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Conceptualizing the Safety and Security Interface in the Transport of Radioactive Materials in West Africa

Nelson Agbemava *, Etornam Ann Mensah, Kwame Appiah, Cyril Cyrus Arwui, Ernest Sanyare Warmann Beinpuo, Emmanuel Akrobortu and Henry Lawluvi

Nuclear Regulatory Authority, P. O. Box AE 50, Kwabenya, Accra, Ghana.

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Abstract

The transport of radioactive materials is governed by two complementary objectives: safety, which protects people and the environment from accidental radiation exposure, and security, which prevents theft, sabotage, or unauthorized diversion of radioactive sources. Historically, transport systems have emphasized safety, focusing on accident prevention, radiation dose limitation, and packaging integrity. However, evolving global security threats and incidents of illicit trafficking have highlighted the need to integrate robust security measures into traditional safety frameworks. This paper examines the safety–security interface in the transport of radioactive materials within the West African context. Using a qualitative analytical approach, the study reviews key international instruments, including the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) and the Nuclear Security Series guidance on Security of Radioactive Material in Transport (NSS No. 9-G), to identify areas of convergence and divergence between safety and security requirements. Field observations and consultations with frontline officers at selected border points were used to assess practical implementation challenges. Findings reveal that safety and security overlap in transport planning, personnel training, inspection, and emergency preparedness, but diverge in information management, where safety promotes transparency while security requires confidentiality. The regional case study highlights vulnerabilities such as under-declaration of consignments, limited radiation detection capabilities, and weak inter-agency coordination. These gaps increase the risk of radioactive materials moving without effective regulatory oversight. The study concludes that harmonized regulatory frameworks, strengthened detection infrastructure, coordinated institutional responsibilities, and sustained capacity building are essential to integrating safety and security and preventing materials from falling out of regulatory control.

Keywords: Radioactive material transport; Nuclear security; Safety–security interface; Regulatory governance; West Africa; Border detection; Inter-agency coordination

1. Introduction

The transport of radioactive material is essential for modern society. Radioactive sources are routinely moved for medical diagnosis and therapy, industrial radiography, agricultural research, and scientific applications. The transport of these materials frequently across national, regional, and international borders has impose regulatory responsibilities on States to ensure both radiological safety and physical security throughout the transport process.

Transport governance is therefore built upon two complementary objectives. The first is **safety**, which seeks to protect workers, the public, and the environment from accidental radiation exposure. Safety measures rely primarily on engineering controls, including certified packaging, radiation dose limits, labelling, and emergency preparedness arrangements. The second is **security**, which aims to prevent intentional unauthorized acts such as theft, sabotage, or

* Corresponding author: Nelson Agbemava

illicit trafficking of radioactive material. Security measures focus on access control, surveillance, communication protocols, and response planning against adversarial behaviour.

Historically, radioactive material transport systems were developed under safety frameworks. Regulatory practice emphasized accident prevention, containment integrity, and radiation protection. However, the global threat environment has evolved. Increasing awareness of terrorism risks and documented cases of illicit trafficking have demonstrated that safety-only approaches are insufficient for maintaining radioactive material under regulatory control. While packaging systems may effectively prevent accidental exposure, they do not prevent theft, diversion, or misuse during transport. Consequently, transport security has emerged as a critical component of nuclear governance.

The divergence between safety and security lies primarily in their operational assumptions. Safety systems are designed to address accidental failures and therefore emphasize transparency, documentation, and information sharing. Security systems assume adversarial intent and therefore prioritize confidentiality, restricted information, and protective measures. When implemented independently, these differing logics can create vulnerabilities. For example, visible labelling and accessible transport information required for safety may expose shipments to targeting if not complemented by security protections.

These vulnerabilities are particularly pronounced in developing regions, including parts of West Africa, where border controls, detection infrastructure, and institutional coordination are limited. Weak verification mechanisms, inconsistent documentation practices, and limited awareness among frontline officers can allow radioactive consignments to cross borders without confirmation of their identity or authorization. Under such conditions, radioactive sources may remain safe from accidental release yet insecure from unauthorized access, increasing the risk of materials becoming out of regulatory control.

Although international guidance exists, notably the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) and the Nuclear Security Series guidance on Security of Radioactive Material in Transport (NSS No. 9-G), implementation challenges remain. Existing literature largely addresses transport safety and transport security separately and focuses primarily on operators rather than regulatory systems and border operations. Limited empirical attention has been given to how the two domains intersect in real transport environments, particularly in regions with evolving regulatory capacity.

This paper therefore examines the **safety–security interface** in the transport of radioactive materials. The study addresses the following questions:

- How do transport safety and transport security requirements converge and diverge in practice?
- What vulnerabilities emerge when the two systems are implemented independently?
- What institutional and technical measures are necessary to achieve integrated transport governance?

To answer these questions, the paper analyses international regulatory frameworks and applies them to a West African case study involving cross-border movement of radioactive material. The analysis demonstrates that effective transport governance requires coordination between safety and security practices, investment in detection and tracking capability, and strengthened institutional cooperation, particularly among frontline officers and regulatory authorities.

1.1. Transport of Radioactive Material

The transport of radioactive material encompasses all operations associated with the movement of radioactive substances from consignor to consignee. According to the International Atomic Energy Agency (IAEA), transport includes the design, manufacture, maintenance and repair of packaging, as well as preparation, consigning, loading, carriage (including in-transit storage), unloading, and receipt at the final destination. The routine movement of radioactive materials across national and international borders necessitates transport governance as a critical component of nuclear regulatory control. It is therefore important that transport systems must address both accidental and intentional risks. Historically, the regulatory frameworks are developed primarily around radiological safety. However, evolving threat perceptions have expanded the governance objective to include security considerations, thereby introducing a dual regulatory mandate.

1.2. Transport Safety

Transport safety is based on the prevention of accidental exposure to ionizing radiation. The IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) establish internationally harmonized requirements for packaging, radiation protection, and operational control [1]. The framework relies heavily on engineering-based protection measures, including:

- Certified Package Design
- Containment Integrity
- Radiation Shielding
- Labelling and Documentation
- Emergency Preparedness

SSR-6 applies a graded approach in which packaging performance requirements depend on the hazard category of the radioactive contents. Protection is achieved through multiple layers: package design standards, administrative controls, competent authority approvals, and emergency planning. The safety system therefore assumes unintentional failure and aims to mitigate consequences should an accident occur [1].

1.3. Transport Security

Transport security addresses intentional unauthorized acts involving radioactive material. The IAEA Nuclear Security Series guidance on the Security of Radioactive Material in Transport (NSS No. 9-G Rev.1) provides implementation measures for preventing theft, sabotage, or diversion [2]. Unlike safety, which relies on physical containment, security focuses on adversarial risk. The key security measures consider the following:

- Threat Assessment
- Categorization of Material for security purposes
- Secure Communication Protocols
- Escort Arrangements
- Detection and Recovery Planning

The guidance also supports implementation of the Code of Conduct on the Safety and Security of Radioactive Sources [3] and its import-export provisions [4]. NSS-9-G further establishes procedures for locating and recovering lost or stolen material [2] and aligns with the UN Model Regulations on Dangerous Goods Transport [5].

1.4. The Safety–Security Interface

Although safety and security share the objective of protecting people, property and the environment, they originate from different professional traditions. Safety is grounded in engineering reliability and accident prevention, while security is rooted in intelligence, law enforcement, and threat mitigation.

The interface between the two systems occurs because both operate on the same material during the same activity transport. However, their operational requirements sometimes conflict. Safety practices encourage transparency, visible labelling, and accessible documentation to ensure proper handling and emergency response. Security practices, in contrast, require confidentiality, restricted routing information, and controlled access to shipment details. Thus, it internationally recommends that safety and security measures be implemented in a coordinated manner to comply with relevant IAEA safety standards and nuclear security guidance [1, 6]. IAEA Safety Standards Series publications state that “Safety measures and security measures must be designed and implemented in an integrated manner so that neither undermines the other [7]. In practice, integration remains difficult because safety systems are compliance-oriented whereas security systems are threat-oriented. This creates operational tension in areas such as documentation disclosure, shipment tracking, and inspection procedures.

The overlap between safety and security in transport, therefore, occurs in several operational activities:

- Transport Planning
- Personnel Training
- Inspection and Verification
- Emergency Preparedness and Response

Failure to coordinate these domains can result in radioactive material being properly packaged (safe) yet insufficiently protected against theft or diversion (insecure).

1.5. Regional Context: Transport Challenges in West Africa

Implementation challenges are particularly evident in developing regions. In West Africa, regulatory capacity varies significantly among States, creating uneven transport oversight across borders. Some systemic issues reported and documented by regulatory bodies include:

- Weak detection architecture at borders and points of entry
    - Radiation detection capability at borders and ports remains limited. Many crossing points lack operational radiation portal monitors, and available handheld detectors are often insufficient in number or poorly maintained. High traffic volumes and informal border routes further complicate systematic screening.

- Under-declaration or misdeclaration of consignments
    - Under-declaration and/or misdeclaration of consignments may occur. Inaccurate documentation may arise from limited awareness of regulatory requirements or deliberate attempts to avoid regulatory scrutiny. Consequently, radioactive shipments may bypass verification procedures.
- Limited trained personnel
    - Frontline officers frequently lack specialized training in radiation detection, transport documentation verification, and source categorization. Even when procedures exist, implementation may be inconsistent.
- High reliance on donor-provided equipment
    - The over-dependence on donor-supplied detection equipment creates sustainability challenges. Without maintenance plans, spare parts, and technical expertise, equipment often becomes non-functional after deployment.
- Complex inter-agency environments with limited coordination
    - The transport governance involves multiple agencies regulators, customs, police, port authorities, and emergency responders but coordination mechanisms are often weak. Fragmented responsibilities and limited information sharing create gaps in oversight.

Collectively, these conditions can allow radioactive materials to cross borders without verification, increasing the risk of materials becoming out of regulatory control.

2. Materials and Method

2.1. Research Design

This study employed a qualitative case study approach to examine the interface between transport safety and transport security in the cross-border movement of radioactive materials. A qualitative design was selected because the research seeks to understand regulatory practices, institutional behaviour, and operational vulnerabilities rather than to quantify transport frequency or incident rates. The approach allows analysis of how international regulatory guidance is interpreted and implemented within real operational environments.

The study adopted a policy-analytic framework that integrates document analysis with field observation and practitioner perspectives. International regulatory guidance was examined alongside operational practices at selected border points to compare prescribed requirements with practical implementation.

2.2. Data Sources

Data were obtained from multiple sources to enable triangulation and strengthen analytical reliability. The primary data sources included:

- International regulatory frameworks
- IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6 Rev.1)
- IAEA Nuclear Security Series No. 9-G Rev.1: Security of Radioactive Material in Transport

- IAEA Nuclear Security Series No. 20: Objective and Essential Elements of a State's Nuclear Security Regime
- National and regional documentation
- Selected national regulatory policies and transport regulations within West African states
- Open-source information on border security and radiation detection challenges
- Field-based information
- Informal interviews with frontline officers and regulatory personnel
- Direct observation at three major border crossings
- Discussions with first responders and customs officials

The use of multiple sources enabled comparison between regulatory expectations and operational practice.

2.3. Case Study Selection

This study uses a West African case to examine how safety and security interact in practice and to identify vulnerabilities that emerge when the two systems are implemented independently. A comparative regional case study involving three neighbouring West African countries, anonymised as Country A, Country B, and Country C for confidentiality and security reasons was adopted.

The case was selected because cross-border transport of industrial radioactive sources frequently occurs within the region, particularly involving radiography sources used in construction and infrastructure development. The region therefore provides a relevant environment for examining transport governance across jurisdictions with differing regulatory capacities.

Country A maintains a relatively established regulatory framework. Frontline officers and first responders possess radiation safety and security training, handheld radiation detection equipment is available, and communication procedures exist between regulatory authority and border agencies.
In contrast, Countries B and C operate with more limited regulatory capacity. Border officials lack radiation detection equipment, nuclear security awareness is minimal, and formal verification procedures are absent at several entry and exit points.

2.4. Case Study Scenario

A regional construction company operating across the three countries routinely transfers industrial radiography sources between project sites. The company provides safety labels and documentation; however, operational verification varies significantly by jurisdiction.
Shipments frequently enter the region through Country B, where border officials lack radiation detection capability and awareness of radioactive material transport requirements. Consequently, consignments pass through without inspection or verification. Movement between Countries B and C is even less controlled, occurring without formal regulatory documentation.

Upon entry into Country A, regulatory authorities conduct documentation checks, confirm source identity, and perform dose-rate measurements in accordance with national regulatory procedures.
This variation in regulatory enforcement illustrates how differing institutional capacities can create transport vulnerabilities despite the existence of safety documentation and packaging compliance.

2.5. Data Analysis

Data were analysed using qualitative thematic analysis. Regulatory requirements derived from SSR-6 and NSS-9-G were used as analytical categories to assess operational practices observed in the case study. Observations and interview information were coded according to four analytical dimensions as follows:

- Regulatory Verification
- Detection Capability
- Institutional Coordination
- Transport Documentation Control

The comparison between regulatory guidance and observed practices enabled identification of areas of convergence, divergence, and operational vulnerability at the safety–security interface.

2.6. Ethical and Confidentiality Considerations

The identities of participating countries, specific border locations, and operational personnel were anonymised to avoid disclosure of sensitive security information. The study relied on non-classified operational observations and voluntary practitioner discussions. No personally identifiable information was recorded.

3. Results

3.1. Overlap Between Safety and Security Requirements

Comparative analysis of the IAEA transport safety requirements (SSR-6 Rev.1) and nuclear security guidance (NSS No. 9-G Rev.1) demonstrates that transport safety and transport security are not independent systems but operationally interconnected frameworks [1, 2]. Both documents require structured planning, trained personnel, and coordinated response mechanisms, although they approach risk from different assumptions. The four (4) principal areas of operational convergence identified include:

3.2. Transport planning and route management

Both frameworks require advance preparation prior to shipment. Safety regulations require hazard classification, package selection, and radiation protection arrangements [8], while security guidance requires route evaluation, threat awareness, and communication protocols.

3.3. Training and competency of personnel

Safety regulations require personnel to understand handling procedures and radiation protection principles. Security guidance requires awareness of unauthorized acts, suspicious behaviour, and response procedures. In practice, the same personnel often perform both functions in most jurisdictions.

3.4. Emergency preparedness and response

Safety systems address accidental release and radiation exposure, whereas security systems address theft, sabotage, and attempted diversion. However, both rely on coordinated response involving regulators, emergency responders, and law enforcement agencies.

3.5. Quality assurance and verification

Safety frameworks emphasize compliance verification, inspection, and documentation. Security frameworks require confirmation of shipment authenticity, tracking, and recovery arrangements. The activities occur simultaneously during inspections and shipment handling.

These findings confirm that safety and security operate on the same transport activity and therefore must be coordinated rather than implemented separately.

4. Case Study Findings

The West African case study provided empirical evidence of how these frameworks function under real operational conditions. Operational condition identified include:

4.1. Uneven Regulatory Capacity

Country A demonstrated established regulatory oversight, including document verification, source identification, and dose-rate measurements. In contrast, Countries B and C lacked consistent regulatory controls. As a result, shipments could travel through parts of the route without verification even though they complied with safety packaging requirements.

This indicates that radioactive material may be compliant with safety standards yet remain vulnerable to diversion, loss, or unauthorized access.

4.2. Undetected Cross-Border Movement

Border crossings between Countries B and C allowed movement of radioactive sources without proper inspection of documentation. Border officials lacked both radiation detection equipment and awareness of transport requirements. Consequently, shipments passed through checkpoints without confirmation of contents.

This demonstrates that safety packaging does not guarantee regulatory control in the absence of security verification.

4.3. Safety Compliance Without Security Assurance

The transporting company followed safety procedures, including proper labelling and documentation. However, these measures only ensured containment of radiation hazards. They did not provide protection against theft, substitution, or misuse.

The case therefore illustrates a key vulnerability: a shipment can be radiologically safe but physically insecure.

4.4. Absence of Radiation Detection Capability

Countries B and C lacked operational radiation detection equipment at border crossings. Officials could not verify source identity or confirm whether packages contained declared materials.

This limitation affects both safety (condition verification) and security (source identification and tampering detection).

4.5. Limited Frontline Officer Awareness

Frontline officers demonstrated limited awareness of nuclear security risks and were unable to identify suspicious transport behaviour or falsified documentation. Even when documentation was present, confirmatory verification was not performed.

This finding highlights that regulatory effectiveness depends not only on regulations but also on human capacity.

4.6. Lack of Harmonised Regional Procedures

While Country A enforced stringent regulatory compliance, neighbouring countries B and C did not apply similar procedures. The absence of coordinated cross-border protocols meant that regulatory controls applied in one jurisdiction were ineffective once a shipment crossed the border.

This created a fragmented transport oversight system across the regional transport route.

5. Discussion

The results illustrate a structural gap between regulatory design and operational implementation. International guidance assumes that radioactive material remains under regulatory control throughout transport. In practice, regulatory control becomes discontinuous when transport crosses jurisdictions with unequal capacity.

The study shows that safety-focused systems can successfully prevent accidental exposure while simultaneously failing to prevent unauthorized access. This occurs because safety frameworks address accidental risk, whereas security frameworks address intentional risk. When implemented independently, they leave an operational gap.

The case study therefore demonstrates that transport safety and transport security are interdependent rather than parallel systems. Effective transport governance requires coordinated implementation of both frameworks across the entire transport route, not merely within a single state.

5.1. Implications for Nuclear Security

The absence of integrated safety and security measures increases the likelihood that radioactive materials may become **out of regulatory control**, thereby facilitating illicit trafficking or malicious use [9]. Weak detection capability, insufficient personnel training, and fragmented inter-agency coordination collectively create exploitable vulnerabilities.

Accordingly, maintaining regulatory control over radioactive material transport requires not only compliance with safety standards but also sustained security oversight across jurisdictions.

6. Conclusion

This study examined the interface between transport safety and transport security in the movement of radioactive materials using international regulatory guidance and a regional West African case study. The analysis demonstrates that radioactive material transport cannot be governed effectively through safety measures alone. Although safety frameworks successfully prevent accidental exposure, they do not address intentional risks such as theft, diversion, or unauthorized access.

Comparison of SSR-6 transport safety requirements and NSS No. 9-G security guidance shows that the two systems operate on the same transport activities and depend on many of the same operational processes, including transport planning, inspection, personnel training, and emergency response. However, they differ in their underlying assumptions: safety systems address accidental failure, while security systems address adversarial behaviour. When implemented independently, this difference creates operational gaps.

The regional case study illustrates how these gaps emerge in practice. Uneven regulatory capacity across neighbouring states allows radioactive shipments to move safely but not securely. Where detection equipment, trained personnel, and verification procedures are absent, regulatory control becomes discontinuous across the transport route. As a result, radioactive material may remain properly packaged yet still be vulnerable to loss, diversion, or misuse.

The findings therefore indicate that the safety–security interface is not merely a regulatory coordination issue but a governance requirement. Maintaining radioactive material under regulatory control depends on integrated implementation of safety and security measures across the entire transport pathway rather than within individual jurisdictions. Strengthening this interface contributes not only to national protection but also to regional and global nuclear security.

Recommendations

Based on the findings, the following measures are recommended to strengthen integrated transport governance in countries utilizing radioactive materials, particularly within West Africa.

Regulatory and Policy Measures

- Align national transport regulations with both the IAEA Regulations for the Safe Transport of Radioactive Material (SSR-6) and the Nuclear Security Series guidance on the Security of Radioactive Material in Transport (NSS No. 9-G).
- Establish formal inter-agency coordination frameworks involving regulatory authorities, customs, police, port authorities, and emergency services.
- Require transport plans submitted by operators to demonstrate integration of both safety and security considerations.

Technical and Operational Measures

- Deploy and maintain radiation detection infrastructure at key border crossings and ports of entry.
- Implement verification procedures that confirm shipment identity in addition to documentation checks.
- Integrate monitoring and communication systems to support real-time awareness of transport movements.

Capacity Building and Training

- Provide structured training programs for frontline officers on radiation detection, transport documentation verification, and security awareness.
- Conduct joint safety-security inspection exercises involving regulators and border authorities.
- Establish continuous professional development programmes to sustain operational competence.

Regional and International Cooperation

- Promote information exchange mechanisms among neighbouring states along transport corridors.
- Encourage participation in regional transport safety and security exercises and workshops.
- Develop regional guidelines to harmonize transport verification and response procedures across borders.

Compliance with ethical standards

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Disclosure of conflict of interest

Nelson Agbemava, Etornam Ann Mensah, Kwame Appiah, Cyril Cyrus Arwui, Emmanuel Akrobortu, Henry Lawluvi and Ernest Sanyare Warmann Beinpuo declare that they have no known competing financial interests or personal relationships that could have influenced the work reported in this paper.

Statement of informed consent

Individual frontline officers were interviewed to obtain relevant information; but their identities are not disclosed in this study to protect confidentiality. However, informed consent was obtained from all participants prior to their involvement in the study.

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