Acadlore Transactions on Applied Mathematics and Statistics
https://www.acadlore.com/journals/ATAMS

An Integrated Risk Management Model for Transporting Explosive Remnants of War: A Case Study in the Republic of Serbia

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Received: 04-24-2023 **Revised:** 05-24-2023 **Accepted:** 06-05-2023

Citation: N. Komazec and K. Jankovic, "An integrated risk management model for transporting explosive remnants of war: A case study in the Republic of Serbia," *Acadlore Trans. Appl Math. Stat.*, vol. 1, no. 1, pp. 44–50, 2023. https://doi.org/10.56578/atams010105.

Abstract: Existing legal and by-law regulations prescribe risk management methodologies for various domains, such as the transportation of hazardous materials, fire and explosion protection, environmental protection, and protection against chemical accidents. However, there is a lack of comprehensive methodological guidance that unifies the management of all risks associated with the transportation of explosive remnants of war (ERW), which pose significant threats to human life, cultural assets, and the environment. Furthermore, the transportation of ERW often occurs along traffic corridors with compromised infrastructure, increasing the range of potential risks affecting the safety of people, their property, and critical infrastructure. This study presents an integrated risk management model for ERW transportation in the Republic of Serbia, developed based on current legal and by-law regulations, as well as modern criteria and risk assessment methodologies. By applying this model, the various risks associated with ERW transportation can be effectively mitigated, ensuring the safety and protection of people, assets, and the environment.

Keywords: Risk management; Explosive remnants of war; Transport; Republic of Serbia

1 Introduction

The Strategic Frameworks and Key Priorities of the Stability Pact for South-Eastern Europe (2001), based on certain European Union documents, highlights the need for national systems in South-Eastern European countries to establish appropriate conditions for the timely prevention of extraordinary situations and effective, efficient responses to accidents. This framework emphasizes the importance of security assessments, risk identification, and prevention of potential threats to regional security. It has been observed that the threat to populations and material assets is inversely proportional to a community's organization for minimizing risks and dangers, rapid response, and effective remediation of affected areas. The program aims to achieve successful emergency responses by creating a complementary, multifunctional platform that integrates monitoring, coordination, information, and prevention systems for both production and local self-government sectors.

Given the Republic of Serbia's historical context, which encompasses numerous armed conflicts on its territory, the transportation of ERW is a critical and essential activity. Ensuring the safety of individuals, property, and the environment while transporting ERW presents a challenge that requires careful attention and measures. ERW poses a considerable risk to human safety, infrastructure, and the environment during transport. Inappropriate handling or uncontrolled detonation of ERW can result in severe consequences, including injury, loss of life, damage to facilities, and disruption of transportation networks. To address these concerns, the Republic of Serbia has implemented a legal framework governing ERW transportation, consisting of laws, regulations, and guidelines aimed at minimizing risks and adhering to international standards. Key institutions, such as the Ministry of Internal Affairs, Ministry of Defense, and Ministry of Transport, play vital roles in implementing and overseeing these regulations.

Despite the existence of legal regulations and guidelines, the transportation of ERW in the Republic of Serbia continues to face unique challenges:

• Identification and Location of ERWs

The first challenge stems from accurately identifying and locating all remaining ERWs within the country. The dynamic nature of past conflicts and shifting terrain increase the likelihood that some ERWs may remain undiscovered or misidentified, posing significant risks during transportation, particularly if inadequately handled or stored.

• Logistics of ERW Transportation

The second challenge involves the logistics of transporting ERWs, which require special consideration in selecting suitable transportation methods, as well as proper packaging and securing of ERWs. Given the various types of ERWs, appropriate procedures and measures must be employed to minimize the risk of uncontrolled activation during transport.

• Training of Personnel

The third challenge concerns the training of personnel involved in ERW transportation. Workers handling ERWs must be adequately trained and informed about potential risks and protective measures. Proper staff training can significantly reduce the likelihood of accidents or incidents during transportation.

These challenges underline the necessity of developing an integrated risk management model for ERW transportation in the Republic of Serbia. The model should consider all relevant risk factors, including the type and state of ERWs, transportation conditions, vehicle features, personnel training, and legal regulations. By identifying critical points and potential risk scenarios, as well as quantifying risk based on probability and consequences, the integrated risk management model can substantially enhance the safety and efficiency of ERW transportation in the Republic of Serbia.

2 Methodology

To conduct a comprehensive analysis of the problem and develop an integrated solution, a multi-method research approach was employed. The methodology comprised the following components:

2.1 Content Analysis

A systematic review of pertinent literature was undertaken to identify existing approaches and research related to ERW transportation risk management. The literature review encompassed scientific papers, professional articles, publications from relevant institutions, and international standards. The analysis of experiences derived from the ERW transportation process played a crucial role in this stage.

2.2 Data Analysis

Data pertaining to the transportation of explosive remnants of war in the Republic of Serbia were gathered from various sources, including relevant institutions, research, and reports. The collected data were subsequently analyzed to pinpoint key risks and issues associated with ERW transportation.

2.3 Expert Consultations

To ensure the validity and accuracy of the information, consultations with experts in the fields of transportation, security, and risk management were conducted. These experts provided additional insights and perspectives to inform the research process.

3 Results

The findings of this study offer valuable insights into the challenges and issues associated with managing the risks of transporting explosive remnants of war (ERW) in the Republic of Serbia and propose an integrated risk management model. The monitoring and evaluation of the effectiveness of implemented measures enable stakeholders to align their activities with established standards and regulations. Furthermore, the recommendations derived from this research suggest potential improvements and future directions for ERW risk management activities in the Republic of Serbia.

Future research could explore the following areas:

1) Environmental Factors Impacting ERW Transportation Risks

A more detailed investigation of the influence of environmental factors on ERW transportation risks, such as climate change, topography, and other elements that can affect the safety and stability of transport, is warranted.

2) Training and Information Programs for ERW Transportation Stakeholders

The development and effective implementation of training and information programs for all parties involved in ERW transportation could enhance risk awareness and foster a safety culture.

3) Comparative Analysis of ERW Transportation Risk Management in Other Countries

A comparative analysis of ERW transportation risk management practices in other countries might identify best practices and opportunities for application in the Republic of Serbia.

By addressing these areas in future research, a more comprehensive understanding of ERW transportation risks and their management can be achieved, further contributing to the development and refinement of risk management strategies in the Republic of Serbia and beyond.

4 Integrated Risk Management for ERW Transport in Serbia

Risk, in a specific system, typically represents the possibility of an unexpected change or loss of system quality with a certain probability. In other words, risk signifies the potential deviation of an activity's outcome from the expected result [1]. Risk assessment, a crucial component of risk management, serves as the foundation for developing preventive and operational plans [2]. Consequently, it is essential to conduct risk assessments in the most accurate manner possible, adhering to realistic assumptions, existing data, and innovative approaches [3]. The risk assessment process is outlined in ISO 31000 and ISO 31010, as illustrated in Figure 1.

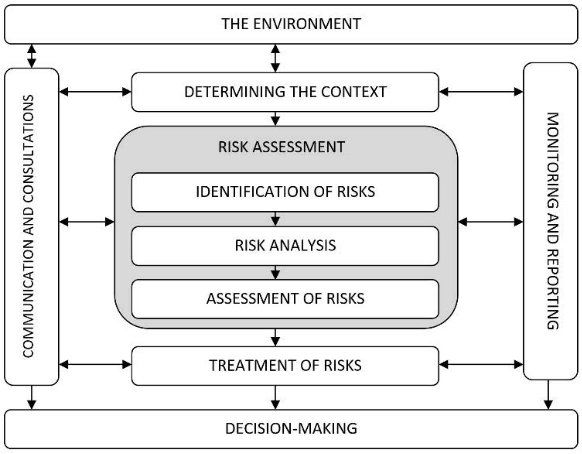

Figure 1. Risk management process [4]

1) Communication and consultation: To gather information on explosive remnants of war, transport routes, capacities, and potential risks, the risk assessment stakeholder in the Republic of Serbia communicates continuously with relevant stakeholders, such as military institutions, police, competent agencies, transport companies, and local communities [5]. Communication is facilitated through regular meetings, workshops, or electronic means. This process also incorporates the opinions and suggestions of interested parties.

2) Establishing context: At this stage, the risk assessment stakeholder examines the external and internal factors that impact the transportation of explosive remnants of war in the Republic of Serbia. These factors include legislation, infrastructure, technological capacity, and the socioeconomic environment [6]. Based on the analysis, potential risks are identified, and priorities for risk management are determined.

The risk assessment aims to provide an overview of all factors influencing the safe transportation of explosive materials in the Republic of Serbia, thereby establishing an effective prevention and preparedness system and a comprehensive platform for recovery processes and business continuity. A complete and complex overview of all factors affecting the safe transportation of explosive materials can be achieved through an integral analysis of potential hazards, individually and in combination [7]. These hazards may include non-compliance with legal regulations related to transport (European Directives, Law on the Transportation of Hazardous Materials, Rulebook on the Method of Transporting Hazardous Materials), inadequate preparation for ERW transport (personnel, equipment, ERW), technical characteristics of the route (road importance, road quality, rest areas, service stops, traffic density, bridges, tunnels), topographical characteristics of the route (terrain elevation, forest cover, proximity to inhabited areas, accessibility of road sections, proximity to water, presence of objects containing other dangerous substances), meteorological conditions during transport (seasonal weather, fog, rain, ice, windy days), acts of terrorism (road attacks, robberies, raids), and inadequate manipulation of ERW (improper loading and unloading, transportation to/from vehicles, use of incendiary devices, use of inappropriate vehicles, poor ERW identification).

3) Risk monitoring: During the transportation of explosive remnants of war, continuous monitoring is conducted, including regular vehicle inspections, route monitoring, and compliance checks with regulations and procedures. Risk monitoring [8] allows for the identification of potential critical points or deviations from planned risk reduction measures and ensures a prompt response in case of accidents or incidents.

4) Risk treatment: Risk treatment measures are applied to the assessed risks; however, this does not eliminate all potential risks. Unacceptable risks must be addressed with specific measures. Prevention may reduce some risks, but not all can be prevented [9]. Preparedness measures are applied to residual risks [10].

5) Example case: Transportation of explosive material from point A to point B:

• Threat (potential danger): Transportation of explosive material

• Risk: Possibility of fire

• Mitigation (probability): Correct vehicle electrical wiring

• Mitigation (impact): Automatic fire extinguishing system
• Prevention: Appropriate packaging
• Preparedness: Fire alarm procedures, extinguishing equipment
The risk assessment should enable us to:
1) Identify specific activities during which potential dangers may arise.
2) Consider the specific legal framework and requirements to ensure our actions are in compliance with them,
a) The risk assessment takes into account that:
• Accidents may be caused by other vehicles on the road.
• An accident may occur due to driver error.
• Explosive materials in ERW could react independently during transport.
• The transport vehicle may need to cross a track without a ramp.
• The impact level of an accident will vary depending on whether it occurs inside or outside a populated area.
In this case, prevention methods will focus on:
• Choosing a route that avoids populated areas and railroad crossings.
• Ensuring there are two drivers for transport that lasts longer than 4-5 hours.
• Attempting to provide alternative transport by rail or ship, either for the entire route or part of it.
• Police escort for the transport.
b) Preparedness measures include:
• Notifying all emergency services in the vicinity of the transport.
• Ensuring the driver has documentation that proves the type of explosive substance being transported.

The integrated risk management of the transportation of explosive remnants of war in the Republic of Serbia is a systematic approach that covers all relevant aspects of risk management related to the transport and handling of explosive materials from previous wars. This approach aims to ensure safe and efficient transport, reduce the risk of accidents, and improve standards and procedures related to risk management in this area [11].

5 Presentation of the Elements of the Integrated Risk Management Model of ERW Transportation in the Republic of Serbia

The primary goal of integrated risk management for ERW transport in Serbia is efficiency in preventing and mitigating the causes and consequences of risky events. To achieve this, the following criteria must be met [12, 13]:
• Minimum losses
• Minimum investments in implementing preventive measures
• Minimum time for implementing operational measures
Limitations include [14]:
• Resource quantity and cost
• Resource dislocation
• Structural constraints regarding the relationship between risky events and necessary measures [15]

The integrated risk management model for ERW transport in Serbia requires establishing criteria and limitations [16]. The basic criteria can be formally described using signal flow graphs (Figure 2). Subgraph (a) of Figure 2 illustrates the realization of risk event Si based on scenario bi, represented by branch ij. Scenario bi would involve events that harm people (vi), cause material damage (ui), and affect natural values (ei). By connecting a set of measures with appropriate procedures, it is possible to act preventively and prevent the occurrence of event Si (Subgraph (b) of Figure 2). If preventive measures are insufficient, the risky event will occur fully or partially, depending on the impact of the applied measures on the event's development scenario (Subgraph (c) of Figure 2) [17]. These measures can influence the causes of the risky event, thus reducing its consequences.

Possible human losses are defined by a function of the form [17]:

$$V_0 = \sum_{i=0}^{I} \sum_{j=i+1}^{I} v_{ij} x_{ij} \tag{1}$$

where are:

V_{ij}-human resources caused by an event related to branch (i, j)
$X_{ij} = 0$ if branch (i, j) is blocked
$X_{ij} = 1$-in the opposite case

Possible material losses are defined by the function [17]:

$$U_0 = \sum_{i=0}^{I} \sum_{j=i+1}^{I} u_{ij} x_{ij} \tag{2}$$

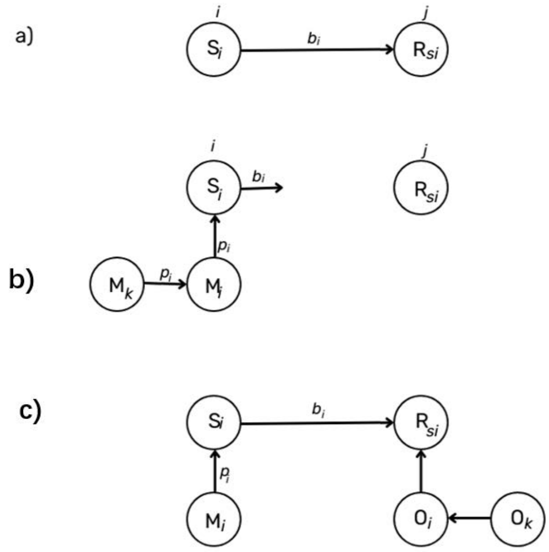

Figure 2. The graph of the preventive plan a) and its connection with the graph of preventive measures b) and the graphs of preventive and operational measures c) [17]

where are:

u_{ij}-material losses caused by event Ui related to the branch

$X_{ij}=1$-in the opposite case

Investments in the implementation of preventive measures (use of resources) can be determined using the expression:

$$\mathrm{C}_0=\sum_{i=0}^{I}\sum_{j=i+1}^{I}c_{ij}x_{ij} \tag{3}$$

in which, X_{ij} has the same meaning as in expressions (1) and (2) for possible human and material losses, and represents the investment in resources necessary for the implementation of preventive measures, which are defined as follow:

$$\mathrm{C}_{ij}=\sum_{m\in M_{ij}}^{I}\sum_{f=1}^{F}\sum_{k=1}^{K}d_{kf}^{(i,j)}P_{mk}^{(i,j)} \tag{4}$$

The labels in expression (4) are:

$P_{mk}^{(i,j)}$ the required amount of resources of the k type for the realization of the m measure (graph node Q) that blocks the branch (i,j)

$d_{kf}^{(i,j)}$ the cost of transporting and putting into effect the resource unit of the k type located at the f place, for blocking the branch (i,j) of the graph G

The task of forming an optimal preventive plan is to minimize total losses:

$$\min=\sum_{i=0}^{I}\sum_{j=i+1}^{I}u_{ij}x_{ij} \tag{5}$$

Limitations in the realization of this task are [17]:

1. Price of planned resources:

$$\sum_{i=0}^{I}\sum_{j=i+1}^{I}\sum_{m\in M_{ij}}\sum_{k=1}^{I}a_kP_{mk}^{(i,j)}x_{ij}\leq\mathrm{C} \tag{6}$$

where are:

a_k the price of a resource unit of the k type

C total cost of planned resources

2. The amount of resources of the k type:

$$\sum_{i=0}^{I}\sum_{j=i+1}^{I}\sum_{m\in M_{ij}} P_{mk}^{(i,j)} x_{ij} \leq P_k \tag{7}$$

where is P_k-the maximum quantity planned of the k type;

3. Time of implementation of necessary measures:

$$\max_{\{x_{ij}\}} \left\{ \mathrm{T}^{(\mathrm{i,j})} \right\} \leq \mathrm{T}_z \tag{8}$$

where are:

$T^{(i,j)}$ the time of realization of the branch measure (i, j)

Tz given maximum time (measure realization time)

In order to formulate the optimal operational plan task, the following variables and labels are introduced:

$$x_i \begin{cases} 1, \text{if the consequences of event } S_j \text{ are eliminated by implementing operational measures} \\ 0, \text{in the opposite case} \end{cases}$$

t_{mk}^{j}–the time of using the k type of resource for the implementation of the m measure from the set of operational measures

$t_m^j = \max_{\mathrm{k}} \left\{ t_{mk}^{j} \right\}$-time of realization of the m measure

The task of forming an optimal operational plan is to minimize the maximum time of its realization:

$$\min_{\mathrm{xj}} \max_{\mathrm{j}} \sum_{m\in M_{ij}} t_m^j x_j \tag{9}$$

As limitations appear:

The magnitude of human losses:

$$\sum_{j=1}^{J} V_j \left(1 - x_j\right) \leq V_d \tag{10}$$

Size of material losses:

$$\sum_{j=1}^{J} U_j \left(1 - x_j\right) \leq U_d \tag{11}$$

The cost of planned resources:

$$\sum_{j=1}^{I}\sum_{m\in M_j} P_{mk}^{j} x_j \leq R_d \tag{12}$$

The total number of risky events included in the plan of measures:

$$\sum_{j=1}^{J} x_j \leq S \tag{13}$$

Scenarios and graphs of cause-and-effect relationships of risky ERW transport events in Serbia form the foundation for integrated risk management under the emergence and development of risky events.

6 Conclusions

In conclusion, the integral risk management, prevention, and preparedness for responding to undesirable events during ERW transport in the Republic of Serbia constitute a crucial aspect of the quality management system for organizations involved in transportation activities. A comprehensive, accurate, and complete analysis and evaluation of potential hazards and risks that may lead to harmful events and negative consequences for protected values is essential for ensuring the successful safeguarding of the organization's and environment's protected values [18].

Overlooking, omitting, or neglecting any group of potential hazards or risks may result in their exclusion from further analysis, thereby creating conditions for the existence of concealed or uncontrolled hazards [19]. Unobserved hazards at the risk assessment's initial stage may give rise to other hazards or even amplify their effects. The risk management [20] process does not conclude with the implementation of risk treatment measures. Instead, it establishes the groundwork for effective and efficient preparedness and the continuation of the organization's business continuity. Despite all risk treatment measures, a portion of the residual risk remains and is accepted. If potential hazards with residual risks lead to harmful consequences, measures based on prepared plans must be taken to mitigate the impacts of the harmful event.

For a successful and sustainable integrated risk management system concerning ERW transportation in the Republic of Serbia, continuous improvement and training of all relevant stakeholders, robust collaboration between state institutions, operative organizations, and experts, as well as the adoption of best practices in this field, are imperative.

By considering various factors in the analysis of the ERW transport system within the Republic of Serbia, it is assumed that the activity is optimally executed. It is vital to examine different factors in the context of transport conditions and implement timely measures based on observed and presumed risks.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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