MONITORING AND CONTROL OF RISKS FOR THE EXECUTION PROCESS OF FOREST ROADS

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***Abstract**: In the context of sustainable forest management, full forest accessibility by a permanent network of forest roads, represents an imperative of our time, because the forest mechanization and use of modern working processes, both in tending and cultural interventions, as well as in timber harvesting. Most forest roads are primarily industrial roads but many are also a public benefit by providing access for recreation activities, to utilities and facilities. The case study details a probabilistic approach to risk management implementation for the construction of forest roads that provide efficient and effective management regarding risks and opportunities associated with planning, identification, assessment, quantification, response, monitoring and control of potential risks. Also, implementing the cause-effect analysis and identifying the root cause of risk, the potential risks can be minimized or eliminated.*

***Keywords**: forest roads execution, risk assessment, risk score, monitoring and control, sustainability.*

***Jel Classification**: D81; D92; H54.*

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1. INTRODUCTION

Forest roads are necessary to provide access to the forest for general management, maintenance, timber extraction and recreation. Apart from the initial establishment, roads represent the single greatest capital investment made by the owner. There is a need not only to provide a cost efficient road design and layout suitable for extraction but also to ensure that the forest road is compatible with environmental values [1]. Forest roads are not just for timber extraction. Their role is much more multifunctional than merely carrying loads of timber. When adequately designed and constructed, forest roads can enhance biodiversity, provide access for better and timely inspection and management, access for fire fighting in the forests and act as a fire break and, subject to landowner approval, give access to the public to enjoy the many and varied recreational opportunities offered by forests [2].

Forest roads are a vital infrastructure for ongoing forest management. Most forest roads are primarily industrial roads but many are also a public benefit by providing access for recreation activities to utilities and facilities (e.g., communications towers, weather stations, research and monitoring sites), and to remote communities or rural residences [3].

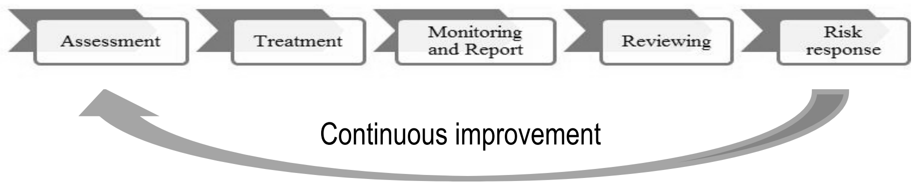
Risk management in forest road construction aims at providing an efficient and effective management regarding risks and opportunities associated enabling planning, identification, assessment, quantification, response, monitoring and control of potential risks.

Risk management processes consist of the following stages [4, 5, 6]:

- Risk management planning;
- Risk identification;
- Qualitative and quantitative analysis of risks;
- Risk response planning;
- Monitoring and control of risks.
- Continuous improvement.

The risk monitoring and control process (Figure 1) involves the identification, analysis, planning and tracking of new risks, constantly reviewing existing risks, monitoring the triggering conditions for contingency plans and monitoring residual risks, as well as reviewing the risk responses while evaluating their effectiveness. The process employs techniques which include variance and trend analysis [5, 7].

Figure 1. Monitoring and control of risks



2. EVALUATION METHOD

There are many techniques for assessing the risks. Some are based on details and ensure quantification; others are scenario-based or qualitative. The process can either be facilitated by specialists or carried out by questionnaire or a combination of both [8, 9, 10].

The risk management processes, applied to execution process of forest roads, consist of [5]:

- Risk Management Planning – deciding how to approach, plan, and carry out risk management activities for a project.
- Risk Identification – determining which risks might affect the project and documenting their characteristics.
- Qualitative Risk Analysis – prioritizing risks for further analysis or action by assessing and combining their probability of occurrence and impact.
- Quantitative Risk Analysis – numerically analyzing the effect on overall project objectives of identified risks.
- Risk Response Planning – developing options and actions to enhance opportunities, and to reduce threats to project objectives.
- Risk Monitoring and Control – tracking identified risks, monitoring residual risks, identifying new risks, executing risk response plans, and evaluating their effectiveness throughout the project life cycle.

In Body of Knowledge, Fourth Edition[5] the methodology of risk evaluation based on risk matrix is presented (Table 1). Two parameters are considered: the likelihood of risks occurrence and their impact.

Table 1. Risk assessment with risk matrix

Likelihood (P)					
0.90	0.05	0.09	0.18	0.36	0.72
0.70	0.04	0.07	0.14	0.28	0.56
0.50	0.03	0.05	0.10	0.20	0.40
0.30	0.02	0.03	0.06	0.12	0.24
0.10	0.01	0.01	0.02	0.04	0.08
	0.05	0.10	0.20	0.40	0.80
Impact (I)					

A relative scale representing probability values from "very unlikely" to "almost certain" could be used. Alternatively, assigned numerical probabilities on a general scale (e.g., 0.1, 0.3, 0.5, 0.7, 0.9) can be used. Another approach to calibrating probability involves developing descriptions of the state of the project that relate to the risk under consideration [5].

The impact scale reflects the significance of impact, either negative for threats or positive for opportunities, on each project objective if a risk occurs. Impact scales are specific to the objective potentially impacted, the type and size of the project, the organization's strategies and financial state, and the organization's sensitivity to particular impacts. Relative scales of impact are simply rank-ordered descriptors such as "very low," "low," "moderate," "high," and "very high" reflecting increasingly extreme impacts as defined by the organization. Alternatively, numeric scales assign values to these impacts. These values may be linear (e.g., 0.1, 0.3, 0.5, 0.7, 0.9) or nonlinear (e.g., 0.05, 0.1, 0.2, 0.4, 0.8). Nonlinear scales may represent the organization's desire to avoid high-impact threats or exploit high-impact opportunities, even if there is a relatively low probability. In using nonlinear scales, it is important to understand what is meant by the numbers and their relationship to each other, how they were derived, and the effect they may have on different objectives of the project[5].

The risk score is calculated based on likelihood and impact of risk:

$$S = P \cdot I \quad (1)$$

The evaluated risks are structured into three domains: low, medium and high. Table 2 presents the zones of risk prioritization.

The risk management process is continuously performed throughout the duration of the project life cycle.

3. EXPERIMENTAL

The case study consists of implementation processes of analysis, evaluation, monitoring and control of risks, and it analyzed the risks for the following stages of execution of forest roads:

- Field studies for preparing the technical documentation;
- Execution of earthworks for forest roads;
- Execution of reinforcement and consolidation works;
- Artworks;
- Superstructure.

The life expectancy of a road depends on the purpose of the road and the duration of its planned operational use. For example, a road may be one of the following [3]:

- Road with a specific seasonal use, such as a winter road;
- Road with a defined lifespan;
- Permanent road.

The potential risk of forest roads mostly depends on:

- Identifying route corridors;
- Selecting life expectancies of various road types;
- Establishing intended road users and vehicle types.

We use a matrix to formalize the responsibilities for designing, evaluating, managing and monitoring risk and control. For each identified risk we determined the likelihood and impact and computed the score *S* (equation 1). The risk scores are estimated by considering the professional experience or consulting experts in the domain of forest roads. This step is considered the initial stage of risk evaluation. The score of major risks obtained during the assessment of forest roads is classified based on risk matrix (Table 1) and are shown in detail in Table 2. In this respect, the risk control plan is elaborated.

Table 2. Risk assessment scoring

Coding	Risks of execution activities of forest roads	Risks score (S)
1.1.3	1.Field studies for preparing the technical documentation • Establishing the crossing works and hydraulic design of bridges and culverts	0.40
	2.Execution of artworks for forest roads	
	2.1.Execution of preparation works	
2.1.2	• Identification of the track	0.225
2.1.3	• Terrain clearing (stumps and bushes)	0.27
2.1.5	• Drainage of the road area	0.255
	2.2.Execution of earthworks	
2.2.1	• Excavation using a right bucket excavator	0.35
2.2.2	• Excavation using a reverse bucket excavator	0.49
2.2.3	• Excavation using a bulldozer	0.30
2.2.4	• Excavation using a grader	0.15
2.2.5	• Earth compaction	0.63
	2.3.Rock excavation	
2.3.1	• Impact on the environment due to wrong execution of rock excavation	0.765
2.3.2	• Risks associated to the possible effects on the fauna	0.81
	2.4.Execution of embankments in special cases	
2.4.1	• Embankment execution in swampy areas	0.56
2.4.2	• Embankment execution in karsts areas	0.375
2.4.3	• Embankment execution in active detritus areas	0.35
2.4.4	• Embankment execution in torrential areas	0.56
	3.Execution of reinforcement and consolidation works	
	3.1. Collection of surface water	
3.1.1	• Execution of lateral ditches	0.40
3.1.2	• Execution of guard ditches	0.40
3.1.3	• Execution of evacuation ditches	0.21
	3.2. Collection of ground water	
3.2.1	• Execution of open drains	0.40
3.2.2	• Execution of closed drains	0.225
3.2.3	• Execution of absorbent pits	0.21
	3.3. Consolidation and protection of embankments	
3.3.3	• Consolidation using fascine	0.165
3.3.4	•Consolidation using herbaceous furrows	0.15
3.3.6	• Consolidation using rock fills	0.15
3.3.8	• Consolidation using gabions	0.225
	3.4. Embankment retaining	
3.4.1	• Lining walls	0.325
3.4.2	• Raw rock resistance walls	0.30
3.4.3	• Dry rock resistance walls	0.30

Coding	Risks of execution activities of forest roads	Risks score (S)
3.4.4	• Resistance walls using mortar	0.15
3.4.5	• Concrete walls	0.165
3.4.6	• Reinforced concrete walls	0.15
	3.5. Road protection against snow avalanches	
3.5.2	• Avalanche breaking works	0.225
3.5.3	• Avalanche deviating works	0.25
3.5.4	• Avalanche stopping works	0.385
	4.2. Execution of tubular culverts	
4.2.2	• Deployment of tubes	0.25
4.2.3	• Covering with earth and stone	0.25
	4.3. Execution of bridges and culverts using	
4.3.1	***wood***	0.20
4.3.2	• Foundation execution	0.225
4.3.3	• Infrastructure execution	0.15
4.3.4	• Joints execution	0.28
	• Deck execution	
	4.4. Execution of bridges and culverts using concrete	
4.4.1	• Infrastructure execution	0.315
4.4.2	• Joints execution	0.15
4.4.3	• Deck execution	0.20
	4.5. Execution of bridges and culverts using reinforced	
4.5.1	concrete	0.315
4.5.2	• Foundation execution	0.385
4.5.4	• Elevation execution including guard walls	0.25
	• Deck execution	
	5.2. Execution of foundation layers	
5.2.3	• Execution of smashed rock foundation	0.15
5.2.4	• Execution of stabilized earth foundation	0.15
	5.3. Execution of cover layer	
5.3.4	• Execution of asphaltic macadam	0.175
5.3.5	•Execution of cover layers from asphaltic admixtures using the mixing procedure	0.175
5.3.7	• Execution of concrete cover layers using cement	0.225
5.3.8	• Execution of cover layers using concrete tiles	0.28

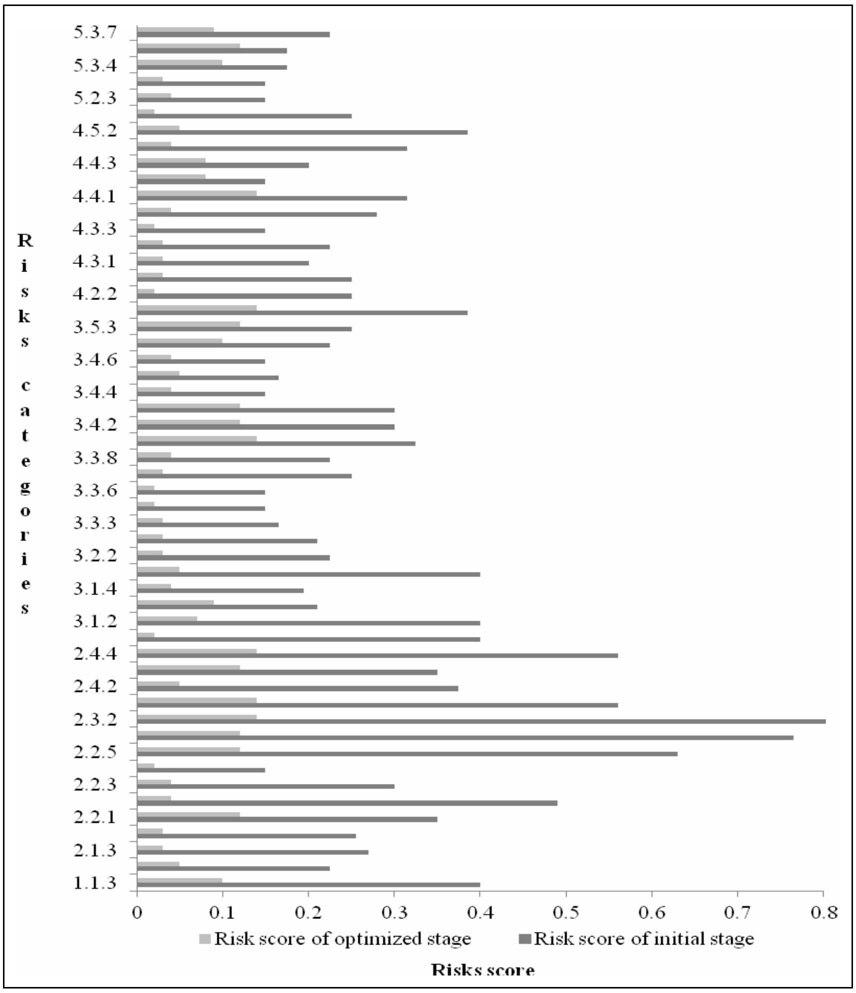
4. RESULTS AND DISCUSION

The basic theory of risk assessment was used for evaluation of the execution of forest roads in order to classify, identify and analyse the potential risks.

The result of the qualitative risk analysis specific to the execution of forest road consists in a general classification of risks: high risk, moderate risk and low risk

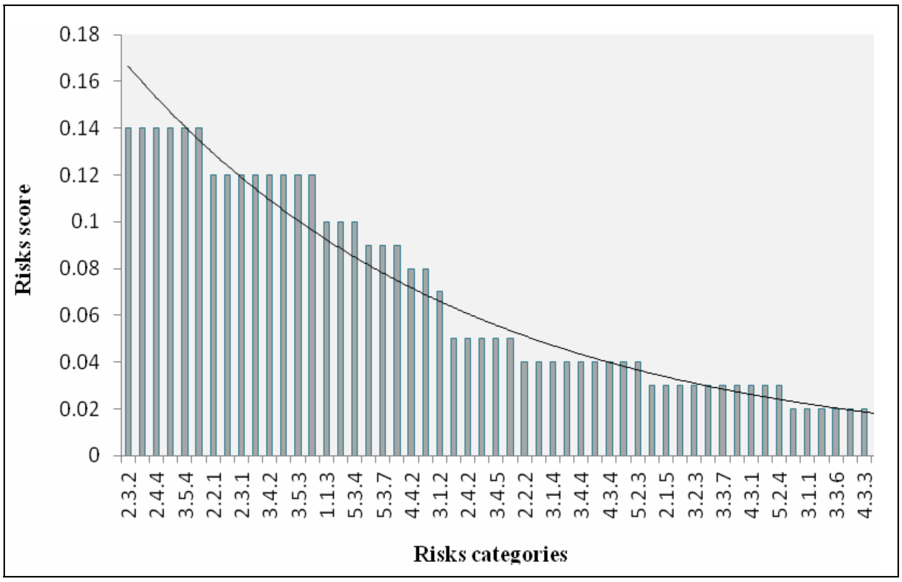
(Table 2). First, it needs to consider the risks with high impact or high probability, and for each risk to reduce the likelihood of occurrence or impact, or both. For each risk, we need to identify the countermeasures that can be used. They must be specified precisely and in detail, depending on their complexity. Analyzing the risk control plan will act on major risks, risks that have scores greater than 0.14 (Table 1), identifying improvement measures to minimize or eliminate them (Figure 2). In the optimized stage, corrective action is taken for major risks in order to minimize the risks score of the initial stage.

Figure 2. Monitoring and control of risks for the forest roads execution



Net benefits of risk reduction measures depend on the variable risk costs and risk transfer methods. As a result of the measures taken to minimize the risk, the potential risk tendency is shown in Figure 3.

Figure 3. The risks tendency after implementation of minimization measures



Some of the measures for risk optimization/reduction are:

- Precise implementation of the technical design provisions;
- Construction activities should be deployed on short sectors;
- Embankment compaction should be done in the second year after execution;
- Rock excavations should be correlated with earth excavations in the rock-earth alternation sectors;
- Avoidance of detritus zones;
- Avoidance of landscape degradation outside the road zone.

Monitoring results indicate that the main problem causing unacceptable risk is non-fulfilment of design technical conditions. Also, implementing the cause-effect analysis and identifying the root cause of risk, the potential risks can be minimized or eliminated.

The risks can have single or multiple causes and single or multiple impacts. These interdependencies can be critical to identifying the real impact of risks, and hence the cost benefit analysis applied to their mitigation.

For the probabilistic assessing of risk, we consider a combined set of events that cause losses and then we determine the probability of losses. We must take into account the degree of uncertainty in compliance with the occurrence likelihood of event and the consequences.

5. CONCLUSIONS

Apart from the tree crop, road infrastructure is the most important physical asset within a plantation forest. Roads enable access in all stages of the forest cycle, from establishment to tending and protection, to eventual harvesting.

The presented case study illustrates how the methodology was used as a tool for monitoring and control of potential risks. All identified risks are monitored throughout the execution process of forest roads, achieving a checklist for their optimal monitoring. After taking measures for improvement (corrective/preventive actions), the risks should range within on acceptable domain. Thus twenty three medium risks and thirty one low risks resulted. It can see a significant decreasing of the risks from the major field to the acceptable risk zone.

The road layout shows a specific road location that [3]:

- Optimizes operational needs;
- Meets safety requirements;
- Meets regulatory requirements for the protection of other resources;
- Satisfies risk management objectives;
- Meets objectives that may have been set through other planning (e.g., forest management plans, watershed management strategies or community forests).

It is particularly important to consider the impact, as well as the financial impact, as a consequence of a risk crystallizing which may go beyond the initial financial impact. Risks associated with the execution process of forest roads should be considered especially from the perspective of the following aspects:

- The relationship between norms / standards / laws in the design and execution of forest roads and concrete conditions imposed by the beneficiary;
- The likelihood of occurrence of specific types of risk and the ability to accept them;
- The idea of "opportunity cost" if we consider that a process, method, technology would not meet the requirements;
- Analysis of the limiting factors of the design process that could generate the high costs of execution and exploitation;
- Based on unacceptable risks specific to the execution stage, the design steps will be reviewed in order to identify and eliminate the problems.

The forest road execution when the level of likelihood is high or the consequences are serious is not acceptable. Maintenance of these kinds of road will not only need high investment but it is also difficult to avoid the impacts on environment. Also, uncontrolled risk during the design process can increase the negative effects of the financial risks to which the contractor and beneficiary of the work are exposed.

Catastrophic events and major consequences of risk are sometimes unavoidable. Generally, risk can be ignored when the likelihood is rare or the consequence is insignificant. In all other situations risk should be investigated. Understanding the exact levels of likelihood and consequences can help managers make better decisions.

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