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NUMO-RMS: A PRACTICAL REQUIREMENTS MANAGEMENT SYSTEM FOR THE LONG-TERM MANAGEMENT OF THE DEEP GEOLOGICAL DISPOSAL PROJECT

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ABSTRACT

NUMO (Nuclear Waste Management Organization of Japan) has the responsibility for implementing deep geological disposal of high-level (HLW) and transuranic (TRU) radioactive waste from the Japanese nuclear programme. A formal Requirements Management System (RMS) is planned to efficiently and effectively support the computerised implementation of the management strategy and the methodology required to drive the step-wise siting processes, and the following repository operational phase,. The RMS will help in the comprehensive management of the decision-making processes in the geological disposal project, in change management as the disposal system is optimised, in driving projects such as the R&D programme efficiently, and in maintaining structured records regarding past decisions, all of which lead to soundness of the project in terms of long-term continuity.

The system is planned to have information handling and management functions using a database that includes the decisions/requirements in the programme under consideration, the way in which these are structured in terms of the decision-making process and other associated information. A two-year development programme is underway to develop and enhance an existing trial RMS to a practical system. Functions for change management, history management and association with the external timeline management system are being implemented in the system development work. The database format is being improved to accommodate the requirements management data relating to the facility design and to safety assessment of the deep geological repository.

This paper will present an outline of the development work with examples to demonstrate the system's practicality. In parallel with the system/database developments, a case research of the use of requirements management in radioactive waste disposal projects was undertaken to identify key issues in the development of an RMS for radioactive waste disposal and specify a number of use cases to guide the overall development of the system. The findings of the case research will also be shown in the paper to provide general information on the application of an RMS in a radioactive waste disposal programme, the difficulties of successful implementation and suggestions on how these difficulties can be overcome.

1. INTRODUCTION

1.1 Background

NUMO (Nuclear Waste Management Organization of Japan) has the responsibility for implementing deep geological disposal of high-level (HLW) and transuranic (TRU) radioactive waste from the Japanese nuclear programme. Three-staged siting procedure for a deep geological repository is provided in the Specified Radioactive Waste Final Disposal Act (the Final Disposal Act). To proceed with these siting stages and the repository implementation after that, careful management strategy and methodology are needed for the technical decision-making at every milestone, balancing the requirements arising from the characteristics of the sites, the safety in the pre/post-closure stages, engineering issues, environmental considerations, socio/economic aspects etc. in an open and transparent manner.

For this purpose, NUMO has been developing a specific management methodology, termed the NUMO Structured Approach (NSA) [1][2], which is applied to manage NUMO's entire technical project including development of the repository concept tailored to the sites. The NSA focuses on decision-making structures consisting of requirements, decisions among them and relevant information. The amount of information to be dealt with in the NSA is quite huge, and a computerised tool is necessary to practice the method. NUMO is currently developing a Requirements Management System (RMS) to support the computerised implementation of the NSA, hereafter NUMO-RMS, which has more advanced functions than the conventional RMS in order to manage not only the requirements relating to NUMO's technical project, but also the decision-making processes covering it.

A trial RMS was developed in FY 2006-2007 [3], in order to develop NUMO's understanding of issues related to RMS development. The database of the trial system was based on the site-independent, but well-established repository concept described in the H12 report [4], allowing a practical approach for designing and implementing a trial system. Through a test installation of the trial system, improvements of the functionality, data structure and graphical user interface were identified. The following two-year programme is underway to develop and enhance the trial RMS to a more practical system towards NUMO-RMS for formal use.

1.2 Objectives and benefits of NUMO-RMS

Since implementation of deep geological disposal takes many decades from early stage site investigation to repository closure, information relating to decisions and requirements on the geological disposal project should be maintained. Some unpredictable event may be happen in the future and its correspondence will be recorded for the future to keep consistency. The objectives and benefits of using NUMO-RMS can be summarised as follows:

- To facilitate structured record keeping from regulation requirements to design requirements
- To facilitate comprehensive information management of the decision-making process
- To support change management by understanding the implications of proposed changes
- To facilitate proactive decision-making.

2. LESSON LEARNT FROM CASE RESEARCH

The management of requirements is an integral part of any large-scale development project and a variety of approaches and methodologies have been developed in different industries. In the case of radioactive waste management, a number of programmes in different countries have developed and used RMSs to support decision-making and programme development. Although these are specific to the programme and country concerned, and may have a very different scope to the system being developed by NUMO, there are sufficient similarities for a review of RMSs in other countries to be worthwhile, with a focus on the lessons learnt regarding their development and use.

Therefore a review of the use of requirements management in other radioactive waste management programmes was undertaken. The review considered the development and use of RMSs in the programmes undertaken by the US Department of Energy at Yucca Mountain in Nevada and the Waste Isolation Pilot Plant (WIPP) in New Mexico, by the Nuclear Decommissioning Authority in the UK, by Posiva, by ONDRAF/NIRAS, by the Environment Agency of England and Wales, and by Dounreay Site Restoration Limited.

The RMSs reviewed were implemented at various stages of programme development, from initial conceptual studies, through site selection and design stages, to construction and operation. This, and differences in scale in terms of personnel and resources, mean that there are significant differences between the scope of the RMSs and how they are implemented. Nevertheless, there are some common features and lessons that can be learned from the survey:

- Requirements management is more than just the design of an RMS. The survey has shown that developing an RMS has generally prompted a detailed examination of requirements. However, if the RMS is to be more than a record of requirements at a particular time, it is important that work on identifying requirements continues throughout the project.
- An RMS can be an effective tool for recording information about requirements, how they are met or plans for meeting them, and other supporting information. Overall, however, the benefits of any particular RMS implementation project are typically related more to the success (or otherwise) of integrating requirements management into routine work than the level of sophistication in system capabilities.
- Developing and maintaining an integrated RMS may require significant resources. It is important that these resources are available, and can be maintained, at a level consistent with the objectives of the RMS. Step-wise development of the RMS, in terms of features and capabilities, may however be more effective than limiting the scope by concentrating on particular areas of requirements.

Because of the extended time-scale over which a RMS will be used it is important that the RMS should be adaptable (e.g., as new computing developments become available). However, because it may not be possible to anticipate what changes might take place, adaptability should not inhibit current development.

The review enabled a set of potential users of an RMS to be identified as the basis for a set of System Use Cases. These present, from the user's perspective, what interactions with the system should be possible and what the outcomes of these interactions should be. The aim of these System Use Cases was not to duplicate components of the Functional Specification and Design Specification for the NUMO-RMS. Instead, they represent a means of reviewing initial designs and provide an opportunity of adding or changing functionality using the experience of other programmes that have used or considered the use of RMSs in radioactive waste management.

In addition to users who will access the RMS, there are users with responsibilities for entering and updating information, reviewing and approving the data entries and for maintaining the RMS and supporting systems. In addition, the review highlighted the importance of users with responsibilities for the identification of new requirements as the programme evolves and the integration of requirements management with other aspects of the programme. Such roles cannot be described through formal use cases associated with software design but they are keys to the long-term success of an RMS.

3. ANALYSIS OF THE DATA STRUCTURE AND THE INFORMATION MANAGED THROUGH RMS

3.1 Structure of the decision-making process

To implement a project in gradual phases means incorporating over time knowledge of the waste to be disposed of, the detailed site environment information and the laws, ordinances and regulations and demands by stakeholders, etc. that are enacted and become clearer in each phase. In the process, the concept of a repository and the technologies developed, among other factors, would be incorporated into the activities of the next phase over and over again. When considering the fact that a given project would be implemented over many decades, it is essential to ensure that the decision-making process can be tracked over time in order to achieve the objectives aimed for in developing RMS, as mentioned in chapter 1.

To this end, it is necessary to clarify what kind of information should be managed through RMS and analyze the relationships among the types of information targeted, with the results to be incorporated into the design process for the database system. The information that NUMO has decided to store in its RMS have been specified as those relating to Decisions, Conditions, Requirements and Arguments (DCRA, see 3.3.2). Therefore, the scope of the NUMO-RMS is somewhat wider than other systems since it aims at storing the basis for decision-making in addition to acting as a record of requirements. This additional functionality allows the RMS to provide greater benefits to the disposal project.

When paying attention to an individual Decision, the pieces of information available at that point including the site environment information, laws, ordinances and regulations, as already mentioned, form the Conditions for the decision-making process, in other word the premises of Decision. Based on the Conditions, there would be Arguments showing what the thinking process was like in exploring how it is possible to satisfy a number of Requirements. Specifically, a Decision 'possible repository depth' includes 'depths shall be greater than 300m below surface', a provision in the Final Disposal Act, as a Condition, and a) 'the rock shall be mechanically stable for excavation', b) 'the groundwater flow rate/velocity shall be low', c) 'the groundwater chemistry shall be in reducing condition' as Requirements. There would be Arguments showing that a) rock stability, b) groundwater flow rate/velocity, and c) redox potential satisfy Requirements. The results from a Decision could constitute a Condition or an Argument for another Decision. In such ways, certain relationships would exist among different Decisions (see Figure 3-1.).

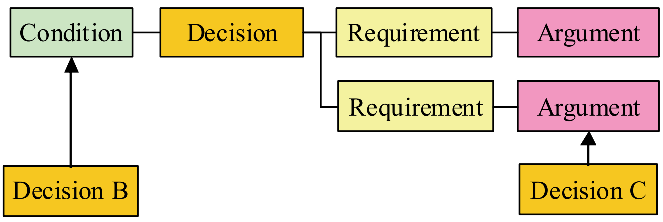

Figure 3-1 Possible relationships among different Decisions

Making a decision is generally understood as a process "seeking to arrive at a solution from among multiple possible ideas, including alternative ideas," and thus making a choice. In RMS, the judgments made in the design and evaluation processes that led to a Decision are also considered as a part of that Decision, in order to ensure that tracking the thinking process is possible. For example, if possible ideas B and B' exist for the layout of an underground facility, multiple Decisions are made in work processes for reaching the Decision on the layout plan for each of these ideas. Thus a single Decision on the layout design of an underground facility encompasses multiple Decisions. It was decided to name a group of related Decisions with such inclusive relationships a "work package" and to ensure management of these work packages. A Decision and selection that chooses from between possible ideas B and B' to decide on the layout of an underground facility, which will become reference information, would include other Decisions that led to that particular Decision, so it was decided to consider such a Decision as a selection work package. The concept of a work package is shown in Figure 3-2. In the figure, Work package A means a Decision made by choosing from Work package B and Work package B'.

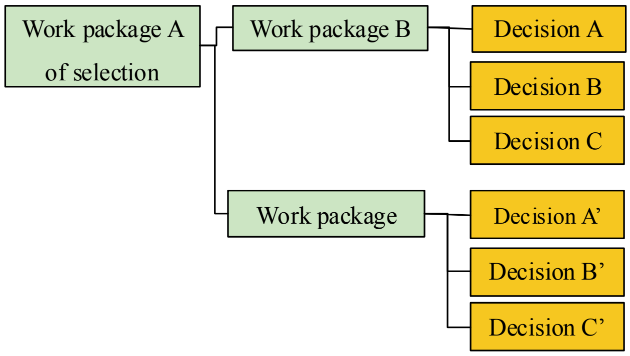

Figure 3-2 Concept of a work package

3.2 What is a Requirement?

In engineering, a requirement is a singular documented need of what a particular product or service should be or do. Some examples of Requirements in this sense that are related to the establishment of the concept of a repository would be the voluntary standards set by NUMO based on the matters stipulated in laws, ordinances and governmental guidelines and societal demands, and the functions and needs that must be met in terms of safety and engineering feasibility (mandatory requirements). At the same time, there are likely to be other features of the disposal system that could be described as "nice-to-have" (desirable requirements). Cost issues would fall under this category. Because such demands and desirable functions are also taken into consideration in the decision-making process, it was decided to think of them also as Requirements in RMS for the sake of convenience. However, to distinguish between mandatory requirements and desirable requirements, it was decided to use the terms "Hard Requirement," and "Soft Requirement" respectively.

The task of defining Requirements on the disposal system will be carried out concurrently with the processes of establishing the standards on the system (initially through development of voluntary standards by NUMO) and preparing design and evaluation manuals. The Requirements would be defined in a definitive way after incorporating the governmental guidelines and standards that will be established as the project moves forward. The process of defining Requirements would initially focus on such matters as safety and viability from an engineering standpoint for possible repository concepts, but would widen as the project proceeds to consider other issues such as environmental impact, socio-economic issues and cost. It is believed that, as progress is achieved in site geological characterisation and technological development processes, the Requirements would accordingly become more specific and detailed.

3.3 The information managed through RMS

For applying the DCRA model described in the section 3.1 to an actual project, the information to be managed as Decisions, Conditions, Requirements or Arguments was categorised in more detail.

3.3.1 Establishment of the tasks related to Requirement management

To identify and specify the types of information to manage, it is naturally necessary to think about design and evaluation methods, but it is also important to clearly grasp the work procedures relevant to the requirement management. When proceeding with a project in gradual phases, there will be top-down-oriented demands at the start of each phase regarding such issues as how detailed the design of the repository concept to be presented should be and to what degree the Requirements should be satisfied in the course of that particular phase. In response to such demands, the decision-making matters and Requirements to deal with in that phase would be determined. At this point, it is desirable that the policies on how to proceed with the study process during the phase with regard to how to satisfy the Requirements (the measures for fulfilling the Requirements) would be established, and that relevant work would be carried out in a well-planned manner (Decision and Requirement definition phase). Then individual personnel in charge of design and evaluation processes will perform tasks including design and evaluation while taking into account the Requirements, and will organize the Arguments for satisfying the Requirements (Task operation phase). The results of the tasks will be compared with the Requirements, and a check will be conducted on the current status of how the Requirements have been satisfied, the suitability of the Requirements, and the level of consistency with other results (Suitability confirmation phase). For those items regarding which it has been confirmed that all the Requirements have been met, the Decision will be finalized (Decision-making phase).

In this way, it was decided to classify the operations concerning the requirements management into four phases, as shown in Figure 4-3. The figure also shows the contents of the data to be entered into RMS, which is considered as a computer system in this context, and the timing of data entry.

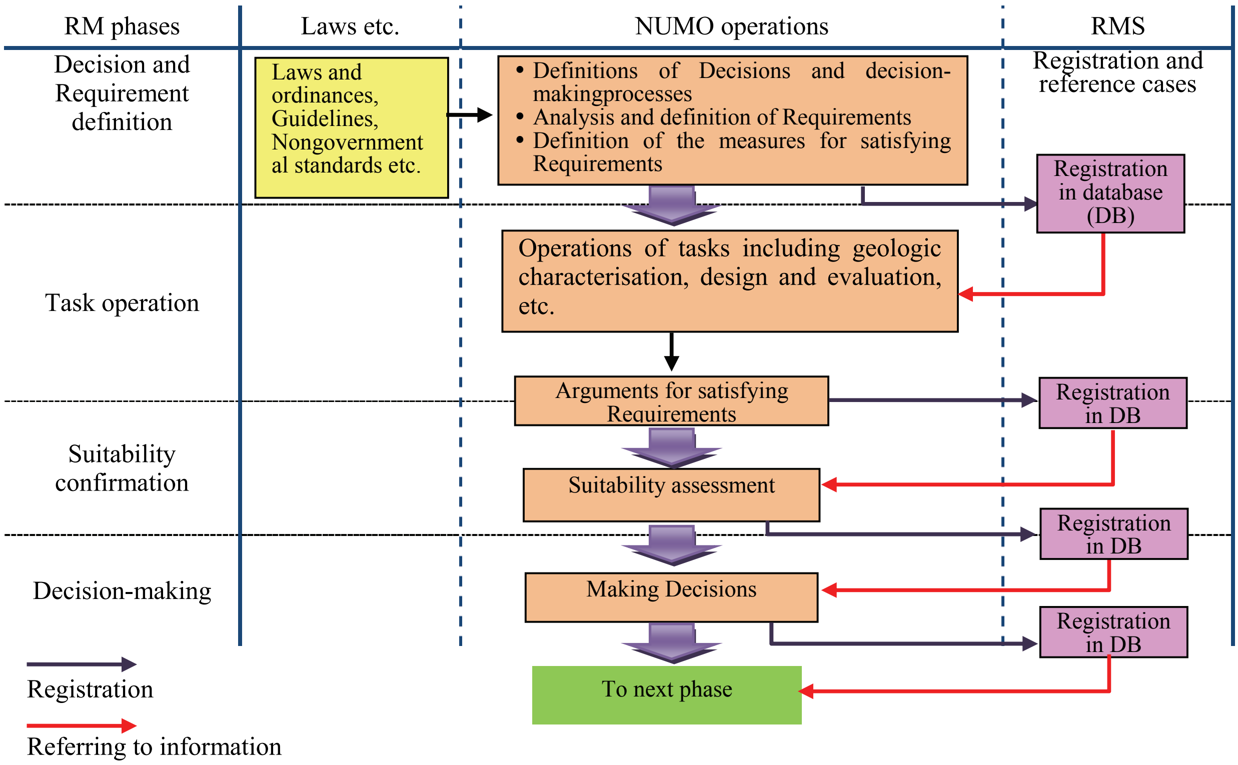

Figure 3-3 The relationship between RM (Requirements Management) phases and RMS

3.3.2 The information managed by RMS

By taking into account the RM (Requirements Management) phases, the information to be managed through RMS was identified and selected for each of Decisions, Conditions, Requirements and Arguments, based on the assumption that actual design work would be carried out for a deep geological repository. What follows are the explanations on the contents of each category, showing extractions of the main types of information to be managed through RMS in Table 3-1.

(1) Decision

The information concerning the "name" of a Decision and "explanations" on the Decision showing what is being decided through the decision-making process is managed. The information is entered in the Decision and Requirement definition phase.

Then information on "Decision results" that resulted from the work carried out thereafter and the "process" leading to the results is entered. The "status" showing the current state of the decision-making process is also handled as information for management, with the assumed status categories being Decision already made, Decision made conditionally, Pending, and No decision-making.

(2) Condition

Premises of actions like task operations, the establishment of Requirements and the decision-making processes are managed as Conditions. Conditions are given a priori, and no particular argument is necessary for their fulfillment. The information to be managed as Conditions consists of boundaries to be observed in carrying out the RM operations, such as siting environments; restrictions from existing laws and regulations; and rules described in the design and performance assessment manuals.

(3) Requirement

The "explanations" on a Requirement should be provided in a qualitative way as much as possible, and in case any quantitative reference value exists, the "index" and the "reference value" should be entered. As mentioned already, Requirements can be categorised into the Requirements that must be mandatorily satisfied (Hard Requirements) and the Requirements fulfilling of which is desirable to improve the functions (Soft Requirements), and results of this categorisation are managed as the "type" of Requirement. When classifying into a Requirement type, the situation in that particular phase is taken into account, so it is important to retain the information on the reason for the categorisation setting. Also managed here are the categorisations regarding such matters as whether a Requirement concerns an engineering viability issue or a safety issue (Post-closure safety, Operational safety). The "design factor" [1] is used in this categorisation process. Entry of the relevant information is made in the Decision and Requirement definition phase.

In the Suitability confirmation phase, the "results" of the suitability evaluation that makes a judgment on whether Requirement has been satisfied or not for each of Requirements are entered.

(4) Argument

As the Argument, "the measures for fulfilling a Requirement" regarding how a Requirement would be satisfied or how to show that a Requirement has been satisfied, etc., as already stated, are entered in the Decision and Requirement definition phase. The "evidence" gathered in the course of the work implemented in line with the measures and the "Argument" providing the judgment that a Requirement has been satisfied based on such evidence, and the reasons for the judgment are entered in the Task operation phase and thereafter. Possible examples of an evidence would include test results, evaluation results, corroboration and the results of other Decisions that are available. In case a judgment is made that a Requirement has not been satisfied, the activities toward relevant technological development or such a plan should be given up; the management of this kind of "status" is also deemed necessary.

Aside from the descriptions above, the information necessary for quality control such as the name of the registrant, the registration date and the name of the person giving approval is also managed, but related explanations are omitted here.

Table 3-1 Main categories of information managed in RMS

DCRA	Category	Detailed explanation on the category
Decision	Name	Name of the particular decision
	Description	Scope of the decision making for the decision
	Result	Outcome of the decision making
	Status	Current state of the decision-making process
	Background	Statement of the confirmation that the hard requirements have been satisfied, etc.
Condition		The geologic environment model, Laws and ordinances, Notifications, Standards, Guidelines, and Premises for the study process (Boundaries for the study process) Used for the relevant Decision
Requirement	Description	Qualitative expression of the R
	Type	Hard (mandatory) requirement/ Soft (desirable) requirement
	Indicator	Name of the index used in judging that the R has been satisfied
	Criterion	The value corresponding to the above-mentioned index
	Result	Result of judgment on conformity
	Design factor	Relevant factor in design
Argument	Scheme	The measures regarding how to show that the R has been satisfied
	Description	The judgment that a requirement has been satisfied based on an evidence and the reasons for the judgment (Forming an Outline)
	Evidence	Test results, evaluation results, corroborations, the results of other Decisions etc.
	Status	Challenges to R&D issues or the rejection of an examined option, etc.

4. SYSTEM DESIGN AND CREATION

4.1 The use case analysis for system design

An analysis was conducted on the use cases for a system by referring to the use patterns assumed for a practical system and the lessons learnt from the cases in various foreign countries, etc. Based on the analysis results, the functions required of a practical system were examined. The results of the use case analysis were complied for the following 6 types of scenarios.

- Overview analysis concerning the registration, search and browsing functions for DCRA
- Analysis concerning the analysis of the effects from any change in DR at the time of the change
- Analysis concerning the approval for DR
- Analysis concerning the registration of D procedures
- Analysis concerning management of the data related to geologic environment, design and safety evaluation (parameter data)
- Analysis concerning data history management

What follows is an outline of each of these scenarios.

(1) Registration, search and browsing functions for DCRA

A series of decision-making work procedures is carried out in this scenario, including the registration of a Requirement, registration of the Decision-making matters providing explanations on what the decision-making process was all about (excluding the Decision-making results), registration of the decision-making procedures, the Decision made (work that is performed outside the system), registration of the Decision-making results, the Argument for satisfying the Requirement and registration of the Conditions. As for the users of this scenario, the personnel in charge within NUMO and related parties outside NUMO were defined as the DCRA data registrants. External parties include the organisations to which maintenance of the RMS is commissioned, the personnel in charge at these organisations, the personnel in charge of related systems (e.g. the knowledge management system being developed by JAEA) and NUMO's domestic and international advisory committees were defined as the DCRA data registrants.

(2) The effects analysis at the time of any change in DR

This scenario is an evaluation of the possible effects in case any change is made in the Requirements and Decisions as more detailed geological environment Conditions gradually emerge in relation to the implementation of work concerning design and safety evaluation, after the registration of Decisions, Conditions, Requirements and the Arguments showing that Requirements have been satisfied. The users of this scenario were defined as the personnel in charge within NUMO and related parties outside NUMO (the organisations to which work is commissioned and the personnel in charge at these organisations).

(3) Approval for DR

This scenario involves the approval for Requirements, the Decision-making matters providing explanations on what the decision-making process was all about (excluding the Decision-making results), the Decision-making procedures, the Decisions made (work that is performed outside the system), the records of Decision-making results, the Arguments showing that Requirements have been met and the Conditions, after the completion of their registrations. The users of this scenario were defined as the officials giving approval inside NUMO.

(4) Registration of D procedures

This scenario includes information concerning the creation and any revision of the DCRA network chart as defined in DRA-D (Decisions / Requirements / Arguments – Decisions) and DC-D (Decisions / Conditions – Decisions). The users of this scenario were defined as the personnel in charge inside NUMO.

(5) Management of the data related to geologic environment, design and safety evaluation (parameter data)

This scenario concerns the cases of registering as master data the information on the geologic environment characteristics not dependent on the actual site that is necessary in carrying out such work as design and safety assessment before the start of the site geologic characterisation process, the common data to be managed when carrying out design work and the common data to be managed in relation to safety assessment work; and the cases of registering any relevant changes. The users of this scenario were defined as the personnel in charge inside NUMO.

(6) Data history management for DR

This scenario provides the registration method for retaining without fail the history of master data for Decisions (D), Requirements (R), Conditions (C) and Arguments (A) and individual user data, as well as the history of work package data and the history of data on DCRA models (groups of individual DCRA units). Descriptions here concern the history of master data (general-purpose information in any phase before the start of the site geologic characterisation process, which is not dependent on local area characteristics) and user data (the information after the start of the site geologic characterisation process, which is dependent on local area characteristics). The users of this scenario were defined as the personnel inside NUMO (the personnel in charge of operations) and people outside NUMO (the organisations to which work is commissioned).

4.2 System concept

Based on the results of case studies and of the analysis of data structures and use cases, the required functions were identified and selected. A study was conducted on the system concept based on the results.

As shown in Figure 4-1, the Requirements Management System uses its database to assume the functions of managing without fail the Decisions and the related information such as Requirements, the issues to take into account, Conditions and design factors, while ensuring consistency and the ability to track information; the functions for registering information and quickly searching and browsing managed information; and the functions for assisting in the decision-making process at NUMO.

The system adopts the configuration of a Web-based system, with all the information managed by a server and the users using the Web browser on their personal computers linked to a local area network to make use of the system. Adopting a Web-based system structure means that information (the data and software) is concentrated in the server, making maintenance and expansion of the system easier. In the future, it would also be possible to access the system from an actual site through the Internet and provide information to stakeholders, among other potential uses.

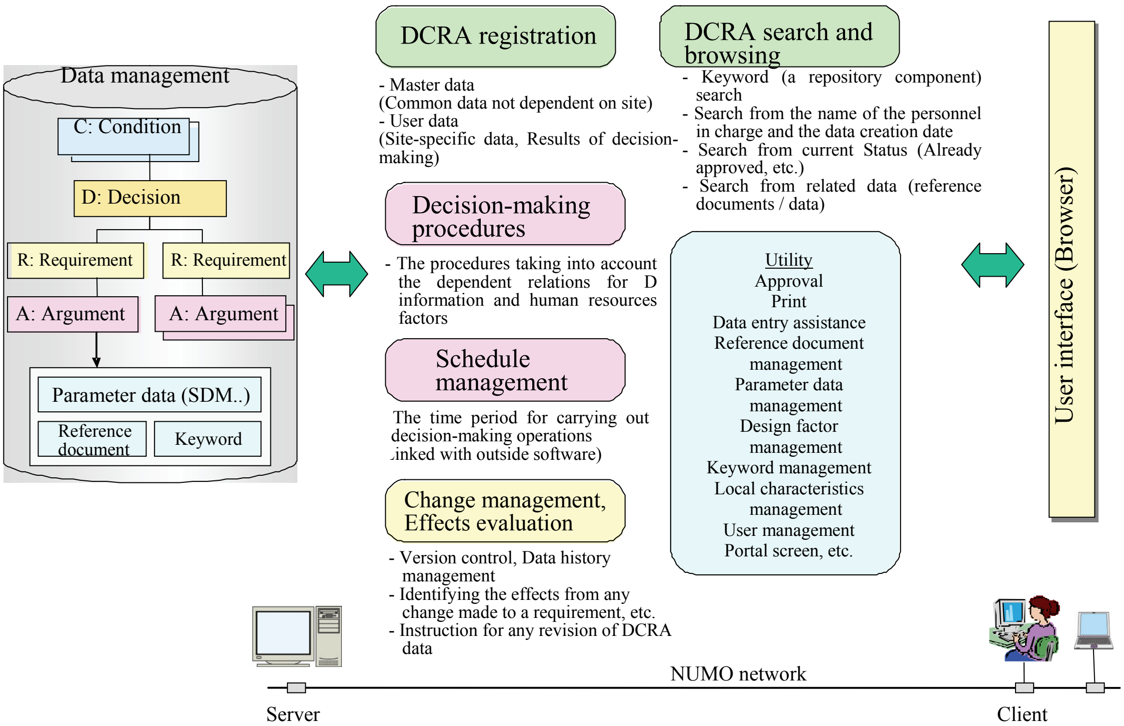

Figure 4-1 System concept

4.3 System functions

Table 4-1 is the list of functions that the Requirements Management System has. For the information managed through RMS as examined in Chapter 3, how the pieces of information registered in each phase would be linked to each other is shown in Figure 4-2. As an example of the screens for registration, the Requirement registration screen is shown in Figure 4-3.

Table 4-1 List of system functions

Function category	Outline of functions
Data management functions	All the information handled in the Requirements Management System such as Decisions (work packages), Requirements, Conditions, Decision-making procedures, design factors, local area information, the information on the site environment, reference materials and keywords, is stored in the relational database.
DCRA registration functions	These functions concern the registration of Requirements and Decisions as defined in the Decision and Requirement definition phase, just as shown in Figure 4-2, and the registration of results of the work carried out after the Task operation phase (Arguments, suitability assessment results and decision-making results). For reference, Figure 4-3 shows an example of the screen for registering a Requirement.
DCRA search and browsing functions	Searching Requirements and Decisions is possible from a component comprising a repository (e.g., tunnel or overpack), registrant name or registration date, etc.
Functions for creating decision-making procedures	The functions for creating decision-making procedures enables the creation in the system of a network chart showing the decision-making procedures based on a work package and a Decision.
Schedule management functions	By linking with a process management software sold on the market, the Requirements Management System manages the starting and finish dates for a Decision and the decision-making process.
Effects evaluation functions	With these functions, the Decisions affected in case any change is made to a Requirement are identified and selected. Other Decisions affected in case any change is made to a Decision are also identified and selected.
Change management functions	With these functions, the history of changes made to data (person making the change, the date of change, summary of the change made) regarding Requirements and Decisions are stored in the database, for the purpose of ensuring the ability to track information.
Approval functions	With these functions, the person creating data decides on the person to give approval and requests for his or her approval, after creation of the data is completed. Then the person to give approval either approves or rejects the relevant data.
Data entry assistance functions	With these functions, the technical terms registered in advance in a dedicated dictionary are presented according to a user's keyboard input operation, for the purposes of preventing any variations in spellings and the styles and terms for expressing certain ideas, and of reducing the burden of data entry work.

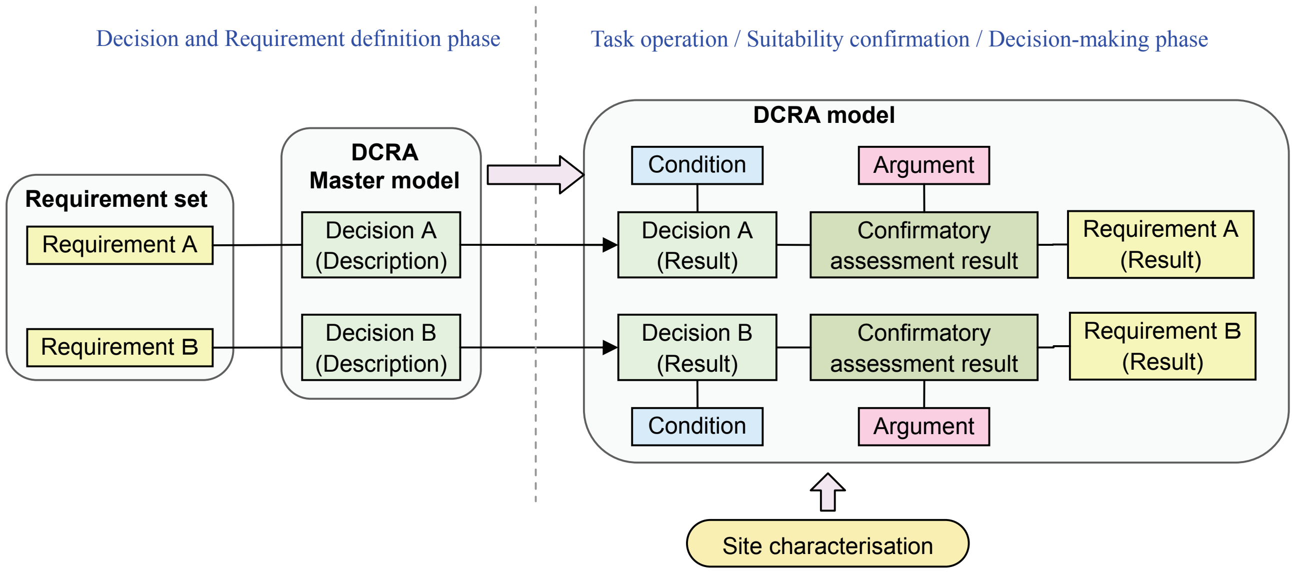

Figure 4-2 Data architecture of DCRA in each RM phase

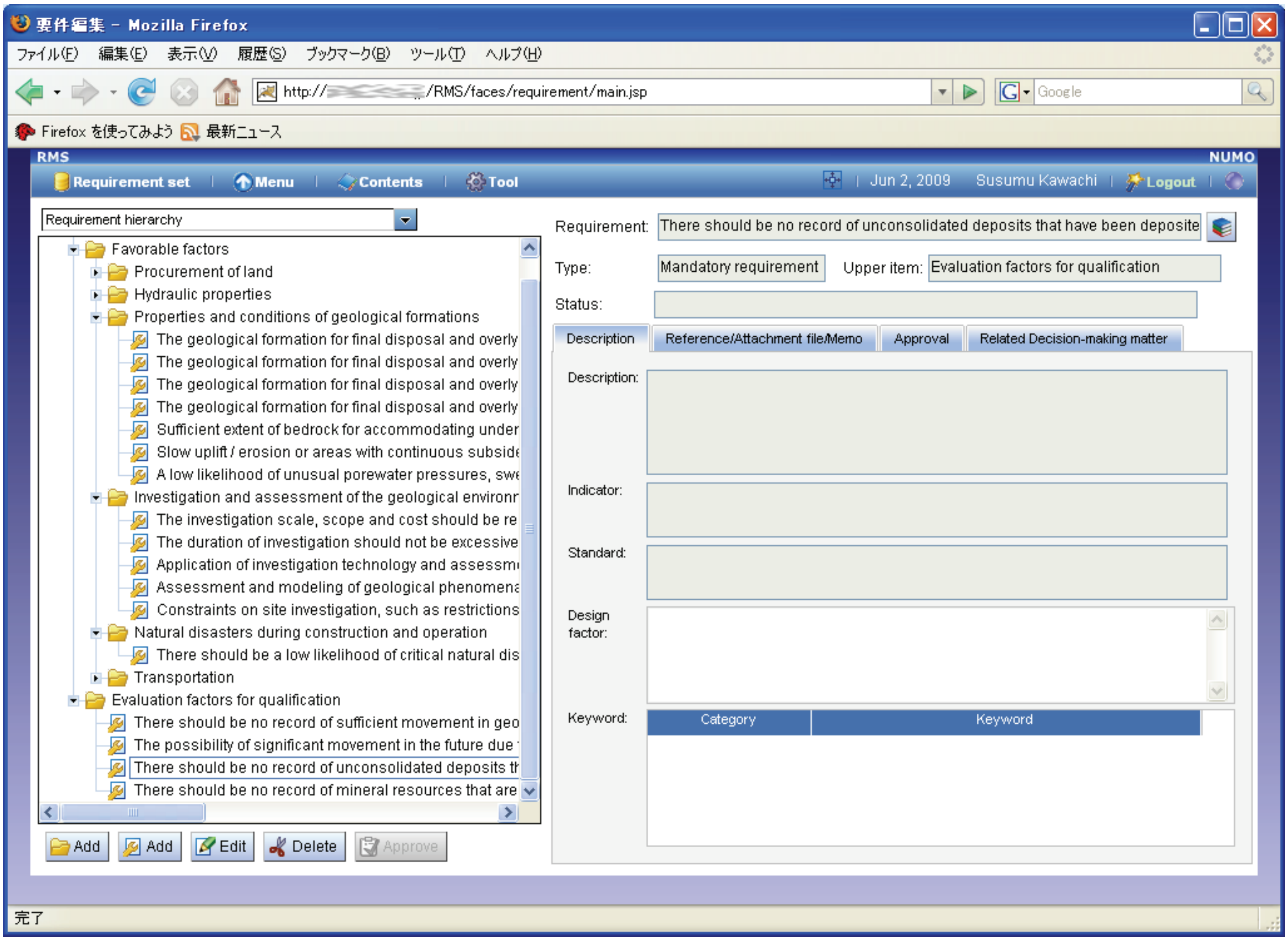

Figure 4-3 Example of the screen for registering a Requirement

5. CONCLUSIONS AND FUTURE DEVELOPMENT

NUMO is developing an innovative RMS for the practical and computerised implementation of the NSA. The development of the practical NUMO-RMS in advance of the formal system is on-going. The preparatory stages, the data structure analysis/modeling and system conceptualisation were almost completed. Development of the functional specifications and other software design work are now being carried out so that the software coding and data input will be started in the second half of FY 2009.

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