Decision Analysis System for Selection of Appropriate Decontamination Technologies

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TABLE OF CONTENTS

LIST OF TABLES.....	iv
ACRONYMS AND ABBREVIATIONS	v
NOMENCLATURE	v
EXECUTIVE SUMMARY	vi
1.0 INTRODUCTION	1
1.1 PURPOSE OF THIS INVESTIGATION	2
1.2 OVERVIEW OF DASD	3
1.2.1 Multimedia Information System for Decontamination.....	3
1.2.2 Decision Analysis System for Decontamination	4
1.2.3 Multi-Criteria Decision Analysis.....	4
1.2.4 DASD Graphical User Interfaces	5
2.0 PROJECT DESCRIPTION.....	6
3.0 ACCOMPLISHMENTS DURING FY97.....	7
4.0 PLANNED ACTIVITIES FOR FY98	11
5.0 CONCLUSIONS.....	12
6.0 REFERENCES	13
APPENDIX A. Literature Survey of Decision Models	
APPENDIX B. DASD Survey Questionnaire	
APPENDIX C. Data and Field Definitions	
APPENDIX D. DASD Graphical User Interface (GUI)	
APPENDIX E. Formulas Used for Calculating Costs	

LIST OF TABLES

Table 1. Status of Project Technical Plan 6

Table 2. Responses to DASD Survey 8

Table 3. Completion Schedule for Release of DASD..... 11

ACRONYMS AND ABBREVIATIONS

D&D	Decontamination and Decommissioning
DASD	Decision Analysis System for Decontamination
DOE	U.S. Department of Energy
DOE-EM	U.S. Department of Energy - Environmental Management
DOE-OST	U.S. Department of Energy - Office of Science and Technology
FEMP	Fernald Environmental Management Project
FERMCO	Fernald Environmental Restoration Management Corporation
FIU	Florida International University
FIU-HCET	Florida International University-Hemispheric Center for Environmental Technology
FY96	fiscal year 1996
FY97	fiscal year 1997
GUI	graphical user interface
HCET	Hemispheric Center for Environmental Technology
INEL	Idaho National Engineering Laboratory
IUOE	International Union of Operating Engineers
MISD	Management Information System for Decontamination
MODM	multi-objective decision making
ORNL	Oak Ridge National Laboratory
PC	personal computer
RAPIC	Remedial Action Program Information Center
SAT	screening of alternative technologies

NOMENCLATURE

ft	foot
ft ²	Square feet

EXECUTIVE SUMMARY

Background

The end of the Cold War and the decision to reduce the size of the United States' weapons production complex have created a need for the U.S. Department of Energy (DOE) to deactivate and decommission a large number of aging surplus facilities. Within the DOE Complex alone, there are some 7,000 buildings that require decontamination and decommissioning (D&D), and material disposition. These buildings present an abundance of challenges for D&D project managers who daily must decide on the safest, most effective and cost efficient means of achieving their remediation goals. In recent years, increasing demand for remediation technologies has fueled rapid growth in the D&D industry and attracted numerous enterprising developers and manufacturers of D&D technologies. The result is that D&D project managers are now faced with the task of selecting from amongst the many commercially available and innovative technologies, the most appropriate technology, or combination of technologies, that will address their specific D&D needs.

Current Means of Selecting Appropriate D&D Technologies

Until now, the technology selection process relied upon the D&D manager pouring over a number of factors, criteria, and data on available technologies then trying to identify the most appropriate solution. Each candidate technology had to be assessed, taking into consideration factors such as the type, scale, and geometry of surfaces to be decontaminated; production rates; primary and secondary waste management; airborne contamination; health and safety; personal protective equipment (PPE); technology effectiveness; and cost. In addition, the pros and cons of the various methods of decontamination (e.g., mechanical, chemical, or thermal) and classes of technologies (e.g., grinding, milling, or blasting) had to be weighed. Although basic data on technologies are available from simple computerized databases (such as spreadsheets), for the most part, the process of distilling all the information and identifying the top candidates remained essentially a manual operation. The selection process can be overwhelming, time consuming, and error prone. Often, managers resort to word-of-mouth referrals; however, due to the uniqueness and idiosyncrasies of each project, without a systematic approach to technology selection, the outcome could be less than desirable and very costly.

DASD—A New Generation of Computer-Assisted D&D Decision Support

At the Hemispheric Center for Environmental Technology at Florida International University (FIU-HCET), work is progressing toward the development of a revolutionary computerized Decision Analysis System for Decontamination (DASD). DASD is a powerful analytical tool that allows D&D project managers to define their site-specific decontamination needs and then searches a comprehensive database of proven D&D technologies to identify the most suitable solutions for a given project.

Key components of the DASD.

Advantages of Using DASD

DASD will radically reduce the time, effort, and uncertainty previously associated with selecting technologies for decontamination projects. Using DASD, D&D project managers will be able to do the following:

- enumerate the scope and scale of their decontamination projects, and identify constraints such as budget and waste handling capacity
- assess the specific needs of their decontamination projects
- tap into up-to-date, reliable information about cutting-edge D&D technologies that are either commercially available or in the process of being developed
- screen alternative technologies to identify leading candidates that are suitable for their projects
- systematically score and rank candidate technologies based on the criticality of project- and technology-specific factors, as well as constraints such as time and budget
- obtain a comprehensive evaluation report on selected technologies for final review and decision

The system is designed to be very user friendly, and context-sensitive help is readily available to guide the user through every step of the process. Users do not have to be computer experts to operate the system; however, familiarity with D&D project management terminology is necessary.

The D&D manager inputs basic site-specific information into DASD and receives detailed comparative information on the most site-appropriate technologies.

FIU-HCET—The Leading Repository of Reliable D&D Technology Information

The most critical feature of any decision analysis system is the comprehensiveness, accuracy, and reliability of the information it provides. Since its inception in 1995, FIU-HCET has amassed a wealth of objective and dependable comparative D&D technology evaluation data. In fact, FIU-HCET has performed some 35 demonstrations and assessments of innovative decontamination technologies and has participated in three large-scale technology demonstration projects at actual DOE nuclear production and research facilities. Working with the DOE and the International Union of Operating Engineers (IUOE), FIU-HCET is currently in the process of codifying technology assessment data for input into a resourceful Multimedia Information System for Decontamination (MISD), which forms the information platform of DASD. These accomplishments uniquely qualify FIU-HCET as the preeminent repository of scientifically sound decontamination technology performance data. Of particular relevance is the fact that FIU-HCET's data were collected under operating conditions that, within practical limitations, are realistic and simulate the conditions normally found at D&D project sites.

Release of DASD

The prototype release of DASD is scheduled for rollout and acceptance testing in early 1998. In this release, the task objectives will cover only the decontamination of concrete surfaces. Gradually, this will be expanded to include all basic building construction components such as

coating and concrete surface removal from floors, walls, and ceilings, and coating and rust removal from structural steel and pipes. This information base is expected to grow rapidly as more and more technologies are scientifically evaluated and as users of the system begin to pool their information and experiences with new and innovative technologies.

This report provides an overview of the tasks involved in the development of DASD and an account of the activities completed during fiscal year 1997 (FY97). It also provides a project completion schedule and describes the activities planned for fiscal year 1998 (FY98).

1.0 INTRODUCTION

Within the DOE's nuclear complex, there are approximately 7,000 radioactively contaminated buildings that require deactivation. Of these, some 1,200 buildings require decommissioning that will involve dismantlement, decontamination, and safe disposal of an estimated 550,000 metric tons of metal and 23 million cubic meters of concrete contained in the floors, walls, ceilings, and support structures of these buildings.

The principal objective of decommissioning is to permit unrestricted use of facilities or otherwise minimize risks to personnel and the environment. To this end, decommissioning plans affected by the DOE must take into account the following major concerns:

- minimizing health and safety risks to personnel and the environment
- minimizing contaminated waste volumes and airborne contamination
- maximizing the amount of recyclable materials salvaged from dismantled buildings
- remaining within budget and time constraints

These concerns pose formidable challenges for D&D project managers and are the driving force behind all decisions made when formulating D&D plans. At DOE remediation sites, the difficulty of decision-making is further compounded by the multiplicity of site- and project-specific factors (such as surface characteristics and geometry and contaminant types and levels) that must be considered. Undoubtedly, the single most critical decision that is affected by the above concerns and factors is the selection of the most appropriate D&D technologies for safely, effectively, and efficiently redressing the unique set of problems and objectives associated with each remediation project.

At present, the process for selecting D&D technologies for remediation projects is, for the most part, a manual exercise. Project managers must research, assess, compare, and evaluate copious volumes of technology performance literature and data to identify candidate technologies for their projects. In recent years, this research has been facilitated by the introduction of Preferred Alternative Matrices (PAMs). PAMs are the result of an initiative by the DOE's Office of Environmental Restoration (EM-40) to provide their field personnel with a tool for selecting "the right [D&D] technology, at the right time, at the right site."¹ However, the process remains essentially a manual one. It is time consuming and costly; it does not consider all pertinent criteria, ignores user assessment of differences in criteria importance, and is sometimes based on inconsistent, incomplete, or inaccurate evaluations of technologies. Furthermore, while current selection methods go a long way in aiding in technology research, they do not provide managers with realistic "*what-if*" scenarios of *what* to expect *if* a particular technology were applied to their specific project and site. Before making decisions, project managers must perform elaborate computations based on their respective site- and project-specific parameters to determine the appropriateness and feasibility of using each candidate technology. This information is needed to support decisions, must be compiled manually, and typically includes the following information:

¹ DOE-EM web site <http://www.em.doe.gov/define/pams.html>

- proven effectiveness of a technology to perform a task
- production rates
- cost of equipment
- cost of labor
- volume of primary and secondary waste generated and costs for disposal
- amount and cost of required PPE
- total cost for performing D&D work

Current means of technology selection do not systematically provide this crucial information that is necessary for making decisions.

This report describes the progress achieved at FIU-HCET in developing a microcomputer-based information and decision support system for assessing D&D project needs and identifying appropriate decontamination technology solutions. The DASD is being designed to provide project managers with reliable comparative information on proven D&D technologies that will address their specific needs. Project and site parameters are inputted into the system, which then searches a comprehensive database of proven DOE-certified technologies for solutions. DASD then provides a ranked listing of candidate technologies that are most likely to perform successfully on the given project, as well as detailed reports on expected results, performance, costs, concerns, and health, safety and regulatory issues, among other things.

From the outset, DASD has been developed with the needs of users in mind. To fully appreciate the needs of D&D practitioners and decision-makers, a detailed survey questionnaire was sent to D&D experts soliciting their opinions on factors and constraints that should be considered when selecting decontamination technologies. Their responses are summarized in Appendix B and, as far as possible, have been incorporated into the design of DASD.

Research and development of DASD is sponsored by the DOE's Office of Environmental Management (DOE-EM) under grant number DE-FG01-95EW55094. The project is described in FIU's Project Technical Plans numbers FIU7DD01 and FIU7DD02.

1.1 PURPOSE OF THIS INVESTIGATION

The principal objective for designing DASD is to support DOE-EM's endeavor to employ the most efficient and effective technologies for treating radiologically contaminated surfaces while minimizing personnel and environmental risks. DASD will provide a tool for environmental decision makers to improve the quality, consistency, and efficacy of their technology selection decisions. The system will facilitate methodical comparisons between innovative and baseline decontamination technologies and aid in identifying the most suitable technologies for performing surface decontamination at DOE environmental restoration sites.

1.2 OVERVIEW OF DASD

Figure 1 illustrates the main processes involved in the development of DASD. The system is being developed on a Windows 95 platform and is supported by an MISD.

Figure 1. Process Flowchart for Decision Analysis System.

1.2.1 Multimedia Information System for Decontamination

A decision support system is only as useful as the quality and comprehensiveness of the information that it contains and the confidence instilled in its users. Regulatory acceptance and routine use of technology assessments by decision makers in the D&D industry and across the DOE Complex will depend largely on the diversity, quality, objectivity, and reliability of the available information. FIU-HCET has performed some 35 demonstrations and assessments of innovative decontamination technologies alongside baseline commercial technologies to provide comparative performance data to DOE. In addition, FIU-HCET has participated in three large-

scale technology demonstration projects at actual DOE nuclear production and research facilities. FIU-HCET is, therefore, a reliable source of scientifically sound decontamination technology performance data that were collected under realistic operating conditions. The compilation and dissemination of these data to environmental restoration decision makers in an objective and easily accessible format is of clear importance and will facilitate technology selection as well as technology transfer to industries.

To facilitate the organization and handling of the large volume of performance data that have been collected, FIU-HCET is currently developing an MISD that will provide not only a convenient interface to data queries but also technology-specific photographic and video data that will serve to further illustrate the performance of a given technology. MISD will provide an info-base framework of specific, comparable performance data that can be easily accessed by the DASD.

1.2.2 Decision Analysis System for Decontamination

DASD is being designed to be the main analytical and computational tool for assessing D&D project parameters and recommending viable technology solutions. Upon entering DASD, users are prompted to input their remediation site objectives and decontamination project parameters (type, geometry, size, etc.). DASD uses this input to query the MISD database and retrieve all (five in the prototype) potential technology solutions. The user can create a new query or modify stored queries that were formulated for similar projects.

To assist users in narrowing their selection, a screening of alternative technologies (SAT) is performed first. This acts as a user-controlled filter to reduce the number of candidate technologies that are retained for further decision analysis. SAT displays a list of eligible technologies that are retrieved from the MISD database and that are capable of performing the specified decontamination tasks. It also lists operational constraints (costs, operations, functionality, and health/safety) that are associated with each candidate technology, as well as the criticality of each constraint rated on a scale from 1 (slightly desirable) to 10 (absolutely must be met by the technology). Figures D.4 and D.5 in Appendix D illustrate the results of this operation. Technologies that do not pass all critical (rated 10) constraints are eliminated. This allows the user to narrow their selection of eligible technologies even further before proceeding to more detailed evaluations. SAT provides a preliminary ranking of technologies for indicative purposes—not for final decisions. The true strength of DASD emerges at this point when users are normally faced with myriad project parameters, constraints, preferences, limitations, concerns, and technology specifications, and must somehow distill all of the information to arrive at the most appropriate technology solution.

1.2.3 Multi-Criteria Decision Analysis

Multi-criteria decision analysis (MCDA) is a tool that takes a user-defined multi-criteria problem set and applies it to all potential candidate solutions (in this case, the MISD database) to arrive at a numerical ranking of the most appropriate solutions. In the case of DASD, decision data associated with each technology are both qualitative and quantitative. Qualitative factors include health/safety/environmental hazards, technology operational descriptions/limitations, and technology performance characteristics (adaptability, maneuverability, media versatility, post-

treatment surface condition, and characteristics of secondary waste). Quantitative factors include the variable costs, production rate, and waste volume, all of which translate into costs. Cost factors include capital/rental cost for decontamination and support equipment; waste disposal cost; labor and training costs for operators, technicians, health physicists and industrial hygienists; and a host of operating expenses for consumables, major equipment transportation/(de)mobilization/maintenance, and PPE. All these costs are calculated by the system based on user input. Most of this information is available in the MISD database and is fed into the decision analysis module as needed. The user will be able to enter site-specific data such as equipment transportation cost from the vendor to the site and back. MISD also provides all qualitative and descriptive information needed for those comparisons. The user can simulate *what-if* scenarios by overriding any information inputted or the results. In addition, the user may add a new technology to the database by providing all pertinent information so that it may be considered along with other candidates.

The core of the system is a series of user-controlled procedures for evaluating the relative importance of each decision factor. The user rates each technology factor based on their individual project circumstances and preferences, and DASD computes a score to each. Various options allow the user to rate qualitative factors, including a method for direct or pairwise comparison of factors. The user is prompted to revise the most inconsistent judgments. A help dialog box provides definitions and explanations of each factor and suggests typical operating characteristics. The final output is a rank-ordered list of qualified technologies and their overall scores. A sensitivity analysis module built into DASD identifies the critical factors that may easily alter the highest-ranked technologies. This information is important to defend judgments and focus on sensitive areas before making a final decision.

1.2.4 DASD Graphical User Interfaces

Graphical user interfaces (GUIs) are simply computer screens that DASD uses to request data from users, as well as to feedback information to the users. Appendix D illustrates some of the GUIs that are used by DASD.

2.0 PROJECT DESCRIPTION

Table 1 summarizes the tasks that were identified for completion in FY97 in connection with the development of the computerized DASD. Also shown is the status of each task as of the end of the fiscal year on October 31, 1997.

Table 1.
Status of Project Technical Plan

Task	Status as of October 31, 1997
3.01. Literature Survey of Decision Models	Completed
3.02. Survey D&D Community for Input on Decision Factors and Selection Criteria	Completed
3.03. Review and Approve List of Decision Factors and Selection Criteria	Completed
3.04. Review Available Data for Applicability to Decision Models	Completed
3.05. Determine Decision Model	Completed
3.06. Update Multimedia Information System	In progress. Data for concrete surfaces entered and being used for DASD system prototype.
3.07. Systems Analysis	Completed
3.08. Design, Implement, and Integrate Software Structures	Ongoing
3.09. Perform Acceptance Testing	Not completed in FY97
3.10. Develop Decision Analysis Software Manual	Ongoing. Context-sensitive user help is being built into the system.
3.11. Distribute Decision Analysis Software	Not completed in FY97.

These subtasks were delineated in the FY97 Project Technical Plan (PTP) and were designed to plan and manage the work activities for the year ending October 31, 1997. The goals for FY97 were to develop, test, document, and distribute the decision analysis software program. These goals were not fully achieved during FY97, primarily due to the considerable time and effort required to define and understand the project parameters, and to develop and distribute the survey questionnaire. In addition, responses to the survey were not returned in a timely manner. Despite these delays, the final deliverable for the work completed during FY97 is a prototype system of the decision analysis software that will be distributed for acceptance testing early in 1998. System enhancements and distribution of the DASD software will be completed in FY98. Section 3 of this report provides details of the status of the above tasks.

3.0 ACCOMPLISHMENTS DURING FY97

Each of the tasks outlined in the FY97 PTPs "Decision Analysis Science Modeling for Application and Fielding Selection Applied to Concrete Decontamination Techniques" and "Decision Analysis Science Modeling for Application and Fielding Selection Applied to Metal Decontamination Techniques" are outlined in the following paragraphs. The tasks as found in the FY97 PTP are shown in italics. The results of these tasks follow the task statement.

3.01 Literature Survey of Decision Models

Task: A literature survey to gather information on decision models related to the project will be conducted. Florida International University resources, particularly, the library and faculty, DOE publications, the Internet, and national consultants are likely research sources. The goals of the task are twofold: formulate a set of potential decision models and, secondly, ascertain criteria for determining the most appropriate decision models. At the conclusion of this survey, a list of candidate decision models will be developed

Status: Completed. See Appendix A.

3.02 Survey D&D Community for Input on Decision Factors and Selection Criteria

Task: Members of the D&D community are currently making decisions regarding the application of decontamination technologies to specific sites. Decision factors and selection criteria will be identified by providing a standardized form to be completed by a group of D&D professionals. A table displaying the spectrum of decision factors and selection criteria, and their relative frequency distributions, will be formulated from the survey forms. This table will serve as a basis for determining the final list of decision factors and selection criteria.

Status: Survey questionnaires were sent to D&D professionals throughout the DOE Complex. Of the 22 questionnaires sent out, only 7 responses were received (Table 2). Appendix B is a sample of the questionnaire that was sent out. It also summarizes the responses that were received.

Table 2.
Responses to DASD Survey

Sites to which Questionnaires were sent	Responses received
Albuquerque Operations	Yes
Chicago Operations	Yes (Argonne National Lab)
Fernald Environmental Management Project	Yes
Idaho Operations	Yes
Nevada Operations	Yes (NV-ETD)
Oak Ridge Operations	No
Oakland Operations	No
Ohio Operations	Yes (Mound, Fernald)
Richland Operations	No
Rocky Flats Operations	Yes
Savannah River Operations	No

The responses indicate that the initial factors selected by the project team were valid and complete. Additional factors that were suggested by the D&D professionals include:

- As low as reasonably achievable (ALARA) considerations as a cost element
- Costs for regulatory approval
- Risk cost associated with using an innovative technology over a baseline system
- Cost for permits, authorization basis, procedures
- Disposal cost of decontamination equipment
- Subcontracting costs

These factors were not addressed in the prototype system. As part of the acceptance-testing task, these factors will be presented to the project evaluators for a decision as to whether they should be included in the system.

3.03 Review and Approve List of Decision Factors and Selection Criteria

Task: Using the results of Task 3.02, a list containing the most frequently named decision factors and selection criteria will be approved. The HCET D&D project manager and program manager, and the DOE focus area manager or his designee, will approve the list of decision factors and selection criteria.

Status: Completed.

3.04 Review Available Data for Applicability to Decision Models

Task: After determining the decision factors and selection criteria, these parameters will be integrated and mapped into the parameters native to the candidate decision models. The decision model that best fits the decision factors and selection criteria will be chosen by the HCET project manager.

Status: The three main modules are User/Project Identification (Table C.1), SAT Table (Table C.3) and the Decision Analysis Model (Table D.1). The data required by the DASD were obtained from multiple sources. These sources include MISD (Table C.4), system calculations (Table C.5) and the system user (Table C.3).

3.05 Select Decision Module

Task: Based on the results of Task 3.04, the selected decision model will be submitted to the HCET program manager and the DOE focus area manager or his designee for approval.

Status: Completed.

3.06 Update MISD

Task: The MISD will be updated to reflect additional data fields that result from the determination of the final decision model. Modifications to the MISD database schema will be performed by the project manager or his assistant, and subsequent population of the MISD database will be performed by data entry personnel at HCET.

Status: This task was partially completed during FY97. Data for concrete surfaces have been entered into the system and are being used for testing the prototype. Updating will be completed in FY98.

3.07 Systems Analysis

Task: A software requirements and requirements specification document will be developed as part of systems analysis. The input to the requirements specification document is the requirements document which provides an abstract description of the functionality of the final software application, the implementation platform, structure of the user interface, and system operations. Using graphical models, the requirements specification document serves to clarify ambiguities, inconsistencies, and incompleteness of the requirements document. Moreover, it describes all of the objects and operations present in the system. A formal graphical model, perhaps an E-R diagram, will be adopted to illustrate system objects while finite state machines, operational models, and life cycle models are mechanisms likely to be used to model system operations. This specification document will be reviewed by a computer science faculty member specializing in the field of software engineering.

Status: Completed by FIU-HCET project team members.

3.08 Design, Implement, and Integrate Software Structures

Task: The object-oriented analysis (OOA), object-oriented design (OOD), and object-oriented programming (OOP) paradigm will be used to design the software structures. The object models and interface models (OOA), created in the specification document, will be used to formulate object interaction graphs, class descriptions, and inheritance diagrams. These constructs serve as graphical descriptions of the modules and algorithms that will be written in the implementation language. Each module or class and algorithm will first be tested on paper, or logically, by the designer and, second, be tested during implementation by the programmer. As classes are put together, they will again be tested until the point that all of the classes appearing in the class description section of the design are manifested as implementation classes. Finally, the entire software application will be tested from its target user interface. Each system operation will be performed and tested methodically. Errors will be documented and submitted by the testers to the project manager for correction.

Status: Ongoing. Most modules and algorithms have already been incorporated into the completed prototype. All remaining work will be completed in FY98.

3.09 Acceptance Testing

Task: Acceptance testing is the process of submitting the final software application to the project initiators by the project manager and development team. A review will be conducted to ensure the software meets the stipulations software requirements document.

Status: Extensive testing is ongoing by testers at FIU-HCET. User testing will be conducted when the prototype is rolled out early in FY98.

3.10 Develop Decision Analysis Software Manual

Task: An online, user friendly software manual will be developed to illustrate the operation and functionality of the software and provide a help menu to facilitate the use of the software. In addition, the manual will address the type of decision models used.

Status: On-going. Context-sensitive help and guidance have been programmed directly into the software. The hardcopy manual will be completed in FY98.

3.11 Distribute Decision Analysis Software

Task: The decision analysis software application will be distributed to end users as determined by the program manager. A CD-ROM template may be developed for mass reproduction. The software may be implemented to execute as an applet, thereby enabling it to be distributed over the World Wide Web. If so, a Web site must be designed and implemented, and the applet must be integrated into the site. Appropriate server hardware and software must be purchased after a determination is made as to the relative frequency of use of the decision software.

Status: This task was not completed during FY97 and is planned for completion in FY98.

4.0 PLANNED ACTIVITIES FOR FY98

During the first quarter of FY98, the prototype of DASD will be distributed to select D&D professionals for testing of the system's comprehensibility, functionalities, and ease of use. Based on feedback from this test, the system will be refined, debugged, and prepared for beta distribution. Concurrently, the DASD users' manual will be compiled for distribution with the beta version. Work will continue on updating the decontamination database with data on media other than concrete. In addition, technology performance data from independent sources (other than FIU-HCET) will be investigated and, where appropriate, validated and entered into MISD. Table 3 summarizes the completion schedule for tasks to be undertaken during FY98.

Table 3.
Completion Schedule for Release of DASD

Task	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Replicate and distribute DASD prototype											
D&D Professionals review DASD Prototype											
Enhance functionalities of DASD online user help											
Distribute enhanced beta version of DASD to D&D prof's.											
Compile user manual for distribution with DASD beta version											
Complete entry of Technology Assessment Data into MISD											
Incorporate technology performance data from other sources											
Upgrade MISD development platform											
Develop seamless data interface between MISD & DASD											

APPENDIX A

LITERATURE SURVEY OF DECISION MODELS

LITERATURE SURVEY OF DECISION MODELS *

Selecting the most suitable decontamination method for a given problem requires the evaluation/comparison of a discrete number of alternative technologies under a multitude of data and conflicting criteria (costs and judgments on health/environmental hazards and verbal performance characteristics). This is what is known as a multicriteria decision analysis or multiattribute decision making (MADM) problem; this is a special case of multicriteria decision making (MCDM) problems that also include multi-objective optimization.

In 1957, Churchman and Ackoff & Arnoff were among the earlier academicians to look at the MADM problem formally using a simple additive weighting (scoring) method. Over the years, different behavioral scientists, operational researchers, and decision theorists have proposed a variety of methods describing how a decision maker (DM) might arrive at a preference judgment when choosing among multiple attribute alternatives. They can be classified as: Checklist, Descriptive, Rank Ordering, Weighted Scoring, Delphi, Pair Comparisons, Utility / Preference Theory (MAUT), Outranking (French School), Fuzzy Sets and Statistical Approaches, like regression for social judgments. For a survey of MCDM methods and applications see Stewart (1992) and Zanakis et al. (1995). The latter study was a survey—based on a literature search of 306 articles published in 93 journals—of MCDM applications in the service and government sectors. The most frequent MADM approaches were pairwise comparisons (including the Analytic Hierarchy Process, or AHP) and utility/preference theory models. However, utility/preference theory models are usually complex and, thus, unattractive to many practitioners. In fact, with input from Dr. Zanakis, a group of 20 engineers and managers participating in a Florida transportation planning project selected AHP as the preferred method over four others and used it to evaluate alternative highway locations/designs involving over 100 initial criteria. For a summary of AHP and its applications, see Zahedi (1986).

Gershon and Duckstein (1983) state that the major criticism of MADM methods is that different techniques yield different results when applied to the same problem, apparently under the same assumptions and by a single user. The inconsistency in such results occurs because:

- The techniques use weights differently in their calculations
- Algorithms differ in their approach to selecting the 'best' solution
- Many algorithms attempt to scale the objectives, which affects the weights already chosen
- Some algorithms introduce additional parameters that affect which solution will be chosen.

This is compounded by the inherent differences between DMs in experimental conditions and human information processing, even under similar preferences. Other researchers have argued the opposite; namely that, given a type of problem, the solutions obtained by different MADM methods are essentially the same (Belton, 1986; Karni et al., 1990; Goicoechea et al., 1992; and Olson et al., 1995). Practitioners seem to prefer simple and transparent methods, which are unlikely to represent weight trade-offs that users are willing to make (Hobbs et al., 1992).

Many MCDA methods have been developed over the years, but more information is needed about their relative merits on similar problems. Comparative studies are either simulation or field tests. In a recent study, Zanakis et al. (1997) compared eight MADM methods on 4,800

randomly generated test problems and concluded that alternative rankings vary across methods less in problems with few alternatives (like the decontamination problem). A literature search revealed that a limited amount of work has been done in comparing and integrating the different methods. Many authors stress the validity of the method as the key criterion for choosing it. Validity implies that the method is likely to yield choices that accurately reflect the values of the user (Hobbs et al., 1992). However, there is no absolute, objective standard of validity as preferences can be contradictory when articulated in different ways. Researchers often measure validity by checking how well a given method predicts the unaided decisions made independently of judgments used to fit the model (Schoemaker & Waid, 1982). Decision scientists question the applicability of this criterion, particularly in complex problems that will cause users to adopt less rational heuristics and to be inconsistent. Studies in decision making have shown that the efficiency of a decision made has an inverted U-shaped relationship with the amount of information provided (Kok, 1986; and Gemunden & Hauschildt, 1985). This is a real concern in decontamination technology assessments because of the vast amount and types of information considered.

Researchers who have attempted the task of comparing the different MADM methods have used either real-life cases or formulated a life-like problem and presented it to a selected group of (Gemunden & Hauschildt, 1985; Belton, 1986; Roy & Bouyssou, 1986; Buchanan & Daellenbach, 1987; Karni, Sanchez & Tummala, 1990; Stewart, 1992; Goicoechea et al., 1992; and Olson et al., 1995). Such field experiments are valuable tools for comparing MADM methods based on user reactions. If properly designed, they assess the impact of human information processing and judgmental decision making, beyond the nature of the methods employed. Users may compare these methods along different dimensions, such as perceived simplicity, trustworthiness, robustness, and quality.

Several authors, such as Ozernoy (1992), have outlined procedures for the selection of an appropriate MCDM method. These classifications are primarily driven by the input requirements of the method (type of information that the DM must provide and the form in which it must be provided). Very often, these classifications serve more as a tool for elimination rather than selection of the "right" method.

Our literature search through RAPIC and other library sources for multicriteria decision analysis (MCDA) applications in decontamination produced very limited results. The study by Roy and Bouyssou (1986) of nuclear power plant siting did not deal with decontamination issues. On a related topic, Henriksen (1997) applied and compared MAUT and AHP to evaluate chemical technologies for remediation of soil and groundwater contaminated with volatile organic compounds. An Information Decision Program for the clean-up of a weapons complex, U.S. Department of Energy (DOE) Office of Environmental Management, Office of Science and Technology (OST), is a management information system (MIS) for data handling without technology evaluations (Johnson et al., 1996). Preferred Alternative Matrices were developed by DOE Office of Environmental Restoration (1997), rating on a six-point scale different decontamination technologies (rows) by surface size and depth (columns). This is a good starting point for a practitioner. However, it is aggregate and static for specific problem scenarios; i.e., the user does not have details on criteria used and their importance, cannot change them according to his preferences, and cannot add new technologies or criteria. Similar benchmark

ratings of technologies for decommissioning were recently provided in a joint DOE-Environmental Protection Agency report (1997).

Determine Appropriate Decision Model

The literature survey and our experiences with MCDA suggest the following desirable characteristics for determining a suitable decision model:

- The model should be simple and transparent to attract user interest and understanding, yet able to handle complex evaluations.
- The model should be able to handle qualitative and quantitative information, and their trade-offs.
- Display of measurement scales should be verbal for novices and numerical for experienced users. The former also facilitate consensus among users.
- The vast amount of information required in a decontamination task necessitates procedures for avoiding user information overload (Carmone, Kara & Zanakis. 1997) either in comparing criteria or rating alternatives. Since this is affected more by the number of criteria, we took special care in the prototype to identify and operationalize only essential criteria. The user, however, should try to keep less than five alternatives for detailed evaluation. Reducing the number of alternatives is also important, since the final results are usually affected more by differences in alternative than criteria weights.
- Screening procedures must be employed, using constraints and desirable features, to eliminate clearly inferior alternative technologies if there are more than four candidates.
- Use *two* multiattribute techniques: First a robust/simple model to get results quickly and build user confidence and understanding of the system by gaining deeper insights into the problem. Second, for more experienced users, a more detailed decision model applied either directly or after the simple model to fine-tune these results.
- The final model must be able to flag irrational judgments and guide the user to revise them to his/her satisfaction. The user must have the power to override any model results.
- Graphical display of results will enhance user perceptions
- Sensitivity analysis of the results should easily identify the crucial criteria that are likely to change the top ranked technology.

The above considerations led us to the following decision model selections:

- Screening of Alternative Technologies (SAT) will be applied first. This will be a simple checklist to eliminate clearly inferior technologies that do not satisfy basic constraints. Then, a simple additive weight scoring will allow the user to screen them further, based on the extent he believes that they satisfy basic requirements.
- Those technologies that pass the SAT will be evaluated according to groups of criteria using a simple additive weight (SAW) scoring model. The user will assign criteria weights and weigh each alternative against each criterion. This decision model is usually adequate when

comparing three to four elements simultaneously. This model will be used by a less experienced user to get problem insight and reasonable results quickly. It may also be used by a more advanced user, to reduce the computational effort involved in the next modeling process.

- A pairwise comparison decision model based on the AHP will next be used, possessing the characteristics outlined earlier. For each pair comparison on a ratio scale (numerical or verbal), the user will be asked: "How many times is A more important (better) than B?" This will be repeated to compare all pairs of criteria at a certain level of the hierarchy, as well as for each pair of alternatives under one criterion at a time. This can be time consuming for larger problems.
- AHP model refinements to expedite the procedure will include a mixed model SAW-AHP model and incomplete pair-comparison algorithms that have been found to produce statistically equivalent results with half the effort of complete AHP (Carmone, Kara & Zanakis, 1997).

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APPENDIX B

DASD SURVEY QUESTIONNAIRE

DASD SURVEY QUESTIONNAIRE

The following is a reproduction of the survey questionnaire that was sent to D&D professionals soliciting their views on the decision factors and selection criteria to be incorporated into DASD.

DATA CATEGORIES REVIEW

The purpose of the Data Categories Table is to provide a definition for each data category and to determine the importance of each. The *site-specific constraints* data category has been omitted because constraints do not need to be rated. Reviewers were asked to assess the data categories and, based on the importance scale provided, rate the general importance of each.

Table B.1. Data Categories Table <i>(Text in italics are results of the survey of D&D professionals.)</i>		Importance Scale 1 not important 2 slightly important 3 moderately important 4 very important 5 absolutely important
Data Category	Definition	Rating
Cost Data	Cost is a data category, which represents the data necessary to reveal which technology is more or less costly than another for the same application in the same project. Please see the cost elements table in Section I for a detailed specification of the cost data.	1 2 3 4 5 <i>Mean: 4.7</i>
Technology Performance	Technology Performance is a data category, which represents the data describing a decontamination technology's capability to perform decontamination. In simple terms these data elements should answer the questions: What can it do? What are its limitations? The data elements are: adaptability to different surface profiles, characteristics of secondary waste, equipment maneuverability, media versatility, production rate, and removal capacity.	1 2 3 4 5 <i>Mean: 4.0</i>
Technology Design	The data in the technology design category describes a decontamination technology's design efficiency. In simple terms, these data elements should answer the question: How does it work? The data elements are: operating details, operational and maintenance requirements, operational limitations, and environmental conditions.	1 2 3 4 5 <i>Mean: 3.5</i>

SECTION I: COST DATA

During the process of selecting a decontamination technology for a project from a group of viable alternatives, a decision-maker analyzes the cost data available for these alternatives to determine which is most cost effective for a given site. All cost elements may not have the same importance with regard to minimizing total project costs because of possible tradeoffs between cost elements due to budgetary, policy, or site-specific reasons. The purpose of this section is to a) present and define the cost elements; b) allow you to rate each cost element; c) allow you to make changes to the cost elements and d) allow you to add new cost elements. The cost items used to determine each cost element are listed in the *Cost Item* column. The parameters used by

the decision analysis model to compute the cost items are listed in the *Parameters* column. Reviewers were requested to examine the cost elements in the table below and, using the importance scale provided, indicate the relative importance of minimizing each. Reviewers were also encouraged, where appropriate, to modify the given cost elements, or to add new ones.

Table B.2. Cost Elements <i>(Text in italics are results of the survey of D&D professionals)</i>			Importance Scale 1 not important 2 slightly important 3 moderately important 4 very important 5 absolutely important
Cost Element	Cost Item	Parameters	Rating
Health and Safety Costs	Industrial hygienist support	Total number of hygienists man hours required Labor rate	1 2 3 4 5 <i>Mean: 3.6</i>
	Health physics support	Total number of health physicists man hours required Labor rate	
	Total PPE (personal protective equipment)	For each type of PPE item: Number of items required Cost per item	
Transportation Costs	(i) Transporting* of capital equipment to vendor from site	Vendor Location Equipment portability User provided cost estimate	1 2 3 4 5 <i>Mean: 2.6</i>
	(ii) Transporting* of capital equipment to site from vendor *Transportation costs are generated by providing the decision-maker with vendor location and equipment transportation information	Vendor Location Equipment portability User provided cost estimate	

Capital Equipment Costs	Case 1: Purchase	Capital equipment cost prorated based on hours to be used	1 2 3 4 5 <i>Mean: 3.9</i>
	Case 2: Rental	Capital equipment rental cost	
Waste Disposal Costs	Waste disposal	Total Volume of waste in ft ³ per ft ² of decontaminated surface Waste disposal cost per ft ³ of waste	1 2 3 4 5 <i>Mean: 4.7</i>
Training Costs	Case 1: Site personnel to operate equipment	Equipment technology training cost per person Amount of equipment operators needed	1 2 3 4 5 <i>Mean: 2.7</i>
	Case 2: Service provider to operate equipment	Site specific health physics and safety training cost per person Amount of equipment operators needed	
Operating Costs	Total consumables cost per ft ² of decontaminated surface	For each consumable item: Consumable item unit cost Consumable item consumption rate per ft ²	1 2 3 4 5 <i>Mean: 3.7</i>
	Total replacement parts cost per ft ² of decontaminated surface	For each replacement part : ▪ Part cost ▪ Life of the part in ft ²	
	Total utility costs per ft ² of decontaminated surface	For each utility: Utility cost per unit Utility consumption rate per ft ² of decontaminated surface	
Labor Costs	Total labor cost for: operating decontamination capital equipment; capital equipment staging; unloading capital equipment from carrier; capital equipment cleaning and decontamination; loading capital equipment onto carrier. Staging refers to the transport and setup of the capital equipment in the target area after unloading.	For each labor classification: Total man hours Labor rate	1 2 3 4 5 <i>Mean: 4.0</i>

Support Equipment/Tools Cost	Case 1- Rental. Total cost of: support equipment/tools needed for decontamination; capital equipment staging and destaging; loading and unloading capital equipment to and from carrier; capital equipment cleaning and decontamination.	For each piece of support equipment: Support equipment use in hours Support equipment rental rate	1 2 3 4 5 Mean: 3.3
	Case 2- Purchase. Total cost of: support equipment/tools needed for decontamination, capital equipment staging and destaging, loading and unloading capital equipment to and from carrier, capital equipment cleaning and decontamination.	For each piece of support equipment: Support equipment purchase cost prorated based on hours to be used	
Please insert and rate any additional cost elements that you feel should be included in the Decision Analysis Model			
Compliance costs	Necessary permits to operate equipment	RCRA, NRA, CAA, etc.	Mean: 3
Secondary waste disposal cost	Cost to treat or dispose of secondary waste generated	Total volume of secondary waste generated per ft ² of surface cleaned.	Mean: 5
Life Cycle Cost	Includes development, implementation, operation, secondary waste cost		Mean: 4
Implementation	Procedures, authorization basis, etc.		Mean: 4
Health and Safety	Layers of PPE	Are multiple layers required? How does this affect production?	Mean: 3
Capital Costs	Rental	Cost per unit processed	Mean: 5
Proposed Cost	Total contract cost for all work		Mean: 5
Disposal Cost of Equipment	Cost associated with disposal of equipment	Decontamination costs Disposal costs	Mean: 4

SECTION II. TECHNOLOGY PERFORMANCE

During the process of selecting a decontamination technology for a project from a group of viable technology alternatives, an environmental restoration decision-maker evaluates the

decontamination performance of these technologies. Data elements for the technology performance category are presented in the table below along with a definition and importance-rating column. The purpose of this table is to provide a definition for each data element and to determine the importance of each element. Reviewers were requested to examine the definition of each data element and, using the importance scale provided, indicate in the rating column the relative importance of the data to making technology performance comparisons during the technology selection process. Users were also asked to suggest and rate additional technology performance data elements that they felt should be included.

Table B.3. Technology Performance Data Elements <i>(Text in italics are results of the survey of D&D professionals)</i>		Importance Scale 1 not important 2 slightly important 3 moderately important 4 very important 5 absolutely important
Data Element	Definition	Rating
Adaptability to Different Surfaces	Information describing the equipment's ability to perform decontamination of different types of surfaces, surface conditions, and surface profiles.	1 2 3 4 5 <i>Mean: 4.0</i>
Characteristics of Secondary Waste	A description of the physical, chemical, and radioactive condition of the waste generated by the operation of the decontamination technology.	1 2 3 4 5 <i>Mean: 4.3</i>
Equipment Maneuverability	Information describing the maneuverability of decontamination equipment during the decontamination process, including ability to decontaminate corners and edges, directions of equipment travel, and ability to operate on walls, ceilings, and confined spaces.	1 2 3 4 5 <i>Mean: 4.0</i>
Media Versatility	Information describing whether the decontamination technology can utilize various grades of decontamination media and if the media is recyclable.	1 2 3 4 5 <i>Mean: 3.3</i>
Post-Decontamination Surface Condition	A brief description of the surface revealed by the decontamination technology with respect to consistency, texture, slope, etc. (Example: leaves a smooth, even surface.)	1 2 3 4 5 <i>Mean: 2.6</i>
Production Rate (ft ² /h)	The surface area successfully decontaminated by a given technology with respect to time.	1 2 3 4 5 <i>Mean: 4.3</i>
Removal Capability	The depth of surface media that can be removed by a given decontamination technology. In the case of concrete, for example, removal capabilities are described in increasing increments as follows: coating, ¼ inch, ½ inch, 1 inch, and crack.	1 2 3 4 5 <i>Mean: 3.9</i>
<i>Please insert and rate any additional technology performance data categories that you feel should be included in the Decision Analysis Model.</i>		
	<i>[No additional data elements suggested]</i>	1 2 3 4 5 <i>Mean:</i>

SECTION III. TECHNOLOGY DESIGN

During the process of selecting a decontamination technology for a project from a group of viable technology alternatives, an environmental restoration decision-maker evaluates the design of these decontamination technologies. Technology design data elements are presented in the table below along with a definition and importance-rating column. The purpose of this table is to provide a definition for each data element and to determine the importance of each element. For each data element, please examine the definition and indicate in the rating column how important you feel this type of data is for making comparisons of decontamination technologies during the decontamination technology selection process. More than one data element can be assigned the same importance rating. Use the importance scale to quantify your judgments. Please include additional Technology Design data elements at the bottom of the table with their corresponding importance rating.

Table B.4. Technology Design Data Elements <i>(Text in italics are results of the survey of D&D professionals)</i>		Importance Scale: 1 not important 2 slightly important 3 moderately important 4 very important 5 absolutely important
Data Element	Definition	Rating
Environmental Conditions	A description of the environment created by the operation of the decontamination technology including, but not limited to, dust generation, scattering of particles and media, fumes, visibility, noise, and temperature.	1 2 3 4 5 <i>Mean: 4.3</i>
Equipment Portability	The number of persons and/or equipment required to transport the equipment during staging. Staging refers to the transport and setup of the capital equipment in the target area after unloading.	1 2 3 4 5 <i>Mean: 3.6</i>
Operating Details	A technical description of how a given technology removes the contaminant from its host. Parameters include: secondary waste system, type of decontamination media, open vs. closed loop system, and descriptions of unique equipment components used or required.	1 2 3 4 5 <i>Mean: 3.7</i>
Operational Limitations	Parameters that limit the operation of a technology as observed during demonstration at HCET and/or as described in vendor provided literature.	1 2 3 4 5 <i>Mean: 4.0</i>
Operational and Maintenance Requirements	The operational and maintenance requirements provide an account of the types of operational and maintenance activities performed during the hours of operation of the equipment.	1 2 3 4 5 <i>Mean: 3.7</i>
Please insert and rate any additional technology design data elements that you feel should be included in the Decision Analysis Model.		

<i>Expected lifetime or replacement information</i>	<i>Amount of decontamination work that can be done before replacing the equipment.</i>	<i>Mean: 3</i>
<i>Simplicity</i>	<i>Operations, maintenance, ergonomics as applied to a radiological environment.</i>	<i>Mean: 4</i>
<i>Engineered safety</i>	<i>Criticality prevention, engineered featured (guards, kill switches) alarms radiological safety</i>	<i>Mean: 4</i>
<i>Durability</i>	<i>Length of use between repair, re-charge, refill, etc.</i>	<i>Mean: 3</i>

SECTION IV. SITE-SPECIFIC CONSTRAINTS

In order to effectively apply the decision analysis model, a screening process will narrow the pool of technology alternatives. Existing project-specific and site-specific constraints can nullify the viability of a given technology alternative. The purpose of this section is to gather a list of general site-specific constraints that can be used to exclude a technology from consideration for a given decontamination project. These constraints are presented in the table below as questions to which you can answer with one of three choices: always, sometimes, or never. Please examine each constraint question and check the correct answer in the applicability column. At the end of this table, you will find additional rows for inserting constraints. Please include additional constraint statements that can be used to screen technology alternatives from consideration in a decision scenario. If necessary, additional constraints can also be noted on a separate sheet and submitted with this survey.

Table B.5.
Site-Specific Constraints Table

(Arrow heads indicate the trend in the responses of D&D professionals to the survey questionnaire)

Applicability			Constraint Questions
<i>Always</i>	<i>Sometimes</i>	<i>Never</i>	<i>Please indicate frequency by placing a checkmark in the appropriate column.</i>
Cost Constraints			
◀			How often is the capital equipment cost a limiting constraint during the process of selecting a decontamination technology?
▶			How often is the operating cost a limiting constraint during the process of selecting a decontamination technology?
	◀		How often is the labor cost a limiting constraint during the process of selecting a decontamination technology?
	⬇		How often is the support equipment cost a limiting constraint during the process of selecting a decontamination technology?

**Table B.5.
Site-Specific Constraints Table**

(Arrow heads indicate the trend in the responses of D&D professionals to the survey questionnaire)

Applicability			Constraint Questions
<i>Always</i>	<i>Some-times</i>	<i>Never</i>	<i>Please indicate frequency by placing a checkmark in the appropriate column.</i>
	◆		How often is the health and safety cost a limiting constraint during the process of selecting a decontamination technology?
Operational Constraints			
	◆		How often is the decontamination method used by a decontamination technology a limiting constraint during the process of selecting a decontamination technology? (Examples of decontamination methods include: mechanical, thermal, and chemical surface removal methods.)
	◀		How often is the decontamination technology's ability to achieve a minimum production rate a limiting constraint during the process of selecting a decontamination technology?
	◆		How often are the decontamination technology's operating personnel requirements a limiting constraint during the process of selecting a decontamination technology?
	▶		How often are the decontamination technology's utility requirements a limiting constraint during the process of selecting a decontamination technology?
	▶		How often is the volume of waste generated by a decontamination technology a limiting constraint during the process of selecting a decontamination technology?
	◆		How often is the removal media type used by a decontamination technology a limiting constraint during the process of selecting a decontamination technology?
Health and Safety Constraints			
	◆		How often is the use of respiratory protection by an operator of a decontamination technology a limiting constraint during the process of selecting a decontamination technology?
	◆		How often is the use of a chemically resistant suit by an operator of a decontamination technology a limiting constraint during the process of selecting a decontamination technology?
Other Constraints			
	◀		How often are the equipment portability requirements a limiting constraint during the process of selecting a decontamination technology?
	◀		How often is the equipment availability time a limiting constraint during the process of selecting a decontamination technology?
Please list additional constraints and applicability below.			
•			Cost of total project (sub-contracting)

SECTION V. GENERAL QUESTIONS

1) During the process of selecting a decontamination technology from a group of viable technology alternatives, what technology-specific information is required to determine the amount of health physics personnel needed for a given project? (Responses are shown below in italics.)

- *This is dictated more by application environment than by technology.*
- *Does the technology add to the existing radiation dosage?*
- *Does the technology mobilize radiation contamination?*
- *How quickly does the technology remove radiation contamination?*
- *Materials used.*
- *Dispersion of contaminants.*
- *Secondary waste generated.*
- *Types and amounts of contamination present; radiological half-life.*
- *Amount of airborne contamination generated.*
- *Size of area affected.*
- *Type/number of equipment surveys to be performed.*
- *Application, productivity rate, waste streams generated, operating environment, labor requirements.*
- *Need to expand on characterization of problem.*

2) During the process of selecting a decontamination technology from a group of viable decontamination technology alternatives, what technology-specific information² is required to determine the amount of industrial hygienist personnel needed for a given project? (Responses are shown below in italics.)

- *This is dictated more by application environment than by technology, but decontamination media must also be considered.*
- *What types of waste are generated?*
- *Are there any technology-specific chemical/physical hazards?*
- *Types and amounts of secondary waste generated.*
- *Dispersion of contaminants.*
- *Materials used.*

² Technology-specific information is that information which pertains to the decontamination technology itself, NOT information pertaining to the decontamination site (i.e., site-specific information).

- *Types, forms and amounts of hazardous chemicals used (if any). MSDSs.*
- *Application, productivity rate, waste streams generated, operating environment, labor requirements.*

SECTION VI. USER PROFILE

Name:	Mr. Ms. Dr. Other _____	
Title:		
DOE Site:		
Organization Name:		
Mailing Address:		
Phone Number:	()	
Fax Number:	()	
E-mail Address:		
Web Site Address:	http://	
Decontamination & Decommissioning experience	Position / Title	Years of Experience
Education (Circle highest achieved)	Associates Bachelors Masters Ph.D. What field? _____	
Internet Connection Circle the type(s) of connection you have access to at work.	28.8k Modem 56k Modem ISDN T1 T3 Other _____	
Operating System Circle the type(s) of operating system available at your organization.	DOS Win 3.1 Win NT 3.5 Win 95 OS Win 3.11 Win NT 4.0 UNIX IBM-OS/2 Other: _____	
Prototype Distribution	Would you like to receive an evaluation version of the <i>Decision Analysis System</i> computer software application that will be developed based on this survey and other sources? (circle one)	Yes No

Table B.6.
Decontamination Technology Usage
(Text in italics are results of the survey of D&D professionals)

Please list the decontamination technology selections you have made within the last 5 years.

Technology Name	Site	Reason Selected
<i>None</i>		
<i>None</i>		
<i>None for field use. For lab use: Bio-decon of concrete; Liquid nitrogen ultra high pressure system; Laser Decon and LN₂ laser assisted system.</i>		
<i>CO₂ Decon</i>	<i>Rocky Flats B883</i>	<i>Effective on depleted uranium contamination; minimal secondary waste.</i>
<i>Scabblers</i>	<i>Tested at various locations</i>	<i>Effective at removing surface contamination from semi-porous surfaces (eg. Concrete)</i>
<i>Strippable coating paints</i>	<i>Rocky Flats Buildings 371 and 707</i>	<i>Effective method for gloveboxes; low spread of contaminants.</i>

APPENDIX C

DATA AND FIELD DEFINITIONS

DATA AND FIELD DEFINITIONS

Table C.1.
User/Project Identification

Field Name	Description (Optional)	Data Type
Data Inputted by User		
Area to be Decontaminated (DA)	The size of the area to be decontaminated (in square feet).	String
Contaminants of Concern	Defines the specific contaminants being decontaminated.	String
Health and Safety Costs (HSC)	A general dollar figure for providing H&S costs on a per hour basis. This includes Industrial Hygiene and Health Physics support.	Monetary/hour
Labor Cost for a Technician (LCT)	The labor rate for one technician, which includes fringe benefits.	Monetary/hour
Labor Cost for an Equipment Operator (LCE)	The labor rate for one equipment operator, which includes fringe benefits.	Monetary/hour
Project Acronym	Specific name of project at the DOE site.	String
Site Name	Broad classification of DOE site. Select from pick list.	String
Site-Specific Waste Disposal Cost (WDC)	Cost in dollars per cubic feet. This includes container cost, waste certification cost, and transportation cost.	Monetary
User Initials	Initials of user. Three digits are available. For first letter of first name, middle name and last name.	String
User Name	Name of person performing analysis.	String
User Phone	Area code and seven digit phone number.	String
User Title	Title of the user	String
Years in D&D industry	Determine experience of user.	Integer
User/Project Identifier Generated by DASD		
Project Identifier	<p>Unique number to index project information VVVVVV-XXXX-YYY-ZZ</p> <p>Where:</p> <p>VVVVVV- Project code based on the problem definition identifier</p> <p>XXXX- Standard site identifier</p> <p>XXXX- Project acronym</p> <p>YYY- User initials</p> <p>ZZ- Integer that identifies each project</p> <p>The system will define the project identifier based on the input from the problem definition information, site name, project acronym, user initials, and an increment to save previous versions of similar projects.</p>	String

Table C.2.
Sources of Data for SAT Tables

Field Name	Description	Data Type
Definition of Data Imported from MISD		
Services Available	Which method will be used to obtain the technology?	String
Basic System Capital Cost	If the capital equipment will be purchased, what is the maximum allowable price?	Monetary
Utility Requirements	Do you have a limitation on the type of utilities which can be used in the facility? If yes, please delete the technologies that do not meet your criteria.	Memo
Scarification Media Type Used	Do you have a limitation on the type of media used by the system? If yes, please delete the technologies that do not meet your criteria.	Memo
Equipment Portability	Is the portability of the equipment a limitation? If yes, please delete the technologies that do not meet your criteria.	Memo
Production Rate	Is there a minimum production rate, which the technology must achieve? If yes, enter input parameter.	String
Waste Volume	Is there a maximum waste volume the technology must not create? This includes primary and secondary waste.	String
Waste Volume	Is there a maximum expenditure allowable for the disposal of waste material? If yes, please enter the not to exceed dollar value.	String
Equipment Availability	Is the availability of the equipment a concern to complete the project? If yes, please delete the technologies that do not meet your criteria.	Memo
Required Personnel	Is the number and type of personnel required to operate the equipment a limiting factor? If yes, please delete the technologies that do not meet your criteria.	String, one for each classification of personnel.
Required Personnel	Is there a maximum expenditure allowable for the labor cost? If yes, please enter the not to exceed dollar value.	String, one for each classification of personnel.
Primary and Secondary Waste	Are there limitations on the characteristics of the waste material generated? If yes, please delete the technologies that do not meet your criteria.	Memo
References, DOE site user, and other site references/publications	Is the maturity of the technology a critical factor? If yes, please delete the technologies that do not meet your criteria.	Memo
Basic Equipment Description	Provide general description	Memo
Benefits	List general benefits of technology.	Memo
Limitations	List general limitations of the technology.	Memo
Vendor Name	Vendor Name	String
Company Address	Company Address	Memo

Field Name	Description	Data Type
Definition of Data Imported from MISD		
Company Phone	Company Phone	Integer
Company Fax	Company Fax	Integer
Email address	Email address	String
Company Website Address	Company Website Address	String

**Table C.3.
Cost Related Data Provided by User**

Acronym	Field Name	Description (Optional)	Data Type
Site User Cost Related Data			
CAPREN (1-5)	Rental Rate per Hour for Capital Equipment	Rental rate for capital equipment. System can handle up to 5 pieces of equipment. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary/ hour
CAPSV (1-5)	Salvage Value for Capital Equipment	The salvage value for capital equipment. System can handle up to 5 pieces of equipment. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
CPPE	Cost for Personal Protective Equipment per hour.	The aggregate total for the use of PPE for one person.	Monetary/ hour
DA	Surface Area to be decontaminated	Area in square feet.	Real number
HSC	H&S Support Cost (HSC)	A general dollar figure for providing H&S costs on a per hour basis. This includes Industrial Hygiene and Health Physics support.	Monetary/ hour
IR	Interest Rate	The interest rate used for capital purchases. (default value .1)	2 digit real number
LCE	Labor Cost for an Equipment Operator	The labor rate for one equipment operator, which includes fringe benefits.	Monetary/ hour
LCT	Labor Cost for a Technician	The labor rate for one technician, which includes fringe benefits.	Monetary/ hour
N	Life in Hours for Total Operation of Capital Equipment	The total number of hours the equipment can be used before salvaged.	Real number

Acronym	Field Name	Description (Optional)	Data Type
RENSE (1-5)	Rental Rate per hour for Support Equipment	The aggregate total for the rental of support equipment per hour. System can handle up to 5 pieces of equipment. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary/ hour
SEPUR (1-5)	Purchase Price for Support Equipment	The cost to purchase support equipment. System can handle up to 5 pieces of equipment. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
SESV (1-5)	Salvage Value for Support Equipment	The salvage value for support equipment. System can handle up to 5 pieces of equipment. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
TH	Number of Training Hours per Person	Based on site specific training requirements for an individual. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Integer
THPO	Total Hours of Possible Operation per Year	The total possible number of hours of operation for the technology for a year period.	Real number
TRAN	Transportation Cost	The aggregate total of transportation costs for capital and support equipment to/from site. MISD will also provide vendor name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
WDC	Waste Disposal Cost	Cost in dollars per cubic feet. This includes container cost, waste certification cost, and transportation cost.	Monetary

Table C.4.
DASD Field Definitions for Data Imported from MISD

Acronym	Field Name	Description (Optional)	Data Type
CAPPUR (1-5)	Purchase Price for Capital Equipment	The total for the purchase of capital equipment. System can handle up to 5 pieces of equipment.	Monetary
CON	Consumable Cost	The cost for media and other consumables, which are needed to provide for operation of the equipment.	Monetary/ hour
DMOBT	Demobilization Time	The time in hours to demobilize the equipment.	Real number in hours
MC	Maintenance Cost	The cost to maintain the equipment. Major replacement parts are not included.	Monetary/ hour
MOBT	Mobilization Time	The time in hours to mobilize the equipment.	Real number in hours
NLCE	Number of Equipment Operators	The number of equipment operators needed to operate the equipment.	Integer
NLCT	Number of Technicians	The number of technicians needed to operate the equipment.	Integer
PROD	Production Rate	The production rate for the decontamination equipment.	Real number Square feet /hour
WV	Waste Volume	The waste volume created by using the technology. This includes primary and secondary waste.	Real number Cubic feet

**Table C.5.
DASD Field Definitions for Computed Costs**

Acronym	Field Name	Description (Optional)	Data Type
CAPAMOR	Amortized Purchase Price for Capital Equipment	Using the formula for present value an amortized purchase price for capital equipment is calculated. MISD will also provide company name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
CAP_REN	Value for Renting Capital Equipment.	Dollar value to rent capital equipment. MISD will also provide company name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
EIT	Effective Interest Rate	The interest rate is used in conjunction with the total possible number of hours for operation per year to calculate the effective interest rate.	Real number
HO	Hours of Operation	Using the size of the area to be decontaminated and the equipment production rate, the hours of operation can be calculated.	Real number
HS	Health and Safety Cost	The total cost to supply health and safety support for the project.	Monetary
LC	Labor Cost	Using the labor cost per hour and the hours of operation the labor cost can be calculated.	Monetary
LCH	Labor Cost per Hour	The total labor cost per hour including equipment operators and technicians.	Monetary/ hour
MOB	Mobilization and Demobilization Cost	The total cost to mobilize and demobilize the decontamination technology.	Monetary
OC	Operations Cost	Factors related to health and safety, mobilization and demobilization, operations and maintenance cost, personal protective equipment, support equipment, training and transportation are summed to get the total operations cost.	Monetary
OMC	Operating and Maintenance Cost	The total cost to operate and maintain the technology. Costs include maintenance, media, and other consumables. MISD will also provide the description of the PPE and environmental conditions used during the assessment.	Monetary
PPE	Personal Protective Equipment	The total cost to supply PPE to the equipment operators and the technicians.	Monetary
SEAMOR	Amortized Purchase Price for Support Equipment	Using the formula for present value, an amortized purchase price for support equipment is calculated. MISD will also provide company name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary

Acronym	Field Name	Description (Optional)	Data Type
SE_REN	Value for Renting Support Equipment.	Dollar value to rent support equipment. MISD will also provide company name, company address, phone number, fax number, equipment and support equipment descriptions to aid in determining this value.	Monetary
TRAIN	Training Cost	The total cost to train the equipment operators and technicians.	Monetary
WD	Waste Disposal Cost	The total cost to dispose of waste material.	Monetary

APPENDIX D

DASD GRAPHICAL USER INTERFACES (GUI)

DASD GRAPHICAL USER INTERFACES (GUI)

This Appendix contains illustrations of the various graphical user interfaces (GUI) that are used by DASD to prompt system users for input, and to feedback information to the users.

D&D PROJECT PROBLEM SET DEFINITION

In order to identify technologies that may be suitable for a given project, three parameters must first be established. They are: surface type, surface geometry, and removal capacity. Figure D.1 below illustrates the graphical user interface (GUI) that prompts the user for input. The user must select one sub-category from each of the three main categories.

PROBLEM DEFINITION

Define the Problem by Selecting:
A Surface Type, A Geometry and Removal Capacity.

SURFACE TYPE

- ☐ Alkali
- ☐ Alkaline
- ☐ Acid
- ☐ Base
- ☐ Neutral
- ☐ Wet
- ☐ Dry
- ☐ Solid
- ☐ Liquid
- ☐ Gas

GEOMETRY

- ☐ Flat
- ☐ Sloped
- ☐ Round
- ☐ Square
- ☐ Rectangular
- ☐ Triangular
- ☐ Circular
- ☐ Elliptical
- ☐ Irregular
- ☐ Other

REMOVAL CAPACITY

- ☐ High
- ☐ Medium
- ☐ Low
- ☐ Very Low
- ☐ None
- ☐ Unknown

NEXT

Figure D.1. Problem Set Definition. The user inputs parameters that describe the nature of their D&D project.

HISTORICAL USERS DATABASE

The Historical Users Database will allow users to access the records of previously-defined problem sets or define a new problem set using system default values. This minimizes data entry

duplication and reduces the time required to complete the decision analysis simulation. The key information that is captured at this point includes:

- Project Identifier
- Site Name
- Project Acronym
- User Initials
- Area to be Decontaminated

Figure D.2 illustrates the GUI that prompts users to enter the required information.

The screenshot shows a graphical user interface (GUI) window titled "PROJECTS WITH COMMON PROBLEM DE...". Inside the window, there is a text box with instructions: "Use left or right arrows to view an existing project. Select NEXT to edit the project selected or Select NEW PROJECT to define new project parameters." Below the instructions is a file explorer showing "HistoricalUser.mdb". The form contains several input fields: "Site Name" with the value "Acme Power", "Project Acronym" with the value "APDD", "Area to be Decontaminated" with the value "45000", and "User Initials" with the value "RT". At the bottom of the form, there is a section labeled "PROJECT IDENTIFIER" with a blank input field. Below the form are three buttons: "NEXT", "BACK", and "NEW PROJECT".

Figure D.2. The user is shown projects with similar problem sets and may use one of these as a template query, or create a new query. The project is then assigned a Project ID number by DASD.

USER/PROJECT IDENTIFICATION

Users and their individual projects are identified by DASD through unique User/Project Identification numbers. DASD prompts the user (Figure D.3) to provide user/project-specific identification information which includes: site name, project acronym, user name, user initials, user phone, user title, area to be decontaminated (in square feet) and number of years in D&D industry. This information aids in characterizing the types of decontamination problem sets evaluated by the user and the system. By characterizing the decontamination problem sets, future users may be able to simplify the system execution sets by implementing previously stored information.

The screenshot shows a window titled "USER/PROJECT I.D." with a prompt "Provide user/project identification information." Below the prompt are several input fields. The "Site Name" field is filled with "Lawrence Livermore National Laboratory", "Sandia National Laboratories - Livermore", "Energy Technology Engineering Center", and "Rocky Flats". The "Project Acronym" field is empty. The "User Name" field is empty. The "User Initials" field is empty. The "User Phone" field is empty. The "User Title" field is empty. The "Area to be Decontaminated (sq. ft.)" field is filled with "1000". The "Number of Years in the D&D Industry" field is filled with "15". The "Size of Decontaminated Area (sq. ft.)" field is filled with "25". The "Size of Decontaminated Area (sq. ft.)" field is filled with "78". The "Area to be Decontaminated (sq. ft.)" field is filled with "10". At the bottom are "NEXT" and "BACK" buttons.

Site Name	Lawrence Livermore National Laboratory Sandia National Laboratories - Livermore Energy Technology Engineering Center Rocky Flats
Project Acronym	
User Name	
User Initials	
User Phone	
User Title	
Area to be Decontaminated (sq. ft.)	1000
Number of Years in the D&D Industry	15
Size of Decontaminated Area (sq. ft.)	25
Size of Decontaminated Area (sq. ft.)	78
Area to be Decontaminated (sq. ft.)	10

Figure D.3. The user inputs company, site and project data that are stored in a user profile database. Project- and site-specific parameters are also inputted.

SCREENING OF ALTERNATIVE TECHNOLOGIES TABLE

After the user has defined the specific problem and has provided the user/project identification information, DASD provides a preliminary list of candidate technologies (Figure D.4) which allows the user to perform a Screening of Alternative Technologies (SAT). The goal of this

screening process is to allow the user to narrow the number of technology alternatives that go forward through the technology selection detailed process. Reducing the number of candidate technologies at this early stage reduces the time required to complete the selection process. Figure D.5 is an example of the results of a preliminary screening that identifies only those technologies that may be rented, and eliminates those that must be purchased.

Answer each question in the CONSTRAINT DESCRIPTION column by entering the appropriate value. If a technology does not meet the appropriate value the color of the data field will be red. And the rating will be zero. Data fields and ratings for each technology are found in the columns below the technology titles. The CV column rates the importance of each constraint. A rating can take on a user defined value between zero and ten. Ten indicating the most favorable rating.

CONSTRAINT DESCRIPTION	CV	TECHNOLOGY 1	TECHNOLOGY 2	TECHNOLOGY 3	TECHNOLOGY 4	TECHNOLOGY 5	TECHNOLOGY 6	TECHNOLOGY 7	TECHNOLOGY 8	TECHNOLOGY 9	TECHNOLOGY 10
1. What method will be used to purchase the technology?											
2. If the required equipment will be purchased, what is the maximum allowable price?											
3. Is there a minimum production rate?											
4. Is there a maximum production rate?											
5. Is there a minimum production rate?											
6. Is there a maximum production rate?											

Figure D.4. SAT table showing initial list of potential technology solutions.

The user then reviews the individual *technology constraints* (column 1 in SAT) to complete the preliminary screening process. These range from absolute constraints to constraints that are minimally important to the technology selection process. Constraints are rated on a *Criticality Index* scale from zero to ten. The lower the rating, the less important the constraint is to the user. If a technology is rated ten, this indicates an absolute constraint, and it is critically important that the technology meets this criterion to be considered a viable solution. For example, if a technology can only be purchased, it is disqualified if the user is only interested in renting equipment. If a technology is rated zero, this denotes a criterion that does not have to be met. Criticality values are entered by the user in column 2 of the SAT Table (Figures D.4 and D.5).

SATs generated by DASD are structured as follows:

- The table consists of a two-dimensional matrix. Each row represents a constraint, and each column lists a candidate technology that satisfies the initial problem set defined for the project (see Table 15).
- The first column describes the nature of each constraint and prompts the user to quantify or qualify his/her specific constraints.
- The second column shows the criticality index for each constraint. DASD assigns a default value of 5 for this field, and the user may modify it to reflect the importance of this constraint to his/her specific circumstances.

The screenshot shows a software window titled "SAT" with a detailed instruction block at the top. Below the instructions is a table with the following structure:

- Column 1: CONSTRAINT DESCRIPTION** - Contains six numbered questions about equipment rental, capital equipment, and maintenance expenses.
- Column 2: CV** - Contains numerical values (e.g., 2, 5, 10) representing the criticality index for each constraint.
- Columns 3-7: Technology Candidates** - Each column lists a candidate technology (e.g., "RENTAL EQUIPMENT", "CAPITAL EQUIPMENT", "MAINTENANCE EXPENSES") and a grid of input fields for user ratings.

At the bottom of the window are three buttons: "EXIT", "BACK", and "REORDER".

Figure D.5. SAT Table showing only those technologies that satisfy critical constraints (e.g., if equipment can only be rented). Technologies that do not qualify are suppressed.

- The cells in columns three through seven of the table describe the characteristics of each candidate technology as they relate to each constraint listed in the first column. Each cell also contains a prompt where the user may indicate his or her preference for each technology characteristic based on how it affects each of his or her specific constraints. The preference scale runs from zero (least preferred) to ten (most preferred) and if the user does not input a value, DASD assigns a default value of five.

- Technology characteristics that do not satisfy user-defined constraints are highlighted in red (e.g., if the cost of purchasing the equipment exceeds the user's budget) (Figure D.4).
- Based on the technology characteristics and features summarized in the SAT matrix, the user may, at this stage, manually eliminate technologies that are not foreseen to be viable solutions due to the constraints that they impose (e.g., if the technology is not available when it is needed). To do so, the user simply double clicks on the name of the technology at the top of the matrix and it will be suppressed (Figure D.5). Eliminated technologies may be reinstated by double clicking on their names a second time. The intent is to distill the number of technologies to a manageable number (ideally three or less) before proceeding with more detailed analysis.

SAT_II

Answer each question in the CONSTRAINT DESCRIPTION column by entering the appropriate value. If a technology does not meet your criteria you may delete it by double clicking on its green label. You may reinsert a technology after deleting it by double clicking its green label. Data fields and ratings for each technology are listed in the columns below the technology title. The CV column rates the importance of each constraint. A rating can take on a user defined value between zero and ten. Ten indicating the most favorable rating.

CONSTRAINT DESCRIPTION	CV	Technology 1	Technology 2	Technology 3	Technology 4	Technology 5
1. Is the portability of the equipment a concern? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	2	1	2	3	4	5
2. Do you have a limitation on the type of location which can be used in the facility? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	3	1	2	3	4	5
3. Do you have a limitation on the type of media used by the system? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	4	1	2	3	4	5
10. Is the availability of the equipment a concern to complete the project? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	5	1	2	3	4	5
11. Is the number and type of personnel required to operate the equipment a limiting factor? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	6	1	2	3	4	5
12. Are there limitations on the characteristics of the waste medium generated? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	7	1	2	3	4	5
13. Is the maturity of the technology a critical factor? If yes, please delete the technologies that do not meet your criteria by double clicking on the appropriate green label.	8	1	2	3	4	5
TOTAL AVERAGE SCORE		25	24	24	24	24

Figure D.6. Additional constraints rated in the SAT by the user. This is a continuation from Figure D.5.

- The total score for each technology alternative is shown in the last row of the matrix.
- Vendor-provided data on each technology (e.g., environmental conditions and vendor contact information) may be accessed simply by clicking on the *vendor information* button at the bottom of the SAT screen and then selecting the vendor's name from a list (see Figure D.6).

DECISION ANALYSIS MODEL

During the process of selecting a decontamination technology, a decision-maker must logically organize and systematically compare data on a group of viable technology alternatives in order to decide which is the most appropriate solution. In the Decision Analysis Model employed by DASD, decontamination technology data elements that are to be examined are first organized into logical data categories as shown in Table D.1.

Table D.1.
Decision Analysis Model Technology Data Hierarchy

<u>Section</u>	<u>Data Category</u>	<u>Data Elements</u>
<i>I.</i>	<i>Cost</i>	<ul style="list-style-type: none"> • Amortized Capital Cost • Labor Cost • Operations Cost • Waste Disposal Cost
<i>II.</i>	<i>Technology Performance</i>	<ul style="list-style-type: none"> • Adaptability to Different Surfaces • Equipment Maneuverability • Ending Surface Condition • Media Versatility • Removal Capability • Characteristics of Waste
<i>III.</i>	<i>Health and Safety</i>	<div> <div>Health</div> <ul style="list-style-type: none"> • Inhalation • Skin Absorption • Heat Stress • Noise • Cold Stress • Ergonomic Hazards </div> <div> <div>Safety</div> <ul style="list-style-type: none"> • Electrical • Fire/Explosion • Confined Space Entry • Mechanical Hazards • Pressure Hazards • Tripping & Falling • Moving Vehicles • Protruding Objects • Overhead Lifts </div>

This decision analysis model is used by DASD to graphically illustrate to the user all the decision factors that are taken into account, and to allow the user to rate the relative importance of each factor. Figure D.7 shows the model, and Figures D.8 and D.9 are examples of the GUIs that prompt the user to rate individual factors when a data category is selected.

Figure D.7. Decision Analysis Model showing the hierarchy of data categories and decision factors considered by DASD.

To rate each factor, the user selects the category containing that particular factor and is then prompted to rate the importance of all factors within the category. For example, to rate

technology cost, the user selects "Goal" and is then prompted to rate all three major factors that affect the project's goals, i.e. cost, technology performance, and health and safety (Figure D.8).

Rate the importance of the TECHNOLOGY CHARACTERISTICS against each other. A value closer to 10 indicates a higher importance. Place the arrow on the sliding scale, hold down the left mouse button and slide indicator to desired value.

COST 10.5

PERFORMANCE 10

HEALTH & SAFETY 12.5

OK Help/Quit

Figure D.8. The user rates the decision factors that impact the goals of the project.

TECHNOLOGY COST EVALUATION

To facilitate the review of the cost elements associated with each technology, four cost categories have been developed. The four main cost categories are capital cost, waste disposal cost, labor cost and operations cost. These costs are calculated by employing user-provided information and information from the MISD technology database. The system will allow the user to modify any cost element in the system, tailoring the results to the user's specific problem and experience. The user then evaluates the cost categories by rating their importance on a scale of zero (least important) to ten (most important) (Figure D.8). Details on the formulas used by DASD for calculating costs can be found in Appendix D.

Form15

Rate the importance of the TECHNOLOGY CHARACTERISTICS against each other. A value closer to 10 indicates a higher importance. Place the arrow on the sliding scale, hold down the left mouse button and slide indicator to desired value.

AMORTIZED CAPITAL COST	<input type="text" value="12692"/>
OPERATIONS COST	<input type="text" value="11923"/>
LABOR COST	<input type="text" value="11923"/>
WASTE DISPOSAL COST	<input type="text" value="12462"/>

Figure D.8. The user rates the importance of each cost category on a scale of one to ten.

This process is repeated for all remaining data categories until each decision factor is assigned a rating.

After decision factors are rated, the cost associated with each can then be calculated. The user selects the cost factor to be calculated and is prompted by DASD to enter relevant data that is required to complete the calculation. Figure D.9 shows the data input screen that must be completed *for each candidate technology* in order that DASD may calculate the cost of purchasing or renting them.

CENTRIFUGAL SHOT BLASTING COST EVALUATION

IN ORDER TO COMPLETE A PURCHASE EVALUATION, VALUES MUST BE ENTERED INTO PURCHASE PRICE, SALVAGE VALUE, TOTAL HOURS OF POSSIBLE OPERATION PER YEAR AND USEFUL LIFE. FIELDS FOR EACH PIECE OF EQUIPMENT. IN ORDER TO COMPLETE A RENTAL EVALUATION VALUES MUST BE ENTERED INTO THE RENTAL RATE/HOUR FIELD. PLEASE CLICK ON A TITLE TO GET A DESCRIPTION OF ELEMENT.

CAPITAL EQUIPMENT EVALUATION

EQUIPMENT NAME	PURCHASE PRICE	SALVAGE VALUE	OPERATING HOURS/YEAR	USEFUL LIFE (YEARS)	RENTAL RATE/HOUR	ANNUAL COST	TOTAL COST
EC7-2 Porta Shot Blast	8000	3000	2000	10000	100	13	2000
						0	0
						0	0
						0	0
						0	0

SUPPORT EQUIPMENT EVALUATION

EQUIPMENT NAME	PURCHASE PRICE	SALVAGE VALUE	OPERATING HOURS/YEAR	USEFUL LIFE (YEARS)	RENTAL RATE/HOUR	ANNUAL COST	TOTAL COST
Vacuum cleaner	2000	1000	2000	10000	100	3	2000
Float magnet	500	250	2000	1000	100	5	2000
						0	0
						0	0
						0	0

Next Back Calculate

Figure D.9. User inputs data required to calculate the purchase and/or rental costs of a candidate technology and any required support equipment.

The user then repeats this process for each of the remaining cost elements. These are shown in Figures D.10 and D.11.

WASTE DISPOSAL COST EVALUATION

WASTE DISPOSAL COST EVALUATION

TECHNOLOGY NAME	WASTE VOLUME/COST	WASTE TONNAGE	WASTE DISPOSAL COST
Centrifugal Shot Blasting	78	18.9	1474
Chemical Coating Removal	78	73	5684
Scabbling - Moose	78	24	1872
Roto-Peen	78	23.5	1833
ARMS	78	95	7410

OK Cancel

Figure D.10. User inputs data for calculating waste disposal costs.

LABOR AND OPERATIONS COST EVALUATION

CLICK ON A TERM TO GET ITS COMPLETE DESCRIPTION.

LABOR COST EVALUATION

Activity	Rate	Hours	Cost	Rate	Hours	Cost	Rate	Hours	Cost
Control Shot Blasting	25	1	15	1	50	800			
Chemical Coating Removal	25	0	15	1	132	114			
Scabbing Moose	25	1	15	1	130	303			
Rot Peen	25	1	15	0	298	845			
ARMS	25	0	15	2	42	214			

OPERATIONS COST EVALUATION

Activity	Rate	Hours	Cost	Rate	Hours	Cost	Rate	Hours	Cost
Control Shot Blasting	2	4	30	4		150			
Chemical Coating Removal	2	4	0	500		50000			
Scabbing Moose	2	4	2	23.31		9150			
Rot Peen	2	4	30	92		9240			
ARMS	5.5	1	2	63.49		6500			

OK REPAIR WATER

Figure D.11. User inputs data required for calculating labor and operations costs.

The user continues this process until all qualitative and quantitative factors are rated and/or costed. The user then requests DASD to display overall technology rating results. These results can be displayed in either a graphical scalar rating format (Figure D.12) or a graphical histogram format (Figure D.13).

Form31

Overall Technology Rating Results

Control Shot Blasting	0.2492
Chemical Coating Removal	0.2067
Scabbing Moose	0.182
Rot Peen	0.2118
ARMS	0.1502

Figure D.12. Scalar display of overall technology rating results.

Figure D.13. Histogram display of overall technology rating results.

In addition, the user may display a sensitivity analysis chart (Figure D.14) that identifies the critical factors that may easily alter the highest-ranked technology(s). This information is important to defend judgments and focus on sensitive areas before making a final technology decision.

Figure D.14. Sensitivity analysis shows the effect that a change in the weighting of cost factors might have on the overall rating of candidate technologies.

APPENDIX E

FORMULAS USED FOR CALCULATING COSTS

FORMULAS USED FOR CALCULATING COSTS

During the completion of the SAT process, the user specifies whether capital equipment will be purchased, rented or a combination of the two options. If the purchase option is specifically checked (no capital equipment will be rented) then equation (1) will be used. If the rental option is specifically checked (no capital equipment will be purchased) then equation (2) will be used. If the combination of the two options is chosen, the user must specify which equipment will be purchased and which equipment will be rented.

The following formula will be used to calculate the amortized capital cost (CAPAMOR) or capital rental cost (CAP_REN):

CAP_REN	⇒ Calculated Value for Rental of Capital Equipment
CAPAMOR	⇒ Calculated Amortized Value for Purchase Price of Capital Equipment over the period of "n" hours.
CAPPUR	⇒ Purchase Price for Capital Equipment
CAPREN	⇒ Rental Rate per Hour for Capital Equipment
CAPSV	⇒ Salvage Value for Capital Equipment
DA	⇒ Area to be Decontaminated
EIT	⇒ Effective Interest Rate
HO	⇒ Hours of Operation
IR	⇒ Interest Rate (Default value .1)
n	⇒ Life in Hours of Total Operation
PROD	⇒ Production Rate
THPO	⇒ Total Hours of Possible Operation per Year

$$(1) \quad \text{CAPAMOR} = (\text{CAPPUR} - (\text{CAPSV} / (1 + \text{EIT}))) * \text{EIT} / (1 - (1 / (1 + \text{EIT})^n)) * \text{HO}$$

Or

$$(2) \quad \text{CAP_REN} = \text{CAPREN} * \text{HO}$$

Where: $\text{EIT} = \text{IR} / \text{THPO}$ $\text{HO} = \text{DA} / \text{PROD}$

The following formula will be used to calculate the operations cost (OC):

$$OC = MOB + OMC + PPE + SE(xxx) + TRAIN + TRAN$$

Where:

$$MOB = (MOBT + DMOBT) * LCH$$

$$OMC = (MC + CON) * DA$$

$$PPE = HO * (NLCE + NLCT) * CPPE$$

$$HO = DA / PROD$$

$$SE_{ren} = RENSE / HO$$

$$SE_{cap} = (SEPUR - (SESV / (1 + EIT))) * EIT / (1 - (1 / (1 + EIT))^n) * HO$$

$$TRAIN = LCH * TH$$

CON	⇒ Consumable Cost
CPPE	⇒ Cost for Personal Protective Equipment per Hour
DA	⇒ Area to be Decontaminated
DMOBT	⇒ Demobilization Time
EIT	⇒ Effective Interest Rate (where ⇒ $EIT = IR / THPO$)
HO	⇒ Hours of Operation
IR	⇒ Interest Rate (Default = 1)
LCH	⇒ Labor Cost per Hour
MC	⇒ Maintenance Cost
MOB	⇒ Mobilization and Demobilization Cost
MOBT	⇒ Mobilization Time
n	⇒ Life in Hours of Total Operation
NLCE	⇒ Number of Equipment Operators
NLCT	⇒ Number of Technicians
OC	⇒ Operations Cost
OMC	⇒ Operating and Maintenance Cost
PPE	⇒ Personal Protective Equipment Cost
PROD	⇒ Production Rate
RENS	⇒ Rental Rate per Hour for Support Equipment
SEAMOR	⇒ Support Equipment Cost Purchase

SE_REN	⇒ Support Equipment Cost Rental
SEPUR	⇒ Purchase Price for Support Equipment
SESV	⇒ Salvage Value for Support Equipment
TH	⇒ Number of Training Hours per Person
THPO	⇒ Total Hours of Possible Operation per Year
TRAIN	⇒ Training Cost
TRAN	⇒ Transportation Cost

$$LC = (LCH + HSC) * HO$$

$$\text{Where: } LCH = (LCE) * (NLCE) + (LCT) * (NLCT)$$

$$HO = DA / PROD$$

The following formula will be used to calculate the labor cost (LC):

DA	⇒ Area to be Decontaminated
HO	⇒ Hours of Operation
HSC	⇒ Site Specific Health and Safety Labor Cost
LC	⇒ Labor Cost
LCE	⇒ Labor Cost for an Equipment Operator
LCH	⇒ Labor Cost per Hour
LCT	⇒ Labor Cost for a Technician
NLCE	⇒ Number of Equipment Operators
NLCT	⇒ Number of Technicians
PROD	⇒ Production Rate

The following formula will be used to calculate the waste disposal cost.

$$WD = WDC * WV * DA$$

DA	⇒ Area to be Decontaminated
WD	⇒ Waste Disposal Cost
WDC	⇒ Site Specific Waste Disposal Cost

WV ⇒ Waste Volume

Assumptions for Cost Calculations:

- Unit cost of implementing the technology will be calculated with units of \$/square foot.
- Utility costs including diesel fuel and electricity are not included.
- The same type and number of people used for the operation of the equipment are used to calculate the mobilization and demobilization costs.
- The costs to determine the location and amount of contamination and verification that the contamination is no longer there after the completion of the decontamination operations is not included in the cost calculations.
- Equipment decontamination costs are not included in the cost calculations.
- Project management costs (i.e. supervisors, etc.) are not included in the cost calculations.
- Overhead rates are not included in the cost calculations.