Structural Models of Road Landscapes and Microlandscapes

V A Zelikov\textsuperscript{1}, A V Skrypnikov\textsuperscript{2}, V G Kozlov\textsuperscript{3}, V V Samtsov\textsuperscript{2}, P V Tikhomirov\textsuperscript{4}, A O Borovlev\textsuperscript{2}

\textsuperscript{1}Automobile faculty, Department of transportation and traffic safety, Voronezh State University of Forestry and Technologies named after G.F. Morozov, 8, Timiryazev Street, 394087 Voronezh, Russia
\textsuperscript{2}Faculty of management and Informatics in technological systems, Department of information security, Voronezh State University of Engineering Technologies, 19, Revolution Avenue, 394036 Voronezh, Russia
\textsuperscript{3}Agroengineering faculty, Department of operation of transport and technological machines, Voronezh State Agricultural University named after Emperor Peter the Great, 1, Michurina ave., Voronezh, 394087, Russia
\textsuperscript{4}Institute of forestry, transport and ecology, Department of transport and technological machines and service, Bryansk state University of engineering and technology, 3, Stank Dimitrov ave., Bryansk, 241037, Russia

E-mail: vya-kozlov@yandex.ru

Abstract. In this paper we examined the developed structural models of the road landscape and the road micro-landscape, which allows taking into account all the necessary conditions for road construction in local territories. In local areas, the complexity of road construction depends on the general characteristics inherent in a given landscape, of which the micro landscape under consideration is a component. For a comprehensive assessment of the conditions of road construction in local territories, a structural model of the road micro landscape is proposed, which is based on the landscape model. The developed structural models of the road landscape and the road micro-landscape reflect the influence of natural and technogenic factors, the value of land and other factors to determine the complexity of the construction of forest roads. Factors are defined and formulas are presented to take into account the features of the relief, climate, physical and geographical processes and phenomena, surface and groundwater, soil, vegetation, human activities when determining the cost of the construction of a forest road. The structural model of the micro landscape allows a comprehensive assessment of local territories in the survey area, to determine micro landscapes in which the complexity of road construction and the value of the territories will have minimal indicators. A correlation analysis was also carried out, which made it possible to establish the most important characteristics of the components of the geographical environment, which affect the complexity of the construction of a forest road for the main types of costs.
1. Introduction

The structural models of landscapes and micro landscapes allow comprehensive assessment of territories for the construction of forest roads. Comparing the models of road landscapes reflecting the complexity of the construction of wood roads, the conclusion suggests itself that the same territory is characterized by different construction complexity, and the complexity is determined by the conditions of the designed road. It can be assumed that structural models of road landscapes for wood motor roads will later include a larger number of characteristics of the geographical environment.

For a comprehensive assessment of the conditions of road construction in local territories, a structural model of the road micro landscape is proposed, which is based on the landscape model. In local areas, the complexity of road construction depends on the general characteristics inherent in a given landscape, of which the micro landscape under consideration is a component. These are the characteristic features of natural and techno genic conditions peculiar only to this territory. Among these factors are waterlogging, humidification conditions, snow depth, communication corridors intersected by the projected road, the value of agricultural land and territories for various economic uses and others.

The main methodological position on which studies on road-landscape zoning are based is the recognition of the existence of territorial differences and physical-geographical complexes. Each complex includes different components - rocks, relief, atmosphere, surface and underground waters, soils, vegetation, wildlife, which are also different in its qualitative and quantitative characteristics.

2. Material and methods

According to the results of the studies, a structural model of the road landscape, reflecting the complexity of the construction of forest roads, can be represented by the following expression [1]:

$$\Pi_{st} = (\Pi^n_{aw} + \Pi^n_o) + \left(\Pi^n_{rp} + \Pi^n_{hp} + \Pi^n_{aw} + \Pi^n_o\right) + \left(\Pi^n_{rp} + \Pi^n_{hp} + \Pi^n_o\right) + \left(\Pi^n_{aw} + \Pi^n_{o}\right) + \Pi^n_o + \Pi^n_c$$

where $\Pi_{st}$ is an indicator characterizing the complexity of the conditions for the construction of roads of category IV; $\Pi^n_{aw}$, $\Pi^n_{rp}$, $\Pi^n_{hp}$, $\Pi^n_{aw}$, $\Pi^n_{hp}$, $\Pi^n_{aw}$, $\Pi^n_{o}$, $\Pi^n_{o}$ - relative indicators reflecting the influence of the characteristics of the landscape components by type of work; $\Pi^n_{aw}$, $\Pi^n_{rp}$, $\Pi^n_{hp}$, $\Pi^n_{aw}$, $\Pi^n_{hp}$, $\Pi^n_{aw}$, $\Pi^n_{o}$, $\Pi^n_{o}$, $\Pi^n_{o}$ - relative indicators characterizing the minimum cost of construction by type of work and relative indicators of the complexity of the construction of the subgrade, are due respectively to the population density (n) of the rhythm of the relief (rp), the average depth of the fragmentation of the relief (hp), the intensity of erosion (Ew); type of soil (so); preparatory work (n); subgrade (s); small artificial structures (u); frost protection and drainage layers (mo); road conditions (o); buildings and structures of the road and motor transport service (c).

The structural model of the road landscape, reflecting the complexity of construction, is characterized by a smaller set of components:

$$\Pi_{st} = \Pi^n_o + \left(\Pi^n_{rp} + \Pi^n_{hp} + \Pi^n_o\right) + \left(\Pi^n_{rp} + \Pi^n_{hp} + \Pi^n_o\right) + \Pi^n_o + \Pi^n_c$$

where $\Pi_{st}$ is an indicator characterizing the complexity of the conditions for the construction of roads of category V; $\Pi^n_{rp}$, $\Pi^n_{hp}$, $\Pi^n_{rp}$, $\Pi^n_{hp}$ - relative indicators reflecting the influence of the characteristics of the landscape components by type of work; $\Pi^n_o$, $\Pi^n_o$, $\Pi^n_o$, $\Pi^n_o$ - relative indicators characterizing the minimum cost of construction by type of work.

The influence of these factors can be taken into account using the relative coefficients of appreciation by type of cost and the relative coefficients of the value of agricultural land and territories of various economic uses.

The relative coefficients of land values are determined according to an expert survey and are presented in Table 1.
To determine the relative appreciation coefficients by type of work, data from a number of authors [2-6] and design materials were used.

The structural model of the road microlandscape characterizes the conditions of road construction in local territories and reflects the influence of natural and technogenic factors, the value of the land of the \( K \).

\[
\Pi_{am} = \Pi_{m}K_{am}K_{x} = [\left( \Pi_{m} + \Pi_{o} \right) + \left( \Pi_{r} + \Pi_{l} + \Pi_{3c} + \Pi_{v} \right) K_{x}K_{1}K_{d} + \left( \Pi_{a} + \Pi_{p} + \Pi_{n} \right) +
\]

\[
+ \left( \Pi_{a}^{oo} + \Pi_{a}^{oo} \right) K_{d} + \Pi_{o}^{' +} + \Pi_{o}^{' -} ] K_{am}K_{x}
\]

(3)

where \( \Pi_{am} \) is an indicator characterizing the complexity of road construction and the value of agricultural land and territories of various economic uses; \( \Pi_{m}, \Pi_{r}, \Pi_{l}, \Pi_{3c}, \Pi_{v}, \Pi_{a}^{oo}, \Pi_{a}^{oo}, \Pi_{x}^{'} \) - relative indicators characterizing the influence of landscape components; \( K_{1}, K_{3}, K_{4}, K_{a}, K_{am} \) - relative coefficients reflecting the influence of local characteristics on the complexity of road construction.

**Table 1. Summary of private factors characterizing the complexity of road construction in local areas.**

| Estimated 5% snow depth, cm | 60  | 70  | 80  |
|----------------------------|-----|-----|-----|
| The coefficient of appreciation \( K_{1} \) obtained by the results of experimental design by the author | 1,0 | 1,15 | 1,3 |
| Wetlands, peat power, m    | 2   | 3   | 4   |
| The coefficient of appreciation \( K_{2} \) when fully peeling | 2,5 | 3,5 | 4,5 |
| Wetlands, peat thickness, m | 6   | 7   | 8   |
| The coefficient of appreciation \( K_{3} \) with partial peat | 4,0 | 4,5 | 5,0 |
| Type of terrain by humidification conditions | 1   | 2   | 3   |
| Rise in price \( K_{d} \) | 1,0 | 1,4 | 1,7 |
| Rise in price \( K_{x} \) | 4,0 | 1,3 | 1,1 |
| Railways                   | transition |
| Main oil pipelines gas pipelines | transition |
| Rise in price \( K_{x} \) | 1,2 |

The structural model of the micro landscape allows a comprehensive assessment of local territories in the survey area to determine micro landscapes in which the complexity of road construction and the value of the territories will have minimal indicators. A set of such micro-landscapes represents a probabilistic «corridor» of tracing.

The regional zoning is carried out to study the regional characteristics of the natural and technogenic conditions for the construction of wood roads in large areas. The main object of study is the landscape.

The structure of the road landscape is represented by the following elements:
- the climate, which is characterized by the average annual temperature, runoff coefficient, freezing rate of soil snow cover 5% probability of exceeding, with the number of days in years with blizzards;
- relief - rhythm and average depth of dissection;
• ecology - the presence of karst phenomena, the intensity of corrosion;
• soil-soils - type of soil and its estimated humidity;
• human activities - the degree of economic use of territories for agricultural purposes, fully populated areas (number of settlements per 100 sq. km), population density.

The main sources of information on the quantitative characteristics of landscape components are stock materials, literary sources, special maps of various scales (topographic, geological, soil, physical and geographical zoning, etc.).

In the process of regional zoning are determined [2, 3]:
• quantitative indicators for each component of the landscape and patterns of its distribution in the study area;
• complexity of the conditions of road construction, engineering assessment;
• spatial distribution of territorial complexes (road landscapes) with varying degrees of complexity of road construction conditions, mapping.

The quantitative characteristics of the climate in the study area are established according to long-term observations on a network of reference meteorological stations (weather stations with a long series of observations and most fully covering climate characteristics). For each station, the following are determined:
• average annual air temperature (annual amount of precipitation, evaporation), and the runoff coefficient characterizing the conditions of humidification of the territory is calculated by these indicators:

\[ f = \frac{r - E}{r} \tag{4} \]

where \( r \) is the annual amount of precipitation, according to observations 5% probability of exceeding, mm; \( E \) - annual evaporation, mm.

• depth of seasonal freezing and duration of winter. Using these data, the parameter \( a_0 \) is calculated, which characterizes the rate of soil freezing:

\[ a_0 = \frac{Z^2}{2T_3} \tag{5} \]

where \( Z \) is the maximum freezing depth of 5% probability of exceeding, cm; \( T_3 \) - duration of winter, day.

• height of snow cover, cm;
• average number of days in a year with blizzards.

Based on these data, a map is compiled of the spatial distribution of climatic characteristics in the study area.

The morphological characteristics of the relief — the frequency of alternation of elevated and lowered terrain points (elevation rhythm) and the average depth of dissection — are determined using indicators proposed by V. Chentsov. [7] Alternation frequency — relief rhythm — average distance between adjacent profile bends.

**Figure 1.** Determination of the rhythm of the relief (according to V.N. Chentsov).
On the profile length \( L \), with the number of kinks \( m \) and the number of intervals between kinks \( m+1 \), the average distance \( rp \) - the rhythm of the relief - is:

\[
rp = \frac{L}{m+1}
\]  

(6)

The average depth of dismemberment along the profile is defined as the average excess of higher points over neighboring lower ones.

Figurfe 2. Determination of the average depth of the dissection of the relief (according to V.N. Chentsov).

If the total number of points on the profile is \( m \), and the difference is higher from two adjacent inflections of the profile line \( h_1, h_2, \ldots, h_{m+1} \), then

\[
h_p = \frac{h_1 + h_2 + \ldots + h_{m+1}}{m+1}
\]

(7)

Between the average depth of the partition and the rhythm of the relief, we stopped the correlation dependence (the correlation ratio \( \eta_{xy} = 0.75, S_\eta = 0.03, t_\eta = 25 \)), which allows plotting (Fig. 3) \( h_p = f(rp) \). The rhythm of the relief is determined by topographic maps on a scale of 1: 300,000, 1: 100,000 by constructing geomorphological profiles on the “key” areas. According to the graph (Figure 3), the average depth of the relief is determined.

Figure 3. The graph of the dependence of the average depth of dismemberment on the rhythm of the relief.

For characteristics and physical-geological processes and phenomena, a four-point rating system is used. The Komi Republic was taken as an example.

The ground conditions of road construction are characterized by three types of soils, the second - non-dusty soils and the third - dusty soils.

The population density per person / sq. km. adopted as an indicator of human economic activity in the study area. According to the Republican Department of Nature Protection, literary sources identify
and map valuable natural complexes, historical monuments and other territories to be protected. While surveying and designing forest roads in these areas, special measures must be taken to protect it.

Figure 4 shows a block diagram of the main stages of regional engineering landscape zoning.

![Figure 4. Block diagram of the main stages of regional engineering and landscape zoning](image)

Thus, the first stage of regional zoning involves the development of maps showing the distribution of quantitative characteristics of landscape components in the study area. Cartographic schemes are compiled on one scale, depending on the area of zoning, maps of scale from 1:2 500 000 to 1:300 000 can be used.

At the second stage of regional zoning, the complexity of the conditions of road construction is determined. There is a correlation between the quantitative characteristics of landscape components and the complexity of road construction, some help to the road landscape model.

The quantitative characteristics of landscape components are determined by cartographic schemes, and the corresponding indicators of the complexity of road construction by type.

The third stage of zoning is the identification and mapping of road landscapes in the study area, road-landscape profiles are divided into cartographic schemes. In the direction of zoning it changes from north to south at a distance of 2-3 cm. The road-landscape profile consists of three parts:

- profile;
- planned strip;
- evaluation graphs that record the characteristics of landscape components and its distribution boundaries.

The number of score lines corresponds to the number of terrain features. In the last column there is the total indicator of complexity for areas of change of private indicators of complexity.

The road-landscape profile is compiled on the horizontal scale of the map (1: 2 500 00 to 1: 300 000), the vertical scale is 1:10 000. The marks on the profile line are determined horizontally, soils are shown under the profile line.
Using maps on the road-landscape profiles are applied characteristics of the landscape components and its spatial distribution. The road-landscape profile is analyzed for each component, homogeneous sections are allocated for which private indicators of complexity are assigned.

The boundaries for determining the final indicator of \( \Pi_{l} \) complexity are areas of change in private complexity indicators.

The road-landscape profiles are applied to the map; on each of it the boundaries of the areas where the \( \Pi_{l} \) is defined are shown. Territories with the same indicators of complexity of road construction are combined into road landscapes.

The road landscapes highlighted on the map are assigned a serial number and indicate an indicator of the complexity of the road construction conditions, for example, road landscape 4-1, 32; the first digit indicates the landscape number in the study area, the second characterizes the complexity of the construction conditions.

3. Results
Planning the construction of a forest road and choosing its rational position on the ground. The engineer is constantly faced with the need to take into account the features of the relief, climate, physical and geographical processes and phenomena, surface and groundwater, soil, vegetation, human activities, as factors that determine primarily the cost of the construction of a forest road.

The correlation analysis carried out for all the arguments made it possible to establish the most important characteristics of the components of the geographic environment that affect the complexity of constructing a wood road by cost type.

4. Conclusion
Comparing the models of road landscapes reflecting the complexity of the construction of forest roads, the conclusion suggests itself that the same territory is characterized by different construction complexity, and the complexity is determined by the conditions of the designed road. We suggest that it is necessary to include a greater number of characteristics of the geographic environment for the development of structural models of road landscapes of forest roads.

For a comprehensive assessment of the conditions of road construction in local territories, we can use the structural model of the road microlandscape, which is based on the landscape model.

References:
[1] Kozlov V.G., Gulevsky V.A., Skrypnikov A.V., Logoyda V.S. and Menzhulova A.S. 2017 Method of Individual Forecasting of Technical State of Logging Machines IOP Conf. Series: Materials Science and Engineering 327 (2018) 042056.
[2] Harutyunyan A.Yu. and others. 2015 Methodology for ensuring a given level of reliability of the functioning of integrated technical support System analysis and modeling of quality management processes in the innovative development of the agro-industrial complex. pp. 594-599.
[3] Birulya A.K. 1966 Operation of highways M.: Transport. p. 326.
[4] Kozlov V.G., Kondrashova E.V., Skrypnikov A.V. and Skvortsova T.V. 2015 Modeling traffic on forest roads. Modern problems of science and education. Vol. 1-1. p. 432.
[5] Kondrashova E.V. An algorithm for finding the optimal transport plan with optimization of wood removal. Bulletin of the Krasnoyarsk State Agrarian University. 2011. No. 9. pp. 34-41.
[6] Logoida V.S. and others. 2016 Methodological substantiation of the design features of the route according to the method of support elements Basic research. Vol. 12-1. pp. 62-68.
[7] Chentsov V.N. 1948 Morphometric indicators on small-scale geomorphological maps. Proceedings of the Institute of Geography, USSR Academy of Sciences. Vol 39. p 306.
[8] Skvortsova T.V. 2011 Optimization of the overhaul periods of wood motor roads. Basic research. Vol 8-3. pp. 667-671.
[9] Kapustin V.P. 2016 Designing the structure of information support for wood transport vehicles. Izvestia Saint-Petersburg Forestry Engineering Academy Vol. 217 pp. 131-141.
[10] Babkov V.F. and Andreev O.V. 2013 Road design. Part I M.: The Book of Requirement p 368.
[11] Treskinsky S.A. 1984 Slopes and slopes in road construction M.: Transport p. 157.
[12] Theoretical foundations of recreational geography [Text] / [resp. ed. V.S. Preobrazhensky]; USSR Academy of Sciences, Institute of Geography. - Moscow: Nauka, 1975.- p. 224.
[13] Bocharov M.K. 1971 Methods of mathematical statistics in geography Moscow: Mysl p. 374.