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SOFTWARE TO SUPPORT PLANNING FOR FUTURE WASTE TREATMENT, STORAGE, TRANSPORT, AND DISPOSAL REQUIREMENTS

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ABSTRACT

Planning for adequate and appropriate treatment, storage, transport and disposal of wastes to be generated or received in the future is a complex but critical task that can be significantly enhanced by the development and use of appropriate software. This paper describes a software system that has been developed at Pacific Northwest Laboratory to aid in such planning. The basic needs for such a system are outlined, and the approach adopted in developing the software is described. The individual components of the system, and their integration into a unified system, are discussed. Typical analytical applications of this type of software are summarized. Conclusions concerning the development of such software systems and the necessary supporting data are then presented.

INTRODUCTION

Proper waste management is an important part of any environmental remediation activity, and is also critical to preventing unacceptable environmental degradation from ongoing operations. At Pacific Northwest Laboratory (PNL),[a] we have been involved in a variety of efforts to develop and implement improved mechanisms to support planning for future waste management needs. This paper discusses one of these areas.

At PNL, we have developed a software system to aid in the planning for future waste storage, treatment, transport, and disposal needs. This software system is conceptually based on modeling the logistics associated with the waste management operations. The system was designed to accommodate the analysis of a large, complex set of facilities handling numerous distinct types of waste. It also incorporates the necessary flexibility to permit easy redefinition to account for changes in the individual facilities or in the waste management system configuration, or to allow application to another, different set of facilities; these changes are made by modifying the data feeding the model, without the need for rewriting the software. In other words, the modeling system is generically applicable to a variety of different situations, requiring only facility-specific data to adapt it to a new situation.

This software system has several major characteristics:

(a) Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute under Contract DE-AC06-76RLO 1830.

- The system provides a unified user interface that simplifies the user's view of the system and facilitates setting up a model run.

- The system is composed of modular components with well-defined interfaces, allowing independent development and upgrading of the components, thus speeding up the development cycle and allowing the development of enhanced replacement modules without significant impact to other portions of the system.

- The system is part of a family of related software systems developed at PNL, promoting code reusability, simplifying software maintenance, and facilitating the development of new systems as needed to meet individual client's specific needs.

This paper provides background information on the analytical needs addressed by this software system, and outlines the approach adopted in developing the system. The key features of the various system components, and the integration of these components into a complete system, are then discussed. Typical analytical applications of the system are described. Conclusions reached as a result of our experiences in this area are then presented.

BACKGROUND

Planning to provide adequate and appropriate storage, treatment, transport and disposal capabilities for wastes to be generated or received in the future is a difficult but critical undertaking. These different waste management capabilities need to be provided in appropriate capacities and types, and on the right schedules, to match the amounts, characteristics, and timing of the wastes to be handled. For example, wastes containing flammable components are required to be stored under different conditions than are other types of hazardous wastes, and are required to be kept separate from various other wastes. Storage overcapacity for one type of waste (e.g., flammable wastes) will generally not substitute for under-capacity for wastes containing some other type of regulated constituent (such as acute toxins). There are a number of similarly exclusive requirements that severely limit options for storage of multiple waste types.

The consequences of poor planning can be substantial. Inadequate provision for waste management needs could result in a lack of approved capabilities which, in turn, could lead to curtailment of the operations generating the wastes. Such action could very possibly jeopardize the viability of a facility or operation. On the other hand, overplanning (either providing more capability or a higher-grade capability than necessary) would needlessly tie up otherwise productive resources, adding significantly to the costs of operation.

A logistics modeling system can be used to effectively project future requirements for these waste management capabilities. A generic representation of the waste management system to be modeled is shown in Figure 1. As shown

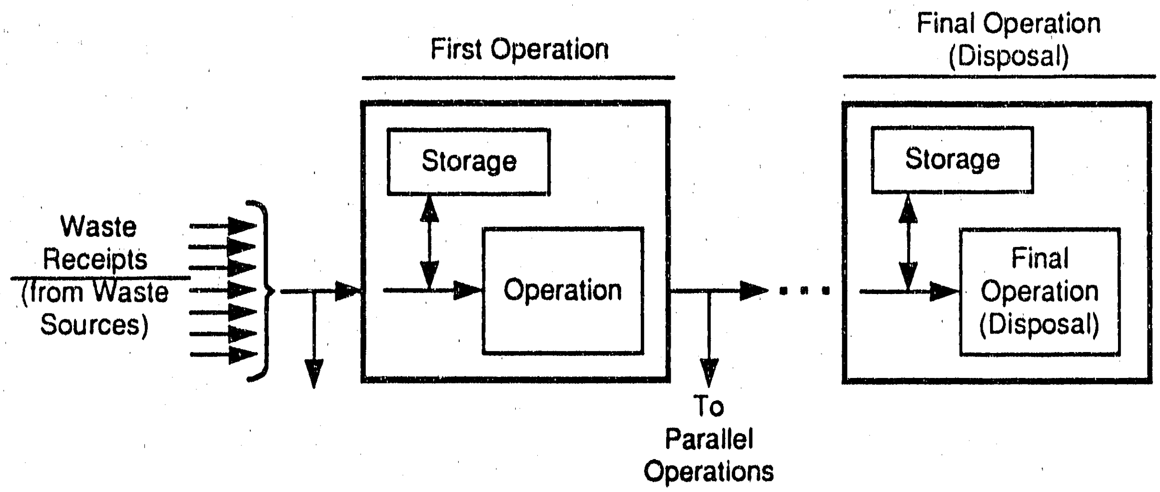

Figure 1. The Waste Management System Representation

in the figure, the system includes both waste sources and waste management operations. A waste management operation can be defined as either treatment, transport, or disposal (if at end of sequence of operations). Operations can be linked together into waste management schemes of any length (although it is advisable to limit the complexity to facilitate data development and analysis). Storage may be required for wastes awaiting any of these operations, and each operation is modeled as having dedicated storage capacity available as needed.

Waste flows are tracked through the system by amount (in our case, volumes). Volumes passing through each operation are corrected to account for changes that would result from the operation (e.g., compaction would considerably reduce the volume of a given waste stream). The output volumes from each operation are then redistributed to one or more subsequent operations, as appropriate based on the characteristics of the output material, until all wastes reach a final operation (i.e., some form of disposal).

Appropriate data to characterize the system are developed and fed to the model to determine the performance of the waste management system. The data include the annual volumes and characteristics of the wastes from each of the waste sources, and the characteristics and capacities of each of the waste management operations. A configuration is defined for the waste management system by specifying the operations involved and their linkages, and the model is run to obtain the resulting operational characteristics of this particular system. The configuration is modified as required to examine variations in the waste management system performance.

Several factors are of prime importance in developing reliable projections of future needs for waste management capabilities:

1. The requirements for handling and managing the different waste types (including the regulatory requirements and management policies as well as the physical requirements) must be clearly understood.

2. The bases used for the projections (i.e., the data and associated algorithms, and the configuration of the system) must realistically represent the actual situation to be encountered.

3. To provide the specific information needed for planning, the projections should be scoped at the appropriate level of detail; insufficient detail will provide results which do not clearly answer the questions involved, while too much detail can obscure the important information and make the performance of the analyses unwieldy.

APPROACH TO SOFTWARE DEVELOPMENT

The approach adopted in developing this software system contributed substantially to the success of the activity. The major elements of this approach are outlined in the following paragraphs.

From the outset, it was agreed with the client to develop the software system in stages, a step at a time. This allowed us to break the problem down into smaller parts and focus on these parts individually and sequentially, to help ensure that we were progressing in the right direction and to allow ample opportunities for course corrections along the way. A series of increasingly detailed prototypes were developed. At a very early stage, the core calculations in the model were mocked up in a spreadsheet prototype, to allow discussion and verification of the basic concept with the client. This was followed by the development of a more detailed prototype model, as a broader test of the concept. Finally, based on tests of this prototype, the complete Version 1 system was specified and developed.

A team was assembled specifically to develop the software system needed to meet the client's requirements. The project manager worked directly with the client, starting well prior to the actual code development, to develop a detailed understanding of the client's needs and to maintain close contact with the client. The project manager translated the client's needs to the software engineering manager and the data development manager, and then worked closely with them during the development process to oversee progress at critical points and to verify that the concepts were being appropriately implemented to meet the client's needs. The software engineering manager and the data development manager directed the day-to-day development efforts by the computer specialist, and were responsible for the detailed implementation.

A specification was developed to guide the development of the software system. The initial draft of the specification was developed at the time of the spreadsheet prototype, and underwent continual refinement and modification over the period of development. Although it would have been nice to have a totally firm specification before the software coding commenced, the research nature of this particular system made this impossible. Therefore, to supplement the specification, the development team held frequent reviews of the progress and also, through the project manager, maintained close interaction with the client. This helped to ensure constant attention to the needs of the system's ultimate user.

This system makes partial use of code from previous modeling efforts as a starting point for the development. This allowed the time required for the development cycle to be shortened somewhat, and also helped to minimize coding errors (because these reused code portions had been previously tested and debugged). In the longer term, by reusing portions of the code, we are reducing the costs to individual clients for their specific code development and maintenance requirements.

Object-oriented programming was chosen for use in developing this family of computer codes to exploit the recurring structures within modeling problems of this type. This approach allowed the model developers to define a limited set of objects (and their attributes and types of relationships) which could be extensively reused to model system's containing a large number of individual waste sources and operations.

THE SOFTWARE SYSTEM

The software system as developed consists of four major components, as shown in Figure 2. The key features of each component are discussed here. Also discussed is the integration of these components into a complete system.

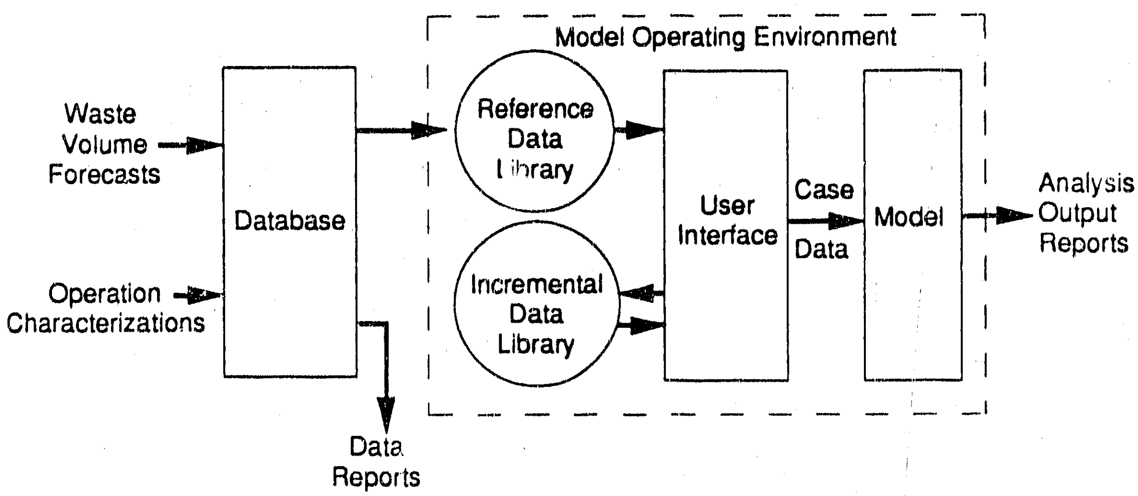

Figure 2. Logistics Modeling Software System

The Logistics Model

The logistics model is the basic calculational engine of the system. Data defining a waste management system to be evaluated are fed to the model, which then carries out the necessary calculations and writes the results to a standard results file.

Within the logistics model, two types of objects were defined: one representing the facilities generating the wastes (i.e., the waste sources), and the other representing the operations carried out in managing the wastes. Based on the number of waste sources and operations specified through the input data, the object-oriented logistics model dynamically creates and links the objects necessary to characterize the function and assess the performance of the waste management system.

The language used to construct the logistics model is an object-oriented interpreter written specifically by PNL for use as a rapid prototyping tool. Although the original application of this language was considerably different than the model described in this paper, an initial working prototype of this model was constructed in less than two weeks and the final version of the model was completed in about a man-month. This component required the shortest development time of all the components of the system.

The Report Writer

The report writer processes the standard results file to produce the specific reports needed by the analyst. A number of predefined reports are available for selection from a menu by the user. In addition, the user can specify additional formatting requirements for the reports.

The report writer runs separately from (in parallel with) the model and the user interface so that the analyst using the system can set up another case for analysis without waiting for the report writer to finish the output from the previous case.

The User Interface

As indicated previously, the software system is composed of four major components. However, from the user's perspective, the system appears to be much simpler. Except for initial data preparation, all user interactions with the modeling system (including the model and the report writer) are through the user interface. This simplifies the analyst's job by providing a consistent interface specifically tailored to his modeling needs.

The windows-oriented graphical user interface (GUI) performs all major functions required to prepare and execute analyses while maintaining system security. The user can develop a case from scratch or can start from a previously defined case. The user interface allows the user to select from all existing object definitions for inclusion in a particular case. Each selected object can be modified to create a new object, as needed to represent changes in the waste management system. The new object is stored as a child of the original parent object, thus allowing a large number of objects to be defined and stored with minimal impact on data storage and maintenance requirements. Upon completion of case specification, the user interface performs internal consistency checks and guides the analyst in resolving any inconsistencies. Once this is completed, the user may save the case and/or immediately execute it.

While a case is executing in the background, the user can monitor it's progress while specifying a new case or selecting reports to be provided.

A possible enhancement to the user interface, not included in the Version 1 system, is to provide the ability to examine results on the screen, in either tabular or graphical format. This would then provide the analyst with complete access to case definition, execution, and evaluation through the user interface.

The Data Base

The data base employs a relational structure specifically developed to store the data required by the model, as well as additional related data collected by the client as part of the same data gathering process. The data includes waste volume projections for the individual waste sources, and pertinent characteristics of the waste management operations (i.e., storage, treatment, transport, and disposal).

As indicated previously in Figure 2, the data base is translated into a Reference Data Library for input to the model. This is primarily a formatting operation, to reduce data handling overhead on the model and the user interface. (This intermediate step, the production of the Reference Data Library, may be eliminated during future upgrades of the software system.)

As part of the system development, a set of standardized data base reports was developed to assist in reviewing, verifying, and documenting the data incorporated into the system. These reports are especially useful during data updates, to ensure that the necessary changes are made without introducing errors.

In addition to supporting the operation of the model, the data base is also useful in performing some analyses without the need for a model run. Standard data analysis techniques can be employed to respond to a variety of questions about future waste management needs.

Integration of the System Components

In order to support the dynamic allocation of objects by the model, virtual memory capability was required. Although similar models had previously been developed on mini-computers, it was decided to develop this system on an 80386-processor-based desktop computer running under OS/2 with Presentation Manager. Presentation Manager provided a favorable environment for developing an appropriate user interface, and the use of OS/2 ensured compatibility with the client's existing MS-DOS applications.

Tests of model performance on the 80386-based machine and on a minicomputer later confirmed that the performance was significantly improved on the single-user desktop machine as configured. However, relatively large amounts of RAM are required to support the object-oriented nature of the model. During testing, it was found that swapping of the objects in and out of memory, when RAM was constrained, resulted in severe degradation of model performance.

TYPICAL APPLICATIONS OF THE SOFTWARE

There are several basic waste management or environmental remediation analyses to which this software system can be applied, as follows:

- projecting requirements for storage of various wastes,
- projecting operational capacity requirements and/or utilizations for waste treatment and transport operations, and
- projecting waste disposal volumes or requirements.

Derivative analyses, using the types of information described above, include the following:

- Trade-off analyses would be used to evaluate a variety of things such as the impacts of new technologies for waste treatment or disposal, or the impacts of availability of different levels of waste transport capability.
- Development of schedules for retrieval and treatment or transport of stored wastes will require iterative trials to balance schedules for handling the retrieved wastes with simultaneous requirements for newly generated wastes, to avoid unreasonable variations in requirements from year to year and to take into account such factors as logistical limitations, budgetary levels, etc.
- Development of waste management budget planning information will help to ensure that adequate resources are available for waste management operations when required. Sensitivities of the results to changes in key parameters or assumptions can also be examined.
- Comparing waste forecasts with actual volumes, or comparing forecasts from different years, can help to validate the usefulness of the forecast information and provide a mechanism to identify trends in the forecast information.

In addition to the above applications, which make use of the complete system, there are a variety of other questions that can be effectively addressed using only the data base portion of the system to query the system data.

CONCLUSIONS

Based on our experience, we have reached the following conclusions regarding the development of software systems to enhance planning capabilities for future waste storage, treatment, transport, and disposal needs.

- It is possible to develop flexible software systems that can facilitate a broad range of analytical needs related to waste management planning requirements.

- It is important to maintain good communications with the ultimate users of the results during the development phase of the software and the supporting data. This will help ensure that the development continues to target their specific needs.

- Although conceptually straightforward, projecting future waste management needs will often involve very large amounts of complex data and results, making implementation of the approach far from simple. Gathering, checking, and integrating the necessary data is time-consuming. Organizing the results to provide relevant insights is also challenging.

- Developing the software and the supporting data in stages, adding successive levels of detail at each stage, provides the opportunity to evaluate the system and make any necessary course corrections before proceeding with the next level of detail. The issues to be addressed at each stage will be much clearer, and the chances of success much better, than if the development is approached in one single step.

- Because applicable waste management requirements are still evolving, and because the waste management system itself is likely to continue to change, it is important to keep the software system flexible to allow changes as necessary to keep up with current conditions.

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