Database Design for Development of Material Balance Evaluation Program

Yong Suk Lee*, Young Beom Song, Young Wook Chung, Jae Won Park, Dong-Min Kim, Mi Ri Park
FNC Tech. Co. Ltd., Floor 32, Heungdeok IT Valley, 13 Heungdeok 1-ro, Giheung-gu, Yongin-si, Gyeonggi-do, 16954, Korea
**Corresponding author: ys028@fnctech.com*

1. Introduction

Material balance evaluation (MBE) is a key method for determining whether nuclear material is diverted based on statistical analysis, and an essential element in the field of safeguards for nuclear material control [1].

In the case of bulk handling facility (BHF), such as nuclear fuel manufacturing facilities, the material unaccounted for (MUF) by the difference between book inventory and physical inventory inevitably occurs because of measurement uncertainties and the nature of the process [2]. The International Atomic Energy Agency (IAEA) has identified the diversion of nuclear materials through the MBE, and developed and operated computation program for such purposes [3]. In addition, several other countries are developing and operating MBE programs for such objectives [4-6].

Independent national safeguards regulation system through the State-Level Approach (SLA) agreement has been applied in Korea since 2015 [7]. However, the MBE methodologies and computation programs suitable for domestic safeguards regulation system have not been developed yet.

The first step can be to build a database (DB) system for Korean regulator's MBE in a certain BHF in Korea, which has not yet been established in Korea due to the confidentiality of nuclear material information. Through the DB, all information related to MBE, such as inventory, characteristics, and measurement uncertainty, will be collected and organized for Korean regulators to determine whether nuclear materials are diverted.

In this study, to develop the own MBE program for Korean regulators, the database is designed and the relationships among the entities in DB are identified.

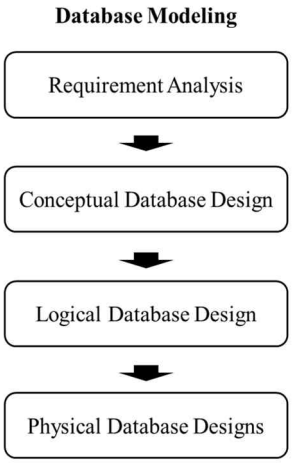

Fig. 1. Database design process

2. Methods and Results

Database design generally proceeds in four steps: requirements analysis, conceptual modeling, logical modeling, and physical modeling. Accordingly, in this study, the database design for the MBE program development was carried out in the same manner, and the design process is shown in Figure 1.

2.1 Requirement analysis

Requirement analysis is the first step in database design. Among the requirements for MBE program, required functions were analyzed and the information to be included in the database was derived.

The information provided from the DB of MBE program, based on the analysis of functional requirements are as follows:

- o System Information
  - Information about the operators of the facility and regulators
  - Authority for use and access on the program of the facility operators
- o Facility information
  - Design information according to design information questionnaire (DIQ) of the facility such as objects, addresses, processes, material balance area (MBA), key measurement point (KMP), types of nuclear materials
- o Nuclear material accounting reports
  - Physical inventory listing (PIL)
  - Material balance report (MBR)
  - Inventory change report (ICR)
- o Nuclear material information
  - Nuclear material information of shipper-receiver
  - Information of stratification in MBA
  - Item information of each stratum
  - Nuclear material inventories and changes
  - Throughput by material balance period (MBP)
  - Significant quantity (SQ)
- o Material balance evaluation statistics
  - MUF, shipper- receiver difference (SRD), inspector's estimated MUF (IMUF), operator-inspector difference (D)
  - Standard deviations (σ_{MUF}, σ_{SRD}, σ_{IMUF}, σ_{D}) calculated by IAEA and 'Guide to the Expression of Uncertainty in Measurement' (GUM)-based methodologies
  - Other MBE statistics by MBR
- o Measurement uncertainty
  - Bulk, sampling, and analytical error elements (random and systematic error) by facility

- International target value (ITV) for measurement uncertainty
- International standards for each type of BHFs in material accountancy

o Statistical methodology
- Based on actual measurement data of items for each stratum with measurement reports (GUM-based methodology) or the estimation of random and systematic error (IAEA methodology), calculation of the measurement uncertainty of each stratum
- Calculation of the representative error (or uncertainty) of the target BHF through error propagation
- Statistical hypothesis verification (ex. if t value is smaller than 1.96, based on the calculated σ_{MUF}, and the hypothesis of MUF = 0 is not rejected)

o Material balance evaluation
- Criteria for outliers (such as 5 times of ITV)
- Alert criteria for diversion (such as 3 times of σ_{MUF})
- Verification of diversion scenario
- Comparison with international standards
- Detection probability of SQ
- Conference interval evaluation
- MBE result report

2.2 Conceptual Database Design

The Conceptual modeling is an abstract structure and conceptualization of the information that emerge in the real world. Based on the information in the MBE program database, important entities were extracted to define the relationship between the entities after selecting the key attributes of each entity.

2.3 Logical Database Design

The Logical modeling is the creation of a data schema by establishing relationships between each entity based on the results of the conceptual design. All entities are represented by many-to-many relationships and relations of multi-valued attributes, and one-to-many and one-to-one relationships are represented by foreign keys. It also determined the data type, length, null, default value, and so on of the attributes.

2.4 Physical Database Designs

The physical model is the end product of the database design. Based on what is defined in logical modeling, storage space is designed to be managed by the actual Database Management System (DBMS). The model is designed in a computer-aware way by defining the primary key, secondary key, data type and data value.

Table 1 shows main table lists in the MBE program database. In addition, Figure 2 shows a physical Entity Relationship (ER) diagram of the MBE program database modelling through physical model design.

Table 1: Main table lists in the MBE program database

Table Name	Description
Facility	Table managing the DIQ information of the facilities
MBA	Table managing information on the MBA of the facilities
KMP	Table managing KMP-related information of a facility
ICR	Table to receive and store the information of ICR
PIL	Table to receive and store the information of PIL
MBR	Table to receive and store the information of MBR
Strata	Table managing information on nuclear material for each strata
SQ	Table managing information on the significant quantity nuclear material
MUF	Table managing information on the MUF
D	Table managing information on the difference of operator and inspector
Error	Table to manage by inputting the measurement error variance of facilities

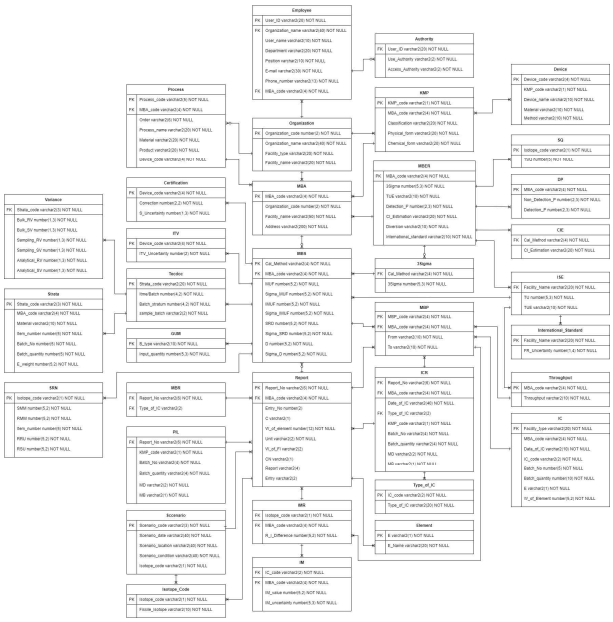

Fig. 2. Physical ER Diagram of MBE program DB

3. Conclusions

In this study, the database for Korean regulator's MBE in a certain BHF is designed. Rather than any other DB for the operation of BHF, it is the unique DB system for regulatory use in nuclear material safeguard activity. As a basis of these results, we will develop a program to perform MBE using various statistical analysis methods (ex. Statistical hypothesis verification based on σ_{MUF} or expended uncertainty of MUF), and

continue to update on additions and changes to the database.

In further study, several types of test will be conducted as part of DB program establishment, to verify that each module linked to the DB operates properly and the entire module is connected well to see if the designed DB's function requirements are met.

ACKNOWLEDGEMENTS

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