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RISK MANAGEMENT IN REQUIREMENTS OF THE ISO STANDARDS IN RELATION TO LOGGING ROADS

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Statement of the problem. The article considers the scientific bases for developing a system of assessing and standardizing risks in the construction and operation of logging roads within the framework of developing the existing logging road network in the Russian Federation. Regulatory documents in the sphere of managing and assessing technological and parametric risks are analyzed.
Results. The principles of standardizing the acceptable level of hazard are considered and approaches by different scientists and regulatory documents to risk calculation in the requirements on technical regulation are compared. A new approach is developed to standardize the acceptable quality parameters which nobody has ever used to assess parametric risks in relation to logging roads.
Conclusions. A scientifically based technology is proposed to calculate the acceptable risk level of a new or of an operating logging road and ways to compensate for residual risks. Ways are suggested of adequate risk reduction in assessing safety of the logging road design conditions with account of the probability of logging truck losing its stability. We are trying to improve the existing system of developing construction and reconstruction projects for existing logging roads thorough their conformity to international risk assessment requirements. That is why our conclusions include one on the front-end use of world-famous geographic information systems which are still scarcely used in domestic practice, particularly for logging roads. They will be instrumental in keeping track of different factors that could entail an increase in risks not considered in projects.
Keywords: risk-management, logging roads, risk assessment, risk theory, critical factors.

Introduction. According to the Constitution and International Agreements of the Russian Federation (Agreement on Technical Barriers to Trade in the WTO (Appendix 9); Protocol on Technical Regulation within the Eurasian Economic Union (EurAsEC) from 05.29.2014;

Treaty on the Establishment of EurAsEC; Decision of the Technical Commission of the Customs Union of April 7, 2011, no. 621), risk assessment is deemed as a service emerging from the enforcement of the Federal Law "On Accreditation in the National Accreditation System". Presently, all the regulatory documents regarding technical regulation call for risk assessment techniques at all stages of a life cycle. The more similar this assessment is to the design stage, the lower will be costs of risk compensation during operation of a forest road. Thus approval and adoption of a forest road project is considered to be the most similar to designing a forest road, or in terms of technical regulation, time when of a forest road project is released. Therefore it is essential to develop a methodology for standardizing acceptable risk levels in order to decide as to whether a project complies with the requirements of technical regulations in terms of risks. However, there are currently no methods in both domestic and foreign practice [18, 19, 21, 22, 24, 27, 28] regarding risk assessment in forest road design, all sources of hazards and threats for forest roads are not identified, there are no experts in the field of identification, assessment and standardization of acceptable risk levels in relation to a forest road.

Hence risk assessment should be performed by specialists on risk hazard in technical regulation (TR) of construction, transport, forestry industry, road safety, building materials, geology, etc. It would be hugely beneficial if these specialists were trained risk assessment specialists or held PhD/doctoral degrees. It is only in this case that timely assessment with risk calculations could contribute to improving safety of forest roads and meet the requirements of Federal Law No. 184-FL (ФЗ) "On Technical Regulation". In this paper the authors seeks to identify sources of hazards, to set forth a methodology for assessing and standardizing acceptable risk levels in relation to a forest road as well as to summarize the experience of risk management and bring to designers' attention the identified sources of hazards for their timely consideration and due adjustments in forest road projects.

The probabilistic-theoretical approach to assessing technical and environmental risks relies on the probabilistic nature of the investigated parameters for TR objects. The known basic methodological principles for employing this approach to assessment and direct calculation of risks to all stages of a life cycle of forest roads and their structures are critical for quantitative calculation and risk analysis. Therefore according to the guidelines and regulations, the development of a scientifically based approach to assessing, calculating and standardizing technical risks for forest highways is an extremely relevant task facing modern scholars.

Based on the experience of foreign standards and national requirements for risk management, a methodology should be developed for calculating and standardizing acceptable residual risks associated with logging in order to better cater for customers' interests in design and reconstruction of existing forest highways. Hence we set out to analyze the requirements of regulatory documents of the Russian Federation and foreign risk researchers and apply them in design, construction and operation of forest highways. After key risks had been identified, the requirements for their standardization were established using the well-known scientific school by Prof. V. V. Stolyarov. The methods for improving reliability in design of forest highways were set forth using the terminology of the new standard ISO 31000-2018 [1].

1. Functional and Parametric Calculations of the Risk Theory. Studies of factors contributing to the operational properties of forest highways were carried out by such scholars as A. V. Skrypnikov, T. V. Skvortsova, V. V. Stolyarov, etc. According to [16], efficiency of a forest road is determined by a level of technical and operational condition to ensure reliable and safe operation of forest transport at optimal costs. Expertise and effective performance in repairs and maintenance is critical for a year-round, uninterrupted, safe and convenient traffic at specific speeds and loads. There is thus an opportunity to optimize a turnaround time of forest highways according to the coefficient of economic functionality given by the following formula:

$$K_f = 1 - C_r / C_v, \tag{1}$$

where C_r is the cost of repairs, C_v is the cost of restoration.

Funding decisions are made based on the results of optimization that is aimed at maximizing the economic effect of repairs and restoration: if K_f = 0.6...1.0, repairs of specific areas of a highway are carried out; 0.4...0.6, major repairs are performed; 0...0.4, a state of emergency occurs.

The scholars in [10] showed the dependence of the economics of repairs of forest highways on transportation costs of construction materials and proposed a model for identifying the boundaries of the zones of action of suppliers of materials to allow for the probabilistic nature of material costs. Thus while using local industrial waste, construction and repairing costs see a dramatic reduction.

Safety measures on forest highways entail a combination of measures taken by designers during the construction. A designer of A forest road has to:

— determine the type of a road (major, temporary) considering its prospective congestion, dimensions of timber trucks, travelling opportunities;

— identify hazards and assess risks;

— eliminate hazards and possibly limit risks;

— apply additional devices, pavement reinforcement, etc. for protection against residual risks;

— inform and warn the user on the remaining risks;

— take additional safety measures into consideration.

All measures that are taken at the designing stage are prioritized over those by the consumer (user). The latter's responsibility in terms of the use of measures for reducing the remaining risks is not discussed. Nevertheless the existing system for assessing compliance with the TR requirements and its methodological base cannot guarantee the quality of incoming construction materials even considering the transition to a new system of standardizing quality indicators in the regulatory guidelines to TR TS 014/2011 [2]. For reliability and longevity of forest highways, it is essential that safety measures are simple and do not interfere with the main purpose of the road, i.e., do not restrict the movement of timber trucks at certain times of the year and do not interfere with movement of heavy-duty equipment at forest road intersections with public roads. They must timely and appropriately ensure the passage of such equipment that could be predicted at the risk assessment stage. Otherwise, this might lead to security measures being avoided in order to achieve a desired outcome, e.g., at night, when it is difficult to identify who was in violation of the restrictions and prohibitions on the movement of heavy-duty equipment.

Failure to danger damage involves any malfunction of a road structure or interruptions in its timely maintenance resulting in an accident. Risk reduction means iterative (repetitive) and several sequentially repeated actions that are needed to reduce risks. Ideally, these principles call for knowledge of purposes of major forest roads, their condition and information on accidents, documentation on road conditions, existing technologies for their construction and risk reduction and territorial conditions when roads are operated. A lot of scholars in Russia and abroad with forest highways seem to agree [10, 13, 19, 24, 25]. Design and conditions of forest roads, which are acceptable at this time, might become unsatisfactory if technological advances make it possible to increase the load or speed of logging trucks with a lower risk of loss of stability of a logging truck and defects (potholes, ruts, etc.). According to the recommendation of the authors [13, 24], it is necessary to work closely on the development and implementation in organizations of transport construction standards of organizations in the framework of regional and climatic requirements. They should be in line with the safety requirements for structures in terms of strength and stability, preservation of the carrying capacity based on acceptable risks to human life, animals, environment as well as property, i.e., forestry equipment.

Over the past 25 years, the Saratov State Technical University has been working on mathematical and economic and mathematical models for risk assessment to humans and environment for roads considering vehicle speeds [9, 11]. Under the guidance of the school by

Prof. V. V. Stolyarov, 20 models (techniques) were designed [20]. Let us present those that seem most relevant for forest roads.

1. Risks of an accident when hitting an obstacle on a concave and convex curves as well as movement in limited visibility and loss of lateral stability of a car on a road curve.

2. Risks of failure of pavement, discontinuity in the monolithic layer, excessive saturation of the soil in relation to optimal humidity and environmental risks (these models were developed by N. E. Kokodeeva) [9].

3. Risks of hitting a vehicle moving in front during braking, risks of overcoming climbs at a specified speed difference.

4. Risks of loss of investment returns in construction of two-lane roads, risks of changing the technical category of a road due to inaccuracy in evaluating traffic intensity.

5. Risks of traffic congestions at a specified marking length prohibiting overtaking.

6. Risks of failure of surfacing due to heaving.

7. Risks of drivers losing relevant information.

8. Risks of soil degradation.

9. Risks of exceeding an estimated flow rate by a large one.

10. Risks of snow skidding on a road.

11. Risks of loss of stability of supports and local erosion at a bridge crossing.

12. Risks of loss of visibility of a road surface and oncoming car in severe weather conditions.

13. Road design considering accident risks.

The authors of [9, 17, 20] also came up with a road classification according to degree of responsibility in the framework of the Federal Law 384-FL (ФЗ). They are divided into categories from 1 to 5 in compliance with the Industry Road Guidelines (ОДН) 218.046-01 [14].

Using the normal distribution law for the risk theory, formulas for identifying critical risks [17] of a dangerous parameter are obtained:

1) in the first case when the value $A > A_{cr}$, the formula (2) is used, it is graphically presented in Fig. 1:

$$r_t = 0.5 - \Phi\left(\frac{A - A_{cr}}{\sqrt{\sigma_A^2 + \sigma_{A_{cr}}^2}}\right), \quad (2)$$

where A is the mathematical expectation of the calculated or actual parameter of a structure; A_{cr} is the same for the critical (minimum) design parameter where a failure probability is 50 %; σ_A and σ_{Acr} are mean square deviations of the current values of the parameters; Φ is the Laplace integral function.

The analysis of the formula (2) shows that if $A = A_{cr}$ is accepted, risks of an undesirable event are 50 %, i.e. $r = 0.5$. At $A > A_{cr}$, we have $r > 0.5$ and in the range when $A >> A_{cr}$, risks tend to 0. At $A < A_{cr}$, we have $r > 0.5$ in the range when $A << A_{cr}$, risks tend to 1;

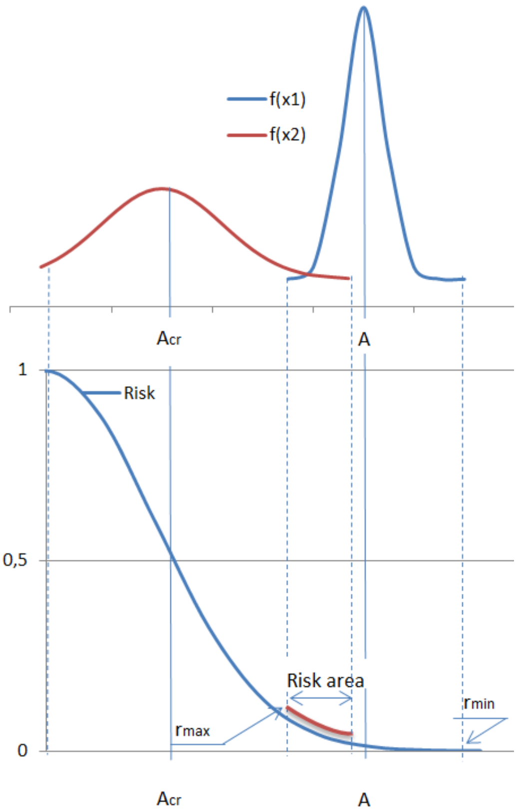

Fig. 1. Density of the distribution of the parameters *A* and A_{cr} with geometric representation of a risk area (A_{cr} is a mathematical expectation of a critical (minimum) parameter)

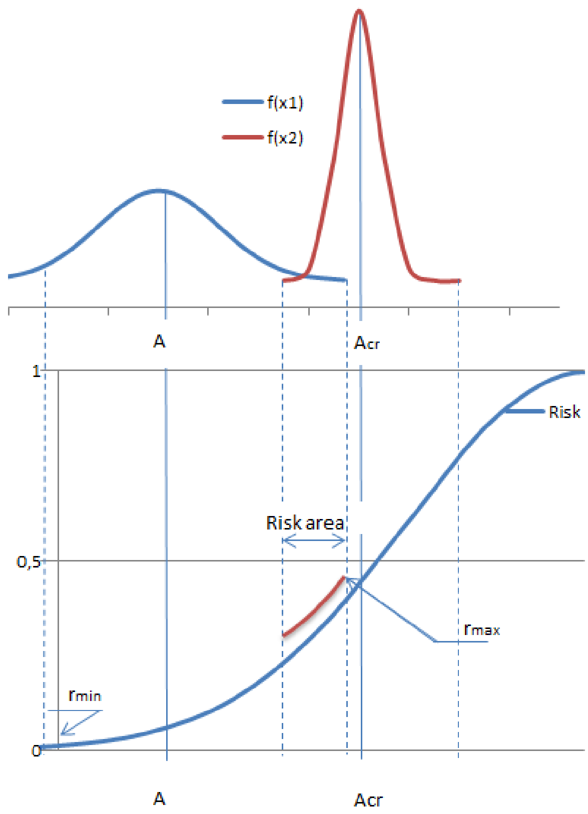

Fig. 2. Density of the distribution of the parameters *A* and A_{cr} with geometric representation of a risk area (A_{cr} is a mathematical expectation of a critical (maximum) parameter)

2) in the second case when $A < A_{cr}$, the formula (3) is used, it is graphically presented in Fig. 2.

$$r_t = 0.5 - \Phi\left(\frac{A_{cr} - A}{\sqrt{\sigma^2_{A_{cr}} + \sigma^2_A}}\right) \quad (3)$$

where A_{cr}, σ_{Acr} are mathematical expectations of a critical parameter of the structure when failure risks are 50 % and its mean square deviation; A, Φ, σ_A – see formula (2).

The analysis of the formula 3 shows that if the parameter $A = A_{cr}$ is accepted, risks of an undesirable event are 50 %, i.e., $r = 0.5$. At $A < A_{cr}$, we have $r < 0.5$ and in the range when $A << A_{cr}$, risks tend to 0. At $A > A_{cr}$ we have $r > 0.5$ and in the range when $A > A_{cr}$, risk tend to 1. These formulas can be employed for parameters distributed according to the normal law, which is acceptable for hazards naturally occurring in forest highways. E.g., when a probability of an undesirable event approaches 0.5, we will have an approximation of the safety margin of a forest road to the weight of a maximum loaded timber truck in unfavorable (calculated) conditions of emergency braking; when centrifugal forces are equal to those of friction and resistance of the timber truck's wheel, which keep it from skidding, when turning in a curve, etc.

According to 184-FL (ФЗ), a degree of damage risks is established: for level I — reduced; for II — average; for level III — increased. Bearing that in mind, we suggest that when designing a forest road to lay in the project a coefficient of variation of quality indicators: for level III (high quality) — a coefficient of variation of road quality indicators $K_v < 0.1$; II level (normal) – $K_v < 0.15$; I level (lowered) – $K_v < 0.2$. Thus, a scientifically based model of rationing acceptable risk levels has been scientifically obtained, what has yet to be done is to identify sources of hazards in order to move on to their quantitative and qualitative assessment, and then to standardizing.

2. Sources of hazard in forest roads. The following types of hazard on forest roads are known:

— hazard that is constantly present (e.g., a dangerous movement of moving elements, uncomfortable position of a driver, noise);

— unexpected hazard (e.g., an explosion, forest fires, collisions as a result of unexpected acceleration, falling loads as a result of acceleration/deceleration).

However, no methods have yet been developed for addressing such a multi-factor problem as maintaining an appropriate level of the carrying capacity of forest highways. There are also a lot of issues surrounding adaptation of the terminology required by the standards for forest roads according to the hazard classification considering all their possible combinations.

In combination, some individual hazards which seem insignificant might develop into significant ones:

— *relevant hazard:* a characteristic hazard naturally occurring in a road or associated with its operation (track, potholes, for road vehicles involved in road construction in accordance with ISO 12100) [3];

— *significant hazard:* a considerable danger defined as a characteristic hazard that requires that a driver take action to reduce associated risks (a possible detour);

— *hazardous situation:* any situation when an individual is exposed to one or more hazards; this effect might cause damage to emerge immediately or after a while;

— *hazard zone, danger zone*: a space in a road where a moving vehicle or driver may be at risk of injury or harm;

— *risk:* a combination of a probability and severity of possible injuries in a dangerous situation in a road or during fires;

— *residual risk:* risk remaining after protective measures have been taken (see Fig. 1 GOST R (ГОСТ Р) 54125-2010) [4].

In accordance with the ISO 73: 2009 terminology [5]:

— *risk estimation:* identifying a degree of possible health dangers and likelihood of any harm being caused;

— *risk evaluation:* an assessment of a possibility of reducing a degree of risk obtained in the analysis;

— *adequate risk reduction:* an adequate reduction in a degree of risk in compliance with the requirements of current standards considering the condition of a road, timber truck loads.

If at the stage of designing a forest road unexpected hazards are calculated considering the probability theory, constantly existing sources of hazards are commonly normalized according to the existing construction guidelines (СП) and local regulations (ВСН). However, if based on the calculation of the standardized parameter considering its standard deviation or a variation coefficient, a total risk is guaranteed that is not over an acceptable risk (e.g., in accordance with an acceptable radius of curvature of a forest road in a plan), making changes to a final project of a forest road will avoid the requirements of regulatory documents and cause an average speed of the timber truck on the road to increase considerably with no danger of a section of a road.

Recurring risk reduction in accordance with section 8.3 of ISO 14121 [6] ends following adequate risk reduction and favorable risk comparison results. We consider a risk reduction adequate if the following questions are answered positively:

— whether all the operating conditions of movement along forest roads and all the recovery procedures for their elimination were considered;

— whether a method identified by means of the standards was employed;

— were the hazards eliminated or the risks associated with the hazards reduced to the lowest acceptable level;

— is there any certainty that the measures do not pose a threat;

— whether users are properly informed and warned on residual risks;

— is there any certainty that the working conditions of a driver of a timber truck are not at risk when protective measures are being taken;

— whether protective measures are compatible;

— are consequences that might occur on a road designed for professional/forestry applications sufficiently assessed if it is being used by common people;

— is there any certainty that protective measures do not compromise the performance of a road.

Protective measures are taken to sufficiently reduce risks: by a designer (when developing a required road construction considering the carrying capacity of timber trucks and possibility of a two-way traffic, presence of additional protective measures, informing users); by users (safety operation of a road, system of signs of hazardous sections, timelynrepairs and other factors that have a particular effect on the carrying capacity of such roads listed by the authors in [13]).

Extra protection measures should be taken in order to protect timber truck drivers from hazards that remain a possibility and are limited by the condition of a road surface as well as to considerably reduce risks. Different forestry systems can also be employed, e.g., emergency stop devices (ISO 12100: 2010) protecting drivers from dangers associated with road surface defects considering that it is necessary a danger zone or additional measures of protection should be accessed to prevent loss of stability at a specified driving speed in the radius of a curvature. Some safety structures might be utilized in order to rule out the effects of a few hazards at a time.

Informing users is a key component of design of major forest roads in compliance with IEC 82079 [7]. To that end, actions to ensure safe and proper operation of forest roads should be described and drivers have to be informed on residual risks (see ISO 12100-1). This is particularly the case for roads that are likely to lose the carrying capacity of their foundation and which require repairs, according to the results of the coefficient K_f calculated using the formula 1.

Depending on the degree of risk and its time, user information is critical and should be placed in a road itself, on the side; or must be spread by other means. However, there must be no “excessive number of warning signals”.

The risk-based approach to managing design organizations involved in construction and reconstruction of forest roads should be continuous and iterative in accordance with the GOST R (ГОСТ Р) ISO 31000-2010 [8] (see Fig. 3), which will ultimately cause an increase in the reliability of a forest road design system, as was proposed by, e.g., the authors in relation to designation of the radius of a highway curvature [10].

As can be seen, risk assessment and standardization are not short-term goals. Therefore an iterative approach is necessary. We have not yet applied the approach based on the analysis of a reject tree, as the factors presented in the paper emerge according to the "either-or" principle. Otherwise, a rejection tree should be designed.

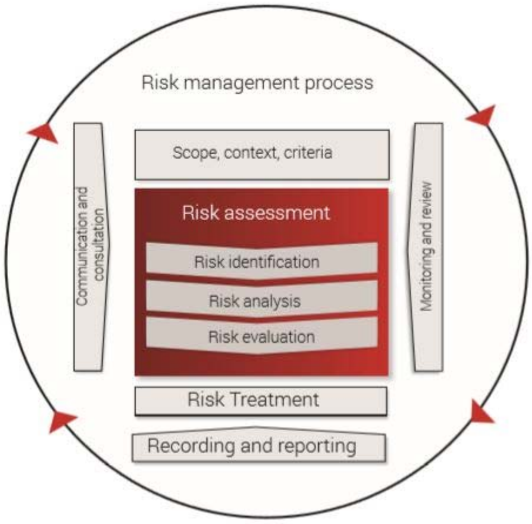

Fig. 3. Risk management according to the international standard ISO 31000-2018

Conclusions

1. According to the experience in interpreting the principles of technical regulation, a comprehensive risk assessment should be a safety criterion for a forest road.
2. The basic methods are set forth for identifying sources of danger for risk assessment of development projects for construction and reconstruction of forest roads.
3. The sum of risks from different sources of danger is suggested using the Laplace function.
4. A mathematical model has been designed for standardizing a permissible hazard level for the key factors, whose likelihood is identified by means of the normal distribution law of a random variable.
5. A graphical interpretation of the assignment of a standardized level of risk based on the well-known scientific school by Prof.V. Stolyarov is set forth.
6. After a permissible value of total risks has been specified in the regulatory documents and the calculated values of project risks have been compared against it, methods of risk compensation can then be selected.
7. The introduction of a risk-based approach in design organizations will make it possible for latest scientific findings in the field of risk management to be employed by standardizing a minimum acceptable level of project risks.

8. The suggested methodology for assessing parametric risks will allow acceptable levels of risks to be standardized as most factors are described by means of the normal law of the distribution of random events during construction, operation and disposal of forest highways.

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