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Design Approaches for Development of Safeguardability Assessment Methodology for Decommissioning Nuclear Facility

Ickhyun Shin[a*], Myungtak Jeong[a], Yeseul Seo[a]
[a] *Korea Institute of Nuclear Nonproliferation And Control, 1418 Yuseong Daero, Daejeon, 34101*
[*] *Corresponding author: ihshin@kinac.re.kr*

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1. Introduction

IAEA guideline document (STR-396) indicates that in order to determine a facility is decommissioned for safeguards purposes, IAEA will assess the efforts and resources that would be required to return the facility to operation from a decommissioned status. And it is also mentioned that the following two factors may be considered to make a determination; 1) Facility's capability to use, process or produce nuclear material if operational 2) Importance of remaining essential equipments for restarting the operation of the facility.

Since there is no specific guideline how to assess the efforts and resources for facility to be operational, an assessment methodology needs to be developed not only to assist IAEA's determination but also to provide facility operator Safeguards guides during the decommissioning status. This paper reviewed and analyzed the popular Safeguards assessment methodologies, one is GEN-IV developed by the U.S. DOE and the other one is INPRO developed by the IAEA, which is to evaluate proliferation resistance as one of the evaluation factors for developing a new type of nuclear reactor. And by comparing and analyzing the methodologies, this paper sought to how to design a new methodology for assessing the facility's capability and importance of the remaining essential equipments (EEs) for restarting the operation of the facility.

2. Methodology Comparison and Analysis

2.1 GEN-IV Assessment Methodology

The GEN-IV International Forum, an initiative of the U.S. DOE to develop a new reactor type, Generation IV, has developed proliferation resistance as one of the evaluation factors for selecting the best model among the new reactor types.

Proliferation Resistance (PR) is defined as "the characteristics of a nuclear system that can prevent the diversion of nuclear material, undeclared production, or misuse of technology," with Safeguards being a key factor in ensuring proliferation resistance.

The assessment consists of three main steps: 1) defining the threat to the nuclear system (Threat), 2) evaluating the system's response through specified pathways (Scenarios), and 3) comparing the results from the pathways to assess the vulnerability of the system (Outcomes).

The first step, threat is countries and entities potentially seeking for nuclear proliferation. Second step is to assess the response of nuclear systems by 1) identifying system elements, 2) identifying targets, 3) analyzing proliferation pathways, and 4) measuring potential criticality for successful proliferation.

The potential significance measures are comprised of six metrics, three are measuring the capabilities of the threat (Proliferation Technical Difficulty, Cost, and Time), two are measuring the detection capabilities of the response system (Detection Probability and Detection Resources), and finally last one is measuring the characteristics of the target (Nuclear Material).

Measures are determined by 5 different scales and each scales has a corresponding PR value categorized as Very Low, Low, Medium, High, or Very High.

Measures and metrics	Metrics scales bin (median)	Proliferation resistance
Proliferation resistance measures determined by intrinsic features		
proliferation technical difficulty (TD)	0-5% (2%)	very low
	5-25% (10%)	low
	25-75% (50%)	medium
	75-95% (90%)	high
	95-100% (98%)	very high

[Table 1. Metrics of GEN-IV Methodology]

Finally, the third step is outcome, which compares each of the pathways identified in the previous steps against each other to provide a baseline for decision makers to prioritize Safeguards investments.

Pathway	Proliferation Technical Difficulty	Proliferation Cost	Proliferation Time	Fissile Material Type	Detection Probability	Detection Resource Efficiency
Pathway #1:	L	VL	VL	VL	VL	L
Pathway #2:	L	VL	L	VL	VL-L	L

[Table 2. Examples of PR comparisons by proliferation pathway using qualitative metrics]

2.2 INPRO Assessment Methodology

The IAEA's Innovative Nuclear Reactors and Fuel Cycles (INPRO) methodology is organized in a hierarchical structure. The top level is the Basic Principle (BP), followed by the User Requirement (UR), and then the Criteria (CR), which consists of Indicators (IN) and Acceptance Limits (AL). The BP is defined as "ensuring that it is unattractive to acquire fissile material for a nuclear weapons development program throughout the entire nuclear cycle."

There are 5 user requirements in total, and the first requirement1 is "National Treaty", which evaluates whether a country is a party to the NPT, has a CSA in force, has an AP in force, or has export controls on nuclear materials.

The INPRO PR UR 2 describes "attractiveness of nuclear materials and technologies" in terms of conversion time (CT) and significant quantity (SQ), and requires that "the shorter the conversion time and the smaller the SQ, the higher the attractiveness of nuclear materials."

	Beginning material form	Conversion time	Significant quantity(SQ)
Indirect use nuclear materials	U4) containing<20% ^{235}U and ^{233}U	Order of months(3-12)	75 kg ^{235}U (or 10t natural U or 20t depleted U)
	Th	Order of months(3-12)	20t Th

[Table 3. CT and SQ according to Material Forms]

The attractiveness is evaluated by the following four indicators (attractiveness of nuclear material quality, quantity, shape, and technology), and the evaluation scale is divided into five evaluation scales (Very Weak, Weak, Medium, Strong, and Very Strong) for each criterion.

The INPRO UR 3 requires that "diversion activities of nuclear material should be reasonably difficult and easily detectable." The difficulty of diversion is evaluated by the following six indicators (quality of measurement system, ease of containment/monitoring, detectability of nuclear material, facility process, facility design, and facility misuse), which are divided into five evaluation scales (Very Weak, Weak, Medium, Strong, and Very Strong) for each criterion.

The INPRO UR 4 states that "multiple barriers" require that next-generation nuclear systems have the characteristics of multiple PR devices. Multi-Barrier has two indicators: the first is a yes/no assessment of whether all possible nuclear material acquisition pathways have been analyzed, and the second is a yes/no assessment of the robustness of the barriers along each acquisition pathway.

The INPRO UR 5 is "Design Optimization," which is a yes or no assessment of whether PR is considered in the design of nuclear systems and whether the cost of increasing proliferation resistance over the entire nuclear cycle is minimized.

2.3 Analysis and New Assessment Design

The GEN-IV PR assessment methodology evaluates the PR of future nuclear systems based on scenarios of nuclear material acquisition by a threat actor, and concludes that if PR is low, i.e., if the resources (time, cost, technical difficulty) required to acquire nuclear material are low, then more Safeguards measures are needed. The results of this methodology can be used by policymakers or system designers to make effective policy or design decisions to increase nuclear proliferation resistance.

The INPRO PR Assessment Methodology presents evaluation items that are not covered by the GEN-IV methodology, i.e., in addition to assessing the country's membership in international treaties such as the NPT and AP, it also provides detailed information about how to assess the attractiveness of the nuclear materials.

Some measurement items and matrix from GEN-IV and INPRO can be applied when designing a new methodology for assessing the facility's capability and importance of EEs to restart the operation of decommissioning facility. One way to assess the importance of the EEs is to assess the resources to acquire essential equipments to restart the operation. And there are several methods to acquires them such as purchase new equipments, repair or reinstall already removed equipments. And the resource for each acquisition methods can be assessed as similar way the INPRO assess the attractiveness of nuclear material. If the resources for the restart of the operation is too high, then it is likely that the decommissioning facility can be terminated from a Safeguards perspective.

3. Conclusions

Two PR assessment methodologies were reviewed and analyzed to design a new method to assess the facility's capability and importance of EEs to restart the operation of decommissioning facility. Measuring the resources to acquire EEs are the key for determining whether the facility can be terminated in a Safeguards obligation. Further study is needed to develop specific measurement factors and scales for the methodology along with acquisition scenarios.

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