Influence of natural and technogenic factors on the complexity of construction of timber highways

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Abstract. The article discusses the issues of assessing the possibility of road construction using engineering-landscape zoning. The complexity of the conditions for the construction of a lumber road, the value of agricultural land and territories of various economic uses, and the location of territorial complexes are determined. The dependence for calculating the total unit cost of road construction is presented. The work has shown a correlation analysis, which made it possible to establish the most important characteristics of the components of the geographic environment, which affect the complexity of the construction of a timber haul road by type of cost. The graphs characterizing the changes in the cost of expenses by type of work are presented, depending on the characteristics of the relief, water erosion, types of soil, population density. Using the dependence graphs, it seems possible to determine the basic cost of building one kilometer of the road by type of work. The basic cost is determined by the dependence that has a greater correlation ratio.

1. Introduction
Engineering landscape zoning is a collection and processing system. The information about natural and man-made conditions of road construction is based on the results of work. The torus quantifies the degree of influence of the characteristics of the geographical environment components on the complexity of road construction, which allows you to identify and map territorial complexes, road landscapes and microlandscapes [1-4].

As a result of engineering landscape zoning, the following has been established [5-9]:
1. Complexity of road construction conditions.
2. Value of agricultural land and territories of various economic uses.
3. Location of territorial complexes (road landscapes and microlandscapes) in various degrees of com-
plexity of road construction.
The linear nature of road construction makes it necessary to study the general and particular features of natural and man-made conditions for the construction of logging roads. The general characteristics of natural conditions and human activity are determined in large territories (road landscapes). On local territories, road microlandscapes, specific features of the location, microclimates, soils, vegetation, and land values that are unique to this territory are evaluated.
Thus, engineering assessment of natural and man-made road construction conditions is carried out in the course of regional and linear zoning.

2. Material and methods

The amount of information is calculated based on the road and landscape profile, which provides quantitative characteristics of the landscape components. On the profile, values are also determined for all these indicators \( x_{\text{max}} \) and \( x_{\text{min}} \), the level of indistinguishability of the attribute – \( \varepsilon \) is set. The number of features is determined from the expression [4]:

\[
K_i = \frac{x_{\text{max}} + x_{\text{min}}}{\varepsilon}.
\]  
(1)

The information price of the attribute is:

\[
\Pi_i = 2(K_i - 1).
\]  
(2)

When moving along the profile, the values change \( x_i \) to the average value \( x_{ij} \). The probability of such transition [4] is:

\[
P = \frac{1}{\Pi_i} = \frac{1}{2(K_i - 1)}.
\]  
(3)

The specific information in this case (in bits) is:

\[
\Delta V = -P \log_2 P_i = -\frac{1}{n_i} \log_2 \frac{1}{n_i}.
\]  
(4)

The maximum information for each of the characteristics of the geographical environment is determined from the expression:

\[
\Delta V_{\text{max}} = (K_i - 1) \cdot P_i \log_2 P_i.
\]  
(5)

To determine the information difference between neighboring points on the profile for all characteristics \( N \), the corresponding amount of information at the profile step is summed:

\[
\Delta V_{ij} = \sum_{i=1}^{N} P_i \log_2 P_i.
\]  
(6)

The increment of information is linear and it only approximates the relationship between the characteristics of the landscape and the complexity of road construction. However, for a preliminary assessment, the information method can be used in road zoning [10-13].

Using a point rating, an information method, the tasks were not solved. This situation forced us to turn to statistics and use correlation analysis to determine, first of all, the role of characteristics of geographical environment components on the complexity of construction of a logging road.
The study involved statistical data from the Department of highways of the Republic of Komi. It made it possible to carry out statistical processing of the average cost of one kilometer of preparatory work \( C_n \), of earthworks \( C_z \), of small artificial structures of \( C_i \), frost protection and drainage layer \( C_{\text{dr}} \), road conditions \( C_o \). That takes into account all those types of work, the cost of which depends on natural and man-made factors.
When planning the construction of a logging road and choosing its rational location on the ground, the engineer is constantly faced with the need to take into account the features of terrain, climate, physical and geographical processes and phenomena, surface and underground water, soil, vegetation, human
economic activity. They are the factors that determine the cost of construction of a logging road in the first place.

The total unit cost $C_c$ of road construction by the type of cost can be represented by the following expression:

$$C_c = C_p + C_s + C_a + C_{fp} + C_{rp} + C_{sr} + C_{bs} + C_r + C_o,$$

where, the unit cost, respectively:
- $C_p$ – preparatory work;
- $C_s$ – subgrade;
- $C_a$ – small artificial structures;
- $C_{fp}$ – frost protection and drainage layer;
- $C_{rp}$ – road pavement;
- $C_{sr}$ – the situation of the road;
- $C_{bs}$ – buildings and structures of the road and motor transport service;
- $C_r$ – recultivation of lands;
- $C_o$ – other work and expenses;
- $C_{fp}$, $C_s$, $C_{fp}$, $C_s$ – the main cost of road construction, regardless of natural and man-made factors;
- $\Delta C_{fp}$, $\Delta C_s$, $\Delta C_{fp}$, $\Delta C_s$ – price increases due to natural and man-made characteristics of the geographical environment.

The role and influence of natural and man-made factors on the complexity of the construction of a logging road was identified in function of the characteristics of the geographical environment listed in table 1 below, acting as arguments.

The correlation analysis carried out for all the arguments allowed us to determine the most important characteristics of the components of the geographical environment that affect the complexity of construction of a logging road by type of costs $C_{fp}$, $C_s$, $C_{as}$, $C_{sr}$, $C_s$.

The results of correlation analysis in the form of correlation relations are shown in table 1.

### Table 1. Correlation relations (own developments)

| Characteristics of the geographical environment | Types of expenses | Correlation relationships |
|-------------------------------------------------|-------------------|---------------------------|
| The rhythm of relief                            | $C_{fp}$          | -                         |
| Depth                                           | $C_s$             | 0.70                      |
| Dismemberment                                   | $C_a$             | 0.66                      |
| Water erosion                                   | $C_{fp}$          | -                         |
| Type of soil                                    | $C_s$             | 0.78                      |
| Population density                             | $C_{fp}$          | 0.43                      |
| Population density                             | $C_s$             | C.o.                      |

*The symbol "C.o." listed in the table should be known as "the link missing".*

Based on the results of the correlation analysis, the expression (7) can be written:

$$C_c = C_o + \Delta C_{pd} + C_{sr} + \Delta C_{fp} + \Delta C_{hp} + \Delta C_{ev} + C_s + \Delta C_{fp} + \Delta C_{sr} + C_{fp} + \Delta C_{v} + C_r + C_{o},$$

where, the rise in price is due to:
- $\Delta C_{pd}$ – population density;
- $\Delta C_{r}$ – the rhythm of relief;
- $\Delta C_{hp}$ – average depth of terrain division;
- $\Delta C_{ev}$ – characteristics of erosion processes;
- $\Delta C_{as}$ – type of soil;
$C^p$, $C^b$, $C^a$, $C^{fp}$, $C^n$ – the main cost of construction, respectively, preparatory work, roadbed, artificial structures, frost protection and drainage layer, road conditions, independent of natural and man-made factors;

$C_{ucp}$ – the unit cost of the pavement;

$C_{scb}$ – specific cost of buildings and structures of the road and road transport service;

$C_{sc}$ – specific cost of land reclamation;

$C_{uc}$ – unit cost of other work and expenses.

Changes in costs by type of work, depending on changes in the quantitative parameters of arguments, were studied using regression analysis. Figure 1-7 shows graphs describing changes in the cost of expenditures by type of work, depending on the characteristics of the terrain, water erosion, soil types, and population density.

3. Results

The selection of empirical formulas reflecting the form of connection between the studied dependencies is performed using modern information technologies. As a result of processing, the following results are obtained.

**Figure 1.** Changes in the cost of the roadbed from the rhythm of the terrain (own developments)

**Figure 2.** Changes in the cost of the roadbed from the average depth of terrain division (own development)
Figure 3. Changes in the cost of the roadbed from the characteristics of erosion (own development)

![Figure 3](image)

Figure 4. Changes in the cost of small and artificial structures depending on the rhythm of the terrain (own developments)

![Figure 4](image)

Figure 5. Changes in the cost of artificial structures from the environment to the depth of terrain dissection (own development)

![Figure 5](image)

Figure 6. Changes in the cost of frost protection and drainage layer depending on the type of soil (own development)

![Figure 6](image)

Figure 7. Changes in the cost of preparatory work and road conditions depending on population density (own developments)

\[
\Delta C_{pd} = 11.8 + 12.4rp - 7.8rp^2 + 1.4rp^3 - 0.1rp^4
\]  

(9)
\[ \Delta C_{pd}^{\text{d}} = 1.2 - 0.02hp + 0.01hp^2, \quad (10) \]
\[ \Delta C_{pd}^{\text{d}} = 11.5 + 0.6 Ev \quad (11) \]
\[ \Delta C_{pd}^{\text{d}} = 3.0 + 10.5rp + 5.4rp^2 + 0.7rp^3 \quad (12) \]
\[ \Delta C_{pd}^{\text{d}} = 0.25hp^{0.99} + 0.5 \quad (13) \]
\[ \Delta C_{pd}^{\text{d}} = 12.9 + \frac{11.5}{Vg} \quad (14) \]
\[ \Delta C_{pd}^{\text{d}} = 2.7 - 0.06Pn \quad (15) \]
\[ \Delta C_{pd}^{\text{d}} = 5.9 + 28.8rp - 23.3rp^2 + 6.2rp^3 - 0.5rp^4 \quad (16) \]
\[ \Delta C_{pd}^{\text{d}} = 8 + 0.4 hp \quad (17) \]
\[ \Delta C_{pd}^{\text{d}} = 2.0 + 11.1rp - 8.5rp^2 + 2.2rp^3 - 0.2rp^4 \quad (18) \]
\[ \Delta C_{pd}^{\text{d}} = 2.1 + 0.03 hp + 0.002hp^2 \quad (19) \]
\[ \Delta C_{pd}^{\text{d}} = -1.9 - 2.1Vg + 7.3Vg^2 - 1.8 Vg^3 \quad (20) \]

Using dependency graphs (figures 1-7), it is possible to determine the main \((C_r)\) cost of building one kilometer of road by type of work, the main cost is determined by the relationship that has a greater correlation. For example, the cost of building a roadbed for logging depends on the rhythm of the terrain, the depth of dissection, the nature of erosive manifestations; \(C_r\) - according to the schedule of dependence \(C_r = f(rp)\).

### 4. Conclusion

The main cost of construction of a logging road determined in this way is the minimum necessary for construction and is accepted as an “standard” that characterizes the most favorable natural and man-made conditions.

Changing one or more characteristics of the geographical environment will result in an increase in cost, which is viewed as an indicator of the complexity of road construction.

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