Review on International Practices of Cross-Cutting Area Frameworks: Implications for Korean Nuclear Security Regulation

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1. Introduction

To ensure the safe operation of nuclear power plants, regulatory authorities worldwide have transitioned toward risk-informed and performance-based oversight framework, such as the U.S. Nuclear Regulatory Commission (NRC)'s Reactor Oversight Process (ROP). Within these systems, regulators use two primary objective inputs to assess licensee safety performance; Performance Indicators (PIs) and Significance Determination Process (SDP) for inspection findings.

These assessments are conducted across seven cornerstones that reflect the essential safety aspects of facility oversight, consisting of six safety-related cornerstones – Initiating Events, Mitigating Systems, Barrier Integrity, Emergency Preparedness, Occupational Radiation Safety, Public Radiation Safety – and one nuclear security-related cornerstone, Physical Protection. In addition to PI and SDP that evaluate the risk and performance of nuclear power plants, the U.S.NRC identifies inherent vulnerabilities by assessing cross-cutting areas, defined as fundamental performance characteristics that commonly affect these cornerstones. Consistent with the U.S.NRC approach, Japan Nuclear Regulation Authority (NRA) and Spain Nuclear Safety Council (CSN) have adopted comparable concepts to evaluate underlying vulnerabilities.

Unlike the U.S.NRC, Japan NRA, and Spain CSN, which regulate safety and security within an integrated framework, the Korean regulatory context is characterized by a dualistic system that separates nuclear safety and nuclear security. Considering this unique regulatory environment, Shin et al. [1] proposed a nuclear security ROP framework. This paper examines international cases (i.e., U.S.NRC, Japan NRA, Spain Nuclear Safety Council (CSN)) and derives implications to establish a cross-cutting area framework within the ROP framework proposed by Shin et al. [1].

2. International Cross-Cutting Area Frameworks

This study examines the cross-cutting area framework to derive implications for its application to Korea's nuclear security regulatory environment. The framework of the U.S.NRC, a representative example of a structured and performance-based oversight system, is utilized as a reference model. Based on this, the regulatory approaches of the Japan NRA and the Spain CSN — which adopted and modified elements of the NRC framework—are analyzed as benchmarking cases. The analysis focuses on the definition of cross-cutting areas, structural characteristics, and regulatory application, while considering data availability by country.

2.1 Cross-Cutting Areas in U.S. NRC

2.1.1. Definition and Structure

The U.S. NRC identifies CCAs as underlying causes to inspection findings (IFs). NRC's CCAs are human performance, problem identification and resolution, and safety-conscious work environment. Human performance is related to the human and organizational activities such as decision-making based on conservative assumptions, the distribution of resources (personnel, equipment, and procedures), work management and coordination, and daily work practices like procedure adherence and supervisory oversight. Problem identification and resolution represent the organization's capability to proactively identify low-level deficiencies, analyze their root causes, and implement effective corrective actions. A safety-conscious work environment refers to a workplace where safety concerns can be raised without fear of retaliation and where such concerns are appropriately addressed. The composition of CCAs is shown in Table I.

Table I: U.S. NRC cross-cutting areas framework [2]

Areas	Aspects	
Problem Identification and Resolution (PI&R)	·Identification ·Evaluation ·Resolution	·Self-assessment ·Operating experience ·Trending
Safety Conscious Work Environment (SCWE)	·SCWE Policy ·Alternate process for raising concerns	·Free flow of information
Human Performance	·Resources ·Field presence ·Change management ·Teamwork ·Work management ·Design margins ·Documentation	·Procedure adherence ·Training ·Bases for decision ·Challenge the unknown ·Avoid complacency ·Consistent process ·Conservative bias

Supplemental cross-cutting aspects	·Incentives, sanctions and rewards ·Strategic commitment to safety ·Roles, responsibilities, and authorities ·Constant examination ·Leader behaviors ·Standards	·Job ownership ·Benchmarking ·Work process communication ·Expectations ·Challenge assumptions ·Accountability for decisions

2.1.2. Operating Process of Cross-Cutting Area

CCA assessments are conducted to promote corrective actions by identifying inherent causes before they develop into more severe safety concerns. When the same CCA is identified more than six times within a one-year period, it is classified as a Cross Cutting Theme. If the Theme is observed across three assessment periods without adequate improvement, it is designated as a Cross Cutting Issue (CCI). Upon the opening of a CCI, regulatory authority request that the licensee perform an underlying cause analysis, independent safety culture assessment, and implement additional corrective measures. CCI is closed when the regulatory authority verifies performance improvements through supplemental inspections and confirms that the closure criteria has been satisfied. Closure criteria include a reduction in the number of inspection findings assigned the same CCA as the opened CCI, restoration of confidence in the licensee's resolution capabilities (considering the operator's scope of effort and progress), and observation of a significant improvement trend in the number of inspection findings with the same CCA. CCIs must undergo follow-up inspections to confirm the effectiveness of their improvements. Follow-up inspections include IP 71152 [3] and IP 93100 [4]. The licensee and NRC's actions regarding CCT and CCI, as well as the primary inspection details, are listed in Table II.

Table II: Management of Cross Cutting Theme and Cross Cutting Issues [5][6]

	Cross Cutting Theme	Cross Cutting Issue
Definition & Identification Criteria	·Human Performance, PI&R – 6 findings with the same CCA in 12 months ·SCWE – 1 finding in 18 months	·A persistent CCT identified in at least three consecutive assessment letters.
Licensee Actions	·Perform voluntary causal analysis and implement corrective actions ·Demonstrate performance improvement to prevent escalation to a CCI	·Conduct in-depth root cause analysis and implement robust corrective measures ·Perform an independent safety culture assessment (if requested) ·Meet specific Closure Criteria defined by the NRC
NRC Actions & Regulatory Pressure	·Formally document the theme in the quarterly or annual assessment letter ·Heighten monitory of the licensee's corrective action effectiveness	·Officially open the issue in assessment letters with clear Closure Criteria ·Conduct intensive follow-up inspections equivalent to supplemental rigor ·NRC management meetings with the licensee's board of directors
Primary Inspection Procedures	·IP 71152 – Conduct Semiannual trend reviews ·Focus on specific organizational or departmental trends	·IP 71152 – Verify and close HU/PI&R-related CCIs ·IP 93100 – Investigate chilling effects and close SCWE- related CCIs ·IP 40100 – Validate third-party safety culture assessments

2.1.3. Analysis of CCA Identified from Nuclear Security Inspection Findings

To identify underlying vulnerabilities in nuclear security deficiencies, the CCA assigned to security inspection findings issued at 18 nuclear power plants over the past 3 years (2023 - 2025) were analyzed. Data on assigned CCAs can be found on the NRC Website [7]. Each finding was classified based on its assigned CCA and categorized into physical security and cyber security domains. A frequency analysis was conducted to examine the distribution of CCAs and to identify dominant underlying causes.

The total number of CCAs assigned to 66 issues, and whether they were related to physical security or cyber security, are shown in Table III. The analysis revealed that Human Performance was the most common CCA, accounting for 54 of the 66. PI&R followed with 12, and no SCWE was identified. Cyber security-related issues accounted for 24, approximately 36% of the total. Among these, Change Management was the most frequently assigned CCA in the cyber security inspection findings, accounting for 6 of the 24. This analysis confirms that Human Performance is a major cause to nuclear security deficiencies.

Table III: Overall Statistics of Assigned CCA for 2023 - 2025

#	CCA	Total
1	Human Performance - Avoid Complacency	8 (PS*–7, CS**–1)
2	Human Performance - Change Management	7 (PS – 1, CS – 6)

3	Human Performance - Conservative Bias	7 (PS – 5, CS – 2)
4	Human Performance - Consistent Process	5 (PS – 4, CS – 1)
5	Human Performance - Procedure Adherence	5 (PS – 3, CS – 2)
6	Human Performance - Resources	4 (PS – 3, CS – 1)
7	Human Performance - Documentation	4 (PS – 1, CS – 3)
8	Problem Identification and Resolution (PI&R) – Evaluation	4 (PS – 3, CS – 1)
9	Human Performance - Work Management	3 (PS – 1, CS – 2)
10	Human Performance - Training	3 (PS – 1, CS – 2)
11	Human Performance - Challenge the Unknown	3 (PS – 2, CS – 1)
12	Problem Identification and Resolution (PI&R) - Resolution	3 (PS – 2, CS – 1)
13	Human Performance - Field Presence	2 (PS – 2, CS – 0)
14	Human Performance - Teamwork	2 (PS – 1, CS – 1)
15	Problem Identification and Resolution (PI&R) - Identification	2 (PS – 2, CS – 0)
16	Problem Identification and Resolution (PI&R) - Operating Experience	2 (PS – 2, CS – 0)
17	Human Performance - Bases for Decisions	1 (PS – 1, CS – 0)
18	Problem Identification and Resolution (PI&R) - Trending	1 (PS – 1, CS – 0)

* PS – Physical Security

**CS – Cyber Security

2.3. International Operating Cases

The Japan NRA established its cross-cutting areas by benchmarking the U.S.NRC's framework. These areas represent fundamental organizational attributes – namely value awareness, performance capabilities, and work processes – that are commonly embedded across activities related to safety and nuclear security. These elements serve as the foundation for organizations and individuals responsible for these activities to perform these activities reliably. These elements are defined as followings; *Safety Culture Fostering Activities (including activities related to the interface with nuclear security culture), Ability of Personnel Work Practices*, and *Problem Identification and Resolution*. [8] These areas differ somewhat from the U.S.NRC's cross-cutting areas.

Similarly, the Spain CSN implements a transversal component similar to the U.S.NRC's cross-cutting area. The framework comprises 13 transversal components, which are grouped into 3 categories; *Human and Organizational Action*, *Problem Identification and Resolution*, and *Safety-Oriented Work Environment*. A significant transversal component (CTS) is identified when at least 8 "green" or higher inspection results are found within a specific component over a four-quarter period. Upon designation of a CTS, the licensee is required to submit a root cause analysis along with a corrective action plan within two months. The CSN may subsequently conduct an inspection of the submitted plan. Once designated, a CTS remains in effect for a minimum duration of four-quarters. If the issue is not resolved within this period, or if the threshold is exceeded again within one year following closure, the CSN may require an additional independent safety culture assessment [9].

3. Implications for the Korean Nuclear Security Context

To provide effective oversight of the root causes of performance deficiencies by reflecting the common characteristics of nuclear power plants in Korea, it is essential to develop specialized Cross-Cutting Area elements. Korea's nuclear security culture can be defined by referencing the IAEA nuclear security culture model [8] specified in Fig 1, which consists of two primary components: the management system and behavior. International CCA frameworks identify underlying organizational characteristics that influence both nuclear safety and security as Cross-Cutting Areas. Consequently, the Korean nuclear security framework must integrate characteristics relevant to safety, necessitating close coordination between the safety and security regulatory domains.

Regulatory authority in the U.S and Spain assign CCAs—referred to as transversal components in Spain—to inspection findings. These frameworks utilize quantitative thresholds to trigger a graded regulatory response; when the number of identified CCAs exceeds a set threshold over a specific period, they are designated as CCT or CCI (referred to as CTS in Spain). For instance, the U.S. NRC identifies a CCT if six or more findings with the same CCA occur within four quarters, and escalates this to a CCI if the theme persists across three consecutive assessment cycles. Similarly, Spain's CSN designates a CTS if eight or more findings are identified within a specific component over a four-quarter period. Accordingly, Korea must develop its own thresholds to define the appropriate levels for increased regulatory attention, which requires a comprehensive review of established domestic practices and historical performance data.

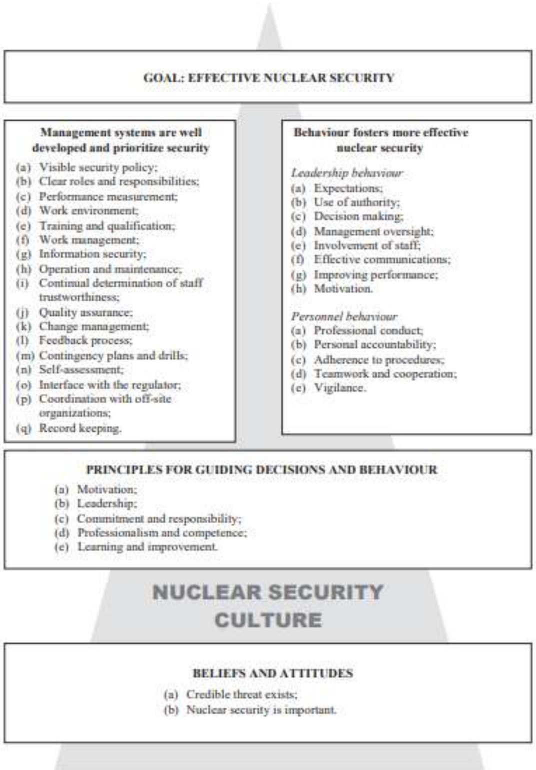

Fig. 1. IAEA Nuclear Security Culture Model Framework [10]

4. Conclusion

This paper analyzes the cross-cutting area frameworks of the U.S., Japan, and Spain. The cross-cutting area system facilitates the identification and management of the root causes underlying performance issues—such as organizational culture and human error—extending beyond traditional assessments of plant performance and risk. International regulatory practices involve identifying the root causes (referred to as Cross-Cutting Aspects or transversal components) of inspection findings. Simultaneously, when these findings accumulate and exceed predefined thresholds, regulators impose heightened oversight, such as requiring licensees to perform causal evaluations and corrective actions or mandating independent safety culture assessments.

To implement such a framework within the Korean nuclear security context, a comprehensive review of domestic security culture is essential. Furthermore, it is necessary to conduct a comparative analysis and application of the CCA criteria currently being developed by KINS. Finally, a thorough evaluation of existing domestic practices will be required to develop objective quantitative thresholds appropriate for the Korean regulatory environment.

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