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Project Summary

A Requirements Study of an Automated Advisory System for Review of RCRA Permits

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Under the Resource Conservation and Recovery Act, hazardous waste management facilities must apply for operating permits. Review by the U.S. Environmental Protection Agency (EPA) of the present backlog of permit applications will cost approximately $40 million. The objectives of this project were to develop a conceptual design and implementation plan for an automated advisory system to make the review process more uniform and productive, and to aid in training new staff. The conceptual design of the advisory system is based on expert system technology. The system will be able to assist reviewers in making decisions that normally require expertise, in exercising analytical models and in generating correspondence and reports. A three-year implementation plan is proposed that incorporates field tests of prototype advisory system modules after 6 months time and deployment of partially completed advisory systems after the first year. Plans for advisory system maintenance, performance monitoring, and feedback from permit reviewers are recommended.

This Project Summary was developed by EPA's Hazardous Waste Engineering Research Laboratory, Cincinnati, OH, to announce key findings of the research project that is fully documented in a separate report of the same title (see Project Report ordering information at back).

Introduction

As a result of the Resource Conservation and Recovery Act (RCRA) of 1976, all hazardous waste management facilities must apply for operating permits. As of the end of 1985, the EPA Regional Offices and states will have an estimated backlog of more than 750 applications for operating permits. The review of each permit application is estimated to cost, on average, $52,000 in 1986 dollars, totaling approximately $40 million over the next 3 to 4 years.

Applications for operating permits under RCRA are reviewed by EPA Regional Offices and state agencies to ensure that they satisfy all regulatory requirements. Many of these requirements are stated in terms of general technical performance criteria. Both detailed calculations and expert judgement are often required from the permit reviewer to determine whether the application satisfies the criteria. Examples of calculations that must be performed include estimates of surface runoff to check for protection against overtopping of surface impoundments and slope stability analysis to ensure the safety of dikes. Expert judgement is required in such areas as evaluating the chemical compatibility of synthetic membrane liners and evaluating the protectiveness of a proposed facility site.

Currently, there is no uniform basis for the review of RCRA permit applications. Variability is inherent in the interpretation of information in permit applications and this variability can result in an application's being approved in one region and being denied in another. Additionally, the complex calculations involved and the necessity of obtaining outside expert consultation introduce significant delays in the permit application review process.

Measures to enhance the productivity and uniformity of the RCRA permit application review process are being sought by EPA. An automated advisory system based on expert system technology can accomplish this goal. Towards this end, the objectives of this project were:

- to develop a conceptual design for a computer-based automated advisory system to assist in the review of RCRA hazardous waste management facility permit applications;
- to determine and specify the resources required to develop, deploy, and maintain the automated advisory system; and
- to recommend an implementation plan.

Expert Systems

The proposed advisory system is to be based on expert system technology. Expert systems are computer programs that solve problems normally requiring the aid of an expert. An expert system consists of a knowledge base, an inference engine, and a user interface. The knowledge base contains information and experience possessed by the expert and additionally, the heuristics that the expert uses in solving problems. The inference engine consists of procedures that draw inferences from the information supplied by the user and from the information stored in the system's knowledge base. The user interface allows the user (e.g., the permit application reviewer) to communicate with the expert system.

The operation of an automated advisory system based on expert system technology is as follows: The reviewer enters general information and design details concerning one section of a permit application (e.g., dike design). The expert system attempts to draw inferences that confirm the acceptability or identify deficiencies in the design. The system may request additional specific information about the design and operation of the facility being reviewed. The conclusions of the expert system are presented to the user in the form of recommendations and suggestions.

Conceptual Design of the Advisory System

The functions performed by the permit application reviewers include: finding specific data and information in the permit application; interpreting information presented in the application; performing calculations and exercising analytical models; comparing data and information in permit applications with information found in regulations and guidance documents; and making decisions that range from the very simple to complex ones requiring expertise.

The conceptual design of the permit review advisory system is presented in block diagram form in Figure 1. The essential components of the system are the supervisory module/inference engine, the user interface, and the expert system library. These three major components of the advisory system form a single expert system and are the minimum set of components for a working system. The expert system library may be thought of initially as a single expert system knowledge base. It contains the facts, heuristics, and system messages associated with the review of one part of a permit application. The working memory associated with this knowledge base stores case-specific data entered by the user and the results of inferences made by the expert system. The supervisory module/inference engine performs all system control functions and inference making. The user interface provides for simple information exchanges between the system and the user.

The analytical model library is functionally the same as the expert system library. Each knowledge base in the analytical model library contains knowledge about how to exercise a particular model such as, for example, the EPA's HELP (Hydrologic Evaluation of Landfill Performance) model. Among other forms of assistance in using analytical tools, the system can assist the reviewer in assembling input data sets and interpreting output data.

The query/answer and explanation subsystems are components of the user interface. The query/answer subsystem allows the advisory system to request specific information that it needs and allows the user to respond by entering that information. The explanation subsystem allows the user to request explanations of the system's queries, inferences, and recommendations.

The report generator is a software printer interface that formats various reports based on the review of an application. For example, if a deficiency is found in the completeness check of an application, the system can generate correspondence to the applicant noting the deficiency and requesting the specific information needed for the review to continue.

The DBMS interface to an external data base is primarily for the storage of data generated in permit applications reviews for later analysis and for incorporation in a data base of waste management facilities.

The advisory system can be implemented in one of two configurations: a separate module configuration and an integrated system configuration. In the separate module configuration, the advisory system is a collection of individual expert systems each of which provides assistance to the reviewer in one specific part of the review process. There is no communication between the individual knowledge bases that make up the expert system library.

In the integrated version of the advisory system, the supervisory knowledge base contains the knowledge required to coordinate the entire permit application review and to provide to each expert system access to knowledge entered and inferred during previously executed expert systems. The knowledge bases that form the expert system library in the integrated system are called task knowledge bases. The supervisory expert system knowledge base also is referred to as the job knowledge base.

In the integrated advisory system, two expert systems are operating in a coordinated manner at the same time. The supervisory or job expert system controls the overall review of a specific permit application. It controls the sequencing of task expert systems in the detailed review of specific sections of the application. The job expert system provides communications between the individual task expert systems such that once specific information is entered by the reviewer, it is available for use by all task expert systems.

Implementation Plan

The recommended implementation plan schedule is shown in Figure 2. This schedule emphasizes the need to provide assistance to permit reviewers as soon as possible and to provide the assistance where it is most needed.

In the first year of the implementation phase, the basic modules of the advisory system are to be developed. These include the supervisory module and inference engine, the user interface, and four knowledge bases. The development software will incorporate basic control (supervisory) functions and an inference engine as well as user interface software modules. The specific

knowledge bases recommended to be developed first are: synthetic liner selection, waste analysis plan, the HELP model, and permit application completeness check.

It is recommended that EPA make the decision to deploy the separate module or the integrated configuration of the advisory system at the end of the first year of the implementation program. At the end of the first six months, prototype modules of the advisory system can be demonstrated in a Regional Office; specifically, the completeness check and waste analysis plan modules. Early demonstration and test of the advisory system by the end user, the permit application reviewer, will allow their recommendations to be incorporated into the system as early as possible. This early field test will facilitate the deployment of partially complete advisory systems in one or more Regional Offices by the end of the first year.

In the second year of the implementation phase, additional high priority task knowledge bases will be developed. Examples of appropriate knowledge bases include: cover systems, soil liners, and facility location information. Knowledge bases for assistance in exercising additional analytical models should be included. The final selection of specific knowledge bases to be developed should be made following input from EPA Headquarters and, especially, Regional Office staff. The development of all remaining knowledge bases is to be completed in the third year.

It is recommended that the advisory system be developed on symbolic processors using sophisticated software development tools and be delivered using microcomputers. This approach allows EPA to take advantage of the features of symbolic processors during the development phase. The use of microcomputers as the delivery vehicle avoids the necessity of having to purchase additional hardware in order to deploy the system. The cost of transferring the knowledge bases from the format appropriate for the development software to one appropriate for the delivery software will be small compared to the cost of knowledge base development.

Maintenance of the advisory system will be required for the following reasons: amendments to RCRA, user suggested changes and enhancements to the system, and system enhancements resulting from new knowledge coming from EPA research and development projects. It is recommended that EPA establish a capability for advisory system maintenance within a contractor organization. This capability should be established in the second year of the development phase and should be, at a minimum, one knowledge engineer with development hardware and soft-

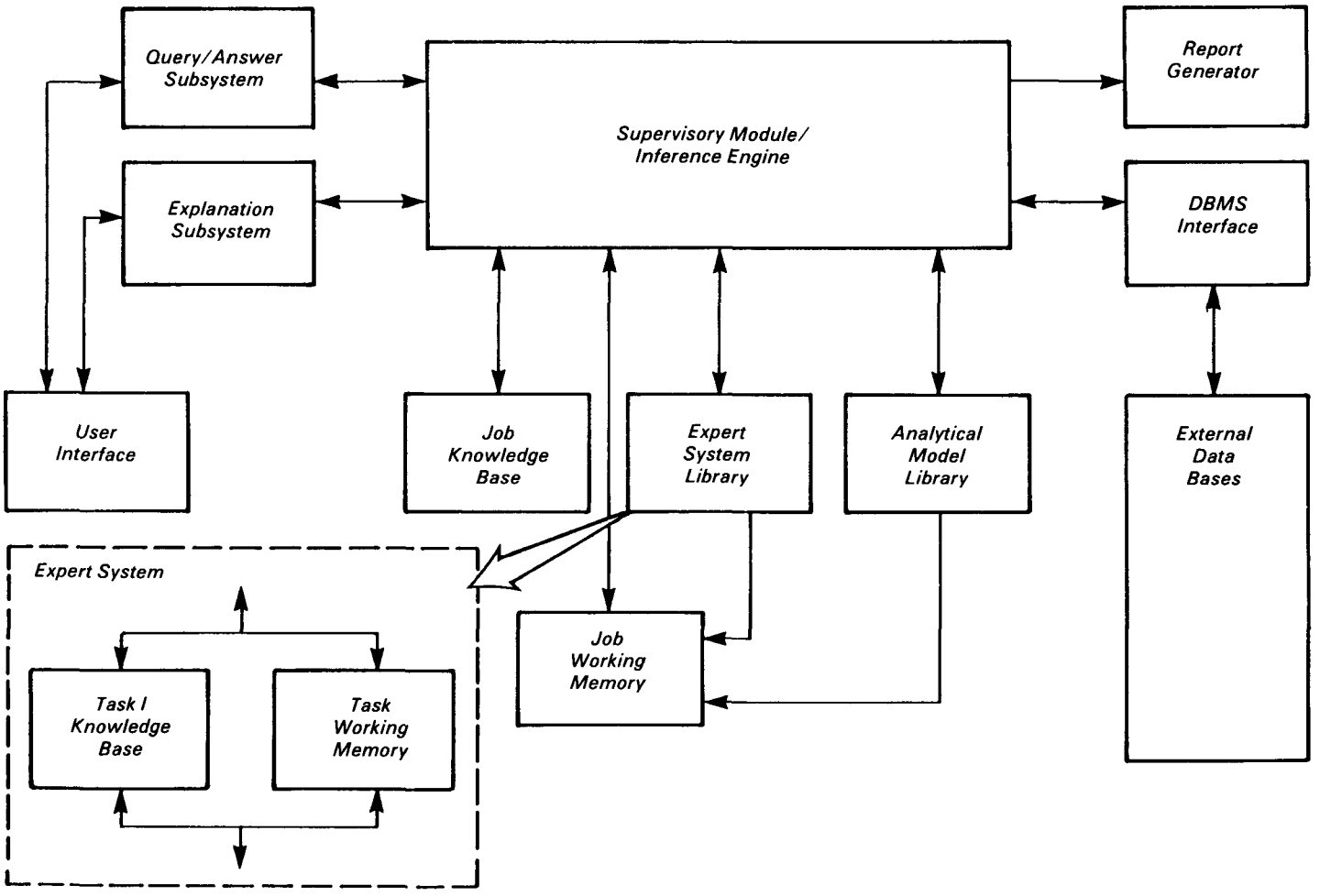

Figure 1. Automated advisory system.

ware; additional capability should be available on an as-needed basis.

It is estimated that the development of the four knowledge bases beginning in the first year of implementation will require 44 person-months. Development of the explanation module and report generator will require an additional 6 person-months as will modification of the supervisory/inference engine. Field tests and demonstration of prototype systems in Regional Offices will require 5 person-months; development of software to demonstrate and test the integrated advisory system configuration will require approximately 11 person-months. Cost estimates for years two and three are 8 to 12 person-years of effort each.

Recommendations

Based on the results of the project summarized herein, it is recommended that the EPA proceed with specific implementation plans and a program to develop the automated advisory system to assist in the review of RCRA permit applications as soon as possible. Specifically, it is recommended that the implementation incorporate the following:

- The integrated version of the advisory system should be evaluated in the first year of the implementation program and a decision on system configuration should be made at the beginning of the second year.
- Knowledge bases for assistance in reviewing waste analysis plans and synthetic membrane liner selection, in checking the completeness of applications, and in using the HELP model should be developed in the first year of the program.
- A program to obtain feedback on system utility and system enhancements from permit applications reviewers should be established early.
- Field tests of prototype expert systems in EPA Regional Offices should be initiated six months after development is started.
- Arrangements for system maintenance and system performance monitoring should be completed in the second year of the program.

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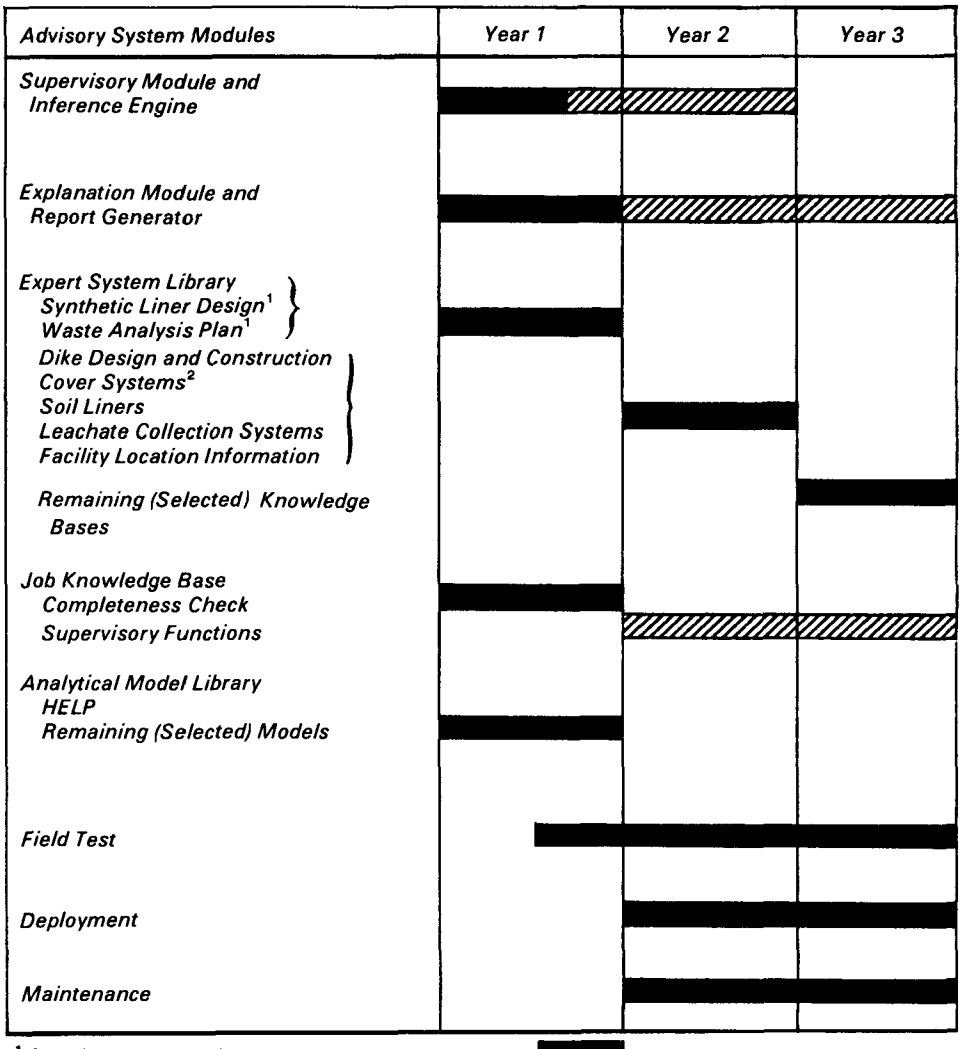

Figure 2. Tentative implementation schedule.