Development of an Automated RMSR Calculation Program to Enhance Regulatory Safety and Consistency in Radioactive Material Transport

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1. Introduction

The Radioactive Material Shipment Record (RMSR) is a legally mandated document for non-special form radioactive materials, requiring accurate determination of the Transport Index (TI), A2 multiples, and package classification in strict accordance with applicable regulatory requirements [1,2]. At KAERI, where research samples encompassing diverse nuclides are routinely transported, manual spreadsheet-based workflows introduce non-negligible risks of transcription errors and inconsistent classification, further compounded when multiple nuclides are present within a single shipment. Automation of regulatory computation not only improves operational efficiency but also enhances procedural standardization, which is critical in safety-governed systems [1,2].

This study presents a Python-based automated RMSR calculation system integrating a nuclide database, regulatory decision logic, and TI computation into a unified workflow, with the objective of improving documentation accuracy, procedural consistency, and operational efficiency.

2. Methods

The proposed system comprises three functionally integrated components: a web-based user interface, a Python-based RMSR calculation engine, and an Excel-based reporting module.

2.1 System Architecture

The system adopts a three-tier architecture comprising presentation, business logic, and data layers (Fig. 1). A browser-based interface was adopted to comply with the security policies governing internal workstations at the institute, enabling immediate access via the institutional network without requiring local software installation. Python was selected as the language for the calculation engine owing to its capacity to process nuclide data for approximately 290 nuclides and to accommodate future regulatory updates through modular logic revisions. Microsoft Excel was designated as the output format on account of its widespread institutional adoption, which facilitates seamless integration with established administrative and documentation workflows.

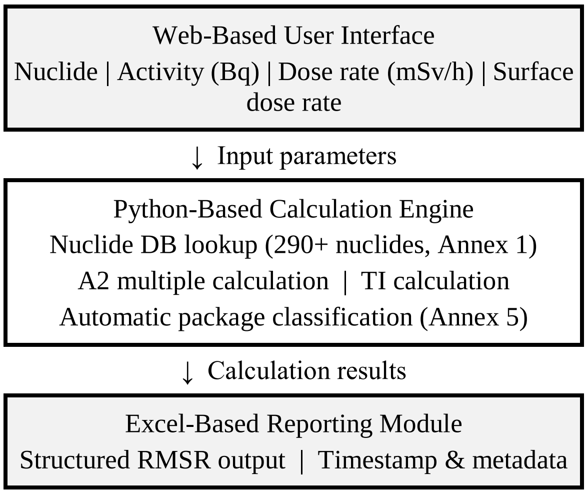

Fig. 1. Three-tier system architecture of the RMSR calculation system

2.2 Calculation Engine

Upon receiving validated input data, with automatic unit conversion applied at the point of entry, the calculation engine computes the TI and the A2 multiple [1,2]. The TI is defined as the measured dose rate at 1 m from the package surface, multiplied by 100, and values not exceeding 0.5 are assigned zero in accordance with regulatory convention [1]. Package classification is subsequently determined by simultaneous comparison of TI and surface dose rate against Annex 5 criteria [2]; Table I summarizes the four categories and their threshold conditions. The more restrictive category is automatically applied when the two criteria yield different results.

Table I: Package classification criteria (Annex 5)

Category	Transport Index (TI)	Surface Dose Rate
WHITE-I	TI = 0	≤ 0.005 mSv/h
YELLOW-II	0 < TI ≤ 1	≤ 0.5 mSv/h
YELLOW-III	1 < TI ≤ 10	≤ 2.0 mSv/h

Category	Transport Index (TI)	Surface Dose Rate
Excl. Use	TI > 10	> 2.0 mSv/h

** Both TI and surface dose rate conditions must be satisfied; the more restrictive category applies when criteria differ.*

Listing 1. Core Python functions for TI computation and package classification.

```
# RMSR Calculation Engine - Core
Module
import pandas as pd
import datetime

NUCLIDE_DB =
pd.read_excel("annex1_nuclide_db.xlsx"
)  # 290+ nuclides

def lookup_nuclide(nuclide_name: str)
-> dict:
    row =
NUCLIDE_DB[NUCLIDE_DB["Nuclide"].str.s
trip() == nuclide_name.strip()]
    if row.empty:
        raise ValueError(f"Nuclide
'{nuclide_name}' not found.")
    return {"A2_GBq":
float(row.iloc[0]["A2(GBq)"]),
            "TI_limit":
float(row.iloc[0]["TI_limit"])}
```

2.3 Output Generation

The reporting module generates structured Excel files that incorporate all input parameters, computed results, and compliance verification data in a standardized format. Each record is timestamped and associated with relevant metadata to ensure audit traceability throughout the documentation lifecycle. The system additionally issues on-screen alerts when computed values approach prescribed regulatory thresholds [1,2], thereby providing proactive notification to the operator.

3. Results

The system was validated against 30 RMSRs from KAERI's 2024 transport activities (17 export, 13 import) [3]. Computed values deviated by less than 1% from reference documents across all test cases, confirming the numerical fidelity of the implemented algorithms. Nuclide selection and package classification previously performed through manual consultation of regulatory annexes [1,2] were executed automatically with fully reproducible outcomes. Table II summarizes key performance metrics. Mean processing time per document decreased from approximately 7 minutes to under 10 seconds, yielding a reduction factor exceeding 40. While the present validation focused on single-nuclide shipments, extension to multi-nuclide aggregation per SSR-6 [1] is underway.

Table II: Performance comparison between manual and automated RMSR preparation

Metric	Manual	Automated System
Processing time / document	~7 min	<10 s
Reduction factor	—	>40×
Calculation deviation	Variable	<1%
Classification consistency	Operator-dependent	Fully reproducible

4. Conclusions

This study developed a Python-based automated system for RMSR preparation pertaining to non-special form radioactive materials [1,2], transforming the conventional manual calculation procedure into an automated regulatory-logic-based workflow. Validation against 30 operational RMSRs from KAERI's 2024 activities confirmed that computed values deviated by less than 1% from reference documents [3], with mean processing time reduced from approximately 7 minutes to under 10 seconds (reduction factor >40). The system enhances regulatory traceability through structured Excel output with embedded timestamps and metadata, while threshold alerts reduce the probability of non-conformance during transport inspections. Extension to multi-nuclide mixtures requiring A2 multiple aggregation per IAEA SSR-6 [1] is identified as the primary objective of future development. By systematically embedding regulatory logic into executable code, the system reduces dependence on individual operator expertise and strengthens institutional regulatory resilience.

REFERENCES

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