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Development of the construction enviornmentally informed decision support system

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**DEVELOPMENT OF THE CONSTRUCTION ENVIRONMENTALLY INFORMED
DECISION SUPPORT SYSTEM**

A Thesis

Presented to

The Faculty of the Department of Civil and Environmental Engineering

San Jose State University

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

by

Chandrani Pramod Nadkarni

May 2000

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A handwritten signature in black ink, appearing to read "Janet K. Yates", written over a horizontal line.

Dr. Janet K. Yates

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Dr. U. J. Ndon

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APPROVED FOR THE UNIVERSITY

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ABSTRACT

DEVELOPMENT OF THE CONSTRUCTION ENVIRONMENTALLY INFORMED DECISION SUPPORT SYSTEM

By Chandrani P. Nadkarni

This research proactively addresses environmental protection issues, and the importance of their inclusion as an integral part of the planning stage for construction. The research aims at developing “CEID: Construction Environmentally Informed Decision Support System”- which will be a proactive environmental decision making tool that integrates environmental issues related to construction processes into the planning stage of a project.

Research reveals that the key reason for the construction industry not adopting environmentally sound practices, is a lack of tools that can assist construction personnel in making environmentally informed decisions during the planning stage of projects. The implementation of the CEID will assist construction personnel in making environmentally sound decisions and in achieving the project objectives of completing a project as specified in the contract, on schedule, and within budget. The other benefits associated with the CEID include reducing pollution in the environment during construction, improved worker safety, and reduced environmental liability.

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Chapter I - INTRODUCTION

BACKGROUND

The environmental consequences of excessive waste production, improperly managed residuals, and contaminant transport through air and water are widely recognized and have led to the pollution prevention and waste minimization paradigms of the 1990s. One industry that is currently implementing environmental protection concepts is the construction industry. One difficulty in their implementation is a lack of tools for providing an informed basis for implementing environmentally sound practices. The availability of a quick and efficient method for quantifying the potential environmental impacts of decisions made during the planning stage of projects is likely to result in the evolution and development of more environmentally sound practices. One way to overcome the deficiencies that exist related to environmental issues in construction is to create a computer decision support system that assists construction personnel in making more environmentally informed decisions during the planning stage of projects.

Until 1969, the national philosophy concerning negative environmental issues of major projects such as highways, industrial plants, shopping centers, housing developments, and others was to ignore them during the planning stage of projects. After the work was completed and the environmental effects were apparent, the attitude was generally one of "Too bad, but it couldn't be avoided" (Bregman and Mackenthum 1992).

During the past decade, the United States Environmental Protection Agency (EPA) conducted a systematic analysis of environmental issues and this led to strict federal regulations that help to protect the environment (Kilbert and Coble 1995). Today, environmental laws are similar to worker safety and tax laws and environmental law compliance is an essential condition for a company to stay in business (Kriz 1994). The EPA receives its direction and powers from a number of statutes as shown in Figure 1: the Clean Air Act of 1970, the National Environmental Policy Act of 1970, the Noise Control Act of 1972, the Clean Water Act of 1972, the Toxic Substances Control Act of 1976 and the Resource Conservation and Recovery Act of 1976. These are all examples of laws that provide the EPA with wide-ranging jurisdiction over environmental matters. The EPA has additional pollution control responsibilities under 40 other statutes (Kriz 1994).

The other two federal agencies that regulate the construction industry are the Occupational Safety and Health Administration (OSHA) and the Department of Transportation (DOT). In addition to federal agencies the construction industry is heavily regulated by a variety of state and local organizations (Kilbert and Waller 1991).

Currently, there is limited awareness associated with environmental issues in the construction industry and for many projects the environmental aspects of construction are only minimally considered during the planning stage of projects. Many of the materials, supplies, tools, methods, and procedures selected for use at construction job sites create environmentally unsafe by-products and hazardous wastes that lead to pollution in the construction environment.

**The 10 major environmental laws administered by the
ENVIRONMENTAL PROTECTION AGENCY**

Figure 1 – The 10 Major Environmental Laws Administered by the Environmental Protection Agency

PROBLEM STATEMENT

Many aspects of construction create environmental pollutants that have a negative impact on the environment. Strict federal, state, and local regulations are used to protect the environment. Environmental citations, penalties, and fines may negatively affect the time and cost of projects.

During the life cycle of a project, important decisions are sometimes made with limited knowledge about environmental factors. Most design, engineering, construction, or construction management firms do not have environmental specialists on their staff. There are very few concise guidelines available for architects, engineers, contractors, construction managers, or project managers to assist them in making environmentally informed decisions during the planning stage of construction projects. Even less knowledge about environmental issues is available at construction job sites where work moves quickly and there is little time for investigating the consequences of chosen actions and decisions.

A key reason for the construction industry not adopting environmentally sound practices that result in environmental liability, and pollution in the environment, is a lack of tools that can assist construction personnel in making environmentally informed decisions during the planning stage of projects. If a quick and efficient method for quantifying the potential affects of decisions, actions, methods, and techniques were available, it would allow construction personnel to review alternatives that are potentially less harmful to the environment, and to achieve the project objectives of completing a project as specified in the contract, on schedule, and within budget.

OBJECTIVES OF THE STUDY

This research will proactively address environmental protection issues, and the importance of their inclusion as an integral part of the planning stage for construction. This research will investigate the environmental issues that should be considered during the planning stage of a construction project to avoid and reduce the undesirable effects of environmental hazards and pollutants that may surface during a project.

One way to address environmental issues at construction project job sites is to provide construction personnel with data and knowledge that will assist them in making environmentally sound decisions during the planning stage of a project. The data and knowledge made available to construction personnel will help establish two types of environmental protection objectives, namely those required by law (regulatory) and those practiced by knowledgeable construction experts (heuristic). Heuristics, or rules of thumb, are plentiful in construction but are difficult to articulate (Kartam 1997). Heuristic knowledge can be best thought of as the experience of experts in identifying problems and incorporating effective environmental protection techniques.

The data and knowledge collected can be organized and stored in a knowledge database. A major part of this research will be the development of a computer decision support system called the **“Construction Environmentally Informed Decision Support System (CEID)”**.

The **“CEID: Construction Environmentally Informed Decision Support System”** will be a proactive environmental decision making tool that integrates environmental issues related to construction processes into the planning stage of a project. The CEID

will provide a decision system that contains a comprehensive knowledge database derived from the experience of construction experts. This knowledge database will assist construction personnel in identifying environmental issues, and adopting environmentally safe alternatives, during the planning stage of projects.

LIMITATIONS OF THE STUDY

The findings of this research were subject to the following limitations:

- the knowledge gathered in the study was limited to the responses obtained from the questionnaires
- the extent of knowledge acquisition was limited by budgetary and time constraints
- the sample surveyed was based within California.

ORGANIZATION OF THE STUDY

Chapter I provides a brief background on environmental issues in construction. It includes the statement of the problem, identifies the objectives of the study, and lists limitations of the study.

Chapter II presents the results of a literature search into the areas of environmental pollution during construction and knowledge based technology aimed at automating various aspects of the construction industry.

Chapter III describes the methodology used for this research project to investigate environmental issues during construction and their incorporation into the planning stage of projects.

Chapter IV describes the development of the Construction Environmentally Informed Decision Support System (CEID) program, discusses the structure and design of the program, and explores the system utilities of the program.

Chapter V presents the results of the research investigation.

Chapter VI presents the conclusions, recommendations, contributions, and discusses topics for further research.

Appendix I contains the cover letter and questionnaire used for this research project.

Chapter II - LITERATURE REVIEW

This chapter presents the results of a literature search into the areas of environmental pollution during construction, and knowledge based technology aimed at automating various aspects of the construction industry.

ENVIRONMENTAL ISSUES AND THE CONSTRUCTION PLANNING PROCESS

The primary goals of a project team are to complete projects as specified in the contract, on schedule, and within the budget. This goal can be achieved by adopting a total project management approach to executing capital projects (Ritz 1990). Planning is the first step of the total project management philosophy for planning, organizing, and controlling the execution of capital projects. Planning can be defined as (Ritz 1990, p. 36):

- A bridge between the experience of the past and the proposed action that produces a favorable result in the future.
- A precaution by which we can reduce undesirable effects or unexpected happenings to eliminate confusion, waste, and loss of efficiency.
- The prior determining and specifying of the factors, forces, effects, and relationships necessary to reach the desired goals.

Throughout the life cycle of a project, the construction planning process can be divided into three identifiable stages (Cormican 1985, p. 29):

- **Prebid Planning:** The prebid planning stage takes place prior to the submission of a bid. The duration of prebid planning varies widely, from several weeks to several months and more depending on the type of contract.
- **Preconstruction Planning:** The preconstruction planning stage lasts up to three months. It expands from bid-award, which is typically not more than one month prior

to mobilization, to a certain point in the construction process (normally not more than two additional months beyond mobilization).

- **During-Construction Planning:** The during-construction planning stage lasts through all of the construction processes.

Construction planning processes can be categorized based on the following areas of planning. Nine functional construction plans are defined and categorized into four areas by Laufer et al. (1993, p. 430), in the article “Prebid and Preconstruction Planning Process”:

- **Base Plan**
Engineering and Method
Organization and Contract
- **Forecast and Control**
Schedule
Cost and Cash Flow
- **Technology**
Major Equipment
Site Layout and Logistics
Work Methods
- **Resources**
Manpower Allocation
Materials Allocation.

Environmental issues in the construction industry are not incorporated into the planning stage of construction projects but are managed reactively. According to the following article environmental issues were ignored in the planning stage of one project (ENR 1997, p. 52):

A demolition contractor in Pennsylvania was indicted on charges of violating the federal Clean Air Act in connection with asbestos-abatement projects. Howard Parsons, owner of Philadelphia Construction and Equipment Inc., was indicted on April 10, 1997 in federal district court for abatement and

waste disposal violations of a facility owned by Grant Paper Co. Grant's corporate successor, TGP Inc., who had previously pleaded guilty to clean-air violations at the site, agreed to a \$1.5 million cleanup of a waste dump site in a minority community in Philadelphia.

The following demonstrates how the costs increased due to negligence in the planning stage of one project (Black 1993, p. 34).

A 1992 U.S. Court of Appeals decision held a contractor who had unknowingly moved contaminated soil from one part of the site to another during excavation, liable for cleanup costs.

Engineering/construction firms are adopting risk control and risk financing strategies to counter the strict federal legislation of their environmental operations. These firms are equipping themselves with protection in the form of extensive insurance coverage to deal with any eventualities leading to litigation.

The following illustrates how environmental issues were managed reactively on one project in the construction industry (ENR 1998, p. 9).

T.J. Lambrecht Construction Inc., Joilet, Ill., pleaded guilty in federal court to violating the Clean Water Act and was fined \$200,000. The excavator's maintenance operation was adjacent to a tributary of the Des Plaines River, and solvents used to clean construction equipment and vehicles were allowed to run into sewer and floor drains on two occasions in December 1996. The effluent contained diesel, oil, acetone, xylene, and toluene. Since the violations, the company has installed a new water treatment system at its maintenance facility.

The following demonstrates how delays occurred on one project in the construction industry due to environmental issues (ENR 1994, p. 24).

Federal and state regulators claimed that the \$1.2-billion generating station in Clover, VA, will be one of the cleanest large coal-burning plants in the east. However, it had various environmental challenges.

An appeal of a permit approval hung it up for nearly two years. The contractor H. B. Zachry Co., San Antonio, Texas, could not break ground on Unit 1 in March 1990 as planned in the schedule. The start-up was delayed 23 months because environmentalists appealed an air permit issued by Virginia's Department of Air Pollution Control.

CURRENT RESEARCH

Research is being conducted at various institutions on developing methods to reduce pollution caused during construction. Several studies have estimated that construction and demolition wastes may account for up to 25% of the municipal solid waste in the United States (Apothekar 1990). Tchobanoglous provides a general definition of construction and demolition wastes in the article "Solid Wastes: Engineering Principles and Management Issues" (Tchobanoglous, Theisen, and Eliassen 1977, p.37):

Wastes from razed buildings and other structures are classified as demolition wastes. Wastes from the construction, remodeling, and repairing of individual residences, commercial buildings, and other structures are classified as construction wastes. These wastes are often classified as rubbish. The quantities produced are difficult to estimate and variable in composition, but may include dirt, stones, concrete, bricks, plaster, lumber, shingles, and plumbing, heating, and electrical parts.

Several studies have attempted to classify construction and demolition wastes. Spivey (Spivey 1974a, p.400) documented one of the earliest efforts to categorize construction wastes in his article "Environmental and Construction Management Engineers". He classified the most common components of work-site wastes as follows:

- Demolition Materials: concrete, brick, wallboard, plaster, and used lumber
- Packaging Materials: paper, cardboard, plastic, excelsior, and metal retaining bands
- Wood: trees, and scarp lumber
- Waste Concrete and Asphalt
- Garbage and Sanitary Waste
- Leftover Metal Products
- Rubber, Plastic, and Glass
- Pesticides and Pesticide Containers

Spivey (1974b) was among the first construction engineers to see the need for construction-waste-management systems and he established a waste-management

hierarchy of recycling, incineration, and landfilling. Unfortunately, Spivey's work did not directly address the issue of source reduction and today it is known that the single most effective way of dealing with any solid waste is not to create it in the first place (Gavilan and Bernold 1994).

Several studies have been conducted in the past to identify the sources of construction and demolition wastes. In the 1994 article, "Source Evaluation of Solid Waste in Building Construction" the authors stated that, "The origins of construction wastes should be studied to determine the most effective methods for dealing with these wastes at their source" (Gavilan and Bernold 1994). Gavilan and Bernold (1994, p.541) developed a conceptual framework that organizes the sources of construction waste into the following six categories:

- Design: blueprint error, detail error, and design changes
- Procurement: shipping error, and ordering error
- Handling of Materials: improper storage/deterioration, and improper handling
- Operation: human error (by craftsmen or other laborers), equipment malfunctions, acts of God (catastrophes, accidents, and weather)
- Residuals: leftover scrap and unreclaimable nonconsumables
- Others not listed

Additional sources of waste generation are: lack of attention paid to the size of the used products, lack of influence by contractors, and lack of knowledge about construction during design activities. External factors that can cause waste generation are theft and vandalism (Bossink and Brouwers 1996).

Several other efforts have been undertaken in the past to quantify the components of construction and demolition debris. Wilson, Foley, and Wiesman (1976) attempted to

quantify the constituents of demolition wastes as early as 1976. The Toronto Home Builders Association was able to quantify the components of waste resulting from residential construction (Apotheker 1990). The results indicated that dimensional lumber, drywall, masonry, and tile account for over half of the construction wastes generated during residential construction.

Research has indicated that construction waste makes a smaller contribution to the generation of construction and demolition wastes, but construction waste is a more important topic to quantify and analyze despite its lower volume in comparison to demolition waste (Bossink and Brouwers 1996). Construction waste is more difficult to recycle due to its high levels of contamination and a large degree of heterogeneity (Brooks, Adams, and Demsetz 1994).

There are several studies being conducted that are investigating methods to reuse materials, methods to reduce the amount of waste being generated, new ways for recycling waste more economically, and the impact of the incineration of waste (Knapp 1992; Castledine 1990; Kalin 1991; Spencer 1990; Schaub 1990).

Research is being conducted, and efforts are ongoing, to encourage the recycling of construction and demolition wastes. Construction and demolition wastes tend to be both bulky and heavy. Landfills reject construction and demolition wastes and illegal disposal of construction and demolition wastes has become an epidemic (Spencer 1990).

The Government is encouraging the development of markets for recycled materials of all types, including construction and demolition. The State of California has enacted legislation that requires the Department of Transportation to review and modify

its bid specifications for road base materials to include use of recycled materials, particularly asphalt, concrete, foundry slag, crumb rubber, ash, and glass (Spencer 1990). Several states have experimented with recycled concrete as pavement, road base, and road shoulders (Spencer 1990). The primary materials recycled are stumps, asphalt, and concrete. The stumps are converted into wood chips, topsoil, and mulch, while asphalt and concrete are converted into crushed aggregate, select fill, asphalt blends, and road base (Spencer 1989). The American Reclamation Corporation of Massachusetts is producing cold-mix asphalt from a blend of oil contaminated soil and asphalt roofing materials, combined with varying amounts of concrete, brick, and tile. This cold-mix paving material has been used in several municipal road surfacing projects in Massachusetts (Spencer 1990).

The U.S. Army Construction Engineering Research Laboratory (CERL) is investigating new and cost effective, methods for asbestos and lead paint removal. CERL is conducting research with the Georgia Institute of Technology to test and evaluate innovative concepts required for the vitrification and destruction of asbestos containing materials using Plasma Arc Technology (Circeo 1995). CERL is also conducting research programs that may lead to more economical lead removal methods. An in-situ vitrification process is being developed that will remove lead base paint from steel surfaces and immobilize the lead in a glass matrix. Wastes that contain no leachable lead may be disposed of as non-hazardous wastes (Drozdz 1997).

A study conducted by Kilbert and Coble (1995) proposed the consolidation of safety and environmental regulations at the federal and state levels either partially, or

totally, to provide the construction industry with one single agency that would provide uniform and accurate guidance. This would avoid unnecessary duplication of guidance and information, and eliminate conflicts that are caused by multiagency oversight.

However, none of these studies incorporate environmental considerations into the planning stage of projects. Unfortunately, environmental impact assessments (EIAs) used during the planning stage of projects, are used by top managers and not by project managers or construction site supervisors. Therefore, EIAs are too broad to be of value in managing environmental pollution on construction sites (Gavilan and Bernold 1994). Also, these studies do not directly deal with those individually involved in decision making processes, whose decisions have a direct impact on pollution in the construction environment, that cause increased environmental liability, and that negatively affect the time and cost on projects.

DECISION SUPPORT SYSTEMS IN CONSTRUCTION ENGINEERING AND MANAGEMENT

In order to investigate the viability of developing a Construction Environmentally Informed Decision Support System the area of decision support systems was also included in the literature review.

Decision support systems (DSS) allow decision makers to combine their judgement with computer output in a human/machine interface for producing meaningful information to support the decision making process. Decision support systems are capable of solving all types of problems (structured, semistructured, and unstructured) and use query capabilities to obtain information by request. As deemed appropriate, they

utilize mathematical and statistical models, as well as database elements, for solving problems under study. Decision support systems can be used as an integral part of the approach used by decision makers to problem solving as they provide a broader perspective by employing the “management by perception” principle.

Building on the capabilities of Management Information Systems, decision support systems are reoriented to produce information to support specific decision processes. There is a human/machine interface where these two components of the decision process are operating interactively to produce quality decisions. This results in synergistic decision making, where a combination of the manager and the computer results in more effective decision making than the two operating independently. Fundamentally, the main thrust of decision support systems is on decisions in which there is a sufficient structure for computer and mathematical models to be of value, but where the judgement of the manager is essential.

Characteristics of Decision Support Systems

The following are characteristics of decision support systems (Adeli 1988, p.116):

- Broad-based approach to supporting decision making-accent on “management by perception”
- Human/machine interface where human retains control over the decision making process
- Support decision making for solving structured, semistructured, and unstructured problems
- Utilization of appropriate mathematical and statistical models
- Query capabilities to obtain information by request (ad-hoc reports, “what if” scenarios”) - interactive mode
- Output directed to organization personnel at all levels
- Integrated subsystems
- Comprehensive data base
- Easy-to-use approach
- Adaptive system over time

Technical Capabilities of Decision Support Systems

A decision support system (DSS) is comprised of three sets of capabilities (Adeli 1988):

- Dialog Generation and Management System (DGMS)
- Data Base Management System (DBMS)
- Model Based Management System (MBMS)

Figure 2 shows the important components of a decision support system. The dialog component supports the use of the system by decision makers and the data component provides access to information on the raw materials used for decision making. The modeling component gives decision makers the ability to analyze the problem fully by developing and comparing alternative solutions. Data base management is an important component of DSS because of the diversity of the data that is required. A data base management system (DBMS) is used in creating, maintaining, accessing, updating, and protecting one or more databases.

Several decision support systems have been developed specifically for construction management. DBID: DSS for Bidding in Construction, is an analogy based decision support system, which assists contractors in preparing competitive bids for building projects (Moselhi, Hegazy, and Fazio 1993). This DSS uses neural networks to help determine the optimum markup for new bids based on past projects in Canada and the United States. The neural networks are able to predict the project outcome when provided with an assessment by the contractor of various project risks. In estimating optimum project markup for a new project, the uncertainty in the assessment of the contractor of the project risks is accounted for by a sensitivity analysis performed using

Figure 2 – Components of a Decision Support System

the Monte Carlo simulation technique which produces a measure of the probability of winning the bid at any desired level of markup.

COMPASS, a decision support system designed by Hastak, Halpin, and Vanegas (1996), is used for project cost control strategy and planning. Throughout the life cycle of a project, COMPASS methodology assists management in identifying attributes such as management errors, regulatory approval, and error/rework that may cause potential project cost escalation. Furthermore, it also assists management in formulating a cost control strategy for the project. COMPASS methodology allows constructors to utilize their experience, and past project performance data, to evaluate the probable escalation in the estimated project cost and in formulating a cost control strategy.

In 1994, Kahkonen (1994) developed an interactive decision support system for building construction scheduling. This DSS provides support for decisions made during early planning stages and helps define the logic of the plan. This DSS can also help in managing activity dependencies in the preparation of schedules.

Activity Duration Decision Support System (ADDSS) evaluates the impact of different factors on activity durations. The ADDSS employs fuzzy modus ponens deduction (FMPD) techniques to assess the impacts of duration factors on activity durations. These factors, which in the past were interpreted in linguistic values, are quantified into numerical values using angular fuzzy set theory. These numerical values are used to modify the activity durations affected by the cumulative impact of different site, climatic, resource, and management factors. A scheduler needs to provide

information regarding each affecting factor to the ADDSS. In return, ADDSS will furnish the scheduler with an assessment of the optimistic and pessimistic durations of an activity (Wu and Hadipriono 1994).

In 1996, a decision support system was developed to help with decisions related to the preservation of the civil infrastructure. The DSS provides assistance for decisions concerned with the three main tasks of infrastructure maintenance and rehabilitation: symptom observation, condition diagnosis, and treatment identification. The architecture of the system consists of knowledge bases, databases, analysis programs, and various interfaces (Shen and Grivas 1996).

A decision support system called DS² was developed to assist with decisions related to the construction of drilled shafts. DS² can reduce construction costs by providing expert advice that would otherwise be both difficult and very expensive to obtain. DS² is composed of three prototype expert systems that interface with spreadsheet, database, and graphics packages. DS² uses a heuristic, rule-based, backward chaining system to analyze geological information, suggests a construction method, prepares a preliminary cost estimate, and suggests key specification items (Fisher, O'Neil, and Contreras 1995).

These studies currently being conducted do not incorporate environmental considerations into the planning stage of projects. These studies do not directly deal with construction personnel involved in the decision making processes, whose decisions have

a direct impact on pollution in the construction environment, that cause increased environmental liability, and that negatively affect the time and cost of projects.

Chapter III - RESEARCH METHODOLOGY

This chapter describes the methodology used for this research project to investigate environmental issues during construction and their incorporation into the planning stage of projects. In addition to investigating the reasons environmental issues arise during construction, the parties responsible for causing environmental issues, and the time and cost impact of various environmental issues during construction, the research developed two modules, a General CEID and an Asbestos CEID.

The first module of the CEID is the General CEID and this CEID module contains a listing of the environmental issues that may arise during construction. This module assists construction personnel in identifying the environmental issues that may affect a project and suggests necessary precautions to be used during the planning stage, before the issues arise. This CEID module does not suggest alternatives to be adopted to avoid the environmental issues, but it will help increase the awareness of construction personnel about the environmental issues and the reasons the issues would be encountered. Construction personnel would then use their own judgement and experience to prevent the issue from arising at a later stage in the project.

The second module of the CEID is the Asbestos CEID and this module will assist construction personnel in making environmentally sound decisions on Asbestos Abatement Projects. This module focuses on Flooring and Roofing Abatement Projects and it can be used during the planning stage of projects. This module is a pilot module that demonstrates how the CEID program can be used as a decision support system.

Additional modules could also be added to the program that deal with other environmental issues existing in construction, such as lead abatement, noise pollution during excavation, and other issues.

The Asbestos CEID will assist construction personnel in:

- addressing environmental protection issues during prebid, preconstruction, and during the construction planning stages
- adopting procedures for reducing environmental pollution at the various phases of asbestos abatement projects, such as testing and inspecting, abatement, on-site waste handling, and off-site waste handling
- using environmentally sound methods for abatement, segregation, transportation and disposal of asbestos containing materials.

To achieve the research objectives, this research was conducted in the following four phases:

- Phase I: Literature Review
 - A literature review of journals, government documents and publications, and regulatory standards was conducted
 - A literature review of construction contracts and specifications was conducted
- Phase II: Development of the Questionnaire
 - The sample of construction experts to be surveyed was decided upon
 - The survey questionnaire was designed
- Phase III: Data Collection and Analysis
 - The data collected from surveys was coded, classified, and statistically analyzed
- Phase IV: Development of the Construction Environmentally Informed DSS (CEID)
 - The CEID program was developed
 - The program was debugged and tested

Knowledge acquisition is a crucial task in the development of a knowledge based system. Table 1 shows the methods that were used for knowledge acquisition on this

project (Adeli 1988). The methods included a literature review, questionnaires, and personal interviews.

Table 1: Methods Used for Knowledge Acquisition

SOURCE	METHOD
Journals, Government Documents and Publications, Regulatory Standards	Literature Review
Construction Contracts and Specifications	Literature Review
Construction Experts	Questionnaire, Personal Interviews

Phase I: Literature Review

A thorough review of the literature in journals, government documents and publications, regulatory standards (especially EPA regulations), and other related documents and publications was conducted to locate information related to this research project. This information was used to:

- Compile a list of environmental issues that have affected various construction projects
- Compile a list of asbestos containing materials encountered on various projects
- Compile a list of the various methods available for asbestos abatement.

Typical construction contracts and specifications for asbestos abatement projects were also investigated. The information collected was used to compile a list of all the materials, methods, procedures, or products (for asbestos abatement) that could have a potential negative impact on the environment.

The information gathered in the literature review was used to develop a questionnaire to gather knowledge from construction experts.

Phase II: Development of the Questionnaire

The CEID program identifies hazardous environmental issues and provides performance suggestions from the knowledge of experts, therefore, it is not merely a computer database of environmental standards. The data and knowledge collected established two types of environmental protection objectives, namely those required by law (regulatory) and those practiced by knowledgeable construction experts (heuristic). Regulatory data was collected during the literature review from the sources identified in phase I. Heuristics, or rules of thumb, are available in the construction industry but are difficult to articulate (Kartam 1997). Heuristic knowledge can be best thought of as the experience of experts in identifying problems and incorporating effective environmental protection techniques. Extracting expert knowledge from domain experts is the most difficult step in the development of any knowledge base.

Expert knowledge was collected by conducting a survey. Questionnaires were used to collect the knowledge of experts in this field. Conducting the survey involved the following:

- Sampling
- Designing the Questionnaire
- Data Collection
- Data Analysis

Sampling

The domain of experts came from a pool of construction management personnel. Experts were selected on the basis of certain capabilities and criteria in various types of projects. The experts must have had experience in working on asbestos abatement

projects. The experts also needed to have been involved in the planning stage of various projects.

The expert sample that was surveyed was selected by systematic sampling. When drawing a systematic sample from a list, the researcher first determines the number of entries on the list and the number of elements from the list that are to be selected. Dividing the latter by the former will produce a fraction which is the sample size to be surveyed (Fowler 1984). A list of construction management personnel meeting the above mentioned criteria was prepared. Construction management personnel working on the Los Angeles Unified School District, Pasadena Unified School District, Mountain View Los Altos Unified School District and other major renovation projects in California were included on the list. The easiest approach to determine the size of the sample being surveyed is an empirical approach that seeks what sample sizes have been used by other researchers with similar problems (Sudman 1983). The study of prebid and preconstruction planning processes by Laufer included a sample of 22 experts (Laufer et al. 1993). During the development of IKIS-Safety DSS by Kartam, interviews were conducted with 30 construction experts (Kartam 1997). The sample to be surveyed for this research project consisted of 43 construction experts.

Designing the Questionnaire

Due to a restricted budget, questionnaires were used for knowledge acquisition. The main advantage of questionnaires is that they place minimal demands on personnel and budgets and have no geographical constraints (Plumb and Spyridakis 1992).

A well-designed questionnaire should (Rossi, Wright, and Anderson 1983, p.14):

- meet the objectives of the research
- obtain the most complete and accurate information possible
- do this within limits of available time and resources.

An effective method of designing a questionnaire proposed by Sheatsley was used for this project and it is shown in Figure 3. This method uses the following cycle (Sheatsley 1983, p.219):

- decide what information is required
- draft some questions to elicit that information
- put them in a meaningful order and format
- pretest the result
- go back to step 1.

Survey questions included in the proposed questionnaire were *closed* and *open-ended questions*. The closed questions gather quantitative information that is used to establish various relationships. Open-ended questions request a reply in the respondent's own words. No answers are suggested and the respondents must provide answers on their own. The main advantage of open-ended questions is that they allow respondents to answer from their own frame of reference and reveal what is most salient to the respondents. Open-ended questions were used in this study to collect expert knowledge. The questionnaire used is provided in Appendix I.

The questionnaire was divided into three parts. The first part collected general company information that included the name of the firm, the position of the respondent within the firm, and the type of the firm. The categories of firms included Owner, Design

Figure 3: Designing a Questionnaire as Proposed by Sheatsley

Build, Construction Management, Engineering/Procurement/Construction, Architect/Engineer, Contracting, and Project Management firms. Table 2 summarizes the categories of firms that participated in this research project.

Table 2 – Categories of Firms

1	Architect/Engineer
2	Construction Management
3	Contractor
4	Design Build
5	Engineering/Procurement/Construction
6	Other
7	Owner
8	Project Management

The second part of the questionnaire collected information about environmental issues encountered on construction projects. This part of the questionnaire included open ended and closed questions. The following information was collected about projects where environmental issues were encountered:

- the location of the project
- the dollar value of the project
- the type of project

The categories of the projects for this research are summarized in Table 3.

Table 3 – Categories of Projects

1	Commercial Building
2	Heavy Industrial
3	Infrastructure
4	Institutional Building
5	Light Industrial
6	Military Construction
7	Other
8	Power Plants
9	Process Plants
10	Retrofitting

The second part of the questionnaire collected the following information about the environmental issues encountered:

- type of environmental issue
- description of the environmental issue
- measures taken to mitigate the environmental issue
- impact on time and cost related to the environmental issue on the project
- reason why the environmental issue was encountered
- party responsible for causing the environmental issue

Closed questions were used to collect information about the type of environmental issue, the reason why the environmental issue was encountered, and the party responsible for causing the environmental issue. Tables 4, 5, and 6 summarize the types of categories involved. Open-ended questions were used to collect information

about the description of environmental issue, and the measures taken to mitigate the environmental issue. The expert knowledge collected by the open-ended questions was used in the CEID program.

Table 4 – Categories of Environmental Issues

1	Air Pollution
2	Noise Pollution
3	Other
4	Pollution due to Toxic Substances
5	Water Pollution
6	Wildlife

Table 5 – Categories of Reasons

1	Errors in Design
2	Errors in Handling Residuals
3	Errors in Material Handling
4	Errors in Operation
5	Errors in Procurement
6	Other

Table 6 – Categories of Responsible Parties

1	Architect/Engineer
2	Construction Manager
3	Contractor
4	Other
5	Owner
6	Project Manager
7	Subcontractor

The third part of the questionnaire contained open-ended questions and collected expert knowledge that was used for the development of the Asbestos module of the CEID program. Information was collected about the procedures for reducing environmental pollution at various phases of asbestos abatement projects such as testing and inspection, abatement, on-site waste handling, and off-site waste handling

Phase III: Data Collection and Analysis

The data collected was analyzed and organized in a knowledge database. A total of 43 cases were documented, and the collected information was coded, classified, and statistically analyzed. The analysis of the collected data is explained in detail in Chapter V. The heuristic knowledge collected was used to develop the knowledge databases of the system.

Phase IV: Development of the Program

The program development is explained in detail in Chapter IV.

Chapter IV - PROGRAM DEVELOPMENT

This chapter describes the development of the Construction Environmentally Informed Decision Support System (CEID) program, discusses the structure and design of the program, and explores the system utilities of the program.

DEVELOPMENT OF THE PROGRAM

The knowledge database system was coded in Microsoft Access '97 as Microsoft Access has all the features of a classic relational database management system (RDBMS). It also allows alternative means of accessing information, as well as potential integration with other computer-based construction systems.

The computerized CEID program was evaluated and debugged several times. A manual was developed and written to support the system software program and to explain its use.

The development of CEID involved the development of General CEID and Asbestos CEID.

Development of General CEID

The General CEID can be used during prebid, preconstruction, and during construction planning stages of projects. This CEID module has a list of environmental issues that may arise on various construction projects. This module assists construction personnel in identifying the environmental issues that may affect a project and suggests necessary precautions to be used during the planning stage, before the issues arise. This CEID module does not suggest alternatives for adoption to avoid the environmental

issues, but it does increase the awareness of construction personnel on environmental issues and the reasons the issues would be encountered. Construction personnel would then use their own judgement and experience to prevent the issue from arising at a later stage in the project.

Data Structure

The main database structure of the General CEID program consists of three types of files: experts knowledge file, access files, and link files.

The experts knowledge file is the main source of heuristic information (collected by the surveys) of construction experts and it contains over 20 records on environmental issues that can be encountered on projects.

The access files allow users to retrieve environmental information according to the following coding options:

- Construction Specification Institute (CSI) System
- Keywords
- Type of pollution
- Type of project

The linkage between the knowledge file and access files is achieved through link files. Each link file simply consists of two data fields: one from the knowledge file, and the other from the access files. The database files created for the General CEID are shown in Table 7. In addition to creating database files, 4 queries, 6 forms, and 4 reports were generated. Several macros were written to facilitate navigation by the user within the program.

Table 7 – General CEID: Data Structure

Type of File	File Name
Experts Knowledge file	Expert Knowledge
Access file	CSI #
Access file	Keyword
Access file	Pollution Type
Access file	Project Type
Link file	Link_CSI
Link file	Link_Keyword
Link file	Link_PollutionType
Link file	Link_ProjectType

Experts Knowledge File

The knowledge file contains heuristic information from construction experts, collected by the survey. This file consists of three data fields: Expert_ID, Issue, and Measure, as shown in Figure 4. Expert_ID is a unique identification number, which identifies each record in the file. The Issue field contains information on environmental issues that may be encountered on projects, and the Measure field contains information on measures to adopt to avoid the environmental issue.

Access Files

The access files allow users to retrieve environmental information from the knowledge file according to the various coding options. Since four coding options,

Name of Database File: Experts Knowledge

Field Name	Field Type	Indexed
Expert_ID	Number	Yes (No Duplicates)
Issue	Memo	No
Measure	Memo	No

Figure 4 – General CEID: Experts Knowledge File

namely Construction Specification Institute system, keywords, type of pollution, and type of project were used for the General CEID, four access files were generated. Each coding option is classified, and the classification system is shown in Tables 8, 9, 10, and 11. Table 8 shows the classification for the CSI coding option, Table 9 shows the keyword coding option, Table 10 contains the pollution type coding option, and Table 11 has the project type coding option. Each access file consists of two data fields: unique classification number and a description of classification. The data structure of the access files generated is shown in Figure 5. Each record in the knowledge file is coded based on the four coding options.

Link Files

The linkage between the knowledge file and access files is achieved through link files. Each link file links one access file to the knowledge file. Four link files were created for linking the four access files to the knowledge file. Each link file consists of two data fields: the Expert_ID data field from the knowledge file and the unique classification number field from the access file. The data structure of link files generated is shown in Figure 6.

Program Features

The General CEID program can be executed by clicking on the General CEID icon through windows. Once the program is executed, the user sees the "Welcome Screen" (Form 1), a customized tool bar, and a customized menu bar. The "Welcome Screen" offers two options to the user as shown in Figure 7. The user may select "Stop" to quit the program, or may choose "Continue" to proceed further. These options are

Table 8 – Classification for Construction Specification System Coding Option

Division 1	General Requirements
Division 2	Site Construction
Division 3	Concrete
Division 4	Masonry
Division 5	Metals
Division 6	Wood and Plastics
Division 7	Thermal and Moisture Protection
Division 8	Doors and Windows
Division 9	Finishes
Division 10	Specialties
Division 11	Equipment
Division 12	Furnishings
Division 13	Special Construction
Division 14	Conveying Systems
Division 15	Mechanical
Division 16	Electrical

Table 9 – Classification for Keyword Coding Option

1	Hydrocarbons
2	Pipe Line
3	Heavy Equipment
4	Dust
5	Underground Tank
6	Petroleum
7	Fuel
8	Storm Water Disposal
9	River/Stream
10	Erosion
11	Trash and Debris
12	Residential Areas
13	Aesthetics
14	Odor Control
15	Pipe Driving
16	Endangered Species
17	Carbonmonoxide

Table 10 – Classification for Pollution Type Coding Option

1	Air Pollution
2	Noise Pollution
3	Pollution due to Toxic Substances
4	Water Pollution
5	Wildlife Pollution
6	Other

Table 11 – Classification for Project Type Coding Option

1	Commercial Building
2	Heavy Industrial
3	Infrastructure
4	Institutional Building
5	Light Industrial
6	Military Construction
7	Other
8	Power Plants
9	Process Plants
10	Retrofitting

Name of Database File: CSI #

Field Name	Field Type	Indexed
CSI_#	Number	Yes (No Duplicates)
CSI_Code	Text	Yes (No Duplicates)

Name of Database File: Keyword

Field Name	Field Type	Indexed
Keyword_ID	Text	Yes (No Duplicates)
Keyword	Text	Yes (No Duplicates)

Name of Database File: Pollution_Type

Field Name	Field Type	Indexed
Pollution_ID	Text	Yes (No Duplicates)
Pollution_Type	Text	Yes (No Duplicates)

Name of Database File: Project_Type

Field Name	Field Type	Indexed
Project_ID	Text	Yes (No Duplicates)
Project_Type	Text	Yes (No Duplicates)

Figure 5 – General CEID: Access Files

Name of Database File: Link_CSI

Field Name	Field Type	Indexed
CSI_#	Number	Yes (Duplicates OK)
Expert_ID	Number	Yes (Duplicates OK)

Name of Database File: Link_Keyword

Field Name	Field Type	Indexed
Keyword_ID	Text	Yes (Duplicates OK)
Expert_ID	Number	Yes (Duplicates OK)

Name of Database File: Link_PollutionType

Field Name	Field Type	Indexed
Pollution_ID	Text	Yes (Duplicates OK)
Expert_ID	Number	Yes (Duplicates OK)

Name of Database File: Link_ProjectType

Field Name	Field Type	Indexed
Project_ID	Text	Yes (Duplicates OK)
Expert_ID	Number	Yes (Duplicates OK)

Figure 6 – General CEID: Link Files

Construction Environmentally Informed Decision Support System General CEID

Welcome to General CEID. This General CEID contains a list of environmental issues that may arise on various construction projects. General CEID provides construction professionals with identifying environmental issues that may affect projects. General CEID suggests necessary actions to take during planning and before the issues arise. General CEID can be used during preconstruction and during construction planning of projects.

Figure 7 - General CEID: "Welcome Screen" (Form 1)

offered in the form of command buttons, and the user may select either of these two options by clicking the mouse button.

The customized tool bar allows users to perform functions such as saving, printing, editing, formatting, and sorting records or data files. The menu bar in the program is a standard Microsoft Access menu bar, with an extra option to update the General CEID data files. The user may use the "Update General CEID Files" option from the menu bar to edit knowledge, access, and link files. The customized tool and menu bar stay available to the user throughout execution of the program.

When the user chooses "Continue" from the Welcome Screen, the screen then displays "Form 2" which is shown in Figure 8. Form 2 allows users to access expert knowledge from the knowledge file based on any of the following coding options: Construction Specification Institute System, Keywords, Type of Pollution, or Type of Project. At this stage users can access expert knowledge records based on keywords, or type of pollution coding options.

When the user chooses the "Keywords" coding option from Form 2, "FrmKeyword" screen appears which is shown in Figure 9. Users can then choose any keyword to access the knowledge records. Users have the option of viewing or printing the report, or they may return to the Welcome Screen. A sample of the report generated is shown in Figure 10.

When users choose the "Type of Pollution" coding option from Form 2, they encounter the "FrmPollutionType" screen, which is shown in Figure 11. Users can choose any pollution type to access knowledge records. Users then have the option of

General CEID

How would you like to access experts knowledge record?

By CSI Number

By Keyword

By Project type

By Pollution type

Figure 8 - General CEID: Form 2

Figure 9 - General CEID: FrmKeyword

General CEID

Expert Knowledge by Keyword

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Issue	Measure
Petroleum	
Hydrocarbons contaminated water due to a broken pipe line	Used a dual pump system to clean-up the area
Soil contamination caused by leaking underground tank storing petroleum	Soil was removed from the jobsite using trucks. Testing lab at jobsite monitored total petroleum hydrocarbons in PPM. Level of contamination determined by haz-mat personnel in accordance with applicable regulations. The soil was taken to appropriate storage/dump facility.
Air, water, and soil contamination caused by leaking underground fuel tanks.	Tanks were removed. Soil treated by bio-remediation.
Storm water disposal from a petroleum refinery contained oily substance that polluted the river in which the storm water disposal was being done	An additional oil interceptor was installed at the plant boundary limit for storm water disposal and periodically the samples were tested.
Soil was contaminated with diesel fuel in the area that needed to be excavated for construction.	The soil was excavated and hauled away by a licensed hauler for contaminated soil, and taken to appropriate landfill for disposal.
Petroleum contaminated soil	Remove soil to haz-mat dump. Burning soil was also considered. However, burning soil has high mobilization costs and permits are difficult and time consuming to obtain.

Figure 10 - General CEID: Keyword Report

Figure 11 - General CEID: FrmPollutionType

viewing or printing the report, or returning to the Welcome Screen. A sample of the report generated is shown in Figure 12.

Development of Asbestos CEID

The second module of the CEID is the Asbestos CEID. This module is a decision support system, which will assist construction personnel in making environmentally sound decisions on Asbestos Abatement Projects.

The Asbestos CEID will assist construction personnel in:

- addressing environmental protection issues during prebid, preconstruction, and during the construction planning stages
- adopting procedures for reducing environmental pollution at the various phases of asbestos abatement projects, such as testing and inspecting, abatement, on-site waste handling, and off-site waste handling
- using environmentally sound methods for abatement, segregation, transportation and disposal of asbestos containing materials.

Hierarchical Program Design

The Asbestos CEID is designed to conform to a hierarchical structure as shown in Figure 13. Asbestos CEID has several levels of hierarchy. The master program is situated at the highest level and it branches out along a second level into four modules that are various phases of an asbestos abatement project. The four modules are as follows:

- Testing and Inspection module
- Asbestos Abatement module
- Onsite Waste Handling module
- Offsite Waste Handling module

General CEID

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Expert Knowledge by Pollution Type

Issue	Measure
Air Pollution	
Construction caused increased dust in jobsite area	Traffic flows were controlled, and jobsite watered every hour.
Air, water, and soil contamination caused by leaking underground fuel tanks.	Tanks were removed. Soil treated by bio-remediation.
Mitigation of air pollution during construction in residential areas.	Wet the soil for dust control.
Odor control during construction	Use scrubbers
Carbonmonoxide in tunnels	No gasoline powered equipment was used

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Figure 12 - General CEID: Pollution Type Report

Figure 13 - Asbestos CEID: Hierarchical Program Design

Each of the above four modules is a separate program. At this stage of the research only the Asbestos Abatement module is complete. This module was being used to test the viability of the program.

Asbestos Abatement Module

The Asbestos Abatement module also conforms to a hierarchical design structure and has three sub-levels of hierarchy as shown in Figure 14. In the first sub-level of this module are the five options regarding the status of the building to be demolished or renovated. The fifth option of the first sub-level, is divided into two options regarding the status of the asbestos containing material in the building, the second of which branches out further along a third sub-level into two options regarding the plan of abatement.

The implementation of a hierarchical design structure facilitates a chronological program execution, which is necessary to maintain logic within the decision tree used for the program.

Data Structure

The main database structure of the Asbestos CEID program consists of four types of files: experts knowledge file, information files, access files, and link files. These files are located at different levels of the hierarchy within the program as shown in Figure 15.

The experts knowledge file is the main source of heuristic information (collected by the surveys) of construction experts and it contains over 10 records on environmental issues that may be encountered on asbestos abatement projects.

Figure 14 - Asbestos Abatement Module: Hierarchical Program Design

Figure 15 - Asbestos Abatement Module: Heirarchical Location of Data Files

The information files contain information on building status, material to be abated, and the method used for abatement. These files are located at different levels of the hierarchy in the program and they maintain the program logic.

The access files allow users to retrieve expert knowledge according to the following options:

- Material to be abated and method to be used for abatement, if asbestos abatement is done prior to demolition
- Method used for asbestos abatement, if building demolition is done with asbestos containing material

The linkage between the knowledge file and access files is achieved through link files. Each link file simply consists of two data fields: one from the knowledge file, and the other from the access files. The database files created for the Asbestos CEID are shown in Table 12. In addition to creating database files, four queries, six forms, and four reports were generated. Several macros were written to facilitate navigation by the user within the program.

Experts Knowledge File

The knowledge file contains heuristic information obtained from construction experts that was collected by the survey. This file consists of two data fields: `Expert_ID`, and `Expert_Knowledge`, as shown in Figure 16. `Expert_ID` is a unique identification number, that identifies each record in the file. The `Expert_Knowledge` field contains heuristic knowledge that can be used to avoid environmental issues that may be encountered on asbestos abatement projects. The `Expert_Knowledge` file is located at the lower most level of the hierarchy as shown in Figure 15.

Table 12 – Asbestos Abatement Module of Asbestos CEID: Data Structure

Type of File	File Name
Experts Knowledge file	Expert_Knowledge
Information file	AA_BldgSts
Information file	AA_Material1
Information file	AA_Method1
Information file	AA_Method2
Access file	AA_Mtrl_Met_1
Access file	AA_Met_2
Link file	AA_Link_MtrlMet1
Link file	AA_Link_Met2

Information Files

Information files contain information that is essential to maintaining the logic within the program. Four information files were created for the Asbestos Abatement module and these files are located at various levels of hierarchy.

The AA_BldgSts file contains information on the status of the building to be demolished and is located in the first sub-level of the Asbestos Abatement module of the program. This file consists of three data fields: Building_Status, Description and Detail, as shown in Figure 17. Building_Status is a unique identification code, that describes the status of a building. The Description field contains a description of the building status and the Detail field has information that can be used to avoid environmental issues.

Name of Database File: Experts Knowledge

Field Name	Field Type	Indexed
Expert_ID	Text	Yes (No Duplicates)
Expert_Knowledge	Memo	No

Figure 16 – Asbestos CEID: Experts Knowledge File

The AA_Material1 file contains information on asbestos containing materials and it is located at the lower most level of hierarchy. This file consists of five data fields as shown in Figure 17. The Material_ID data field is a unique identification code, the Material field describes the asbestos containing material, the Type field identifies the category to which the material belongs (Category I or Category II), and the Material_Info_I and Material_Info_II fields contain heuristic information on the asbestos containing material.

The AA_Method1 file contains information on the various methods that can be used to abate asbestos containing material prior to demolition. This file consists of four data fields as shown in Figure 17. The Method_ID data field is a unique identification code, the Method_Description field describes the method used for abatement, and the Method_Info_I and Method_Info_II fields contain heuristic information on the method.

The AA_Method2 file contains information on the various methods that can be used to demolish a building with asbestos containing material. This file consists of four data fields as shown in Figure 17. The Method_ID data field is a unique identification code, the Method_Description field describes the method used for abatement, and the Method_Info_I and Method_Info_II fields contain heuristic information on the method.

Access Files

The access files allow users to retrieve expert knowledge. Two access files were created for the Asbestos Abatement module and these are shown in Figure 18.

Name of Database File: AA_BldgSts

Field Name	Field Type	Indexed
Building_Status	Text	Yes (No Duplicates)
Description	Memo	No
Detail	Memo	No

Name of Database File: AA_Material1

Field Name	Field Type	Indexed
Material_ID	Text	Yes (No Duplicates)
Material	Text	No
Type	Text	Yes (Duplicates OK)
Material_Info_I	Memo	No
Material_Info_II	Memo	No

Name of Database File: AA_Method1

Field Name	Field Type	Indexed
Method_ID	Text	Yes (No Duplicates)
Method_Description	Text	No
Method_Info_I	Memo	No
Method_Info_II	Memo	No

Figure 17– Asbestos CEID: Information Files

Name of Database File: AA_Method2

Field Name	Field Type	Indexed
Method_ID	Text	Yes (No Duplicates)
Method_Description	Text	No
Method_Info_I	Memo	No
Method_Info_II	Memo	No

Figure 17-- Asbestos CEID: Information Files

Name of Database File: AA_Mtrl_Met_1

Field Name	Field Type	Indexed
Material_ID	Text	Yes (Duplicates OK)
Method_ID	Text	Yes (Duplicates OK)
Method_Result	Text	Yes (Duplicates OK)
No.	Number	Yes (No Duplicates)

Name of Database File: AA_Mtrl_Met_2

Field Name	Field Type	Indexed
Method_ID	Text	Yes (Duplicates OK)
Method_Result	Text	Yes (Duplicates OK)
No.	Number	Yes (No Duplicates)

Figure 18— Asbestos CEID: Access Files

The AA_Mtrl_Met_1 file allows users to access expert knowledge for abatement of asbestos containing material prior to demolition. This file consists of four data fields. The Material_ID field from the AA_Material1 file and the Method_ID field from the AA_Method1 file, contain information about the material and the respective method that can be used for abatement. The Method_Result field contains information on whether the method used to abate the asbestos containing material makes the abated material regulated asbestos containing material (RACM) or not. The No. field identifies each material-method combination with a unique number.

The AA_Mtrl_Met_2 file allows users to access expert knowledge for demolition of buildings with asbestos containing material. This file consists of three data fields. The Method_ID field from AA_Method2 file contains information about the method that can be used for demolition. The Method_Result field contains information on whether the method used to demolish the building with asbestos containing material, makes the abated material regulated asbestos containing material (RACM) or not. The No. field identifies each method with a unique number.

Link Files

The linkage between the knowledge file and access files is achieved through link files. Each link file links one access file to the knowledge file. Two link files were created for linking the two access files to the knowledge file. Each link file consists of two data fields: the Expert_ID data field from the knowledge file and the unique classification number field from the access file. The data structure of link files generated is shown in Figure 19.

Name of Database File: AA_Link_MtrlMet1

Field Name	Field Type	Indexed
No	Number	Yes (Duplicates OK)
Expert_ID	Text	Yes (Duplicates OK)

Name of Database File: AA_Link_Met2

Field Name	Field Type	Indexed
No	Number	Yes (Duplicates OK)
Expert_ID	Text	Yes (Duplicates OK)

Figure 19— Asbestos CEID: Link Files

Program Features

The Asbestos CEID program can be executed by clicking on the Asbestos CEID icon through windows. Once the program is executed, the user sees the “Welcome Screen” (Form 1), a customized tool bar, and a customized menu bar. The “Welcome Screen” offers two options to the user as shown in Figure 20. The user may select “Stop” to quit the program, or may choose “Continue” to proceed further. These options are offered in the form of command buttons, and the user may select either of these two options by clicking the mouse button.

The customized tool bar allows users to perform functions such as saving, printing, editing, formatting, and sorting records or data files. The menu bar in the program is a standard Microsoft Access menu bar, with an extra option to update the General CEID data files. The user may use the “Update Asbestos CEID Files” option from the menu bar to edit knowledge, information, access, and link files. The customized tool and menu bar stay available to the user throughout execution of the program.

When the user chooses “Continue” from the Welcome Screen, the screen then displays “Form 2” which is shown in Figure 21. Form 2 allows users to access any of the four modules: Testing and Inspection module, Asbestos Abatement module, Onsite Waste Handling module, or Offsite Waste Handling module of the Asbestos CEID. At this stage the Asbestos Abatement module is completely designed and is available to users.

When the user chooses the Asbestos Abatement module option from Form2, the user sees the form “AA_fmBldgSts”, which is as shown in Figure 22. This form offers

Figure 20 - Asbestos CEID: "Welcome Screen" (Form 1)

<h2>Asbestos CEID</h2> <p>A typical asbestos abatement project consists of following four phases. On which of the following phases would you like to have information?</p>
☐ Testing and Inspection		
☐ Asbestos Abatement		
☐ Onsite Waste Handling		
☐ Offsite Waste Handling		

Figure 21 - Asbestos CEID: Form 2

Asbestos CEID Asbestos Abatement
Is the building to be demolished any of the following?
☐ Under State and Local Regulations
☐ Under Unsafe Building Declarations
☐ Utilized by Fire Departments for Practice Exercises
☐ Will be Demolished by Intentional Burning
☐ None of the above

Figure 22 - Asbestos CEID: AA_frmBldgSts

the user five options regarding the status of the building to be demolished. These five options regarding the building status are shown in Table 13. If the user chooses any of the first four options he sees a report which contains special instructions to be followed for the respective building status. A sample report for a building under state and local regulations is as shown in Figure 23. When the user chooses the last option on form AA_frmBldgSts he sees form “AA_frmMtrlSts”.

Table 13 – Asbestos CEID: Status of the Building to be Demolished

1	Under State and Local Regulations
2	Under Unsafe Building Declarations
3	Utilized by Fire Department for Practice Exercises
4	Will be Demolished by Intentional Burning
5	None of the above

The AA_frmMtrlSts form offers the user two options regarding the status of the material in the building, as shown in Figure 24. The two options offered on this form are shown in Table 14. The first option is not available at this stage. When the user chooses the second option he sees the form “AA_frmPlnAbt” which is as shown in Figure 25.

Table 14 – Asbestos CEID: Status of the Asbestos Containing Material in the Building

1	Friable
2	Non-Friable

Asbestos CEID**Asbestos Abatement****Instructions for Special Building Status***Description of Building Status*

Under State and Local Regulations

Special Instructions

State and local asbestos regulations are more stringent than the asbestos NESHAP standards.

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Figure 23 - Asbestos CEID: Building Status Report

Asbestos CEID
Asbestos Material
Testing and Inspection Results indicate that the Asbestos Containing Material in the building is:
☐ <i>Removable</i>
☐ <i>Non-Removable</i>

Figure 24 - Asbestos CEID: AA_frmMtrISts

Asbestos CEID Asbestos Abatement
How do you prefer plan to abate the material? © Demolition of the facility with Asbestos Containing Material © Abatement of the Asbestos Containing Material prior to demolition

Figure 25 - Asbestos CEID: AA_frmPInAbt

The AA_frmPlnAbt form offers the user two options regarding the plan of abatement, that are shown in Table 15. When the user chooses the first option he sees the form “AA_frmMet2” and when he chooses the second option he sees the form “AA_frmMtrlMet1”.

Table 15 – Asbestos CEID: Plan of Abatement of the Asbestos Containing Material

1	Demolition of Facility with Asbestos Containing Material
2	Abatement of Asbestos Containing Material prior to Demolition

The AA_frmMet2 form, which is, as shown in Figure 26, allows the user to choose a method to carry out the demolition of the building with the asbestos containing material. The various methods are listed in Table 16. The user has the choice of viewing, or printing the report. A sample report is shown in Figure 27.

Table 16 – Asbestos CEID: Methods Available for Demolition of Facility with Asbestos Containing Material

1	Bulldozers and Similar Machinery
2	Cranes
3	Explosions/Implosions
4	Hydraulic Excavators

The AA_frmMtrlMet1 form, which is, as shown in Figure 28, allows the user to choose the material and respective method to carry out the abatement of asbestos

Asbestos CEID Asbestos Abatement Demolition of facility prior to asbestos abatement	Hydraulic Excavators
Which method will you use to demolish the facility?

Figure 26 - Asbestos CEID: AA_frmMet2

Non-friable asbestos; Demolition of facility prior to asbestos abatement***Method Description***

Hydraulic Excavators

Method Information

Easier to use and provide greater control during demolition.

Nearby buildings must be protected from the falling debris; plywood may be applied over the windows and rubber tires may be used to cushion and prevent damage to walls of adjacent structures.

Method Result

Causes CatII ACM, but not CatI ACM to become RACM

Expert Knowledge

None

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Figure 27 - Asbestos CEID: Report for Demolition of Facility with ACM

Asbestos CEID	
Abatement of Asbestos Containing Material prior to demolition	
Which material do you wish to abate?	Resilient Floor Covering
Which method will you use?	Dry Ice
☐	☐

Figure 28 - Asbestos CEID: AA_frmMtrlMet1

containing material prior to demolition. The various materials and their respective methods are listed in Table 17. The user has the choice of viewing, or printing the report. A sample report is shown in Figure 29.

Table 17 – Asbestos CEID: Asbestos Containing Materials and Methods used for their Abatement prior to Demolition

	Asbestos Containing Material	Method for Abatement prior to Demolition
1_a	Resilient Floor Covering	Demolition with Floor Tiles in Place
1_b	Resilient Floor Covering	Dry Ice
1_c	Resilient Floor Covering	Infrared Machines
1_d	Resilient Floor Covering	Shot Blasters
1_e	Resilient Floor Covering	Water/Amended Water/Solvents
2_a	Asbestos Cement Products	Cranes
2_b	Asbestos Cement Products	Explosions/Implosions
2_c	Asbestos Cement Products	Hydraulic Excavators
3_a	Asphalt Roofing Products	Power Plows
3_b	Asphalt Roofing Products	Sawing
4_a	Gaskets	Data not available
5_a	Packings	Data not available
6_a	Transite Board Shingles	Data not available

The CEID program was debugged and tested several times.

Asbestos CEID

Non-friable ACM; Abatement of ACM prior to demolition

Material	Resilient Floor Covering
Type	CatI
Material Information	Removal prior to demolition is required when the substrate to which the floor covering is attached is to be recycled or salvaged.

Method Description	Dry Ice
Method Information	As long as tiles are not extensively damaged, they are not RACM.

Result	Not RACM
---------------	----------

Expert Knowledge	On school projects, communication with the school principal assures that the teachers are prepared for the work
-------------------------	---

Expert Knowledge	On school projects, arrange for swing classrooms so that the classrooms where asbestos abatement is being carried out are free of occupation, to avoid any hazard
-------------------------	---

Figure 29 - Asbestos CEID: Report for Abatement of ACM prior to Demolition

Chapter V - RESULTS OF THE STUDY

This chapter presents the results of the research investigation. As a result of the research, a total of 43 cases were documented and the information collected was coded, classified, and statistically analyzed. The heuristic knowledge collected was used to develop the CEID program databases of the system.

DATA ANALYSIS

In addition to developing the Construction Environmentally Informed Decision Support System (CEID), the research also investigated environmental issues during construction and the following parameters:

- the reason why a particular environmental issue was encountered
- the party responsible for causing the environmental issue
- the time and cost impact of environmental issues encountered on the project

Tables 18, 19, 20, and 21 contain the results obtained from the study.

RESULTS OF THE STUDY

The data collected from the questionnaires was used in the following three analyses. Expert knowledge collected in the study was used to develop knowledge databases of the CEID program.

Analysis One

Table 18 shows the trend between environmental issues and the reasons why the environmental issues were encountered. Out of the 43 cases documented, environmental issues on approximately 65% of the cases were due to existing site conditions. *Therefore, existing site conditions are the major causes of environmental pollution during construction and they negatively affect the time and cost of projects.*

The following examples formulate a better understanding of the above analysis. Existing site conditions are often not revealed during the testing and inspection stages of projects but are encountered during construction. On a Los Angeles harbor project that involved demolition of an underground pump station situated inside a reinforced concrete shell a soils test was carried out prior to the beginning of construction. However, during construction soil contaminated by hydrocarbons was encountered. The emissions from the soil caused excessive air pollution during construction. The boring samples had failed to reveal this site condition which negatively affected the project by 33 working days and \$80,000. As construction progressed, it was revealed that the existing paint on the concrete shell was lead-based paint that had to be abated prior to demolition of the pump station. This site condition delayed the project by 44 working days and increased construction costs by \$60,000.

During construction of tertiary filters for a wastewater treatment plant in Los Angeles, soil contaminated with diesel fuel was encountered during excavation. Core drilling had been performed, but the cores had missed the contaminated soil area. The diesel fumes caused air pollution. The contaminated soil was excavated and hauled away

Table 18- Type of Pollution Vs Major Reason

Type of Pollution	Errors in Design	Errors in Procurement	Errors in Material Handling	Errors in Operation	Errors in Handling Residuals	Existing Site Conditions	Other	Total No. of Cases
Air				3		11		14
Noise				2		2		4
Pollution due to Toxic Substances	1				1	7		9
Water	3			2	3	5		13
Wildlife						2		2
Other						1		1
Total	4	0	0	7	4	28	0	43
Percentage	9%	0%	0%	16%	9%	65%	0%	100%

by a licensed hauler to an appropriate landfill for disposal. This site condition delayed the project by 30 working days and increased construction costs by \$150,000.

Testing carried out prior to construction often leads to an increase in project costs, and the owner may sometimes choose not to perform thorough testing. At a \$ 1.7 million project in Pasadena, in an area that used to be a landfill, the owner had elected not to perform soils test. During trenching debris and trash several feet deep were encountered. The unsuitable soil was removed to a depth of 4 feet and new soil was imported for filling. This site condition delayed the project by 30 working days and increased construction costs by \$50,000.

In some cases, environmental issues due to existing site conditions are known to construction managers during the preparation of the Environmental Impact Report (EIR). At a \$ 60 million retrofitting project in San Jose, the construction manager was aware that air, noise, and water pollution might occur during construction and necessary measures were taken to avoid environmental pollution. The project was adjacent to a housing area, and the construction manager met with the community to solicit their input during planning and decision-making stages. These measures helped avoid environmental pollution during construction but the impact on the project cost and time due to environmental issues increased the project costs by \$ 600,000.

At a \$84 million project in El Segundo, the construction manager expected environmental issues to occur during construction. Necessary measures were taken to mitigate the issues, but environmental issues extended the project duration by 10% and increased the project costs by 15%. The construction manager on the project stated: "The

job and the circumstances created the issues. These issues were expected. The project's proximity to housing, ocean, and wildlife was responsible for negatively affecting project time and cost".

Analysis Two

Table 19 shows the trend between environmental issues and the party responsible for causing the environmental issue. As suggested in hypothesis one, and as shown in Table 19, existing site conditions create environmental issues during construction and no one party can be held responsible. However, out of the 43 cases documented, the contractor was responsible for causing environmental issues on approximately 14% of the cases. *Therefore, there is no one party responsible for creating environmental issues during construction. However, construction managers agreed that the contractor is responsible for environmental pollution during construction, in a significant number of situations.*

A construction manager for the Los Angeles Unified School District project stated: "In many cases the contractor does not care about the jobsite environment, and preventing pollution during construction is not a priority for the contractor. The only factors contractors consider during construction are time and money. At a project in Las Vegas, the contractor's equipment was leaking and causing excessive soil contamination. The contractor was willing to repair his equipment only if the cost of the potential citation was more than getting his equipment fixed. On another project, the contractor was dumping hazardous residuals into the drainage system and on being asked to take the

Table 19 - Type of Pollution Vs Party Responsible

Type of Pollution	A/E	CM	Contractor	Owner	PM	Subcontractor	Existing Site Conditions	Other	Total No. of Cases
Air			2	1		0	11		14
Noise			2				2		4
Pollution due to Toxic Substances	1					1	7		9
Water	3	1	2	1		1	5		13
Wildlife							2		2
Other							1		1
Total	4	1	6	2	0	2	28	0	43
Percentage	9%	2%	14%	5%	0%	5%	65%	0%	100%

waste to an appropriate landfill, the contractor remarked that he had been dumping waste in the drainage system for as long as he could remember”.

A construction manager for the Los Angeles Metro Rail project stated: “The large contracting firms are more sophisticated, and are more sensitive to jobsite environment than the small or the medium size contractors. The large contractors usually have a safety officer on their staff, who establishes procedures and guidelines to minimize environmental liability during construction. The small and medium size contractors are usually not aware of the various environmental laws that apply during construction. When working with small or medium size contractors the construction manager should follow the following three basic steps to avoid environmental penalties and citations: prior to the beginning of construction make a list all the environmental laws that will apply during construction; develop a plan with the contractor to abide by all the laws; and implement the plan”.

At a \$ 4 million project in San Luis Obispo, the contractor dumped construction debris in a dry creek. The department of fish and game got involved and directed the contractor to remove all debris.

Analysis Three

The time and cost impact of environmental issues on projects is documented in Tables 20 and 21 respectively. Out of the 43 cases documented, only 28 cases had information regarding time and cost impact of environmental issues on projects. A median value was calculated for the time and cost impact of environmental issues which formulates the following analysis. *Each environmental issue encountered on a project*

Table 20 - Time Impact of Environmental Issues

Case #	Negative Time Impact
	<i>Working Days</i>
1	132
2	20
3	25
4	20
5	1500
6	10
7	0
8	44
9	30
10	30
11	396
12	120
13	120
14	30
15	22
16	15
17	30
18	30
19	30
20	0
21	0
22	33
23	44
24	396
25	NA
26	NA
27	40
28	10

Median:	30
----------------	-----------

Working Days

NA: Data not available

Table 21 - Cost Impact of Environmental Issues

Case #	Negative Cost Impact
	<i>Dollars</i>
1	\$15,840.00
2	NA
3	\$85,000.00
4	\$5,000.00
5	\$250,000,000.00
6	\$0.00
7	\$0.00
8	NA
9	\$25,000.00
10	\$150,000.00
11	\$2,500,000.00
12	\$125,000.00
13	\$125,000.00
14	\$125,000.00
15	\$100,000.00
16	\$100,000.00
17	\$250,000.00
18	\$150,000.00
19	\$50,000.00
20	\$60,000.00
21	\$120,000,000.00
22	\$80,000.00
23	\$60,000.00
24	\$400,000.00
25	\$12,600,000.00
26	\$15,000.00
27	\$0.00
28	\$5,000.00

Median: \$92,500.00

NA: Data not available

will negatively affect the project by approximately 30 working days, and \$90,000 in direct costs.

The following discussions provide a better understanding of the above analysis. When an environmental issue is encountered on a project, the project is delayed by approximately 30 working days, during which the environmental issue will be “fixed”. However, several construction managers agreed that for a significant number of projects, a project might be delayed in spite of no pollution being caused at the jobsite. The delay is due to the difficult and time-consuming process of obtaining environmental permits.

At an infrastructure project in Los Angeles petroleum contaminated soil was encountered during construction. The soil was excavated and moved to a hazardous material dump. The contractor had considered a less expensive alternative of burning soil, but could not do so because obtaining a permit for the job would have delayed the project by an unreasonable period.

Each environmental issue increases the project’s direct costs by approximately \$92,500. The increase in cost is due to “fixing” the environmental issue. Sometimes environmental issues cause “impacts” on projects and may lead to a further increase in project costs.

A construction manager on Los Angeles harbor project stated: “On this project an environmental issue was encountered due to existing site conditions. The issue resulted in a change order increase of \$60,000 in project costs and delayed the project by 2 months. As the project was nearing completion, the contractor made an “issue”. Due to an unexpected delay the project had encountered, the contractor had to renew his equipment

lease in order to complete the project. The contractor had to be paid the lease amount, which increased the project costs further”.

Chapter VI – CONCLUSION

CONCLUSION

This research work was conducted to gather information on environmental issues during construction. This information was analyzed, to investigate the reasons environmental issues arise during construction, the parties responsible for causing environmental issues, and the time and cost impact of various environmental issues during construction. The knowledge of experts collected during the study was used in the development of Construction Environmentally Informed Decision Support System.

The implementation of the Construction Environmentally Informed Decision Support System program will result in significant advances for members of the construction industry. The CEID proactively addresses environmental protection issues and can avoid or reduce the undesirable effects of environmental hazards and pollutants that may surface during a project. The CEID assists construction personnel in making environmentally sound decisions and in achieving the project objectives of completing a project as specified in the contract, on schedule, and within budget. The other benefits associated with the implementation of the CEID include reducing pollution in the environment during construction processes, improved worker safety, and reduced environmental liability.

Each environmental issue that occurs during construction generates expertise and experience in recognizing and rectifying mistakes. This knowledge generated, is however costly to the companies in time, actual costs, and worker safety and also causes

environmental pollution. This knowledge can be accumulated by the CEID, and can be used by future construction personnel to avoid the costs of relearning the same environmental lessons on various projects.

FURTHER RESEARCH

Further research can be conducted to gather additional knowledge relating to environmental issues during construction. This additional knowledge can be incorporated by the extendable data structure of the CEID program, and can enhance the capability of the program.

Asbestos CEID module is a pilot module that demonstrated how the CEID program can be used as a decision support system. Similar additional modules can be developed and added to the program that deal with other environmental issues existing in construction, such as lead abatement, noise pollution during excavation, and other issues. The data structure designed for Asbestos CEID is adaptable and can be very easily used for additional modules.

Also, the research methodology used in the development of the CEID provides a framework that can be used to address other issues that are usually managed reactively in the construction industry such as political issues, social issues, historical issues, and funding issues.

A practical implementation of the CEID program on an actual construction project will provide more information on how the CEID program, and this research in general can be expanded.

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October 1, 1998

Dear Construction Expert:

Your expertise is being solicited to help identify the environmental issues that may affect construction projects and provide suggestions on the precautions to be used during the planning stage, before the issue arises. This research project is being conducted in the Civil Engineering Department at San José State University in San Jose, California. A major part of this research will be the development of a computer decision support system called the "Construction Environmentally Informed Decision Support System (CEID)".

The "CEID: Construction Environmentally Informed Decision Support System" – will be a proactive environmental decision making tool that integrates environmental issues related to construction processes into the planning stage of a project. The CEID will be a decision support system that contains a comprehensive knowledge database developed from the experience of construction experts such as yourself.

You have been identified as a potential contributor to this research project and it is hoped that you will be able to provide your expertise. The information you provide will be used to develop the CEID that will assist construction personnel in making more environmentally informed decisions during the planning stage of projects. All the information that you provide will be kept strictly confidential. The information collected during this project will be used in a Master's Thesis by the research assistant.

Enclosed please find a copy of a questionnaire. Due to the restricted time schedule of this project, we request that you complete and return the questionnaire by October 30, 1998. The completed questionnaire should be mailed to 6101 W Colgate Ave., Los Angeles, CA 90036 or faxed to (213) 487-1145.

If you have any questions, or need further clarification on any matter, please call (213) 931-7410. We would like to thank you in advance for your time and cooperation.

Sincerely,

Chavaldar
Chandran Havaladar
Graduate Research Assistant

Dr. Janet K. Yates
Professor and Coordinator
Construction Engineering
and Management Program

DEVELOPMENT OF THE CONSTRUCTION ENVIRONMENTALLY INFORMED DECISION SUPPORT SYSTEM

RESEARCH INTENT

The environmental consequences of excessive waste production, improperly managed residuals, and contaminant transport through air and water are widely recognized and have led to the pollution prevention and waste minimization paradigms of the 1990s.

One industry that is currently implementing environmental protection concepts is the construction industry. Strict federal, state, and local regulations are used to protect the environment. Environmental citations, penalties, and fines can cause significant negative time and cost impacts to projects. During the life cycle of a project, important decisions are sometimes made with limited knowledge about environmental factors. A key reason for this situation is a lack of tools that can be used to provide an informed basis for implementing environmentally sound practices. Most design, engineering, construction, or construction management firms do not have environmental specialists on their staff. There are very few concise guidelines available for construction personnel to assist them in making environmentally sound decisions during the planning stage of construction projects. Even less knowledge about environmental issues is available at construction job sites where things move quickly and there is little time for investigating the consequences of chosen actions and decisions.

One way to overcome the deficiencies that exist related to environmental issues in construction is to create a computer decision support system that assists construction personnel in making more environmentally informed decisions during the planning stage of projects.

This research will proactively investigate the environmental issues that should be considered during the planning stage of a construction project to avoid and reduce the undesirable effects of environmental hazards and pollutants that may surface during a project. A major part of this research will be the development of a computer decision support system called the Construction Environmentally Informed Decision Support System (CEID). The CEID will provide a decision support system that contains a comprehensive knowledge database derived from the experience of construction experts. This knowledge database will assist construction personnel in identifying environmental issues, and adopting environmentally safe alternatives, during the planning stage of projects.

The research will develop 2 modules, the General CEID and the Asbestos CEID.

The General CEID module will have a list of environmental issues that may arise on various construction projects. This module will assist construction personnel in identifying the environmental issues that may affect the project and suggest necessary precautions to be used during the planning stage, before the issues arise.

The Asbestos CEID will assist construction personnel in making environmentally sound decisions on Asbestos Abatement Projects. This module will focus on Flooring and Roofing Abatement Projects and it can be used during the planning stage of projects. This module will be a pilot module that demonstrates how the CEID program can be used as a decision support system. Additional modules could also be added to the program that deal with other environmental issues existing in construction, such as lead abatement, and noise pollution during excavation.

PROJECT MANAGEMENT QUESTIONNAIRE
CEID: Construction Environmentally Informed Decision Support System
San Jose State University

Section I: General Company Information

1. Name of Company: _____

2. Address: _____

3. Phone: _____ 4. FAX: _____

5. Name of Respondent (Optional): _____

6. Position in the Company: _____

7. What type of firm is your company? (Please choose only one)

Architect/Engineer	
Construction Management	
Contractor	
Design Build	
Engineering/Procurement/Construction	
Owner	
Project Management	
Other	

8. Number of years in construction: _____

Section II:

"Environmental Issues" include citations from the Environmental Pollution Agency (EPA), the impact on project cost and time due to environmentalists, environmental pollution due to construction and other issues.

Please answer the following questions pertaining to any one environmental issue you have encountered on a specific project.

1. Location of Project (City, State): _____

2. Dollar Value of Project: _____

3. Type of Project (Please choose only one):

Commercial Building	
Heavy Industrial	
Infrastructure	
Institutional Building	
Light Industrial	
Military Construction	
Power Plants	
Process Plants	
Retrofitting	
Other	

4. Please identify from the following the type of environmental issue you have encountered on the project (Please choose only one).

Air Pollution	
Noise Pollution	
Pollution due to Toxic Substances	
Water Pollution	
Wildlife	
Other	

5. Please describe the environmental issue you have encountered.

6. Please describe the measures taken to mitigate the issue.

7. What was the approximate impact on time and cost related to the issue on the project?

Time impact: _____ Working Days

Cost impact: _____ Dollars

8. Please identify the major reason why the above mentioned issue was encountered.

Errors in Design	
Errors in Procurement	
Errors in Material Handling	
Errors in Operation	
Errors in Handling Residuals	
Other	

9. Please identify the party responsible for causing the issue.
(Please choose only one).

Architect/Engineer	
Construction Manager	
Contractor	
Owner	
Project Manager	
Subcontractor	
Other	

Section III:

Typical Asbestos Abatement Projects involve testing and inspection, asbestos abatement, onsite waste handling, and offsite waste handling.

Please answer the following questions pertaining to the environmental issues encountered on Asbestos Abatement Projects.

Please describe the environmental issues encountered or anticipated, and the measures taken to mitigate the issues on the following stages of Asbestos Abatement Projects.

Testing and Inspection:

Asbestos Abatement:

Onsite Waste Handling: Segregation:

Onsite Waste Handling: Material Transport:

Onsite Waste Handling: Waste Load Out:

Offsite Waste Handling: Material Transport: _____

Offsite Waste Handling: Disposal: _____