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PRIORITIZING RADIOLOGICAL THREATS: FRAMEWORKS FOR ASSESSING RISKS TO RADIOACTIVE MATERIALS

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Abstract

Ensuring the safety and security of radioactive materials continues to be a global priority. Despite progress in improving the safety and security of radioactive materials, incidents of theft or intent to misuse radioactive materials demonstrate the continued importance of radiological security. The International Atomic Energy Agency (IAEA) and other international organizations stress the importance of a risk-based approach to understand, and effectively manage, the threat and consequences associated with the use of radioactive materials. Yet, the numerous types of radiological materials and their extensive use in medical, industrial, and research applications can make applying risk-based approaches challenging. Prioritization frameworks that systematically and logically identify and prioritize radiological risks are a useful tool for breaking through this complexity. Sandia National Laboratories (SNL) has a demonstrated history of conducting assessments of the malicious use of radiological materials using risk-based approaches and developing models prioritizing the risks of radiological (and other nuclear, biological, chemical, and explosives) materials.

The paper provides an analytical framework for prioritizing radiological risks and demonstrate how risk-based approaches can assist in the development of effective security measures for radioactive materials. The paper will: (1) discuss the process used by SNL to assess risks to radioactive materials. This includes: the presence of radiological materials, security of those materials, and the presence and intent of threat actors aiming to acquire and/or misuse radioactive materials; and (2) discuss strengths and some limitations of this framework.

1. INTRODUCTION

Ensuring the safety and security of radioactive materials continues to be a global priority. Despite progress in improving the safety and security of radioactive materials, incidents of theft and loss of radioactive materials and interest from non-state actors in acquiring radioactive materials for malicious use demonstrates the continued threat to radioactive material and the importance of radiological security. Indeed, the IAEA Incident and Trafficking Database (ITDB) recorded between 1993-2019, 290 confirmed or likely incidents of trafficking or malicious use of nuclear or radioactive material [1].

As part establishing a nuclear security regime for radioactive materials and associated facilities, IAEA guidance suggests, "The State should follow a structured risk management approach to reduce the risks of malicious acts to an acceptable level. The State should assess the potential threats, the potential consequences and the likelihood of malicious acts, and then develop a legislative and regulatory framework that provides for efficient and effective security measures to address the threat [2]". Yet, because of the extensive use of radioactive materials in medical, industrial, and research applications applying risk-based approaches challenging.

To aid States in developing threat and risk assessments, the IAEA also provides example methodologies [3]. Prioritization frameworks that systematically and logically identify and prioritize radiological risks are a useful tool for breaking through this complexity.

2. SANDIA PRIORITIZATION FRAMEWORK

Over the past fifteen years Sandia National Laboratories has provided risk and decision analysis frameworks and models to United States' Government nonproliferation programs. A core element of Sandia's risk and decision analysis work are a set of threat prioritization frameworks and models developed to provide

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the United States' Government a systematic and logical process to identify and prioritize global chemical, biological, radiological, and nuclear (CBRN) threats; and a foundation for strategic implementation of global CBRN risk reduction efforts. countries will provide a defensible rationale for country engagement, a foundation for strategic implementation of threat reduction measures in a country or region, and a metric to measure the impact of threat reduction activities.

2.1. Multiple Criteria Decision Analysis Framework

The Sandia threat prioritization models are based upon a multiple criteria decision analysis framework. In a multiple criteria decision analysis (MCDA) approach, criteria are organized into a hierarchy of factors down to measurable attributes. MCDA is used in decision analysis and risk analysis where decision issues have multiple objectives, often in conflict, requiring trade-offs as each alternative is evaluated for a set of objectives or criteria. MCDA integrates common sense with empirical, normative, descriptive, and value judgment analysis. MCDA models are well proven to help support policy decisions. A MCDA model is ideal when the decision requires organizing and aggregating many variable and conflicting attributes in a clear, transparent and accountable way. Additionally, the MCDA approach is appropriate when our understanding is limited and the measurement of data is problematic. Finally, the MCDA approach provides a structured, consistent method for looking at and comparing abstract concepts (e.g. 'threat'), or concepts that can only be approximated because of the limited amount of available data [4].

While each of Sandia's threat prioritization models have specific elements developed for a specific problem space, they all rely on the same methodology. Each model relies on the creation of value functions to explicitly analyze each criterion. The creation of each unique value model consists of four components: defining the attributes used to measure the criteria, defining value functions for each attribute based upon the preference toward the objectives, assessing the weights of each criteria, and defining an algorithm for combining all the attribute scores into a single score reflecting the final relative value. The majority of the value functions are linear. In some cases, however, there are some specific functions that are exponential or logarithmic. The use of value functions allows the combination of attributes to be aggregated using value as the common yardstick. For the case where attributes are preferentially independent, the additive form is used. For the case where two attributes are value dependent, a two-dimensional value function is used to characterize the dependence. Subject matter experts are used to define the value matrix for created the two-dimensional value function.

Looking specifically at a prioritization model for radiological threats, the goal of the framework is to assess the relative likelihood of a non-state threat actor being able to acquire radioactive material for a malicious purpose – either theft for sale or for use in a dispersal device. As such, the resulting radiological prioritization model examines both the presence of threat actors within a country with both the intent and capabilities to misuse radioactive materials, and the presence of radioactive materials within a country that may be attractive and vulnerable to a non-state actor (see Fig. 1.).

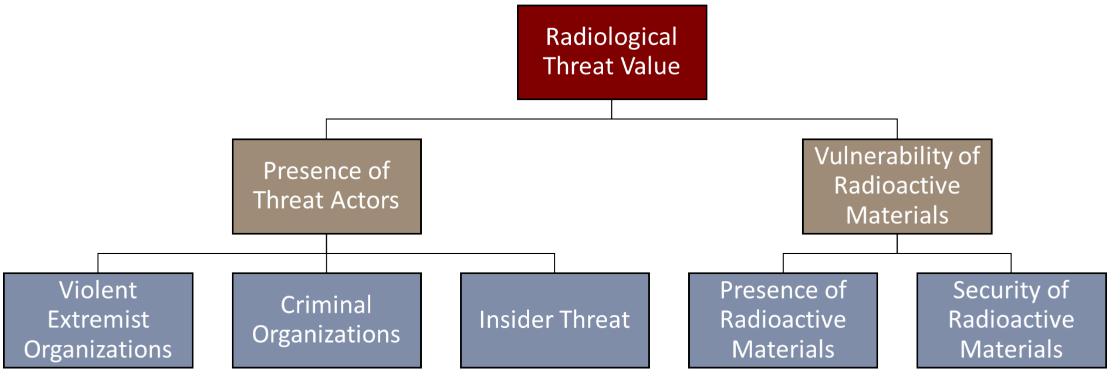

FIG. 1. Higher level attributes of Radiological Threat Prioritization framework

2.2. Vulnerability of Radioactive Materials

Assessing the vulnerability of radioactive materials to malicious acts is given by two attributes within the prioritization model, the presence of radioactive materials and the security of those materials.

2.2.1. Presence of Radioactive Materials

Determining what radioactive materials exist within a country is a critical first step in understanding the vulnerability of radioactive materials in a country. The first attribute of this framework examines the presence of radioactive materials within a country. Radioactive materials are widely used in industry, medicine, agriculture, and research, making a full collection of the number, type, and activity of radioactive sources potentially complex. Because of this challenge data for the presence of radioactive materials can be supplemented by making informed assumptions of types of materials that are typically associated with a site as part of normal operations. Radioactive materials can be weighted by their potential attractiveness to a threat actor. Attractiveness is based on the type of material, the quantity/activity level, the physical state of the material, and the feasibility of use as an RDD. Moreover, the attractiveness of a material may vary based on the ultimate objectives of an adversary. The United States National Research Council notes that the U.S. has identified americium-241, cobolt-60, iridium-192, and cesium-137, as the four radionuclides of most concern because of their prevalence and the "potential to cause contamination of large areas resulting in area denial [5]." A simplified approach could rely on Category 1 and 2 radioactive materials, as while the rationale for categorization is primarily safety based, the definition of a "dangerous source" also includes, "dispersion situations that may be relevant to malevolent acts [6]."

2.2.2. Security of Radioactive Materials

The security of radioactive materials is based on measures that demonstrate a country's overall commitment to the security of radioactive materials. Four different criteria are evaluated:

- International commitments: the extent to which a state has signed and ratified various radiological and nuclear security related international agreements;
- Regulatory frameworks: the presence and extent of regulatory frameworks specific to the security of radiological or nuclear materials;
- Source security upgrades: the extent to which devices/sites within a country have undergone upgrades to enhance their security;
- Transportation security: the overall security of radioactive sources while in transport. This could be evaluated by the overall security of transportation in a country, and previous incidents of theft of radiological material.

2.3. Presence of Threat Actors

The presence of various types of non-state threat actors forms the other half of the threat prioritization framework. Rather than looking exclusively at the intent and capability of violent extremist (i.e. terrorist) groups to perpetrate a RDD attack, the threat prioritization framework also includes the criminal organizations that may have the intent and capability to acquire radioactive material, as well as the general potential for individuals to become radicalized within a country, and as a result become insider threats. Yet, as information about specific group capabilities can be difficult to develop, threat prioritization frameworks can try to model group capabilities through a two-step process. First, create a typology of factors required for an adversary to create and deploy devices – both rudimentary and sophisticated. These factors can include technical capabilities as well as the financial, organization, and tactical capabilities necessary to design and deploy a device. Second, ascribing the typology to specific groups. Because specific data on group capabilities' may be difficult to obtain using estimates from subject matter experts may be necessary.

3. STRENGTHS AND LIMINATIONS OF THE FRAMEWORK

There are multiple strengths of using a threat prioritization framework such as the one explained above. First, using a systematic approach to a complex problem has the advantage or removing potential biases from the decision-making process by forcing a standard approach across all facets of the problem. In addition, prioritization models that rely on a clear methodology allows others to assess the assumptions going into the process as well as how the ultimate scores are produced. Transparency can create greater confidence and buy-in from potential stakeholders. Finally, by using a standardized approach, if assumptions need to be adjusted, or newer data becomes available, the methodology is sufficiently flexible to adjust and produce new results.

However, no model is perfect and may not fit every circumstance equally, as a result there are several limitations to preforming a threat prioritization framework using a MCDA methodology. First, poor data availability can severely limit the utility of a model. While this is true of any modelling project, poor or missing data can have major implications for the final results of a MCDA model. Because of this, modellers should be explicit in noting potential data quality problems and the potential impact on results. Second, a rigorous MCDA model may not be necessary for countries with a small number of radioactive sources. Such modelling projects provide the greatest added value when trying to provide clarity to a complex situation; if complexity is not present a model may not be necessary. However, even under circumstances where a complex model is not necessary, a systematic framework that forces stakeholders to analyze the problem space could still prove valuable.

4. CONCLUSION

While challenging, developing a graded risk-based approach to radiological security is critical for states. Utilizing a systematic methodology, such as a threat prioritization framework demonstrated in this paper, that systematically and logically identify and prioritize radiological risks can be a useful tool is breaking through the complexity. Such an approach may be useful to other countries.

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