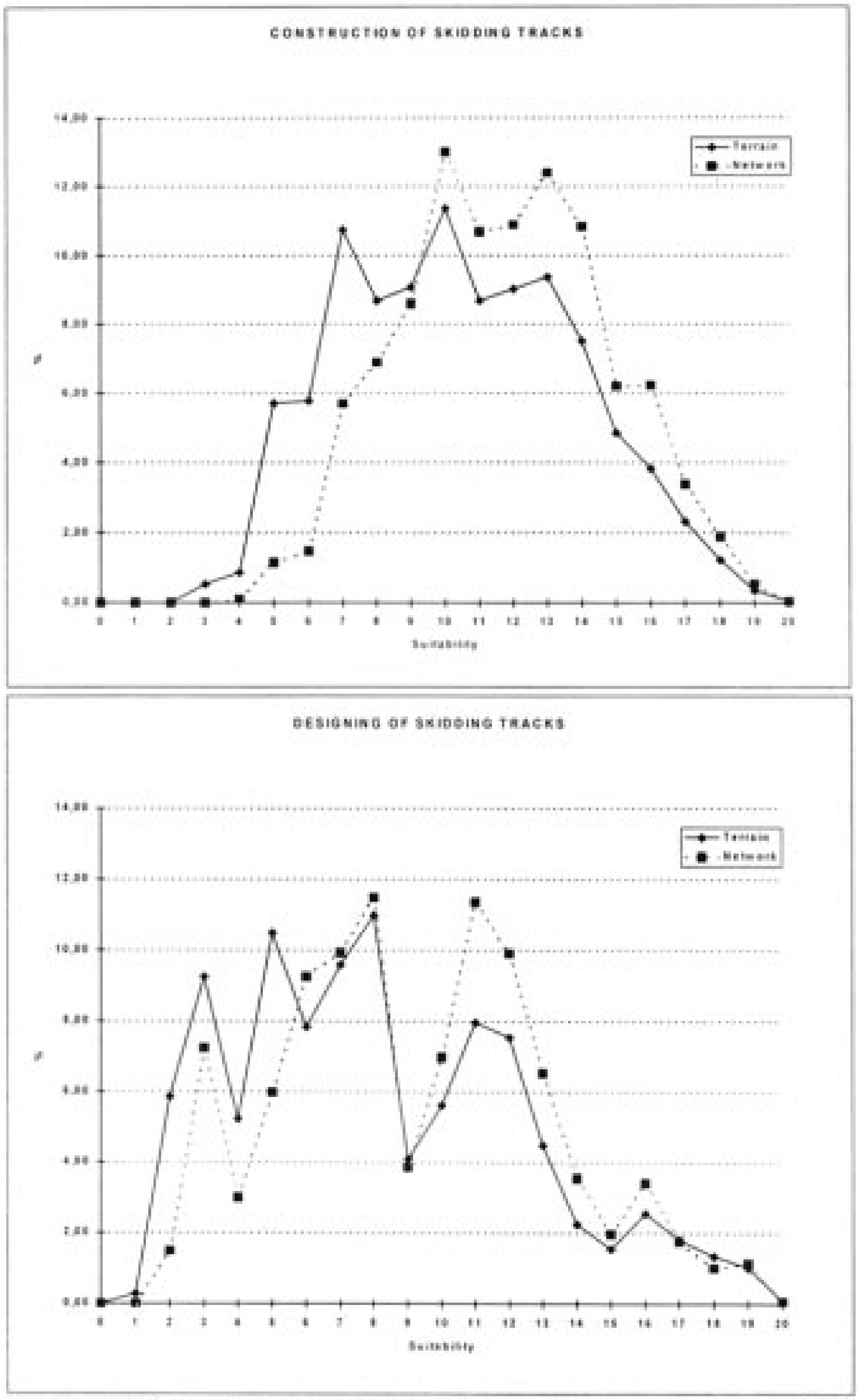

Figure 5. Relative frequency distributions of the suitability of basic terrain cells and the cells through which the existing transport network leads for the designing and construction of skidding tracks.

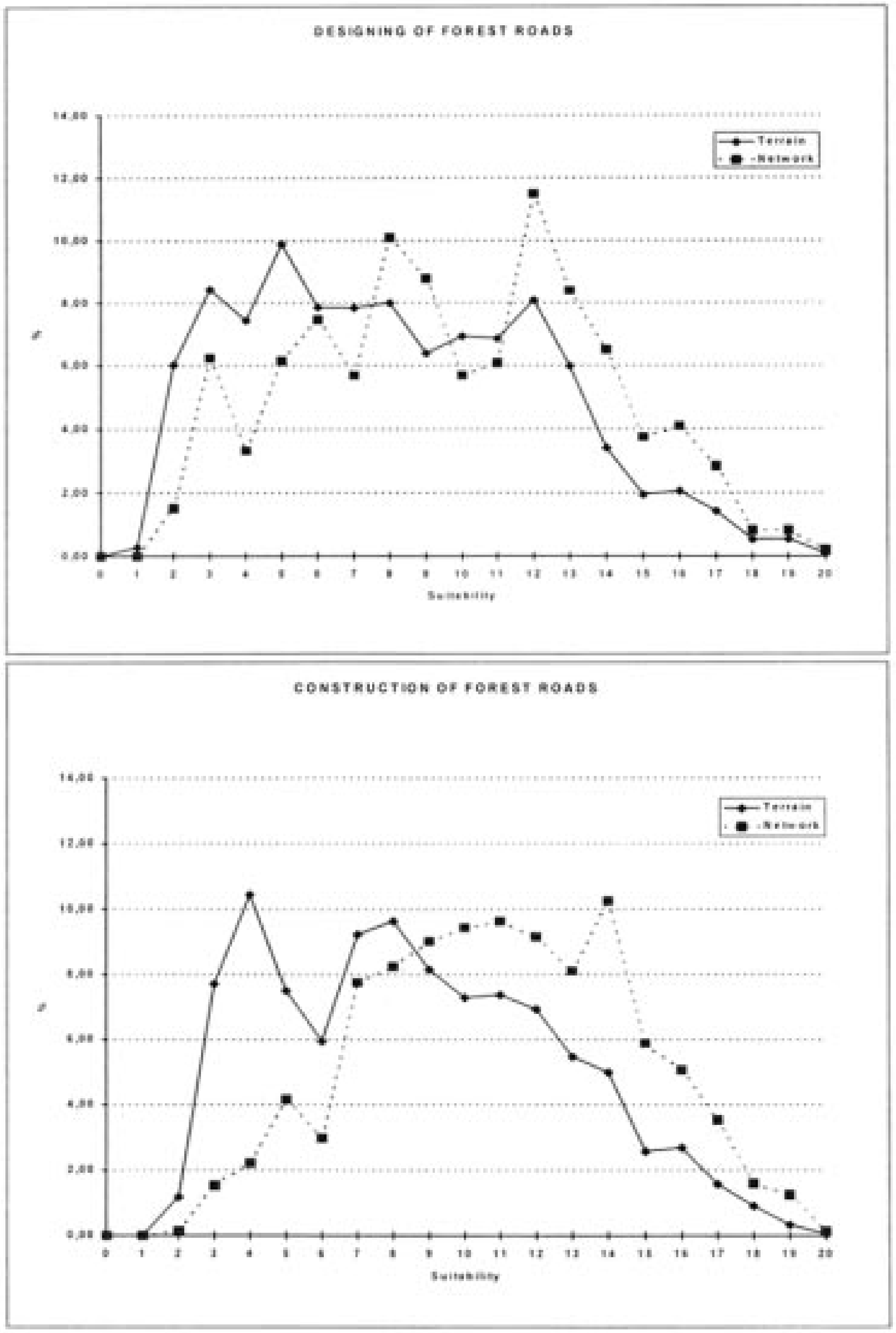

Figure 6. Relative frequency distributions of the suitability of basic terrain cells and the cells through which the existing transport network leads for the designing and construction of forest roads.

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APPENDICES

Appendix 1. Suitability matrix for the selection of wood skidding [6].

Factor	Terrain slope	Distance*	Stoniness	Rockiness	Ground firmess	Soil depth
Terrain slope	1					
Distance	1/3	1				
Stoniness	1/7	1/5	1			
Rockiness	1/3	1/3	5	1		
Ground firmess	1/5	1/7	3	1/3	1	
Soild depth	1/8	1/7	1/3	1/5	1/5	1

*A distance to a truck road.

Appendix 2. Suitability matrix for the designing of forest roads.

Factor	Terrain slope	Annual cut	Ground firmness	Rockiness	Stoniness	Forest function
Terrain slope	1					
Annual cut	3	1				
Ground firmness	3	1/3	1			
Rockiness	1/3	1/5	1/3	1		
Stoniness	1/5	1/9	1/5	1/5	1	
Forest function	3	1/3	1	5	7	1

Appendix 3. Suitability matrix for the construction of forest roads.

Factor	Terrain slope	Annual cut	Ground firmness	Rockiness	Stoniness	Forest function
Terrain slope	1					
Annual cut	1/7	1				
Ground firmness	1/3	5	1			
Rockiness	1/5	3	1/3	1		
Stoniness	1/7	1	1/5	1/3	1	
Forest function	1/5	3	1/5	1/3	1	1

Appendix 4. Suitability matrix for the designing of skidding tracks.

Factor	Terrain slope	Annual cut	Ground firmness	Rockiness	Stoniness	Forest function
Terrain slope	1					
Annual cut	5	1				
Ground firmness	5	1/7	1			
Rockiness	1	1/5	1	1		
Stoniness	1/3	1/9	1/3	1/3	1	
Forest function	3	1/5	3	5	7	1

Appendix 5. Suitability matrix for the construction of skidding tracks.

Factor	Terrain slope	Annual cut	Ground firmness	Rockiness	Stoniness	Forest function
Terrain slope	1					
Annual cut	1/7	1				
Ground firmness	1	7	1			
Rockiness	1/3	5	3	1		
Stoniness	1/5	3	1	1/3	1	
Forest function	1/9	1	1/7	1/5	1/5	1

Appendix 6. Weight (%) of individual influential factors in the establishing as to the terrain suitability for the designing and construction of forest roads and skidding tracks and the selection of wood skidding type.

Factor	Skidding type selection	Road designing	Skidding track designing	Road construction	Skidding track construction
Terrain slope	40.77	11.08	6.44	45.45	37.45
Annual cut	-	39.19	49.48	4.38	3.66
Ground firmness	8.11	18.74	11.82	25.57	19.1719.17
Rockiness	15.20	6.6	7.01	12.62	25.16
Stoniness	4.61	2.72	3.07	5.12	11.31
Forest function	-	21.66	21.82	6.92	3.24
Distance*	28.54	-	-	-	-
Soil depth	2.77	-	-	-	-

*A distance to a truck road.