STRATEGIC DEFENCE IMPLICATIONS OF HAZARDOUS MATERIAL TRANSPORT

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Abstract: *The topic of hazardous material management and transport, especially nuclear waste, is gaining even more importance in theoretical and professional research, as well as in the everyday life in the EU countries, since the awareness of environmental protection and safety is on the rise. Nevertheless, the implications of transport of nuclear waste are an increasing concern of other European countries (non EU), especially in the Balkans. Furthermore, this topic has significant political and security implications on the global level, since nuclear waste storage and transport is prone to potential terrorist attacks. This paper analyses current approaches to nuclear waste management and transport in terms of its influence on the global security and proposes a model for transportation cycle that has implications on the security of the EU countries and the Balkan, non EU, countries.*

Keywords: *Radioactive material, Transportation risk model, Nuclear waste management.*

1. INTRODUCTION

The concept of radioactive waste management has been successfully applied to the industry and it is an integral part of national waste management strategies worldwide since the mid-20th century. According to the International Atomic Energy Agency (IAEA), radioactive waste means „any material that contains or is contaminated by radionuclides at concentrations or radioactivity levels greater than the exempted quantities established by the competent authorities and for which no use is foreseen" (1995: p. 3). The effective management of radioactive waste includes a various range of activities from handling, treatment, conditioning, transport, storage and disposal (Saling, 2018). Nuclear and radioactive waste are generally recognized as a pertinent factor that directly threatens the air, soil, surface and groundwater, human health and other living organisms.

Developed industrial countries and international organizations have performed researches that have produced a huge number of rules and principles governing the functioning of the radioactive waste management system. In order to mitigate the unintended consequences of nuclear waste, a wide range of measures are in place during the manipulation with waste, especially in the process of waste transportation. The question has emerged whether the success achieved by radioactive waste management in the developed countries, could be successfully applied (with the different approach) in the developing countries. The revision and adoption of the new law in 2019 is an important step for Serbia towards strengthening the domestic legal framework as well as striving to harmonize regulations with the EU. Additionally, in order to arrange the

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nuclear and radiation protection system as a whole, several strategies are foreseen in the future, including the Strategy for spent fuel and radioactive waste management.[4]

The goal of this paper is to analyse existing literature on the topic of nuclear and radioactive waste management, analyse the perception of the participants in the different scientific and practical fields regarding to transportation risk management (TRM), and to develop a model of excellence for TRM in line with the future Strategy for spent fuel and radioactive waste management in the Republic of Serbia.

2. THE NATURE OF NUCLEAR WASTE TRANSPORTATION RISK

For the domestic purposes, when it comes to nuclear waste, two terms are relevant and have to be explained. First, according to national Law on Radiation Protection and on Nuclear Safety (Official Gazette RS, 95/2018, 10/2019), spent nuclear fuel (SNF) "is nuclear fuel that is irradiated into, and permanently removed from the nucleus of a nuclear reactor" (Art. 5). Secondly, the radioactive waste (RW) is defined as "radioactive material in a gaseous, liquid or solid state whose further use is not planned or intended" (Art. 5).

According to the standards for risk management established by the International Organization for Standardization, risk is determined as the result of two factors - the consequences produced by materialized hazard and the likelihood of its occurrence (ISO, 2018). In the transportation process, a risk analysis should answer the question: what is the degree of probability that the emerging hazard will produce an unintended consequences on the values acquired, such as life and human health, material goods and the environment?

The transport of radioactive materials is carried out in almost every phase of the nuclear fuel cycle, from mining to disposal (Wilson, 1996). It is important to underline that transport does not only include nuclear fuel but also includes the transport of other types of radioactive waste generated in medicine, industry or from scientific waste generators. Transportation of nuclear and radioactive waste is an important process in the overall waste management system. The term „transport" in this sense means the transport of radioactive material from the place of its generation to the place which is provisionally envisaged for further operations for material manipulation or the final place for its disposal. Consequently, it is important to point out that there are different types of radioactive waste. Various nuclear waste taxonomies can be found in literature. Classification nomenclature for nuclear waste can distinguish waste in terms of three different features (Besnard et al., 2019):

- Through the level of radioactivity: low, intermediate and high
- Through the period of radioactive decay: short-lived and long-lived
- Through the management option: type of storage/disposal facility.

The International Atomic Energy Agency (IAEA) with its General Safety Guide on the Classification of Radioactive Waste offers an extensive basis of classification. This approach is widespread in use especially among countries that do not have higher-level nuclear waste generators (Schneider & Froggatt, 2018). Radioactive waste is typically categorized as either low-level (LLW), intermediate-level (ILW), or high-level (HLW), dependent on the level of its radioactivity. Each has its own characteristics and we will represent the IAEA taxonomy and description in

4 The other strategies that have to be adopted are: Radiation and nuclear safety strategy, Radiation and nuclear security strategy, and Existing exposure management strategy.

this regard (Table 1). For each waste type, there are defined recommendations, procedures, and safety standards to minimize the level of unintended consequences (IAEA, 2018). For example, transporting a small amount of HLW requires a higher level of safety procedures than transporting a larger quantity of LLW. So, the type of waste will depend on how it is transported.

Table 1. Waste classes defined by the IAEA

Waste class	Typical characteristics
Short-lived low/intermediate-level waste (L/ILW-SL)	Restricted long-lived radionuclide concentrations, e.g. long-lived a-emitters average <400 Bq/g or 4000 Bq/g maximum per package
Long-lived low/intermediate-level waste (L/ILW-LL)	Long-lived radionuclide concentrations exceeding limitations for short-lived wastes
High-level waste (HLW)	Thermal power greater than about 2 kW/m3 and long-lived radionuclide concentrations exceeding limitations for short-lived wastes (includes spent fuel and High-level waste)

Source: Adapted from IAEA, (2009: 5-7).

In its extensive historical research of transport incidents, Connolly & Pope have concluded that the three main incident's categories are: radioactive contamination on the surface of the casks or the transport vehicles, accidents in transportation route, and the Incidents caused by public protests (2016). Contamination may result from the use of inadequate transportation equipment (inadequate type of casks) or as a result of damage to casks. Therefore, as one of the mandatory preventive measures before and during the transport, the radiation level is measured at 1 meter from the transport vehicle (Gelder & Shaw, 2000). Accidents in transportation routes are very difficult to predict and eliminate due to a large number of factors that may vary. Population density, traffic infrastructure level, traffic density, time of day, weather conditions, etc. can cumulatively affect the degree of onset of the consequences. There are many risk management options, most of them combining different strategies and tools. In order to include different types of variables in the analysis, the authors formulate complex models for risk analysis structured as a decision support system using intelligent maps and a variety of GIS (Gheorghe et al., 2005; Tena-Chollet et al., 2013). Another model is the use of game theory for route planning (Bell, 2007; Reilly et al. 2012), or the use of composite risk assessment systems like RADTRAN (Kros & Weiner, 2013; Weiner, 2013; Choi et al., 2020). When it comes to incidents caused by public protests, it should be emphasized that they were not due to the direct unintended consequences of radioactive contamination but because of animosity and negative perceptions of radiation, nuclear energy in general, or even because of radiophobia (Connolly & Pope, 2016; Kesavan, 2017). However, they affect the transport of materials by disabling the normal transportation process, delaying it and making the whole process more expensive. Other consequences may also arise which have the most severe effects in terms of public order and safety, such as multiple injuries and extensive material damage during the 2010 riots in Germany (Weaver, 2010).

The main security concern about the radioactive and nuclear waste management is due to the natural characteristics of waste - radioactivity. This means that the waste cannot be completely destroyed as other types of waste such as biological, medical or other waste. Consequently, the waste treatment technology is actually about translating the waste into a form that meets the safety requirements and into a form that is suitable for the final disposal (Oh, 2001). Waste management procedures should be carried out in such a way as to take care of the people who manage the waste, the population, material assets and the environment. According to Zhang et al. (2000), there are different ways for risk valuation, and in they represented seven different models. Erkut et al. (2007) proposed the model which is established on quantitative risk assessment method, and contains three phases: hazard and exposed receptor identification, frequency analysis, and consequence modelling and risk calculation. However, the risk can be enlightened in more comprehensive approach. International Organization for Standardization proposed the risk management model which is established on both quantitative and qualitative risk assessment method and contains several phases: communication, establishing the context, risk assessment, risk treatment, and monitoring and review (ISO, 2018).

3. SCOPE OF THE STUDY AND DATA COLLECTION

3.1. Objectives

The goal of the empirical part of the paper is to analyse the perception of the nuclear and radioactive security experts on key factors of nuclear waste risk management with particular emphasis on the waste transportation cycle. The data was collected in November 2019 through in person semi-structured interviews and the answers have been transcribed by the authors.

3.2. Survey design

The interviewees were asked to identify the main focal point regarding transportation of the spent fuel and radioactive waste management. The questions were specified as follows:

1. Identify the main decisive factors for excellence in nuclear and radioactive waste management.
2. Identify the main factors for excellence in risk assessment process for transportation of the spent fuel and radioactive waste.

The participants were able to give additional comments on the approaches of achieving excellence in spent fuel and radioactive waste management.

3.3. Description of the sample

For the purpose of this study ten participants in different fields were interviewed. The interviewees were members of the fields of security sciences, organizational sciences, transport engineering, and practitioners in nuclear and radioactive security (PNRS) with various education and working experience. The data on the demography of the sample are given at Table 2.

Table 2. Demographic variables

Code Name	Field or sector	Position	Higher education/ working experience(years)
P1	Organizational sciences	Assistant professor	6-10
P2	Organizational sciences	Associate professor	<5
P3	Security sciences	Assistant professor	11-15
P4	Security sciences	Associate professor	6-10
P5	Transport engineering	Associate professor	6-10
P6	Transport engineering	Associate professor	6-10
P7	PNRS	Logistics manager	6-10
P8	PNRS	Logistics manager	11-15
P9	PNRS	Security manager	11-15
P10	PNRS	Security manager	6-10

Source: Authors

4. RESULTS

The participants were identified developing the context, risk assessment procedure, monitoring and the evaluation of a whole process as the crucial factor of engineering a model of excellence based on ISO standard 31000:2018 principles.

The participants recognized the importance of legislative principles in achieving safety transportation, especially regarding state institutions, and identified the Ministry of Energy, Ministry of Interior and the Ministry of construction, transport and infrastructure as the key stakeholders in radioactive waste management. Among the other stakeholders, the Serbian Radiation Protection and Nuclear Safety Agency and Public Company Nuclear Facilities of Serbia play one of the most important roles.

The participants recognized industrial production, residues from the medical use, and the use of radioactive isotopes in scientific research in Vinca nuclear facilities as the main radioactive waste sources.

Definition of the context was recognized as the first step in which all important decisions are made regarding the content and purpose of the TRM. At this stage, internal and external risk factors are identified. External factors such as traffic infrastructure level, traffic density, lack of risk information, weather conditions, public order status and other political factors may directly affect the project's effectiveness. On the other hand, internal risk factors include two groups of factors: human (personnel and organization) and technological (equipment and infrastructure) factors. All participants agreed that the "context" phase is crucial, and that decisions in subsequent phases will depend directly on the decisions made at this stage.

The participants also stated the implementation of both continual internal and external communication is the important issue in order to implement and coordinate the TRM. On the question of defining and prioritizing transportation risks, participants responded that the main risks are: traffic accidents, waste leaking, contamination of staff and the population which is in direct contact with waste, contamination of emergency service workers, contamination of parts of the population, and the contamination of environment as a whole.

Also, the participants identified evaluation of the whole processes and the detection of the possible weak points requesting immediate action as important elements of the commitment to quality transportation risk assessment and identified the Serbian Radiation Protection and Nuclear Safety Agency as the key institution. The question of defining the strategies for high-level waste has remained open, because there is no such waste in Serbia.

The participants have also stated the implementation of the national educational strategy, consisting not only of the practitioners in nuclear and radioactive security and the staff, but of the employers, legislators, community representatives, non-governmental organizations as well. The question of the nuclear and radioactive waste risk cartulary has remained open.

5. THE MODEL FOR TRANSPORTATION RISK MANAGEMENT

In the Republic of Serbia the starting point in developing and implementing a model of excellence for TRM are the standards and principles that are partially implemented in domestic legislation[5]. According to ISO 31000:2018 principles, the requirements for risk management, and the results of the interviews with the participants, the model of excellence for nuclear and radioactive waste transportation risk management were developed.

The leaders of a working group should form special teams for the analysis of multiple hazards and then agree and determine the final external and internal parameters that can actually contribute to the unintended consequences of radiological accidents.

For the risk assessment process all levels of employees are important, including the driving personnel and other stakeholders, especially the employers, legislators, and the community. The result of risk identification should specify exactly what types of risks exist, when and at what stage they may occur, the intensity of their occurrence and what consequences they may cause. After that, an analysis is made in terms of determining the degree of probability and the level of negative consequences. Finally, the evaluation process determines the final level of risk, which results in an answer to the question of whether it should be tolerated or treated.

Risk monitoring represents a continual review and control of the transportation process as well as the risks in order to accurately determine the risk status. The purpose of monitoring is to conclude all identifiable parameters from the first phase in order to determine deviations and to implement risk treatment in an adequate manner. This is achieved by monitoring the situation in real time throughout the whole transport cycle and recording any possible changes to existing or new parameters that are not anticipated, but that may contribute to the occurrence of the hazard.

Public or private management should periodically evaluate the implementation of TRM, revise basic quality principles if necessary, and suggest changes and improvements of the implementation process.

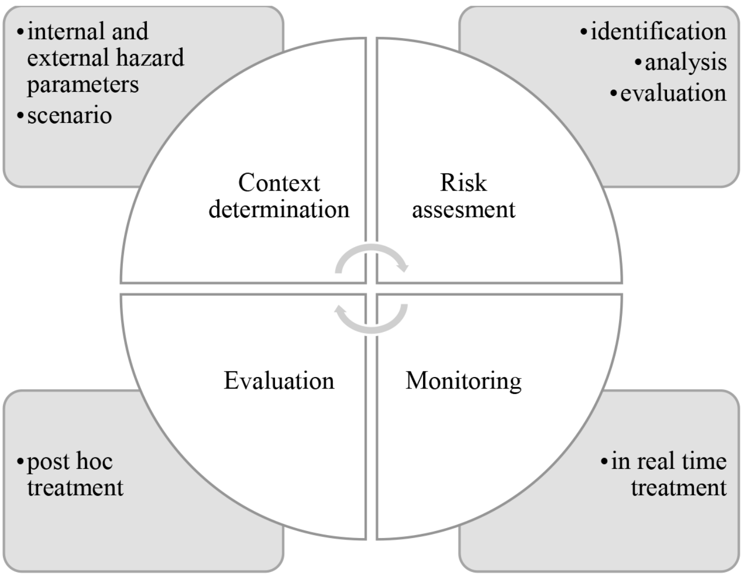

Figure 1. Proposed model of excellence for TRM
Source: Authors

5 Some of the domestic legislation regarding to radioactive waste management are: Law on Radiation Protection and on Nuclear Safety (OG 95/2018, 10/2019), Law on Occupational Health and Safety (OG 113/2017), Law on disaster risk assessment and emergency situation management (OG 87/2018), The methodology and content of the disaster risk assessment and protection and rescue plan, Law on Transport of Dangerous Goods (104/16).

6. LIMITATIONS AND SCOPE FOR FURTHER RESEARCH

Like most studies, this research study has its limitations. The sample size is rather small and the topic requires a wider sample and implementation of various statistical methods. Further research is needed in order to additionally explore on a wider sample the perception of the participants on the key elements of excellence in nuclear and radioactive waste management.

7. CONCLUSION

As a result of accession to the EU, Serbia has had to amend its legislation on radioactive material. As part of the trend, important documentation for the country at the strategic level is being implemented and one of them is the Strategy for spent fuel and radioactive waste management. In the Republic of Serbia, radioactive materials are regularly transported between national and international destinations. Packages can include radioactive materials from several sources: industrial production, residues from medical use, or from the use of radioactive isotopes in scientific research. The transport of nuclear materials is carried out in full compliance with existing international regulations that define minimum safety standards for transportation.

Risk assessment based on the ISO 31000 principles have been implemented in various institutions in different countries and national cultures. As the context of radioactive waste management is a key element for future strategy, the goal of this research has been to analyse the perception of the participants regarding transportation risk management based on ISO 31000 principles. The interviewees recognized the significance of ISO guidelines and principles and identified context determination as the first step in achieving the excellence of the risk assessment. According to the literature review and the results of the interviews with the participants in different professional positions, the model of excellence for TRM has been developed consisting of the key elements such as context determination, risk assessment procedure, monitoring and the evaluation of a whole process.

Also, great effort has to be made in the educational process of employees and those who have access to and manipulation of radioactive materials, which is a necessary condition for safe transportation. All of these activities have to be built and upgraded parallel with a comprehensive monitoring and control system for the transport of radioactive waste, which aims to improve the transport service from one, but also to maintain the level of transport safety at the desired level.

At the strategic level, the radioactive transportation system does not represent and should not be observed as a rigid system. On the contrary, it should be perceived as a systematical network of actors and interested users, on the one hand, and a set of the most advanced legal regulations, on the other. Together, they should contribute to transport as efficiently and safely as possible with the aim of minimizing the likelihood of causing negative consequences. Therefore, persistent communication between the actors and the coordination of activities in all spheres of radioactive waste management, especially during the transport phase, is necessary.

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