

A Review of the Criteria for Evaluating the Nuclear Non-Proliferation System

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1. Introduction

Proliferation involves the transfer and export of items, software, and related technology that could be used in nuclear, chemical, or biological weapons-related programs, including delivery systems. Efforts to prevent the spread are called non-proliferation. The Nuclear Non-Proliferation Treaty (NPT) concluded that preventing the spread of nuclear weapons can be the basis of the nuclear non-proliferation regime. Because of the ambivalence of nuclear energy, the spread of nuclear weapons should be prevented, but peaceful use should be encouraged. An in-depth review of various factors is essential to evaluate whether it is for the development of nuclear weapons or peaceful use. This study intends to review major cases and evaluation criteria for evaluating nuclear non-proliferation regimes and evaluation indicators in nuclear security.

2. Evaluation Cases for Nuclear Non-Proliferation

Nuclear non-proliferation can be realized through international treaties, multilateral regimes, legislation of individual countries, or regulation by international organizations. After establishing the IAEA, the NPT entered into force in 1970, the multilateral nuclear non-proliferation regime was strengthened, and adopted the UNSCR-1540 in 2004, leading to international standardization. Whenever the intention of a nuclear test is discovered or successful, or the nuclear weapon state declines, the international community has been seeking additional measures to prevent the proliferation of nuclear weapons. This paper reviewed the nuclear non-proliferation regime, major evaluation factors, export, and import control evaluation factors, NTI indicators, and PPI indicators.

2.1 Nuclear Non-Proliferation Regime

Starting with the Nuclear Non-Proliferation Treaty, there are efforts to prevent the horizontal spread of the number of countries with nuclear weapons and the vertical spread of the increasing amount or quality of nuclear weapons. This system is shown in Figure 1.

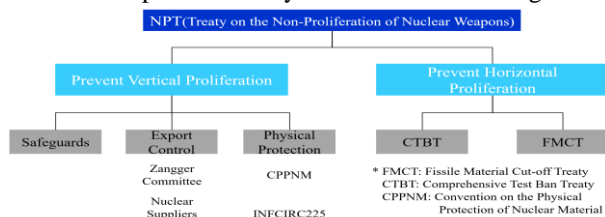


Fig. 1. International Nuclear Nonproliferation System

2.2 Indicators for Proliferation Resistance Assessment

The IAEA and the U.S. Department of Energy initiated the nuclear proliferation resistance evaluation in 1980 and are being actively performed by the IAEA-led International Project on Innovative Nuclear Reactors and Fuel Cycles (INPRO) and the 4th Generation International Forum (GIF). For evaluating nuclear proliferation resistance in 2011, KAERI divided it into three areas and prepared a total of 14 evaluation factors [1].

Table I: Barriers for Assessing Proliferation Resistance

Type	Barriers
Material barriers	Isotope, Chemical, Radiological, Mass and bulk, Detectability
Technical barriers	Facility unattractiveness, Facility accessibility, Available mass, Diversion detectability, Skills, expertise and knowledge, Time
Extrinsic barriers	Safeguards, Access control and security, Location

2.3 Evaluation Variables for Nuclear Non-Proliferation

The model for quantitatively evaluating nuclear non-proliferation began in 1984 and is being continuously studied. It can be used as a tool to receive a danger warning. After quantifying the history of the nuclear weapons program, the Korea Advanced Institute of Science and Technology evaluated the nuclear proliferation risk using a statistical method using the dependent variable and other variables as independent variables [2]. The nuclear proliferation-related variables were evaluated in risk (search, pursuit, and acquisition) in three categories: the country's current capacity, domestic political situation, and international political situation.

Table II: Variables for assessing Nuclear Non-proliferation

Determinants	Category	Variables
Capacity	Economic capability	GDP, openness, military expenditure
	Industrial capability	Industrial indicators, electricity production
	Nuclear capability	Fuel cycle, nuclear power, cooperation, assistance
Domestic Politics	Intention of leader	Leader type, Coup d'État experience, leader's years on power

	Political structure	Democracy score, domestic unrest, regime length, regime type
	Public opinion	None
External Security Influences	Rivalry	Frequency of disputes, conventional/nuclear threat, regional power, world power
	Alliance	Security commitment, nuclear umbrella, nuclear/troop deployment, UN noting data
	International Norms	IAEA (member, safeguard agreement), NPT (signed, ratified)

2.4 Export Control Review for Export Licensing in ROK

The IAEA, an international organization, is responsible for nuclear non-proliferation and the safety of nuclear cycle facilities and related technologies and determines the level of safeguards based on the evaluation of the country. Export control and physical protection are the nuclear non-proliferation regimes that evaluate each other's government at the national level. In the international transfer of more than a certain amount of nuclear material, physical protection is considered along with export control. For export control, follow the guidelines of INFCIRC-254, and for physical protection, follow the guidelines of INFCIRC-225 and CPPNM. In the case of import/export control, export license approval is decided by Articles 18 and 22 of the Notice of Import and Export of Strategic items [3].

Table III: Review Items for Export Licensing

Article	Review items
18	<ul style="list-style-type: none"> ✓ Government Assurance (Peaceful use only) ✓ Applying physical protection to the introducing facility ✓ Clarification of Transport Responsibilities ✓ Apply IAEA safeguards ✓ Prior consent of Korea for re-export ✓ Strict restrictions on export related to enrichment and reprocessing
22	<ul style="list-style-type: none"> ✓ Whether it is a strategic item ✓ Importing country ✓ Importing country technology level ✓ Importing country military and diplomatic sensitivity ✓ Whether to use in sensitive areas ✓ Buyer, Consignee, End-User reliability ✓ End-use reliability ✓ Possibility of re-export to third countries ✓ Concerned trader, Denial List ✓ Attention has been raised by international organizations or related organizations

In the case of import/export control, it can be seen that the item, importer, importing country, and purpose

of use are the most important evaluation criteria in the case of export licensing approval. Of course, there are no detailed standards or quantified values for these evaluation items. In the international system, only overall guidelines are presented. However, the evaluation methods and standards for detailed items vary from country to country, and even if these standards exist, they are not absolute values, so they are managed privately or secretly.

2.5 Nuclear Threat Initiatives (NTI)

NTI is an independent, non-profit organization established in the United States in 2001 and is an assessment and tracking index of the nuclear security situation [4]. The NTI Index includes two Theft indexes and one Sabotage ranking according to the presence or absence of nuclear material and has been issued biennially since 2012. As of 2020, 22 countries have nuclear materials that can be weaponized, 154 countries do not, and 47 countries have nuclear cycle facilities. Countries are scored on a scale of 0 to 100, where 100 is the top score. Weights are applied to categories and indicators to reflect relative priorities. In the case of Theft Ranking, it is evaluated and ranked by country according to 21 evaluation items in a total of 5 categories. These evaluations are made by publicly available information provided from government data and international panel experts advisory. This is shown in Figure 2.



Fig. 2. Support Global Efforts Results for South Korea

In Korea, Global Support Efforts ranked 4th out of 154 countries with 92 points, and Protect Facilities ranked 18th out of 47 countries with 77 points. These results are shown in Figures 3 and 4.

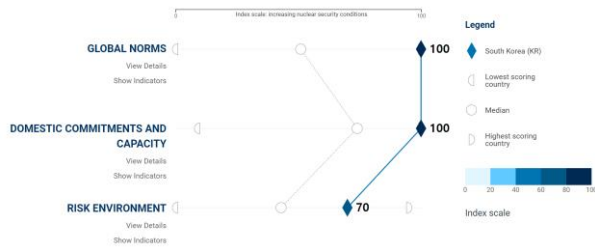


Fig. 3. Support Global Efforts results for South Korea



Fig. 4. Protect Facilities Results for South Korea

NTI can be used as a standard for evaluating the level of nuclear threat rather than an index for evaluating the nuclear non-proliferation of the country as a whole.

2.6 PPI (Peddling Peril Index)

PPI is an index ranked by the Institute of Science and International Security (ISIS), a U.S. non-profit research institute, by evaluating strategic trade control systems in 200 countries worldwide [5]. Three editions have been published in 2017, 2019, and 2021. The PPI is based on five criteria (1. International Commitment 2. Legislation 3. Monitor and Detect Strategic Trade 4. Prevent Proliferation Financing 5. Enforcement) to determine how transparently the state controls the proliferation of Weapons of Mass Destruction, which can pose an international nuclear threat. It is derived as the sum of the evaluation results (1300 points). The ranking is derived from over 100 indicators pertinent to strategic trade controls and non-proliferation. PPI evaluates Prevent Proliferation Financing and Adequacy of Enforcement as important pillars enough to give 400 points out of the five indicators. Table IV below summarizes indicators 1 and 2.

Table IV: The impact of each International Commitment sub-criterion

Impact	Sub-criterion
High-Impact (7)	NSG, AP, Convention for the Suppression of Acts of Nuclear Terrorism, MTCR, WA, PSI, WCO
Medium-Impact (12)	NPT, IAEA CSA, IAEA Safeguards Conclusion 2019, SQP, OECD

	Convention on Bribery, NWFZ, CWC, BWC, AG, CPPNM & Amendment, Convention of the Suppression of Unlawful Acts Relating to International Civil Aviation, Convention for the Suppression of Unlawful Acts Against the Safety of Maritime Navigation and associated 2005 protocol
Low-Impact (3)	IAEA member, HCOC, Reporting to IAEA Trafficking

Here, it is unique that two of the six international export control regimes are designated as High Impact, three as Medium-Impact, and the Arms Trade Treaty is omitted. Of course, it can be said that there is some uncertainty about the criteria for determining the impact for each indicator.

Table V: The impact of Legislation sub-criterion

Impact	Sub-criterion
High-Impact (4)	Catch-all clause, Comprehensive export control Legislation, Transit control, Transshipment control
Medium-Impact (4)	Export licensing process, End-use statements, Civil and crime investigations authority, Import control legislation
Low-Impact (4)	Import license or declaration, Certificates of Origin, Bill of Lading, IP protected

Korea was ranked 10th with a total PPI score of 987 points, with 88 points for criteria 1, 197 points for criteria 2, 140 points for criteria 3, 224 points for criteria 4, and 331 points for criteria 5. This can be evaluated as a country leading the non-proliferation of nuclear weapons with major advanced countries.

Examining these indicators reveals several problems. First, according to the UNSCR-1540, U.N. member states are obliged to have an export license process, which is medium-impact. Next, when reviewing export licenses, most end-use statements are included in the process as submission documents. Finally, there is a lack of validity and association between identification of the origin and I.P. protection as a factor for evaluating nuclear proliferation. In other words, it seems that the review of the interrelationship, subordinate relationship, inclusion relationship, and weight of each factor is insufficient.

2.7 Regulatory Compliance Country for Nuclear Technology Control

In the past, as part of strengthening Korea's nuclear technology control, there have been cases in which a quantitative evaluation system has been developed for countries that are the criteria for exemption or reinforcement of export license [6]. At that time, the criteria selected important factors from the perspective

of export control and safety measures, and the evaluation results are shown in the table below.

Table VI: Evaluation Criteria for Regulatory Compliance Country

Category	Criteria	Score
1	NPT, CTBT, PSI, CWC/BWC	25
2	NSG, MTCR, WA, AG	25
3	CSA, AP, NTI	25
4	NCA with ROK, NCA with US	25

2.8 Improvement of Proliferation Risk Assessment

Most of the evaluation methods reviewed so far are static evaluation methods and standards at the national level. Nuclear proliferation is not static but continuously changes over time and requires a means to evaluate and contain the risk at a specific point in time or a specific event.

It is necessary to develop a proliferation scenario based on past nuclear proliferation cases and prepare a dynamic evaluation system that can evaluate the risk for each possible event. Research on this is currently underway [7].

3. Conclusions

This paper reviewed various methods for evaluating nuclear non-proliferation and nuclear security.

These various methods and indicators can be very subjective except for objective indicators, and they contain a lot of uncertainty because they are the results of evaluation by U.S.-oriented experts. In addition, consideration of dynamic factors such as change with time and time required for actual proliferation is omitted.

Uncertainties about the causes and consequences of nuclear proliferation are very high. In order to evaluate them in real-time, it will be necessary to prepare a system for quantitative and probabilistic evaluation through such as the Bayesian network evaluation method based on the nuclear proliferation scenario. In addition, since the proliferation cases in this era are increasing through intangible factors rather than tangible factors, it is necessary to prepare an evaluation method for the spread in the human factor and the Internet environment.

4. Acknowledgement

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