Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2023

Review of regulatory applicability of acquisition path analysis methodology

Yonhong Jeong*, Hojung Do, Dongjin Kim
Center for Nuclear Nonproliferation Strategy & Technology, Korea Institute of Nuclear Nonproliferation and Control, 1418 Yuseong-daero, Yuseong-gu, Daejeon 34101, Republic of Korea
**Corresponding author: jyh1404@kinac.re.kr*

1. Introduction

The Korea Institute of Nuclear Non-proliferation and Control (KINAC) is developing a model for estimating nuclear material production to evaluate a specific state's nuclear capability. However, as a model developed to prepare for the verification of the denuclearization of the Korean Peninsula, it is difficult to use it as a regulatory technology at the usual time. Therefore, we propose a plan to apply the acquisition path analysis methodology so that it can be used as a regulatory technology even in the usual time.

2. Background

In order to review about acquisition path analysis methodology, first, it is necessary to understand the IAEA's State-Level Approach (SLA). The revelation of Iraq's secret nuclear weapons development program in 1991 provided an opportunity to reevaluate the existing fundamental safeguards agreement. The IAEA attempted the following two efforts to achieve completeness and correctness in safeguards approaches.

- A state-level approach was developed to evaluate the state's nuclear capabilities from an integrated perspective instead of a safeguards approach previously limited to evaluating individual facilities.
- In 1997, a new system for additional access to undeclared facilities was proposed by introducing the Additional Protocol (AP), INFCIRC/540.

The IAEA has made a Broad Conclusion (BC) on countries with guaranteed accuracy and completeness. Integrated Safeguards (IS) was introduced to efficiently distribute safeguard measures for countries that drew a BC. IS laid the basis for implementing safeguards approaches at the state level. In 2018, a report (GOV/2018/20) was published that drew improvement points based on the experience, and a methodology was developed to improve the existing national-level approach. SLA analyzes state-specific factors (SSF), and acquisition path analysis (APA), establishes technical objectives (TO), checks safety measures, checks performance targets (PT), etc., done through the process of acquisition path analysis. Acquisition paths, including hypothetical undeclared facilities and processes, are analyzed to complete technically viable acquisition paths. These acquisition paths can be divided into the following five categories.

- P: Indigenous production of pre-34(c) nuclear material;
- D: Diversion of declared nuclear material in declared facilities or locations outside facilities (LOFs), including nuclear material in transit (shipment/receipts);
- M: Undeclared production or processing of nuclear material in declared facilities or LOFs;
- F: Undeclared production or processing of nuclear material in undeclared facilities;
- I: Undeclared import of nuclear material.

3. Methods

The acquisition path analysis methodology can be applied through the following process.

First, information about the target state's nuclear capabilities must be acquired. The information on nuclear capabilities mentioned above includes all information related to nuclear power, such as past, present, and ongoing nuclear fuel cycle related facilities, nuclear material stocks, technological capabilities, and infrastructure. The information provided by the state following the safeguards agreement can be used, as well as information identified through safety measures activities and information acquired through open source analysis.

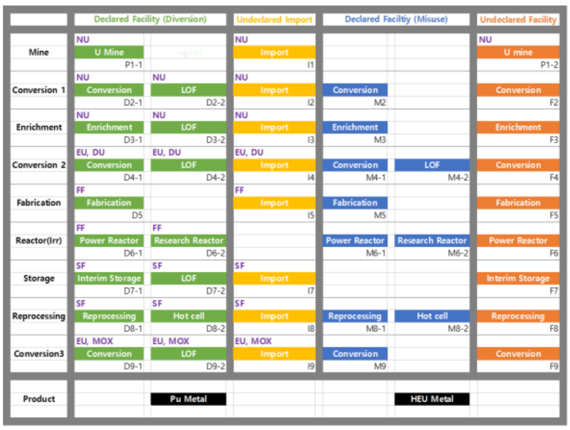

Fig. 1. Simplified nuclear fuel cycle information

Second, it is necessary to identify the feasible acquisition path of the target country. The acquisition route to be derived can acquire weapons-grade nuclear material 1 Significant Quantity (SQ) and is identified based on the target country's nuclear fuel cycle and nuclear material inventories. As mentioned above, a path is formed by combining P, D, M, F, and I. Visualizing diagrams helps understand routes more intuitively.

Layer	1	2	3	4	5	6	7	8	9	10
Start	P1-1, I1, P1-2	D2-1, D2-2, I2	D3-1, D3-2, I3	D4-1, D4-2, I4	D5, I5	D6-1, D6-2	D7-1, D7-2, I7	D8-1, D8-2, I8	D9-1, D9-2, I9	
Process		M2, F2	M3, F3	M4-1, M4-2, F4	M5, F5	M6-1, M6-2, F6	F7	M8-1, M8-2, F8	M9, F9	
End				HEU						Pu

Fig. 2. Start points and end points for diversion

Finally, diversion scenarios are derived and evaluated based on the identified acquisition path. Diversion assumes a normal nuclear fuel cycle to produce HEU and Pu. However, if undeclared facilities are in the diversion path, the time required to R&D, construct, and operate the facility is considered the time required for diversion. However, if the state has a will for diversion, it is assumed that the above malicious acts will be performed simultaneously.

In order to reproduce the acquisition path analysis methodology as a simulation tool, the following considerations are required.

- Utilize the already developed nuclear fuel cycle model for estimating nuclear material production as a framework.
- In the case of undeclared facilities, a standard facility optimized for annual 1SQ production is assumed.
- Based on the number of all possible acquisition paths, only possible paths are extracted according to the capabilities of the target state.
- Designate the technological maturity of the target country as an input value and reflect the time required for diversion in a differential manner.

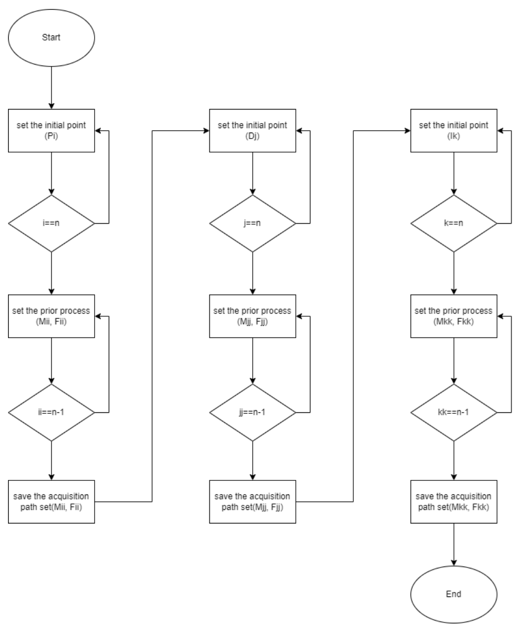

Fig. 3. Algorithm for deriving the number of acquisition path cases

4. Conclusions

The number of acquired pathway cases derived through the algorithm amounted to 2,451 (Pu cycles) and 21 (HEU cycles). The acquisition path for quantitative evaluation is derived by excluding impossible paths depending on the state's capabilities. Finally, the results are presented in order of the shortest diversion time. Through this, it is possible to derive a quantitative evaluation of the target state's nuclear transparency and the most vulnerable path, and finally, help to set technical objectives and performance targets.

Table I: List of possible scenarios for conversion from spent nuclear fuel (applicable example)

No.	Start	Process		End
1	D8-1	M9		Pu
2	D8-1	F9		Pu
3	D8-2	M9		Pu
4	D8-2	F9		Pu
5	I8	M9		Pu
6	I8	F9		Pu
7	D7-1	M8-1	M9	Pu
8	D7-1	M8-1	F9	Pu
9	D7-1	M8-2	M9	Pu
10	D7-1	M8-2	F9	Pu
11	D7-1	F8	M9	Pu
12	D7-1	F8	F9	Pu
13	D7-2	M8-1	M9	Pu
14	D7-2	M8-1	F9	Pu
15	D7-2	M8-2	M9	Pu
16	D7-2	M8-2	F9	Pu
17	D7-2	F8	M9	Pu
18	D7-2	F8	F9	Pu
19	I7	M8-1	M9	Pu
20	I7	M8-1	F9	Pu
21	I7	M8-2	M9	Pu
22	I7	M8-2	F9	Pu
23	I7	F8	M9	Pu
24	I7	F8	F9	Pu

ACKNOWLEDGEMENT

This work was supported by the Nuclear Safety Research Program through the Korea Foundation Of Nuclear Safety (KoFONS) using the financial resource granted by the Nuclear Safety and Security Commission (NSSC) of the Republic of Korea (No. 1905008).

REFERENCES

[1] IAEA, "The Conceptualization and Development of Safeguards Implementation at the State Level," GOV/2013/38, August 12, 2013
[2] IAEA, "Strengthening the Effectiveness and Improving the Efficiency of Agency Safeguards: Report by the Director General to the General
Conference," GC (39)/17, August 22, 1995, annexes 1 and 4.
[3] IAEA, "Model Protocol Additional to the Agreement(s) Between State(s) and the International Atomic Energy Agency for the Application of Safeguards, INFCIRC/540 (Corrected), September 1997.
[4] IAEA Presentation Materials for SAGSI, 2016-Mar-06.
[5] IAEA Guideline, SG-GD-12278(restricted), 2014.