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Planning the forest transport systems based on the principles of sustainable development of territories

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Planning the forest transport systems based on the principles of sustainable development of territories

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Abstract. The article identifies a new method of dynamic modeling in the design of the transport system in the forest fund (TSFF), which is based on economic and mathematical modeling and fuzzy logic tools. The combination of the indicated methods is designed to reduce the disadvantages of their use and increase the benefits. The article substantiates the choice of assessing the forecast level of the impact of risks on the activities of forestry enterprises (the method of expert assessments), using the methodological tools of fuzzy logic. The indicated method makes it possible to take into account a large variety of risk factors of the internal and external environment. At the same time, methodological aspects of fuzzy logic make it possible to formulate a quantitative assessment of qualitative indicators. The article substantiates the choice of tools for economic and mathematical modeling in order to state the design problem of the planned TSFF. Since the indicated method enables the formalization of the functioning of the timber transport system in the given conditions. The article presents a developed model that correctly takes into account the influence of risk factors when planning a TSFF, through the combination of fuzzy logic methods and economic and mathematical modeling. The advantages of the developed model include: considering the multivariance of material flows, vehicles, points of overload, etc.; automated processing of input parameters and effective data; using the model for forecasting, i.e. the possibility of deriving a fuzzy estimate of the efficiency of the timber transport system by identifying cause-effect relationships between the modeling object and the influence of risk factors on its functioning.

1. Introduction

The presence of an optimally developed transport infrastructure is a necessary condition, without which sustainable development of territories is impossible [1, 6]. Planning a transport system in the forest fund (TSFF) is a multi-criteria task, since the cost of its construction and operation, environmental, social, and technical efficiency are contradictory [9-12]. Proceeding from this, the planned TSFF and the territory of the forest fund proposed for development should be considered as a single system, i.e. in synergistic relationships between the designated components. In turn, this system is influenced by a number of risk-forming factors.

2. Objects and Research Methods

Risks in the forest industry is the probability of losses due to changes in the economic, environmental, social, and technical condition of the forest industry [7, 8]. The risks shown in Figure 1 have the greatest impact on forestry enterprises.
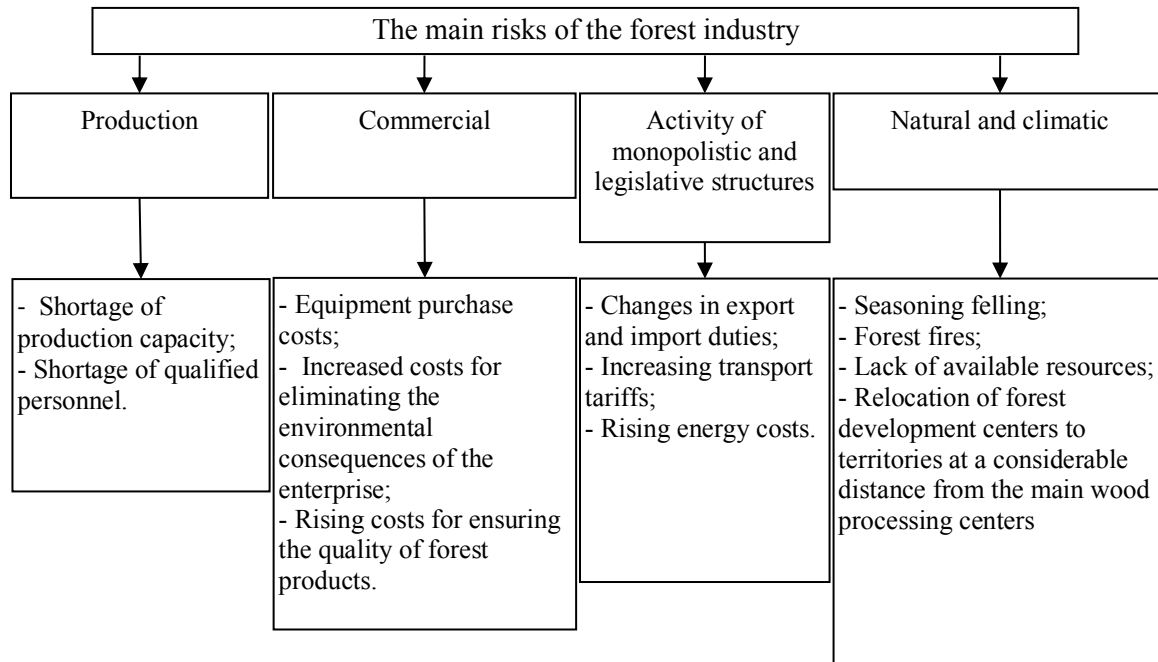
Figure 1. Risk classification in the forest industry.

Since the main criterion for evaluating any system is its effectiveness (the ratio of results to costs), we propose to predict the effectiveness of the planned TSFF's functioning, taking into account environmental and economic indicators and risk factors accompanying the project. Qualitatively, this can be expressed as reaching the maximum of all potential incomes, taking into account the influence of risk-forming factors.

3. Results and Discussion

Taking into account the analysis of sources [2-4; 15-19], quantitatively, the objective function of the efficiency of the TSFF E_{ef}^{n} can be the total value of the resulting functional E_{ef}^{n} and $£(T)$, which is a predicted value, determining the degree of influence of risk-forming factors on the effectiveness of planning a TSFF for the period of forest fund development *(T)*.

The final functionality E_{ef} in the first approximation is the ratio of net present value (NPV), obtained as a result of the development of the forest fund during the period of development of the forest fund T, to the total cost of construction and operation of the TSFF (*S*). It shows the amount of net profit per ruble of total costs over the time periods *t*. In this case, the mathematical model of the stated optimization problem takes the form:

$$\begin{cases} \mathrm{E}_{ef}^{n} = \mathrm{E}^{ef} - £(T); \ \ \mathrm{E}^{ef} = \mathrm{HTC} \cdot S^{-1} \to \max; \ £(T) = \sum_{b=1}^{B} g_b(t); \\ £(T) = \sum_{t=0}^{T} £(t); \ £(T) \to \min; \ b = 1,...B. \end{cases} \tag{1}$$

The coefficients $g_b(t)$ given in expression (1) should be determined by the method of expert assessments by forest industry specialists [8]. Taking into account these factors, the forecast of the degree of influence of one or another risk factor on the value of the current gross income at points in time *t* can be carried out. In the

mathematical model, only those types of risks (B) are included, which, according to experts, have the greatest impact on the TSFF effectiveness [13, 14].

It should be noted that, according to some sources [5, 8], the forecast of the influence of risk-forming factors on the TSFF planning project for the period of forest fund development is short (from 3 to 5 years). Consequently, the predicted value, which determines the degree of influence of risk-forming factors on the TSFF planning project during the forest fund development period $£(T)$, is the sum of $£(T) = T$ over time periods (t).

The net present value obtained as a result of the development of the territory of the forest fund through the implementation of the TSFF (for periods of time t) is determined by the following expression:

$$HTC = DT - S \qquad (2)$$

where D_T – the current gross income from the development of the forest fund, for a period of time t, ruble; S – planned total costs as a result of the development of the forest fund, for periods of time t, ruble.

The current gross income as a result of the development of the forest fund for periods of time t is determined by the expression (3):

$$\begin{cases} D_T = (1+e)^{-T} \cdot \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{K} \left[C_i(t) + C_{ij}^{TP}(t) \right] \cdot Q_{ijk}(t) - \sum_{t=0}^{T} £(t) \rightarrow \max; \\ £(t) = g_v(t) + g_G(t) + g_w(t) \rightarrow \min; \\ D(t) = \sum_{i=1}^{m} \sum_{j=1}^{n} \sum_{k=1}^{K} \left[C_i(t) \cdot (1 \pm g_v(t)) + C_{ij}^{TP}(t) \cdot (1 \pm g_G(t)) \right] \cdot Q_{ijk}(t) \cdot (1 - g_w(t)); \\ (i = 1,...m), (j = 1,...n), (k = 1,...K), (t = 0,...T). \end{cases} \qquad (3)$$

where C_{ij} is the selling price of 1 m^3 (or other units of forest resources) by types of forest resources from the i-th forest plot, $i \in \{1,...,m\}$, (hectare, allotment, m^2), to the j-th warehouse (near-land plot, to the consumer), $j \in \{1,...,n\}$, rub.; $C_{ij}^{TP}(t)$ – transportation costs per unit of output, rub. at time t; $Q_{ijk}(t)$ – a total volume of forest resources from the i-th forest area (quarter, section, m^2), to the j-th warehouse to be harvested and transported by the k-th type of transport at time t, $k \in \{1,...,K\}$, m^3 (or other units of forest resources); e – a discount factor; T – a period of the forest fund development, years; t – time from the moment of evaluation to the moment of resource procurement, $t \in \{1,...,T\}$, years; $g_w(t)$ is the coefficient for assessing the impact of the resource factor on the volume of (shipped) products, as well as the effect of the risk of short delivery or delivery of products of inadequate quality at the time t; $g_v(t)$ is the coefficient for assessing the influence of the factor of shadow economic relations, as well as the effect of inflation on the cost of (shipped) products at time t; $g_G(t)$ is the coefficient for assessing the impact of the legislative and monopolistic factors on transportation costs at time t; $D(t)$ is the current gross income from the development of the forest fund, for periods of time t, corrected for the influence of risk-forming factors (B), rub.

The planned total costs (maximum allowable costs associated with logging, reforestation, construction and operation of the TSFF for the period of development of the forest fund) are determined by the expression (4):

$$S = \sum_{t=0}^{T} (O_z + O_v + P_{ij}' \cdot \Delta t(t)) \cdot (1+e)^t \cdot (1 + (1+e)^{-T}) + \sum_{t=0}^{T} £(t) \rightarrow \min \qquad (4)$$

where O_z – reduced costs for the creation and operation of TSFF, rub.; O_v – regulatory costs for the reproduction and protection of forests, guaranteeing their restoration in clearings, growing up to the age

of maturity, protection and protection, rub.; $P_{ij}^{'}$ stands for deadening the forestry asset (not sales) from not developing the forest fund due to the absence of LDS, per $1m^3$ hectare, land plot, m^2) at time t, rub.; Δt – the period of non-development of the forest fund. $P_{ij}^{'}$ - those costs that include the potential income lost due to the postponement of income from forest use plus the cost of removing income from future production cycles for a period of time Δt.

When implementing the proposed mathematical model for assessing the effectiveness of the TSFF, the following limitations should be considered:

1. Payback project planning:

$$\sum_{t=0}^{T}(O_z + O_v + P_{ij}^{'} \cdot \Delta t(t)) \cdot (1+e)^t \cdot (1+(1+e)^{-T}) + \sum_{t=0}^{T} \pounds(t) \leq O_{max} \tag{5}$$

where O_{max} is the financial capabilities of the enterprise.

2. The distance between the i-th forest site and the j-th raw material storage (according to the source [4], the effective shoulder of forest resource removal from the i-th forest area to the j-th raw material warehouse should not exceed 120 km) determines the accessibility of forest sites:

$$L_{ij} \leq 120 \tag{6}$$

where L_{ij} is the distance between the i-th forest site and the j- th raw materials storage, km.

3. Natural non-negativity of freight traffic:

$$L_{ijk}(t) \geq 0, \ i = 1,...m; j = 1,...n; t = 1,...T; k = 1,...K. \tag{7}$$

4. The requirement of continuous, inexhaustible forest management, taking into account the influence of risk-forming factors:

$$\sum_{t=0}^{T}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{K} \begin{Bmatrix} Q_{ijk}(1-g_w)(t+1)_l \cdot \left[C_i(1\pm g_b) + C_{ij}^{TP}(1\pm g_G) \right](t+1)_l - \\ -O_z(t+1)_l - O_v(t+1)_l - P_{ij}^{'} \cdot \Delta t(t+1)_l \end{Bmatrix} -$$

$$-\sum_{t=0}^{T}\sum_{i=1}^{m}\sum_{j=1}^{n}\sum_{k=1}^{K} \begin{Bmatrix} Q_{ijk}(1-g_w)(t)_l \cdot \left[C_i(1\pm g_b) + C_{ij}^{TP}(1\pm g_G) \right](t)_l - \\ -O_z(t)_l - O_v(t)_l - P_{ij}^{'} \cdot \Delta t(t)_l \end{Bmatrix} \geq 0, \tag{8}$$

where l is the number of the economic section (breed), $l = 1,...,L$.

Based on the short-term efficiency forecasting of the forest transport systems functioning, the final functionality should be adjusted for the influence of risk-forming factors $\pounds(T)$ each time period (t).

4. Conclusion
The proposed dynamic model of forecasting the impact of risks on the forest transport system of forest industry enterprises is able to provide: a comprehensive assessment of external and internal environment factors that influence risks in order to predict the level of certain types of risk of forest industry enterprises; a wide range of indicators in order to comprehensively study the influence of environmental factors on sustainability and risks when planning a TSFF; application of expert methods in assessing the influence of risk factors; using the method of fuzzy inference to obtain the final predicted values of the level of risk; the possibility, using qualitative values of the indicators, to obtain a quantitative result.

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