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# The Use of Organizational Knowledge Within Public Works Engineering Construction and Maintenance Agencies

by
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When providing engineering services, the U.S. Army Corps of Engineers must comply with certain public laws and regulations by using the traditional project delivery process. This process is a fragmented set of sequential phases, each with its own requirements, creating a lack of integration and coordination among project participants, both within a project and across many projects. Consequently, knowledge and experience gained from one phase or project in a civil works organization are usually inadequately transferred, or not transferred at all, to other phases or other projects. Another problem that many civil works organizations are facing is the loss of many veteran personnel who have a vast amount of knowledge and experience in the civil works organization.

The implementation of an automated system that can capture, store, and share the knowledge and experience of all project participants, throughout all phases of the project life cycle, will help reduce the problem caused by a fragmented delivery process. This system can also capture the experiential knowledge of veteran personnel before they leave the organization.

This report describes the development and implementation of such a system, the Organizational Knowledge Bank (OKBank). The OKBank system takes the advantages of the world wide web and other relational software programs in effectively capturing, processing, and disseminating organizational knowledge. The knowledge base in the OKBank contains not only organizational experiences such as lessons learned, good work practices, and success stories, but also include geographically oriented project information.

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When providing engineering services, the U.S. Army Corps of Engineers must comply with certain public laws and regulations by using the traditional project delivery process. This process is a fragmented set of sequential phases, each with its own requirements, creating a lack of integration and coordination among project participants, both within a project and across many projects. Consequently, knowledge and experience gained from one phase or project in a civil works organization, are usually inadequately transferred, or not transferred at all, to other phases or other projects. Another problem that many civil works organizations are facing is the loss of many veteran personnel who have a vast amount of knowledge and experience in the civil works organization.

The implementation of an automated system that can capture, store, and share the knowledge and experience of all project participants, throughout all phases of the project life cycle, will help reduce the problem caused by a fragmented delivery process. This system can also capture the experiential knowledge of veteran personnel before they leave the organization.

This report describes the development and implementation of such a system, the Organizational Knowledge Bank (OKBank). The OKBank system takes the advantages of the world wide web and other relational software programs in effectively capturing, processing, and disseminating organizational knowledge. The knowledge base in the OKBank contains not only organizational experiences such as lessons learned, good work practices, and success stories, but also include geographically oriented project information.

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# Foreword

This study was a collaboration with the Corps of Engineers Vicksburg District, Georgia Institute of Technology (Georgia Tech), and the Engineering Processes Division (PL-E) of the Planning and Management Laboratory (PL), U.S. Army Construction Engineering Research Laboratories (USACERL).

The USACERL Principal Investigator was E. William East. Dr. Jorge A. Vanegas is an Associate Professor with the Georgia Tech School of Civil and Environmental Engineering, and Tuan Nguyen is a Georgia Tech graduate student working onsite at USACERL. Michael P. Case is Chief, CECER-PL-E, and L. Michael Golish is Operations Chief, CECER-PL. The USACERL technical editor was Linda L. Wheatley, Technical Information Team.

COL James A. Walter is the Commander of USACERL, and Dr. Michael J. O'Connor is Director.

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# 1 Introduction

## Background

The mission of the U.S. Army Corps of Engineers is to provide quality, responsive engineering service to the Army and the Nation. The Corps plans, designs, builds, and operates water resources and other Civil Works projects to provide to the taxpayer a variety of benefits, including flood damage reduction, navigation, and environmental restoration. They also provide military construction for the Army and Air Force and provide design and construction management support for other Federal agencies.

Under the Civil Works Program, the Corps operates and maintains almost 300 deep draft harbors, 275 locks, and 12 thousand miles of navigable waterway. The 383 lakes and 8,500 miles of levees managed by the Corps prevent an estimated $26.8 billion in potential flood damages annually. Since the Corps flood control program began in 1928, the Corps estimates that its projects have prevented a total of $319 billion in flood damages at a Federal cost of about $37.5 billion, which is $8.51 in damages prevented for each dollar expended. The Corps operates 75 hydropower facilities, providing 25 percent of the nation's hydropower capacity. Last year more than $500 million was spent on environmental activities under the Civil Works program, including major restoration efforts in the Everglades and the Pacific Northwest and in smaller ecosystem projects. The Corps is the nation's largest provider of water-based recreation, with more than 4,000 recreation sites hosting 377 million visits in 1997.

In the process of delivering these civil works projects, the Corps has to comply with certain public laws and regulations, which generally require civil works projects be delivered using the traditional process. The traditional project delivery process comprises a fragmented set of sequential phases, each with its own requirements (Figure 1). This fragmented delivery process creates a lack of integration and coordination among project participants, both internally within a project and externally across many projects. Consequently, knowledge and experience gained from one phase or one project in a civil works organization are usually retained exclusively as personal property and are inadequately transferred, or not transferred at all, to other phases or other projects.

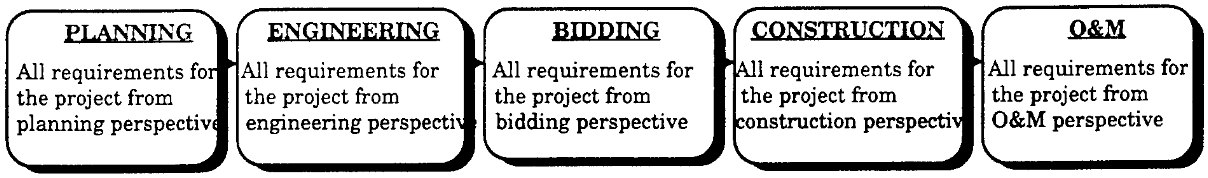



**Figure 1. Traditional capital project delivery process.**

Another problem that many civil works organizations are facing is the loss of many veteran personnel as a result of budget reduction. These personnel possess a vast amount of knowledge and experience in the civil works organization.

The implementation of an automated system that can capture, store, and share knowledge and experience of all project participants, throughout all phases of the project life cycle, will help reduce the problem caused by a fragmented delivery process. This system can also capture the experiential knowledge of veteran personnel before they leave the organization. The information these people possess is essential to the civil works organization's future existence.

This report describes the development and implementation of such a system, the Organizational Knowledge Bank (OKBank). The OKBank system takes the advantages of the world wide web (WWW) and other relational software programs in effectively capturing, processing, and disseminating organizational knowledge. The knowledge base in the OKBank contains not only organizational experiences such as lessons learned, good work practices, and success stories, but also includes project information that is geographically oriented.

## Objective

The objective of this research was to investigate how organizational knowledge in design, construction, and operations offices may be captured, evaluated, stored, retrieved, and applied to enhance the cost, time, quality, and operational value of future work.

## Approach

This work was conducted as a joint project between the Corps' Vicksburg District office, the Department of Civil and Environmental Engineering at the Georgia Institute of Technology, the Construction Technology Transfer Center, and the

U.S. Army Construction Engineering Research Laboratories (USACERL). The approach used to complete the research was to investigate and review existing automated lessons learned systems, to identify deficiencies within those existing systems, to develop strategies required to support the engineering of large public works structures, and to demonstrate the approach by developing a prototype software system.

## Mode of Technology Transfer

The results of this work apply to all levels of government and private firms that manage public works structures and facilities. In addition, the results may also be applied to the private sector as an approach to consider when developing tools for the capture of corporate knowledge.

The results of this work are available at http://www-2.cecer.army.mil/okbank/ index.html. The demonstration system is under evaluation by various members of the Corps of Engineers and the Construction Technology Transfer Center. Following this informal review, plans to complete and distribute or serve the completed system may be created.

# 2 Current Industry Efforts and Practices

## Approach

Most organizations have recognized the potential benefit of lessons learned systems in construction projects. However, only in the past several years, as the computer's technologies became more and more powerful and accessible, have automated lessons learned systems become more feasible.

Literature reviews indicated that much research and development effort has been done in this area. A thorough search of various sources (libraries, the Internet, and personal contacts) revealed many automated lessons learned systems.

Each of the available automated lessons learned systems was reviewed to determine the current state of the art. An evaluation guideline, which focuses on project life cycle, was developed to provide consistency and to guide the reviewing process. Questions addressed include:

1. Which phase or phases within the project life cycle does the system address?
2. Are all aspects in each phase covered?
3. How does the system define "lessons learned"?
4. How are the lessons and data captured?
5. How and what information is stored?
6. How are the lessons disseminated?
7. Can the data be updated and maintained?
8. What are the missing pieces?

## System Reviews

Overall, the reviews indicated that many systems share a common belief that the most effective form of constructability is the integration of construction lessons learned in the design process. Most developers of the latest systems also agreed that the best mechanism for integration of lessons learned is through the Internet. A multimedia system (i.e., with pictures, graphics, audio, and video clips) was also strongly recommended for enhancing the application of lessons learned. Each system is described, analyzed, and evaluated in the following text.

### *The Constructability Lessons Learned Database System*

***General description.*** The Constructability Lessons Learned Database (CLLD) system provides an interactive computerized method of collecting, storing, and making constructability knowledge available (Kartam 1995). This system is designed to capture only lessons that are generated and can be applied during the construction phase. The system description and lessons learned examples used in the system prototype indicate that its primary emphasis is on construction techniques and construction methodologies.

The system defines lessons learned as knowledge generated through daily construction activities. The lessons involve both positive and negative experiences gained during the construction phase.

***System design and implementation.*** The primary source of construction knowledge for the CLLD system was from personal interviews with all construction employees, from vice presidents and project managers to the foremen and construction laborers. The personal interview process followed a three-step format. The pre-interview planning was done by phone to give the interviewee a brief overview of the reason for calling, a description of the CLLD capabilities, a detailed description of what was being requested from the employee, and a time and date for the actual interview. The actual interview was conducted using the two-interviewer approach. Probing questions and previous examples of usable lessons learned were used during the interview. The post-interview activities included follow-up contacts with the employee for final revision or further contribution of lessons.

In addition to the interview method, an automated mechanism called a "discussion window" has been added to the CLLD system so contributors can input their lessons directly into the system.

Each of the submitted lessons is reviewed and approved by a company's committee before it can be added to the permanent database. The committee is composed of construction practitioners with ample experience in the trade.

The primary classification source used in this system is based on the 16 Division CSI MASTERFORMAT System for building construction. Users can access the database through such routes as category, keyword, lesson title, etc. The database contains primarily written text. The lessons learned database operates on IBM-compatible personal computers through the use of Lotus Notes™ software in MS-Windows™.

***Evaluation.*** One highlight of this system is the systematic interviewing approach used for knowledge acquisition. The personal interviews not only provided a significant source of information for the database, but also gave the employees the opportunity to learn about and be part of the system. This knowledge, in turn, will promote and ease the acceptance of the system.

Another useful concept presented in this system was to include both positive and negative experiences in the database. Wording the failures in a manner that offers positive preventive advice rather than reporting negative results is excellent. Doing this will encourage users to contribute their personal experience.

The CLLD system only addresses lessons learned within the construction phase of the project life cycle, with emphasis on construction techniques and methodologies. It is not clear whether the system will also cover lessons in other aspects of the construction phase such as cost, schedule, and quality. No systematic method exists for applying the lessons to future work.

The system developer mentioned that pictures and graphics can be incorporated into the CLLD system with Lotus Notes' capabilities to import files from other software programs. However, no particular software was mentioned.

### *The Intelligent Information Retrieval and Expert Advice for the Construction of Highway System*

***General description.*** The Intelligent iNformation Retrieval and Expert Advice for the Construction of Highway (IN REACH) system assists both veteran and novice practitioners in fashioning more informed decisions concerning problems that may arise during normal and abnormal highway construction operations (Epstein 1995). This system primarily focuses on "inspection operations" in the construction phase.

This system defines lessons learned as any information that can assist construction personnel to better perform their jobs. Developed under this concept, the knowledge base in the IN REACH system is not limited to construction knowledge and expertise of veteran personnel, but also includes existing data and documentation. Examples of existing documents include: standard specifications, standard drawings, construction administration manuals, and inspection manuals.

***System design and implementation.*** The initial data in the IN REACH system are captured directly from selected sections of manuals and documents already existing in the organization. This existing information makes up the majority of the data for the IN REACH system. The initial data are supplemented by knowledge and expertise of veteran personnel derived from mandatory post-construction conferences.

Although IN REACH uses an expert system approach, it does not represent the captured information in terms of rules. Rather "...the documents themselves, along with the comments collected from the post construction conferences, were utilized to represent the captured knowledge of the organization" (Epstein 1995). The data are stored under six general categories: bridge, roadway, asphalt, signaling and lighting, maintenance of traffic, and other. Each general category is further broken down into source indexes. Each source index contains information for a specific operation such as pile driving. Most of the data are written text.

The system is operated in a Windows environment and is menu driven. Users can retrieve information either by selecting a topic on the menu or by searching for a topic. The program is written in KnowledgePro Windows™, a combination of objected-oriented programming (OOP), expert systems, and hypertext.

***Evaluation.*** The use of both veteran expertise and existing documentation to represent the system's knowledge base is an interesting concept. Because the main objective of all lessons-learned systems is to improve performance, these systems would be more complete if they also contained information (other than lessons learned) that can assist personnel in doing their jobs better.

The post-construction conference is a good way to capture lessons learned while they are still fresh in the minds of the involved parties. Most organizations have numerous meetings and conferences before and during the task, but not after the task is finished. The lessons derived from these conferences could be used to update or supplement the existing data. In this way, the system becomes a "living" electronic document that becomes more and more useful.

The IN REACH program contains primarily text with sketches or drawings. No mechanism exists for users to input new lessons. How the data will be maintained and updated was not discussed.

### *Constructability Support Multimedia System*

***General Description.*** The Indiana Department of Transportation (INDOT) Constructability Support Multimedia System is a computer tool that captures, records, and stores constructability concepts and lessons learned while providing design professionals with easy access and graphical retrieval of concepts and lessons to deepen their understanding of constructability issues (Patty 1995). The system was developed for use by designers.

This system stores constructability information and lessons learned during construction. The author defines constructability as the integration of construction knowledge and experience during all phases of the facility development process. The construction "lessons learned" is not clearly defined.

A special feature of this system is its use of multimedia to represent a broad field of knowledge. The developer argued that text alone was rather unnatural and difficult to see when explaining a wide range of construction knowledge. This system used text, full color images, and video clips to represent and explain constructability.

***System design and implementation.*** The knowledge acquisition process begins with videotaping interview sessions with construction contractors, INDOT personnel, and the design consultant. The interview sessions are reviewed to identify lessons learned candidates. Then information and data related to each lesson are collected to fully explain the lessons.

The system has four windows and each window represents a level. The Main Level represented four main construction categories: Bridges, Roads, Environmental, and Contracts. The second window was the Organization Level, which contained design category icons of the Main Level choice. The third window was the Detail Level, which contained icons of actual constructability lessons learned. The fourth level contained a graphic representing the lessons learned. At this level, users could activate a search process for the lessons learned. The lessons learned are described in a textual format that also contains hyperlinks to other multimedia such as pictures, graphics, audio, and video clips. Users maneuver throughout the system simply by clicking on an icon in any window.

The system is composed of a custom access interface written in Microsoft Visual Basic™ and FolioViews™ electronic publishing software. As of July 1997, INDOT was in the process of producing this system in a CD-ROM format.

***Evaluation.*** This system provides an excellent answer to the retrieval phase by describing a multimedia system that contains meaningful lessons learned. Many lessons learned in construction may not be adequately described with written text. The multimedia capability will enhance the lessons tremendously.

The establishment of each lesson will require significant time and effort. When put on a CD-ROM, the data are permanent and cannot be updated, unless a new CD is burned. The CD-ROM format will limit the dissemination of lessons learned to only a small number of users. No systematic approach is available for applying the data to future projects.

### DOE Complex-wide Lessons Learned Program

***General description.*** The Department of Energy (DOE) Complex-wide Lessons Learned Program is designed to promote consistency and compatibility among existing lessons learned programs across the DOE complex.

In the existing programs, lessons learned are defined as the utilization and sharing of information relative to improving the health and safety at DOE's facilities, and to make recommendations for improvement. In the new program, the concept of lessons learned is broadened to include all areas of DOE business. The lesson learned is also redefined as a "good work practice" or innovative approach that is captured and shared to promote repeat application. It may also be an adverse work practice or experience that is captured and shared to avoid recurrence.

***System design and implementation.*** Information used to generate lessons learned may come from numerous sources such as personal experiences, occurrence reports, safety meetings, quality council meetings, nonconformance reports, safety bulletins, project planning and evaluation results, performance improvement initiatives, and process improvement initiatives. The sources are not limited to DOE but include other Federal agencies and the industry as well.

Information that has potential to become a lesson learned is required to undergo two review processes before dissemination. The technical review is performed by subject matter experts or the Lessons Learned Coordinator to determine the applicability and significance of a potential lesson learned and whether the experience has been included in a previously issued lessons learned document.

The lesson learned is then reviewed for compliance with organizational security requirements before being stored.

The DOE lessons learned program uses electronic and non-electronic approaches in lessons dissemination. Lessons learned are electronically disseminated by the DOE Lessons Learned Information System (LLIS). This system uses the Internet to make information developed at local levels available to other sites across the DOE complex. Lessons learned posted in this system follow a specified template. Non-electronic dissemination methods include meetings, teleconferences, workshops, publications, and direct mailings.

Some of the electronic means used in this system are: List Server, Newsgroups, Electronic Mail, and Internet Web Site. The List Server is limited to the DOE community. The Internet Web Page, as part of a pilot program, is used as a means to quickly share information among the field offices.

***Evaluation.*** One highlight of the DOE program is the support by upper management. Programs such as the DOE Complex-wide lessons-learned system impact and require the cooperation of many employees, not to mention the need for other resources. Without the support from the top echelon, this program will not survive even the developmental phase.

This system also encourages the submission of "good practices," which is missing in many other lessons learned systems. This concept fits well into the main objective of all lessons learned: that is, to improve performance of the project.

The use of the Internet to widely disseminate the lessons learned is excellent. In this way, the whole industry can benefit from the system.

The program covers all areas of DOE business, including construction. In the construction area, however, the program only focuses on safety aspects of the construction phase and the operation phase of the project life cycle. The lessons are primarily safety related and operational in nature. Most lessons learned are presented primarily in written text.

The program requires that stored lessons learned information be reviewed for usefulness. Information that is no longer pertinent to organizational activities is to be eliminated or archived in accordance with organizational policies and procedures. It is not clear how and under what format the lessons are stored.

The DOE lessons learned program also includes a requirement for applicable lessons-learned information to be incorporated into DOE and contractor activities. However, no mechanism ensures that the information will actually be used.

### *Linking Lessons Learned System*

***General description.*** The Linking Lessons Learned (L3) system is an effective means for communicating experiences of construction and operation teams to benefit the designer on subsequent projects (Phillips 1996). The L3 system is designed to be used by designers during the design process.

It is not clear how lessons learned are defined in this system. However, from the system description and examples of the lessons in the database, it seems that the lessons are derived from design deficiencies discovered during construction and operation phases.

***System design and implementation.*** The main source for the lessons learned comes from employee experience. A lessons submittal form (both electronic and hard copy) is required to facilitate the submission process. Other sources of lessons include knowledge and experience of customers, contract changes, contract claims, value engineering change proposal (VECP), biddability, constructability, and operability (BCO) review comments, and post-construction conferences.

An oversight committee then reviews each submitted lesson. This committee is also responsible for keeping data current, publicizing the system and inspiring enthusiasm for it in the organization, and ensuring the software is up-to-date and progressive.

Once a lesson is reviewed and approved, the system administrator will enter it into the database called the L3 Application System. This database system was developed using Microsoft Access 2.0™ relational database software. The developer also uses the Internet as a supplemental method for making lessons available. The L3 Application system can be downloaded from the Internet.

The lessons are organized under the combination of phases (planning, design, construction, and operation) and disciplines (architectural, civil, electrical, environmental, mechanical, sitework, and structural). Users can access the lessons either from the Internet or from the L3 Application system. All lessons learned in the database contain only written text.

The system developer proposes that designers of all projects be required to certify that they have reviewed all applicable lessons learned in the system as part of the design process. Training and partnering efforts are recommended to overcome the resistance from the designers to such a requirement.

*Evaluation.* One highlight of this system is a clear mechanism to ensure the utilization of the system by designers. The lesson is not "learned" until it is used to avoid the same mistakes or to improve performance.

As in the DOE LLIS, this system also uses the Internet to widely disseminate the lessons learned. Again, by making the lessons globally available, many other construction organizations can also learn.

The system has some options for application in other phases of the project life cycle. However, it is evident from the system design concepts that the main focus is on the design review process.

The system does not have the capability to capture the lessons automatically as it is designed for a "...data storage and retrieval purpose" (Phillips 1996).

### *Design Review and Checking System*

*General description.* The Design Review and Checking System (DrChecks) uses a client/server approach across the Internet to capture successes and failures of experienced design and construction personnel for use within the design review process (East 1996). The program demonstrates in detail a complete cycle process of capturing, reviewing, storing, and retrieval of lessons learned via the WWW.

This system defines lesson learned as "...knowledge or understanding gained by experience. The experience may be positive, as in a successful test or mission, or negative, as in a mishap or failure. Successes are also considered sources of lessons learned. A lesson must be significant in that it has a real or assumed impact on operations; valid in that it is factually and technically correct; and applicable in that it identifies a specific design, process, or decision that reduces or eliminates the potential for failures and mishaps, or reinforces a positive result" (East 1996).

DrChecks also defines a lesson learned as a good work practice or innovative approach that is captured and shared to promote application. It may also be an adverse work practice or experience that is captured and shared to avoid recurrence.

The developer specifically proposes that the lessons captured must have a real impact on operations, be factually or technically correct, have application to a specific process or component and have limited management implication. Once captured items become lessons learned, they must be shared with personnel at the time when the lessons can be applied at the least cost (typically during design) to improve the success of each new project. The system is developed based on the corporate learning process where project-based learning is extracted from the personnel directly involved in the project cycle to be shared throughout the organization.

***System design and implementation.*** The "author" submits the potential lesson learned directly into the system. Three types of information are required: (1) the project on which the lesson has occurred, (2) a description of the problem, and (3) a recommended solution.

The submitted lesson is then reviewed. The reviewer, either personally or by routing the item to appropriate personnel, determines if a submitted item has a real impact on operations, is factually and technically correct, has application to a specific process or component, and has limited management implication. Once the reviewer (or technical specialist) has evaluated the potential lesson, the lesson is made available to the user group for access.

All of the above steps are facilitated by DrChecks. The major components of this system and the general flow of information are illustrated below.

The user uses the system by accessing standard WWW pages containing Hypertext Markup Language (HTML) tags. The user begins a query through a form action contained in the HTML page. The web server receives the query and executes another web page called the template file, which contains both HTML and scripts formatting tags. Based on the scripting information contained in the template file, a query is posted to the scripting processing program. The scripting tags and the script processing program are provided by Allire Corporation's Cold Fusion product. The script processing program uses a set of HTML extensions called Data Base Markup Language (DBML).

Then the query is posted to the data source, Microsoft Access database (version 2.0), and the result of the query or other actions are taken. Based on the formatting information provided in the template file, query results are returned, and an HTML document is produced. The result page is provided to the user through the web server.

*Evaluation.* This system is one of the most recently developed lessons learned system. It took the advantages of the WWW and other relational software program in effectively capturing, processing, and disseminating lessons learned. This approach is realistic and useful for integrating the capture and use of lessons learned.

Like many other lessons learned system, DrChecks focuses on the design review process. The system limits itself to include only lessons that are technically oriented. It is mainly textual and does not include other multimedia data.

## Overall Summarization of System Reviews

The review indicates that most systems were developed for use during the design process. Two of them, however, are designed and used mainly for the construction phase. Many of these systems focus on one or two aspects in each phase of the project life cycle, such as design deficiencies, safety, construction methods and techniques, inspection, etc. No system covers the entire project life cycle.

All systems basically agreed that the definition of lessons learned is both positive and negative experiences captured and shared to improve performance. However, there was a big difference in what information needed to be captured. Four of these six systems limited their database to include only lessons learned. These lessons were primarily technically related. The database of the other two systems included a wide range of information, and lessons learned data were just part of a much larger database. Except data in the INDOT system, which includes multimedia information, data in other systems were primarily written text.

Most of the systems capture lessons manually. Some systems are supplemented by electronic means. DrChecks is the only system that is fully automated to capture potential lessons via a WWW site. Except the DOE LLIS, which uses both electronic and non-electronic methods to promote the widest distribution of lessons learned, the rest of the systems were designed for automated retrieval. Three of the six systems can be accessed through the Internet.

All systems have a mechanism for reviewing and approving lessons learned before placing them into the permanent database. This review function is usually done by an assigned individual or by an appointed oversight committee. Except for INDOT's permanent database, information from other systems can be updated as needed. Table 1 summarizes the system reviews.

Table 1. Highlights of lessons-learned system reviews.

| | Primary Focus | Data Captured | Type of Data | Multi-media | Fullest Dissemination Capability | Operating System |
|---|---|---|---|---|---|---|
| **CLLD** | Construction | Semi-auto | LL only | No | In house | Windows |
| **IN REACH** | Construction | Manual | Includes other data | No | In house | Windows |
| **INDOT** | Design | Manual | LL only | Yes | In house | Windows |
| **DOE LLIS** | Operation | Manual | Includes otherdata | No | Global | Windows |
| **L3** | Design | Manual | LL only | No | Global | Windows |
| **DrChecks** | Design | Automated | LL only | No | Global | Windows |

## Other Recent Developments

In addition to the above systems, other research has been done on this topic recently. One of the major research efforts is a 2-year study by the University of New Mexico under the sponsorship of the Construction Industry Institute (CII). The study emphasis on "process" rather than "database" allows flexibility for companies to adapt the model to their own in-house capabilities. The result of this study is a "flow process model that should guide the industry on the mechanics of utilizing LL, how they can be captured, how to filter information and how to organize it for retrieval" (Fisher 1997).

A special product in the form of a WWW-based lessons learned server has also been created, but is not yet available. Based on the description of this product in Fisher (1997), it is very similar to that of DrChecks discussed in detail earlier in this chapter.

The CII's study also summarizes the attributes of an ideal software tool for a lessons learned system. This excellent tool will be discussed in Chapter 3.

Another system currently under development is the Constructability, Operability, and Maintainability Lessons Learned (COML2) system (Vanegas 1997). Again, this system proposes using the WWW site as a means to receive, store, and allow retrieval of lessons learned similar to that of DrChecks.

The COML2 system is based on the global concept of integrating lessons learned, which includes constructability, operability, and maintainability with all phases of the facility development processes, across multiple organizations and disciplines. This global concept has been missing from most lessons learned systems now implemented. The idea of integrating lessons learned to include all phases, across multiple organizations and disciplines, will be discussed further in Chapter 3.

# 3 System Development

As mentioned in Chapter 2, the idea of integrating lessons learned to include all phases of the project life cycle, across multiple organizations and disciplines, is very interesting. This global concept is missing from most lessons learned systems currently implemented. This chapter explores this concept to determine its applicability to the design of a system for use in the Corps of Engineers Vicksburg District.

The evaluation of current systems indicated that major differences exist in the types of information that make up the system knowledge base. Some systems only include lessons learned, while some contain other organizational information. The type of information that will make up the knowledge base for the proposed system, and how it will be acquired, will also be determined and described in this chapter.

Along with knowledge acquisition, one critical aspect of the knowledge and experience capture program is the proposed method of disseminating the captured information. The captured information must be validated, organized, stored, and presented in such a way that it is readily available and easily accessible to anyone wishing to benefit from the knowledge base. All of these processes will be described in this chapter.

Finally, computer technology will be examined to determine what software is most complementary and suitable to the processes.

## Project Life-Cycle Concept

It is universally agreed that the most effective way to improve future project performance is the integration of construction lessons learned into the design process. However, some system developers recognize that performance during the construction phase could also be improved through a similar formalized feedback system. The CLLD and IN REACH systems are developed to do just that. It is just a matter of time until other phases within the project life cycle such as planning, contracting, and operations and maintenance (O&M) will be included in the effort.

In civil works, each phase within the project life cycle has a unique focus, multiple stakeholders, and a wide range of specific tasks that need to be accomplished. For example, the planning process for a water resource problem starts with a brief study to determine whether the project falls within the Corps' statutory authority and meets national priority. Should that be the case, the Corps will carry out a full feasibility study to develop alternatives and select the best possible solution. This process normally includes public meetings to determine the views of local interests. The planning phase might also involve other Federal and state agencies with interests in the project.

Unquestionably, lessons will be learned in this lengthy review and approval process. Certain knowledge and experience gained from the planning stages (e.g., how to conduct a productive public meeting, why a certain project is stopped, things that can be done to expedite the approval process) might be valuable to future projects.

Likewise, knowledge and experience gained during the O&M of a project, even if they could be applied only within the O&M process, would result in tremendous cost savings. The O&M cost of a levee system, for example, is far greater than its design cost or initial construction cost. Knowledge and experience gained by one Levee District, such as what piece of equipment works best for mowing the levee, will benefit other Levee Districts. Knowledge and experience gained from fighting a recent flood would also benefit future operations.

The above examples suggest that many incentives exist for the effective application of knowledge and experience gained at all phases throughout the project life cycle, across multiple organizations and disciplines, from one project to another. Figure 2 shows the potential role and value of knowledge and experience when applied within a project's life cycle and to future projects at Vicksburg District.

Figure 2 represents the concept of a global system that can capture knowledge and experience gained throughout all phases of a project's life cycle to be used to improve performance of both current and future projects. This global concept serves as the basis for the design of the system prototype.

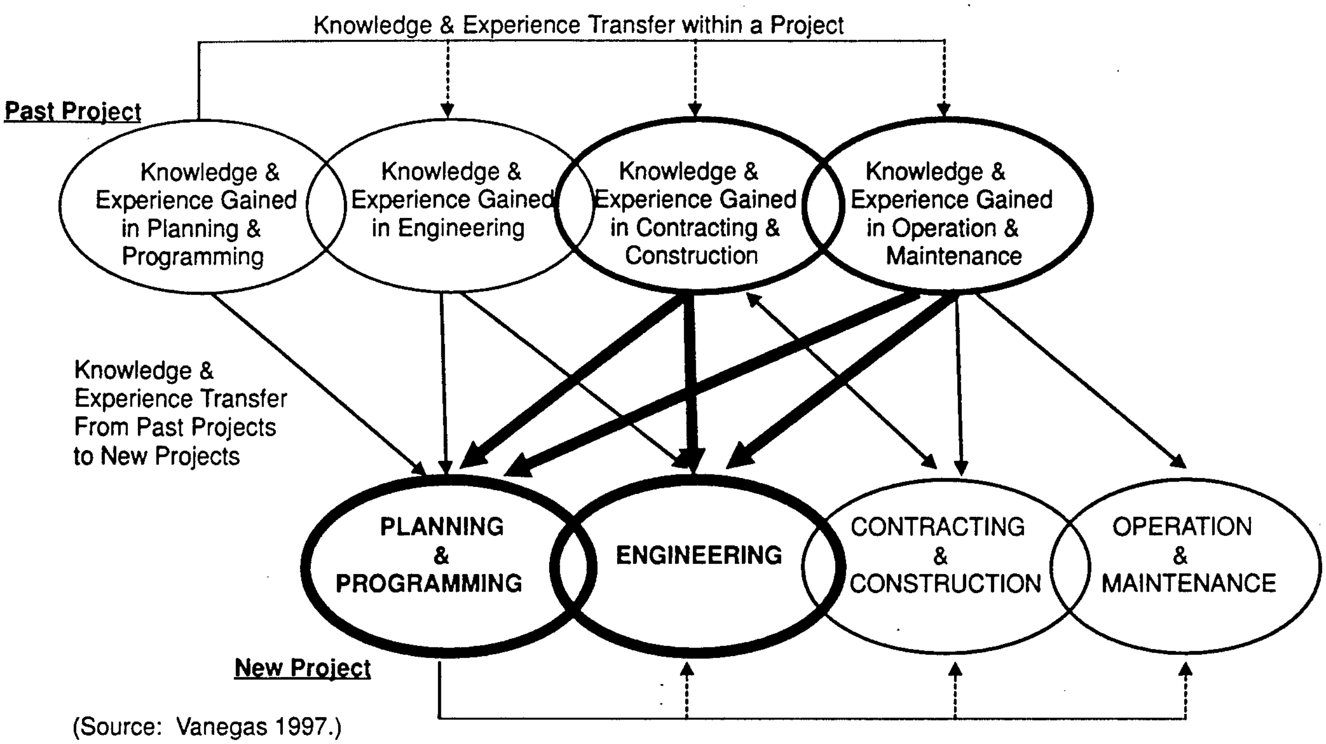



**Figure 2. Knowledge and experience transfer within and between projects.**

## Type of Knowledge and Experience Captured

The overall goal of this research project was to develop a systematic approach for capturing knowledge and experience of veteran Corps personnel, to organize this information, and to disseminate it to the widest audience possible. As an example of the civil works projects referred to in Chapter 1, Vicksburg District is responsible for a variety of projects in Arkansas, Louisiana, and Mississippi. These projects include levees, channel improvement, emergency bank protection, waterways, and erosion control. The Red River below Denision Dam Levees system (in Arkansas and Louisiana) was selected as the area of focus for the design of a system prototype. The main reason the levees system was selected was because of several recent flooding events in the United States.

Although many lessons learned system developers have defined lessons learned as both positive or negative experiences that are captured and shared to improve performance, the term "lessons learned" itself inherently projects a negative image. Because this system was designed to capture experiences of an organization, the term "organizational experiences" seemed more appropriate. In the proposed system, organizational experiences (OEs) are defined as good work practices, success stories, or innovative approaches in an organization that are captured and shared to promote application. They may also be adverse work practices or negative experiences that are captured and shared to avoid recurrence. It is under this definition that the knowledge acquisition process was focused. To gather the initial knowledge base for the system prototype, a personal interview approach similar to that of the CLLD system (Kartam and Al-Tabtabai 1995) was used.

The interview process included three steps. First, the responsible parties from all phases of the Red River Levees project were contacted. This list included the divisions for Planning, Program and Project Management, Real Estate, Engineering, Construction, and O&M. The initial contacts were made by telephone to give the interviewee a brief overview of the reason for the call, a detailed description of what was requested from the employee, and a time and date for the actual interview. The initial contacts revealed that, besides the common stakeholders of traditional projects, most civil works projects such as Red River Levees also involve local authorities such as the Levee District Boards, landowners, and private citizens. Since the local Levee Boards are responsible for O&M of the levee, they also were contacted for interviews.

The initial contacts also indicated that, besides OEs, specific project information associated with a certain region should be included in the proposed system to assist the employees in performing their day-to-day duties. This type of information is usually available but is scattered throughout all Divisions within the District. Most often the information is possessed by certain employees or individuals who have lived or worked in that region for a long time. If this information is not captured, it will be gone when these parties are no longer available for consultation. Even if it is captured in official reports and documents, but is not readily available and easily accessible, its benefits will never be fully recognized.

In the case of the system prototype, information such as the levee's history might seem trivial to many employees, but it is very important to the archeologists, planners, and designers. Furthermore, factual data such as the final quantities and final itemized payment of a project in a certain region generated by the Construction Division can be very helpful to the Planning Division in the preliminary estimates for a similar contract within the same geographical area.

Other project information about boundaries and points of contact for each Levee District and specific permitting requirements associated with each Levee District is very important. This type of specific information will not only benefit the organization and the Levee Districts in their daily operation, but also can help the general public in applying for a permit or coping during flooding events. The idea of centrally locating this type of information is very attractive to the customers. The Levee Boards and landowners will no longer have to search several places, or call several people, for specific information related to a project in their jurisdiction or on their properties.

It is interesting to note that other systems such as IN REACH and DOE LLIS do not limit their knowledge base to just project lessons learned. This broader knowledge base approach is also supported by the CII study, which recommended that "lessons learned should not be limited to project lessons learned only, they can also come from personnel, legal, insurance, or any other department which does not directly participate in projects" (Fisher 1997).

Because the main objective of all lessons learned systems is to improve performance, and the initial contacts indicated a need for other information that can assist personnel in performing their day-to-day jobs, it was determined that the system prototype would include not only OEs, but also other projected-related information.

The focus of the knowledge acquisition process was then expanded to include other applicable information. The intention was to supplement and not to replace the information system already in place, so the project information captured for use in this system was the knowledge and experience that were either not documented or documented but not properly shared. To determine what project information to include in the system prototype, the scope of the interview was also changed to include questions such as what project-related information/data the users wanted to see in the system that might benefit their day-to-day operation. Appendix A shows a questionnaire created to assist in the interview process.

As the second step in the interview process, the actual interviews were conducted in person. Table 2 summarizes the results of the interviews, including information that the users would like to see in the prototype system.

The table indicates that, besides OEs, project-related information can be useful to the employees and the customers. Incorporating the suggested information into the knowledge base of the system will make the system more attractive, which in turn might increase the contribution of experiences.

The personal interviews also revealed that major interest exists in information on projects that have a somewhat indefinite life cycle, such as levees, flood control structures, and navigation.

Table 2. Summary results of the personal interviews.

| Office/Division Contacted | No. Persons Interviewed | No. OE Items Collected | Other Information Suggested To Be Included in the System Prototype |
|---|---|---|---|
| Planning | 1 | 0 | Historical cost data for certain region (geographical area) |
| Programming & Project Management | 1 | 3 | Brief project overview, Authorizing legislation, & local cooperation requirements |
| Real Estate | 1 | 0 | |
| Engineering | 1 | 1 | As-built drawings, typical cross sections |
| Contracting | 1 | 0 | Description of upcoming works, anticipated award dates |
| Construction | 3 | 6 | Progress update of the overall project/program, upcoming works |
| O & M | 1 | 10 | Flood reports, flood fighting methods, boundaries, points of contact for each levee district |
| Levee Boards | 4 | 5 | Points of contact for permit requirements. Other applicable Federal standards/regulations |

The final step of the interview process included follow-up contacts with the employees for final revision and/or contribution of additional experiences.

The majority of the above information was obtained from the interviews and throughout the development process of the prototype system. The collected information, along with OEs, makes up the knowledge base for the system prototype.

It is important to note that, because of the time constraint, only a few employees in Vicksburg were contacted/interviewed. A complete system will need contributions from everyone, including the customers/clients. In addition, although the personal interview method probably is the best method to "jump start" the system as reasoned in Chapter 2, organizational knowledge and experience can be extracted from many other sources. A complete description of knowledge acquisition, processing, and dissemination will be discussed in the following section.

## System Modules

The proposed system includes three basic modules: acquisition, processing, and dissemination of information. This section will describe the techniques and approaches for each module.

Because the proposed system contains not only OEs but also project information, the OEs and project information will both go through the three modules. However, different techniques and approaches will be used in each module for each type of data because of the differences in their requirements. The OEs, which are the focus of the proposed system, will need to be systematically captured, processed, and disseminated. On the other hand, the project information, which is somewhat static and readily available, will require much simpler techniques and approaches. The components of the modules for both project information and OEs will be described separately.

### Modules for Projected Information

***Acquisition of project information.*** The acquisition process starts with contacting each Division and customer to find out what project information they need. This step can be taken concurrently with the interview to collect OEs as was done in the development of the system prototype. When the list is established, data collection will be fairly simple because most information related to a project is already documented and available somewhere within the District. Some specific data and knowledge (i.e., the history of a river) might be hard to get. However, besides available written documentation, this information can be collected by interviewing veteran personnel and locals who have worked or lived in the area for a long time. The collected information should not be limited to text but should also include maps, sketches, drawings, pictures, video clips, etc.

The initial efforts should result in a majority of the project information being captured. The project information can be expanded to include additional information requested by employees.

***Processing of project information.*** Most of the project information is validated documentation, so processing of the project information is fairly simple. However, project information, especially any data collected from the interview, should be reviewed for accuracy and suitability before being incorporated into the system.

In addition, project information needs to be categorized, structured, and presented in a manner that allows fast and easy retrieval by anyone wishing to benefit from the knowledge base.

In the OKBank system, described in Chapter 4, the focus is on specific knowledge that relates to a certain geographic area. For that reason, the project information is organized around six main rivers within the Vicksburg District's jurisdiction: the Mississippi, Red, Pearl, Quachita, Tensas, and Yazoo rivers. A variety of projects are associated with each river. Each of these projects might stretch across several states and might contain a series of work items (individual construction projects). Each work item or individual construction project normally falls within a jurisdiction of a local authority because of the requirement for local cooperation (including cost sharing). The project information is structured based on this breakdown. Using the collected data on the Red River Levees project for the system prototype, Figure 3 illustrates how the project information is organized.

Figure 3 represents the typical data structure for project information. The details will vary from one project to another.

***Dissemination of project information.*** The project information captured is general information and might benefit both the Corps' employees and customers, and the general public. Therefore, the information should be disseminated as widely as possible. However, because it is hard to know who needs what and when, only electronic means with search capabilities are recommended.

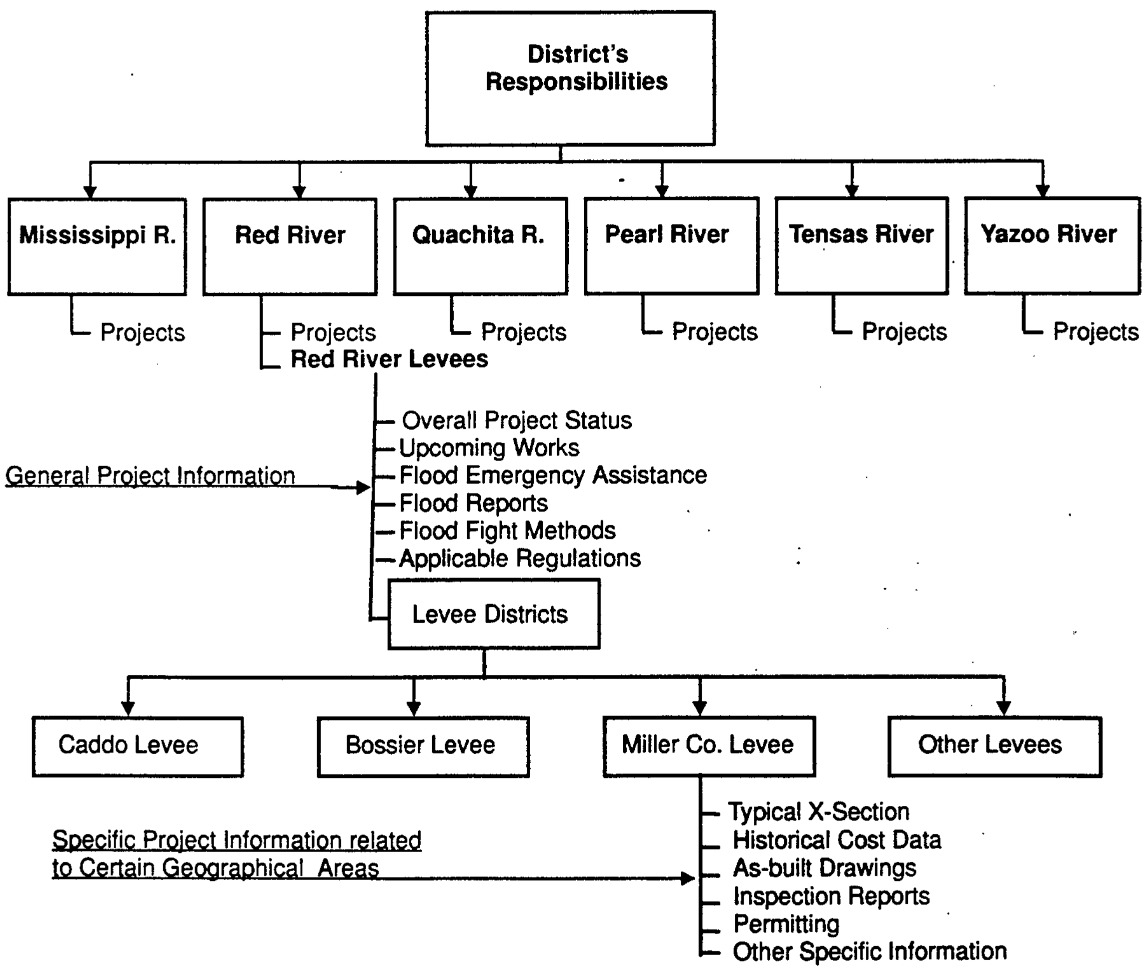



**Figure 3. Data structure of project information.**

***Project information update.*** Although the project information is fairly static, some data will need to be updated or deleted. For the proposed system, it is recommended that certain project information such as project status, upcoming works, etc., be reviewed monthly to keep the system current. Other periodic information such as cost data and flood reports should be updated as soon as new reports are generated.

### Modules for Lessons Learned

***Acquisition of lessons learned.*** A major number of OEs can be collected initially using the same personal interviewing approach used in the development of the system prototype. For a complete system, the interview process (especially the initial contacts phase), should be expanded to cover as many employees and customers as possible. It is understandable that not everyone will be able to contribute to the system; however, employees being contacted will at least know about the proposed system and might be able to contribute in the future.

Besides personal interviews, there are many other sources from which OEs can be generated. Change orders, contractor claims, value engineering change proposals (VECPs), design reviews comments, accident reports, and other official reports are sources that can be screened for applicable items. While collecting these items, it is important to ensure that sufficient information is available to understand the items and their solutions. The information might include sketches, drawings, pictures, video clips, etc.

Personal interviews and screening of existing documents should result in a significant number of potential OE items. The initial knowledge base can be continuously supplemented by using an input form which shall be available in electronic form. The format of the input form will be described in Chapter 4.

***Processing of organizational experiences.*** All potential OE items will be reviewed for accuracy, suitability, and completeness before being incorporated into the system. The item originator will be contacted to acknowledge the receipt of the item or to request additional information if needed.

Similar to project information, the approved OE items will be organized to allow fast and easy retrieval by multiple parameters. Because the proposed system will be designed for use throughout all phases of the project life cycle and across multiple disciplines, the OEs will be classified around major offices/divisions where the lessons are generated and can be applied (e.g., engineering, construction, O&M, etc.). Major projects, individual contracts, and specification sections will be used to indicate more specific information if applicable. Other alternative means of information access such as project location, associated life-cycle stages, and key words are also available.

The search and navigation features of the proposed system will be discussed further in Chapter 4.

*Dissemination of organizational experiences.* OEs are information that will benefit the entire organization. Whether they should be disseminated outside the organization is a management decision not discussed in this study. However, the OEs should be disseminated as widely as possible within the organization, and OEs from one District should be shared with other Districts. Both electronic and non-electronic means should be used for dissemination.

*Organizational experience update.* The OEs database will need to be monitored, maintained, and updated regularly. The database should contain only applicable and current items. Items that are obsolete or no longer applicable will need to be deleted. The database should be periodically reviewed for items that can be incorporated into guide specifications, design criteria, standard procedures, policies, and regulations so the organization can learn as a whole. In addition, those items that are incorporated may be removed from the database, making the system easier to manage. New, valid items should be added to the database as soon as possible so employees can benefit from them immediately.

### Computer Technology

None of the above processes can be effectively completed without a computerized system. The fundamental goal of the proposed system is to capture organizational knowledge and experience for retrieval and use later. The automated system will be a fast and efficient tool for capturing, processing, and disseminating the information. The selection of software for this system will be discussed in the next section.

## Software Selection

Many major research efforts and studies have been done to determine the best software tools for a system that can automatically capture, process, and disseminate OEs. Most of the developers of the latest systems also agreed that the best mechanism for integration of OEs is through the Internet. A multimedia system was also strongly recommended for enhancing the application of OEs.

One of the major extensive efforts was the study done by CII and the University of New Mexico (Fisher 1997). This study suggested a list of attributes that an ideal software package should have for a multimedia system. Table 3 summarizes this list.

**Table 3. Summary of attributes of ideal software tools.**

| Phase* | Attribute | Explanation |
|---|---|---|
| I | Network-based | Ensures organization-wide multiple access points. Should use a commonly used protocol to facilitate access outside the organization. |
| C | Open system | Contributions from anyone should be possible. Anonymous logins should be possible. An "all accepting" system. |
| C | Narrative and structured input | To support varying experiences and ease of screening the input. |
| C, I | Multimedia | Makes use of human senses to avoid overload on a single one. Simplifies perception and lessens cognitive load. |
| I | Database | A relational, heterogeneous, distributed multi-database for organized storage and quick retrieval of knowledge. |
| I | Navigation and search | Effective, user-oriented retrieval of stored information. Chronological, theme searches to augment traditional key-word searches. Situational data guarantees user-oriented information seeking without overwhelming the user with irrelevant information. |
| C, I | Security | No unauthorized access. Authenticated and encrypted communication. Preservation of integrity of stored information. |
| I, Co | Administration and management | Centralized or distributed management should be possible. High level interface designed for nonprogrammer administrators. |
| A | Decision support | Semi-automated screening, sorting, and classification of information for determining validity of information to be entered in the storage. |
| C, I, Cul | Informal communication, collaboration, and appreciation platform | The tool can act as a "town-hall" where members of the organization can communicate informally because an organization learns a lot (i.e., through E-mail, bulletin board, chat channels, etc.) Appreciation on this platform will provide an incentive for further participation. |
| I | Solicited and unsolicited dissemination | A user should be able to get additional (and available) information upon request. A user must receive some information by virtue of his/her function, despite personal choice, in the organization's interest. |
| All | Designed for human interaction | User-friendly system. Matches with users, their tasks, cognitive and physical capabilities, and their social aspirations. Interface designed with users' tasks in mind and helps them carry out the task in a manner seamless to their everyday work. |
| I, A | Usage tracking | This can help to determine usability (hence returns) of the system. Usage patterns can be used to selectively modify/amend the system. |
| Co | Cost | Lower initial costs are desirable. Hard dollar returns on knowledge systems are often hard to judge; hence, the system's usability is difficult to show. |
| Co | Speed | Should not test user's patience and lose the interactive nature. |

| Phase* | Attribute | Explanation |
|---|---|---|
| Co | Extensibility and development tools | Should be designed for modifications/extensions in future. Should provide tools to carry out such modifications or develop the system further for customization. |
| I, Cul | Social activity indicators | Seeing that others are using the system will prompt more people to use it. Solution to the problem of "critical mass" to get the system going upon start-up. |
| I, Cul | Human extension of knowledge base | To tap into the organization's social network (individual expertise) in the case stored knowledge does not solve a problem. |
| All | User Support | Unobtrusive, accurate, robust, consistent, and flexible help system. Searchable and context-sensitive on-line documentation. On-line tutorials for training. |

*C = Collection, A = Analysis, I = Implementation, Co = Coordination, Cul = Culture.
(Source: Fisher 1997.)

Another major effort was the development of DrChecks by USACERL. This system is one of the latest developments on the topic. It took the advantages of the WWW and other relational software programs in effectively capturing, processing, and disseminating OEs. This approach is realistic and useful in integrating the capture and use of OEs. DrChecks is fully developed and under official testing for implementation.

Although DrChecks was specifically developed for use in facility construction by designers during the design review process, it has many ideal attributes recommended by CII. For a detailed description of the software tools used in the development process of DrChecks, refer to system reviews in Chapter 2. Table 4 compares the DrChecks software tools against the ideal tools recommended by CII.

The comparison in Table 4 indicates that the software tools used in DrChecks are very close to the ideal software tools recommended by CII. This reason alone suggests that the same software should be used for the development of the system prototype. Furthermore, by selecting a software package that has been developed and tested for other types of U.S. Army Corps' projects (i.e., military construction), the initial development cost and time will be reduced tremendously.

It is important to remember that DrChecks focuses on the design review process. The system captures OEs that are technically oriented. It is textual based and does not include other multimedia data such as graphics, video clips, etc.

Table 4. DrChecks' software tools vs. CII's ideal software tools.

| Ideal Attribute | DrChecks | Remarks |
|---|---|---|
| Network-based | Yes | The Internet platform ensures organization-wide multiple access points. |
| Open system | Yes | During the official test period, some restriction is imposed. However, contribution from anyone is possible. |
| Narrative and structured input | Yes/No | The input is fairly structured because its primary focus is for use by designers in the design review process. |
| Multimedia | No | Although the system has the capability to support multimedia, currently DrChecks contains only text. |
| Database | Yes | Microsoft Access 2.0 is a relational, heterogeneous, distributed multidatabase. |
| Navigation and search | Yes | Search selection criteria in DrChecks include but are not limited to the following: keywords, location, specification number, and the issue category of design, construction, or operations. |
| Security | Yes | DrChecks requires passwords for accessing certain information. |
| Administration and management | Yes/No | DrChecks is centrally managed by a system administrator. |
| Decision support | Yes | DrChecks has mechanism for semi-automated screening, sorting, and classification of information for determining validity of information to be entered in the storage. |
| Informal communication, collaboration, and appreciation platform | Yes | E-mail is used in DrChecks for informal communication. |
| Solicited and unsolicited dissemination | Yes | Users can get additional (and available) information upon request. This practice has long been part of the culture of the Corps. |
| Designed for human interaction | Yes | DrChecks is designed with users' tasks in mind and helps them carry out the task in a manner seamless to their everyday work. |
| Usage tracking | Yes | DrChecks tracks number of usage and kind of users. |
| Cost | | The exact actual system cost is not available. However, DrChecks uses existing organizational standardized software, so its initial cost is minimal. |
| Speed | Yes | DrChecks is designed with speed in mind. |
| Extensibility and development tools | Yes | DrCheck can be modified and extended in future. |
| Social activity indicators | No | |
| Human extension of knowledge base | Yes | Users can contact the lesson originators or other Corps experts anytime when stored knowledge does not solve a problem. |
| User Support | No | There is no on-line help. |

The proposed system will be designed with emphasis on the project life cycle and will not limit OEs to only technical issues. Multimedia will be used whenever applicable. Therefore, many modifications will need to be made to the DrChecks system to accommodate these new requirements. In addition, the proposed system will also contain project information besides OEs. This information is specific project information that is geographically oriented. The best software tool to represent this type of information is map-related software. In selecting the map-related software, the emphasis is on their cost. Shareware or demonstration software will be used whenever possible. The software tools used in the development and programming of the system prototype will be discussed further in Chapter 4.

# 4 The OKBank System

The process of capturing, storing, and retrieving organizational knowledge is very similar to the process of depositing, saving, and withdrawing money from a bank. For this reason, the system was named Organizational Knowledge Bank (OKBank). As with any "bank," the best automated tool for performing many "banking transactions" has to be the Automated Teller Machine (ATM). The ATM is probably one of the automated machines that are most familiar to and most often used by people. It is under this user interface concept that the system prototype was modeled.

## General Description

The basic component of the OKBank system is a web site that can receive the deposit (submission) of experiences from the users. It allows users to review the submitted items in the OKBank account. Users can also withdraw (retrieve) helpful project information and OEs.

In general, a user begins to use the system by accessing the homepage of the OKBank system. The homepage presents as a screen similar to that of an actual ATM. A button bar on the left side of the screen contains common navigation buttons such as home, back, up, help, about. This button bar remains in place throughout the system. Another button bar on the right side contains subject/ topic buttons linked to HTML pages and other menus. The right button bar menu changes throughout the program depending on the button selection. Between the two bars, the screen displays the information related to the selected topics.

Because the processes involved with the project information are different than those associated with OEs, they will be discussed separately. The system is best described by illustrating the processes involved in it.

## Project Information

As discussed in Chapter 3, the project information is organized with a hierarchical approach. Each item in the hierarchy represents a specific topic that contains information related to that topic. The information is electronically stored in a series of HTML pages. Each topic or subtopic is represented by a button on the right button bar menu, which is hard linked to the HTML pages. Figure 4 further illustrates this configuration.

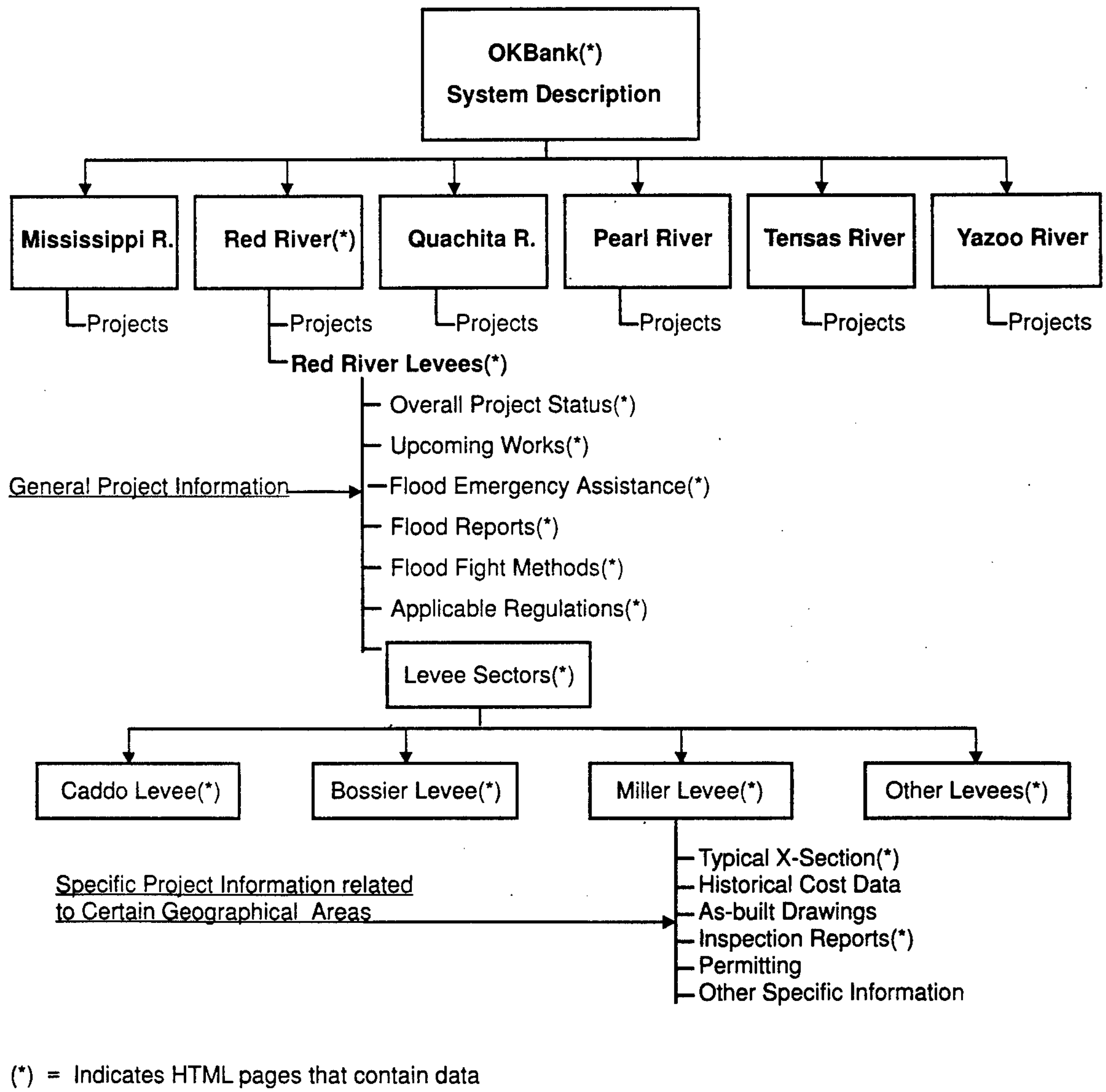



**Figure 4. Configuration of project information in the OKBank.**

The project information HTML pages contain text, graphics, and image maps. They were created using the following software tools: Homesite™, Deskscan II™, PaintShop™, and MapThis™. Homesite was used to create standard HTML pages; Deskscan II for scanning maps, pictures, sketches, drawings, and text; PaintShop for constructing the images; and MapThis to make image maps. Demonstration versions of most of these tools are available via the Internet.

Any user can access the project information contained in the OKBank. The project information can be accessed by clicking the appropriate buttons.

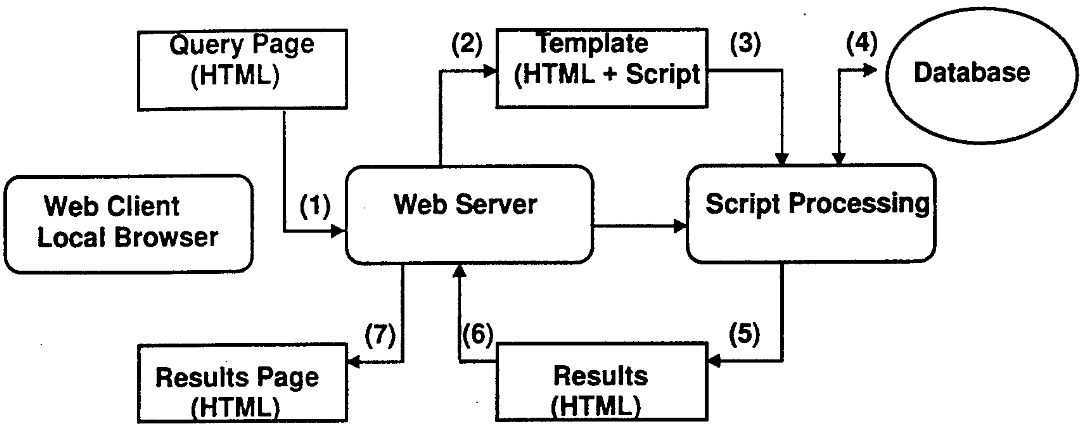
Users can also search for information using key words. Begin the search by clicking on the "site search" button on the right-hand button bar. The search will find every indexed page that contains the key words. This search mechanism is provided by the Verity search engine.

## Organizational Experiences

OEs are the main part of the OKBank system. They share the same web site with the project information. However, the processes associated with the OEs also require other major components. These components and the general flow of the OEs are described below.

The user begins a query through a form action contained in the HTML page. The web server receives the query and executes another web page called the template file, which contains both HTML and script formatting tags. Based on the scripting information contained in the template file, a query is posted to the script processing program. The script processing program is provided by the Allire Corporation's Cold Fusion™ product and uses a set of HTML extensions called Cold Fusion Markup Language (CFML).

The query is then posted to the data source, Microsoft Access™ database (version 7.0), where the result of the query is returned or other actions are taken. Based on the formatting information provided in the template file, query results are returned and an HTML document is produced. The resulting page is provided to the user through the web server. Figure 5 further illustrates the flow of information.




(Source: East 1996.)

**Figure 5. General Flow of Organizational Experiences.**

The OKBank ATM is designed as an "open" system so that it can benefit as many users as possible. However, the OKBank ATM will require a Personal Identification Number (PIN) in certain processes where the database could be compromised. This security mechanism is built into OKBank so that only authorized individuals can update and delete items from the database. Situations where the PINs are required will be identified throughout the following discussion of processes.

### *Deposit an Item*

The user can begin to deposit (submit) an item by clicking on the "deposit" button in the right-hand button bar of the OKBank ATM. A deposit form will be displayed. The deposit form has spaces for narratives and multiple-choice answers. It also has a field for the user to upload related text files or image files (sketch, drawing, pictures, etc.). The image file must be in "GIF" format. This feature is currently under development. The form is divided into three parts: general information, description, and recommendations. Each part has certain required optional fields. The fields for each part are listed in Tables 5, 6, and 7.

After the user has completed the form, he/she can press the "submit" button at the end of the form. A "reset" button clears values on the form. The format of the deposit form is depicted in Figure 6.*

* Figures 6 through 10 can be found at the end of the chapter, beginning on p 41.

**Table 5. General Information (Part 1).**

| Field | Required | Selection List |
|---|---|---|
| Division/Office | Yes | Planning<br>Project and Program Management<br>Real estate<br>Engineering<br>Contracting<br>Construction<br>Operation & Maintenance<br>Other |
| Project (these are projects that contain several individual contracts) | No | Red River Levee and Bank Stabilization<br>Red River Emergency Bank Protection<br>Red River Waterways<br>Other |
| Emergency Operations | No | Flood fight<br>Flood reports<br>Emergency assistance<br>Other |
| Regulatory Issues | No | Wetlands<br>Waterways<br>Levees<br>Other |
| Contract Name | No | User inputs |
| Customer | No | User inputs |
| City | No | User inputs |
| Author | Yes | User inputs |
| Author's Phone | Yes | User inputs |
| Author's Email | No | User inputs |

**Table 6. Description (Part 2).**

| Field | Required | Selection List |
|---|---|---|
| | Yes | User inputs |
| Type of Issue | Yes | Success story<br>Good work practice<br>Potential error<br>Potential omission<br>Possible oversight<br>Coordination<br>Safety<br>Other |
| Occur During | Yes | Planning<br>Programming<br>Design<br>Procurement<br>Construction<br>Operations & Maintenance<br>Rehabilitation<br>Other |
| Specification No. | No | User inputs |
| Related Discipline | No | Architecture<br>Civil<br>Electrical<br>Environmental<br>Geotechnical<br>Mechanical<br>Structural<br>Other |
| Describe Problem | Yes | User inputs |
| Sketch to Upload (gif) | No | User inputs |

Table 7. Recommendations (Part 3).

| Field | Required | Selection List |
|---|---|---|
| Recommended Solution | Yes | User inputs |
| Benefits expected/realized | Yes | Cost savings<br>Time savings<br>Quality improvement<br>Customer satisfaction<br>Environmental sustainability<br>Hazard reduction<br>Other |

### *Review Items*

After an item has been submitted, it is stored in the database pending review. The reviewer is a person or persons designated by management to take action on the submission. The reviewer can start the review process by clicking the "account" button on the right-hand button bar. The reviewer will be prompted for a "PIN." After the correct PIN is provided, the reviewer will be presented with a list of pending items. Figure 7 shows the list of pending items. Notice that only subjects or short titles are shown.

To take action on any of the pending items, the reviewer can click the title to access the full set of data available for that item. Figure 8 shows an item's detailed data screen.

The reviewer is not permitted to edit the author's item. The reviewer can, however, update the status fields of the comment record to provide feedback on the status and final disposition of each lessons-learned item. This comment record is located at the bottom of the detailed data screen (Figure 8). Figure 9 shows the pending item update form. Once the reviewer has evaluated the item, he/she will either approve or disapprove it. If the item is approved, it will be ready for retrieval. Otherwise, it will be removed from the database.

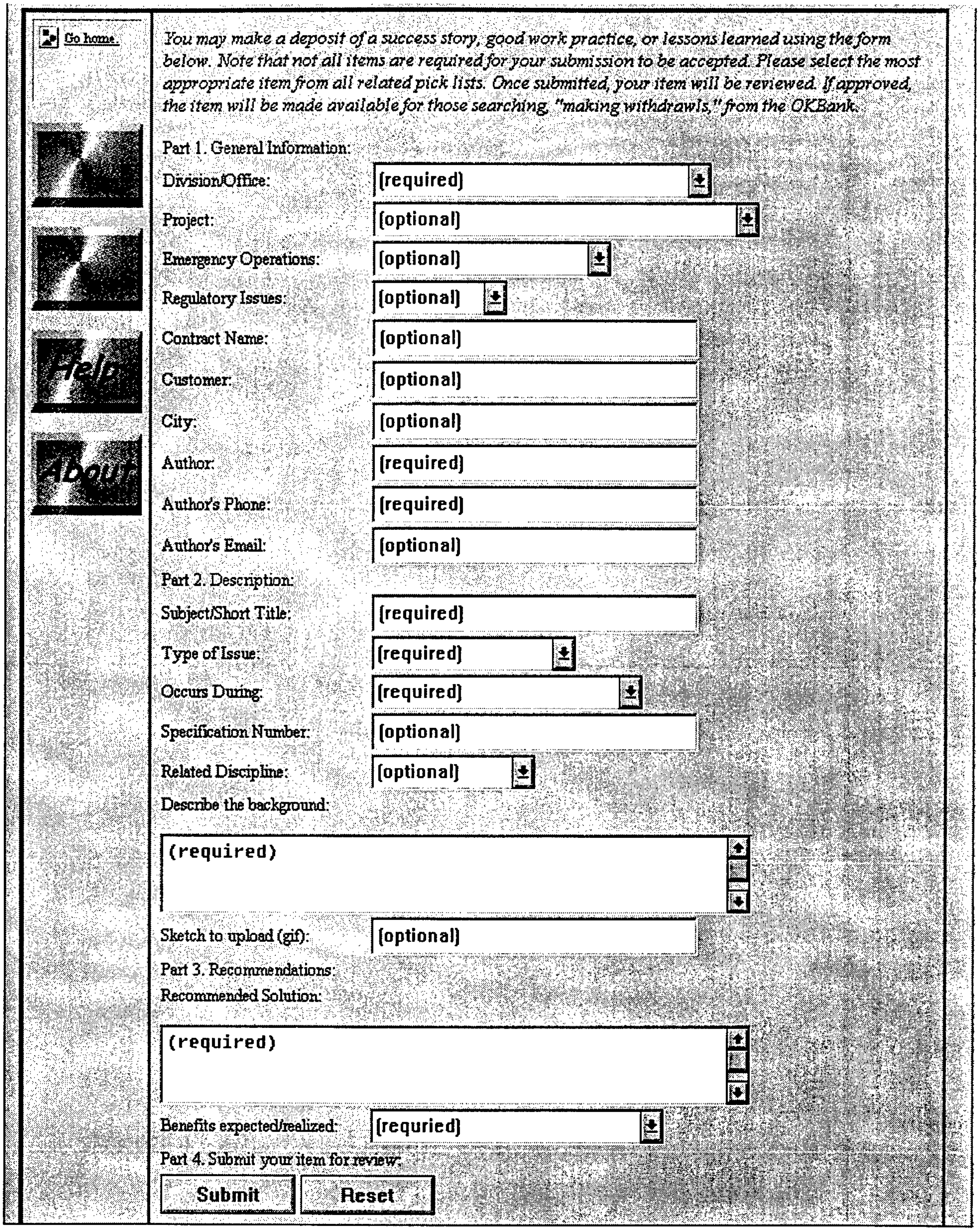
### *Withdraw Items*

Users can find approved items by first clicking on the "withdraw" button on the right-hand button bar. The user will be presented with a search page (Figure 10) that includes several criteria. The search criteria include: offices/divisions, project, emergency operations, regulatory issues, contact name, customer, city, author, subject/short title, type of issue, associated phase, specification number, related discipline, benefits expected/realized, and key words. Users can select any of these criteria or any combination of criteria for searching.

Figure 11 shows an example of the results of the search presented to the user. Users can click on the title of the item found to see the full details of an item. The detailed screen of a found item is similar with the screen depicted in Figure 8.

Users can also search for approved items in the OKBank using key words or phrases similar to the search for project information. This search feature will allow the users to search for approved items in the OEs database without having to navigate through the above screens.

The previous three sections provided a complete description of the system prototype. However, remaining issues such as system security, system administration and management, and system integration will need to be addressed before the system can be implemented. These are management-related issues, which are outside the scope of this investigation. However, each of these concerns, along with the recommended solutions, will be briefly discussed in Chapter 5.



Go home.

*You may make a deposit of a success story, good work practice, or lessons learned using the form below. Note that not all items are required for your submission to be accepted. Please select the most appropriate item from all related pick lists. Once submitted, your item will be reviewed. If approved, the item will be made available for those searching, "making withdrawls," from the OKBank.*

Help

About

Part 1. General Information:

Division/Office: (required)

Project: (optional)

Emergency Operations: (optional)

Regulatory Issues: (optional)

Contract Name: (optional)

Customer: (optional)

City: (optional)

Author: (required)

Author's Phone: (required)

Author's Email: (optional)

Part 2. Description:

Subject/Short Title: (required)

Type of Issue: (required)

Occurs During: (required)

Specification Number: (optional)

Related Discipline: (optional)

Describe the background:

(required)

Sketch to upload (gif): (optional)

Part 3. Recommendations:

Recommended Solution:

(required)

Benefits expected/realized: (requried)

Part 4. Submit your item for review:

Submit Reset

**Figure 6. Deposit submittal form.**

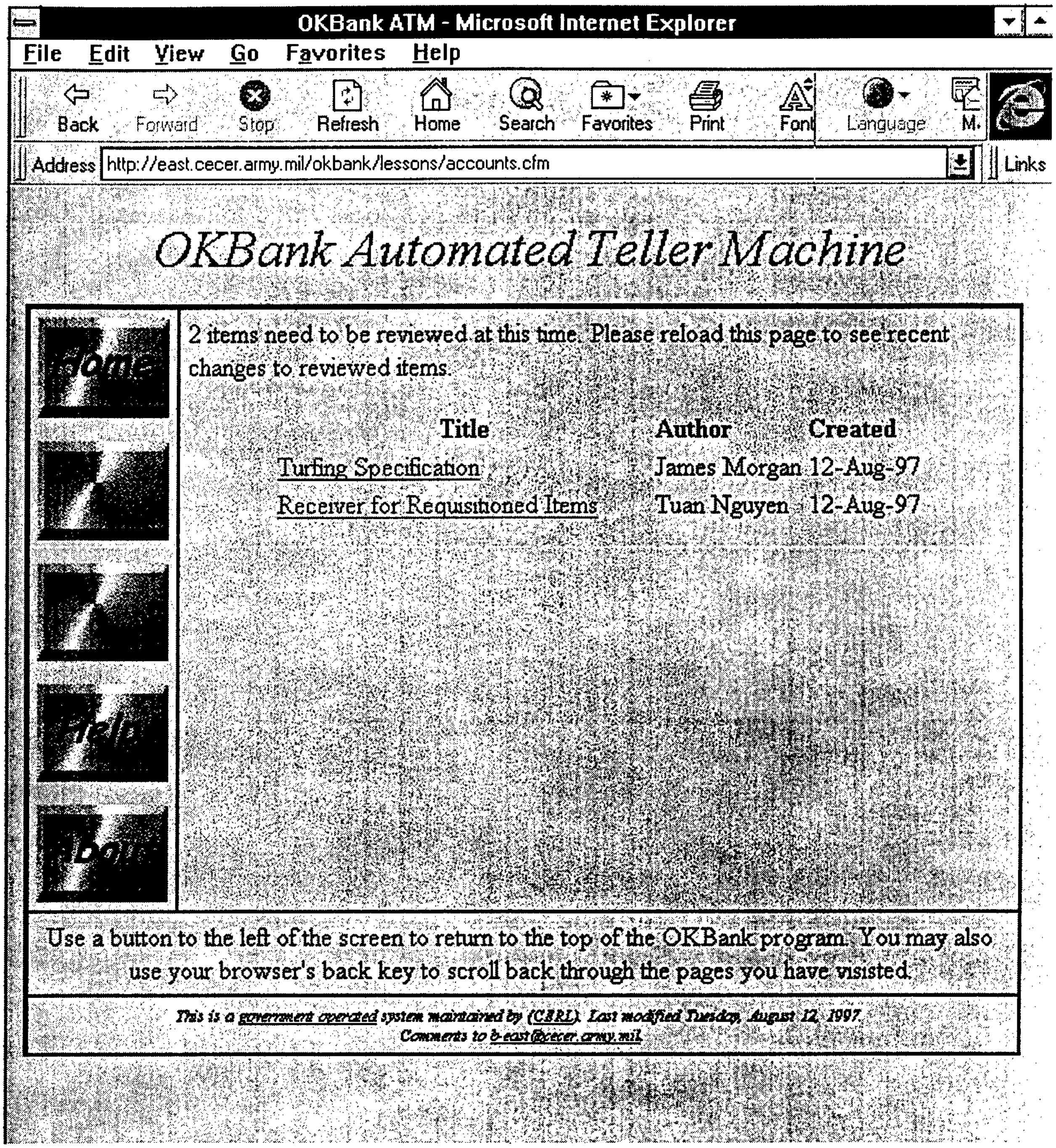
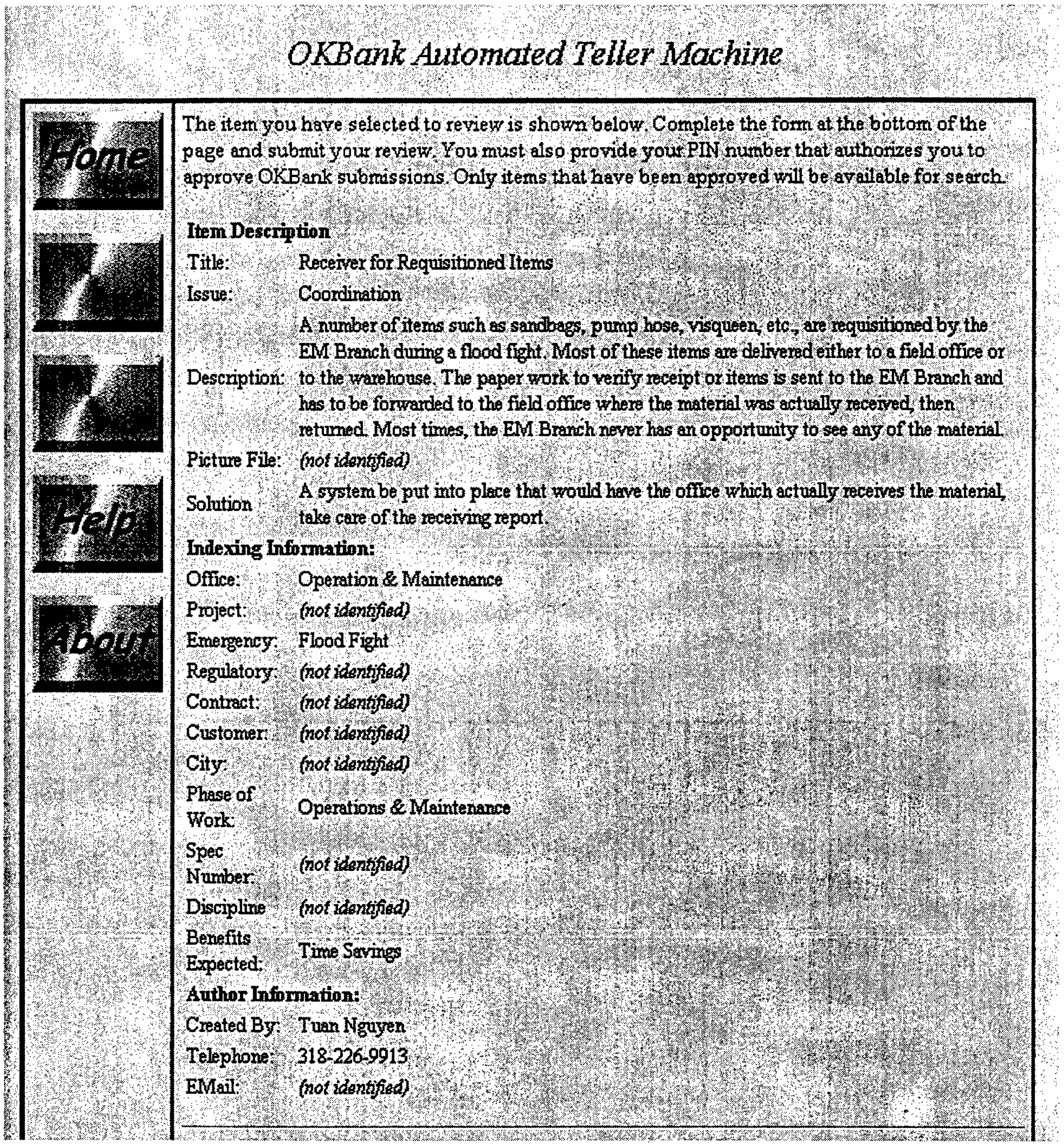



**Figure 7. Items pending review.**



*OKBank Automated Teller Machine*



The item you have selected to review is shown below. Complete the form at the bottom of the page and submit your review. You must also provide your PIN number that authorizes you to approve OKBank submissions. Only items that have been approved will be available for search.

**Item Description**

| | |
|---|---|
| Title: | Receiver for Requisitioned Items |
| Issue: | Coordination |
| Description: | A number of items such as sandbags, pump hose, visqueen, etc., are requisitioned by the EM Branch during a flood fight. Most of these items are delivered either to a field office or to the warehouse. The paper work to verify receipt or items is sent to the EM Branch and has to be forwarded to the field office where the material was actually received, then returned. Most times, the EM Branch never has an opportunity to see any of the material. |
| Picture File: | *(not identified)* |
| Solution | A system be put into place that would have the office which actually receives the material, take care of the receiving report. |

**Indexing Information:**

| | |
|---|---|
| Office: | Operation & Maintenance |
| Project: | *(not identified)* |
| Emergency: | Flood Fight |
| Regulatory: | *(not identified)* |
| Contract: | *(not identified)* |
| Customer: | *(not identified)* |
| City: | *(not identified)* |
| Phase of Work: | Operations & Maintenance |
| Spec Number: | *(not identified)* |
| Discipline | *(not identified)* |
| Benefits Expected: | Time Savings |

**Author Information:**

| | |
|---|---|
| Created By: | Tuan Nguyen |
| Telephone: | 318-226-9913 |
| EMail: | *(not identified)* |

**Figure 8. Detailed data screen.**

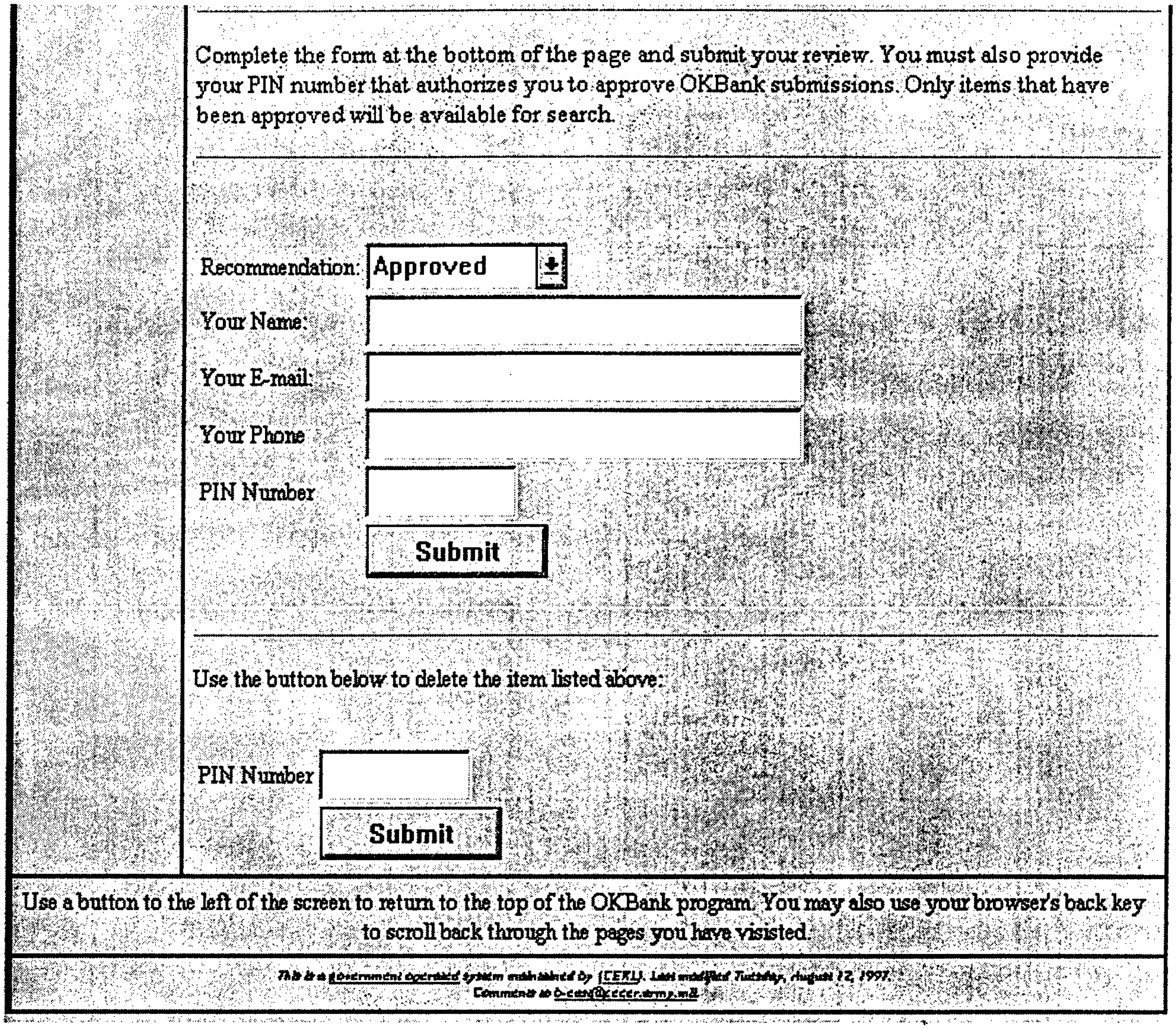



Figure 9. Reviewer's action screen.

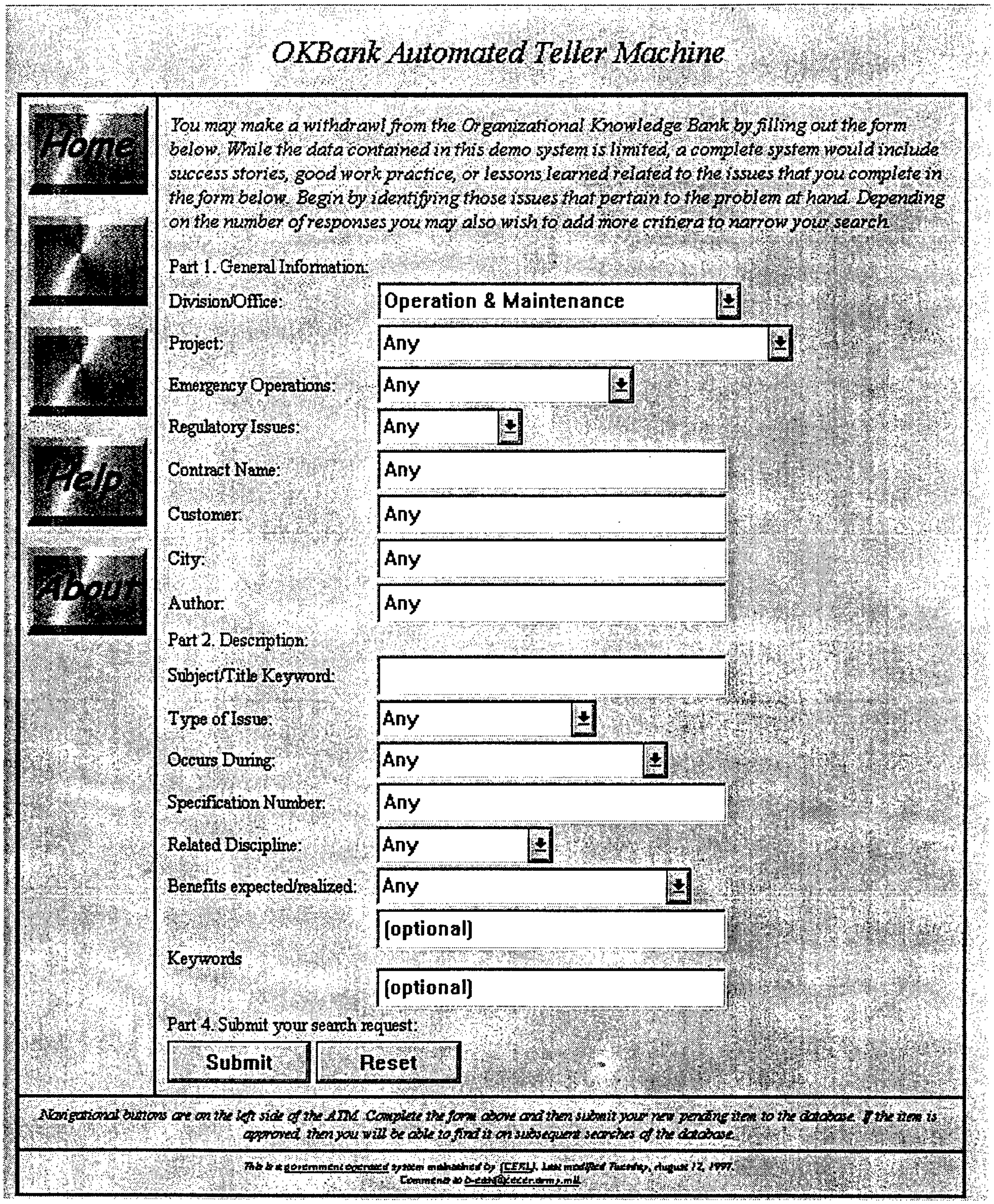



Figure 10. The withdraw (search) screen.

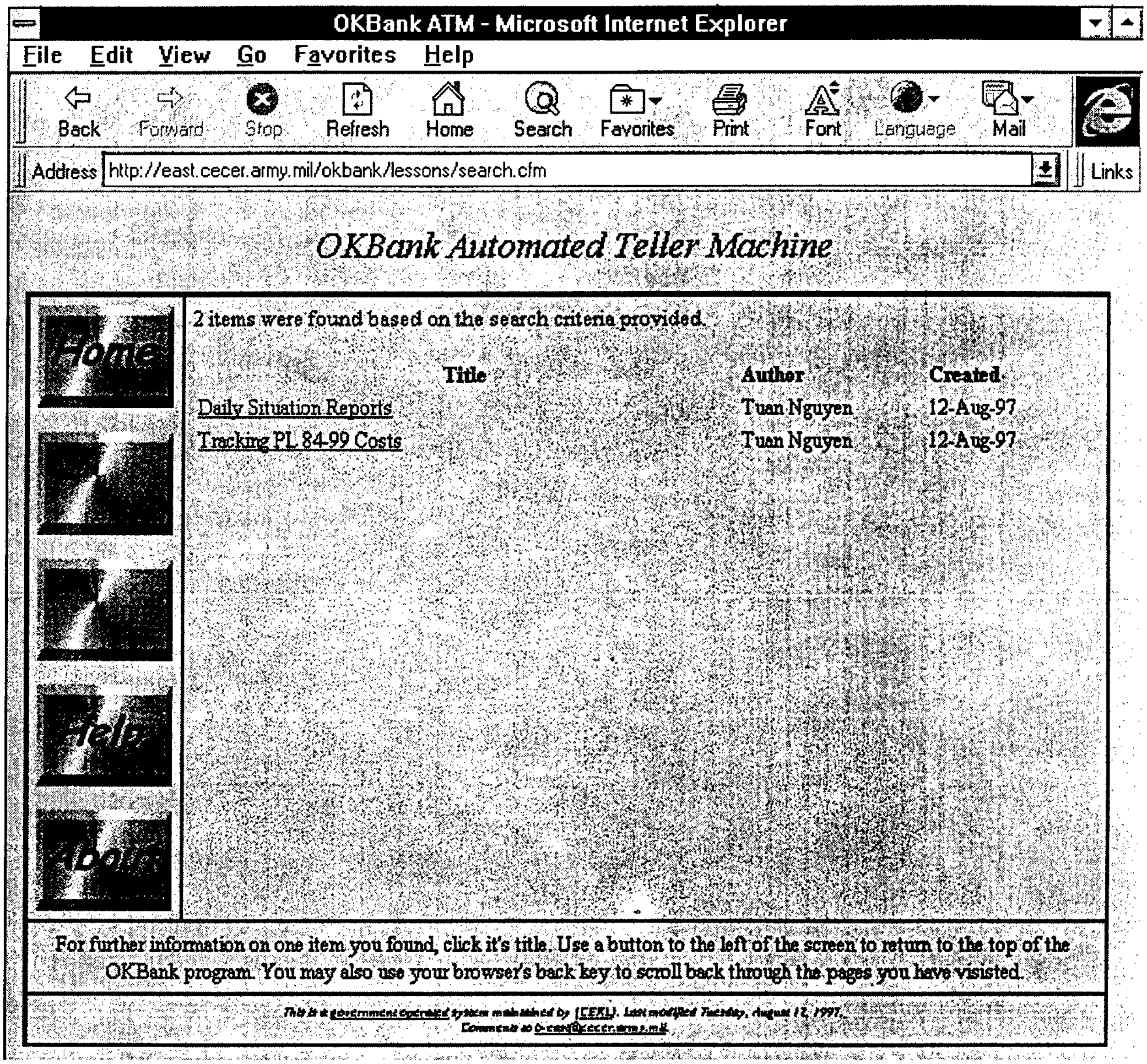



Figure 11. List of items found.

# 5 Review, Recommendations, and Conclusion

This chapter is a final overview of the research effort, including a review of the original research objectives. It will also include recommendations for future enhancements to the OKBank prototype system.

Part of the recommendations will focus on implementation issues such as system security, data management (gate keeping), and system integration mentioned in Chapter 4.

## Review of Original Objectives

The original overall objective of this research was to develop an automated system that can capture, store, and disseminate lessons learned from all project participants, throughout all phases of the project life cycle in a civil works organization. The overall objective was broken down into several specific objectives.

Objective No. 1 was to investigate and review the most significant automated lessons learned systems. This task was accomplished by reviewing published literature and contacting experts in the field. Many systems were identified, but only six systems are available. These six systems were thoroughly reviewed as described in Chapter 2, which also contains highlights and specific features of each system. In addition, some other major research efforts were also studied. These efforts provided many good concepts, a framework, and recommendations for an automated lessons learned system.

Objective No. 2 was to identify the deficiencies of these systems within the context of civil works projects, with an emphasis on the project life cycle. An evaluation guideline was developed to assist in achieving this task. It was concurrently performed with Objective No. 1. The results are also indicated in Chapter 2.

Objective No. 3 was to collect sample data for system development and to design the system. Because the system is designed to cover all phases of the project life cycle, a major levee project was selected for sample data collection purposes. The data collection process was accomplished by using the personal interview approach. It is interesting to note that the interviews not only resulted in data for the system, but also caused a shift in the system's design. The system was originally intended to contain only lessons learned. However, the responses from the interviewees indicated that geographically oriented project information should also be included in this system. The design was then modified to include applicable project information in addition to lessons learned. Furthermore, although many system developers have tried to define lessons learned as both positive and negative experiences, the term "lesson learned" itself inherently projected a negative image. Because this system was designed to capture experiences of an organization, the term "organizational experiences" seemed more appropriate. It was determined that the term "organizational experiences" would replace the term "lessons learned" in the system. This task was completed as described in Chapter 3.

Objective No. 4 was to program the prototype system. This task was probably the most ambitious and difficult of all the objectives. One of the biggest factors was the time constraint. Fortunately, USACERL provided programming support. The result is the OKBank system described in Chapter 4. The OKBank system can be visited through the Internet at http://east.cecer.army.mil/okbank/.

The review indicated that, in general, all original objectives were accomplished. However, since the main purpose of the OKBank system is to help the organization to continuously improve, the system itself should also be improved upon primarily through feedback from the users.

## Implementation Issues

### *Future Enhancement to the Submittal and Search Forms*

The submittal and search forms used for depositing and withdrawing OEs in the OKBank system are fairly long because they are designed to be used by all project participants, across multiple disciplines, throughout all phases of the project life cycle. Although most of the input fields are multiple choice and many fields are optional, the long forms might discourage people from participating. It would be very difficult to simplify these forms at this time because of the possibility of certain important fields being left out. After the system is in operation for awhile, these forms can be monitored and reviewed for certain usage patterns. Fields that are never used can be deleted from the forms. Other fields that are seldom used can be combined. The simpler forms will require less effort from the user. Consequently, the system will be used more often.

### *Security*

As described throughout Chapter 4, the OKBank system prototype is designed so that any user can withdraw information, including OEs. Any user can also submit an OE item. No PIN is required for these processes. The PIN is only required in the review and approval process.

While working level employees and the customers prefer an "open" system, management might not want to share certain information with the general public. This concern is valid if the information is classified and sensitive. In the case of a civil works organization such as the Vicksburg District, all information (including OEs) related to a project are generally public records. In addition, as discussed before, civil works projects involve many stakeholders, including the general public. The OEs, as broadly defined in the OKBank system, including items such as successful flood fighting methods, may also benefit the general public. Therefore, it would be senseless to restrict the system to internal use only. After all, through the review and approval process, management still has the final say on what information will be permanently stored for retrieval.

In the current version of the OKBank, any user can submit an item to the system. This accessibility has raised some concerns about inappropriate submissions. Improper items may be submitted into the system. However, this drawback is small compared to the advantages of a fully open system. The system needs contributions from everyone. An open system will increase the opportunities for submission, and the reviewers can always delete invalid items.

For these reasons, the "open" system concept used in the prototype shall also be used for the implementation of the OKBank system in Vicksburg District.

### *System Gatekeeping*

For this system to serve effectively, the database will need to be properly maintained and managed. Authorizing access to the database, reviewing or coordinating the reviewing process, and updating the database are just some duties required of the gatekeeper. The two approaches in handling these duties, centralized and distributed gatekeeping, are described below.

***Centralized gatekeeping.*** The centralized gatekeeping method is used quite often, especially in new systems. This approach requires a gatekeeper to perform all the gatekeeping functions. The gatekeeper monitors the database. If an item is pending for review, the gatekeeper will either review the item or consult with the appropriate expert for assistance. The gatekeeper then takes appropriate actions. If the item is approved, it will be ready for retrieval. Otherwise, the gatekeeper will remove it from the database. Figure 12 further illustrates this centralized gatekeeping approach.

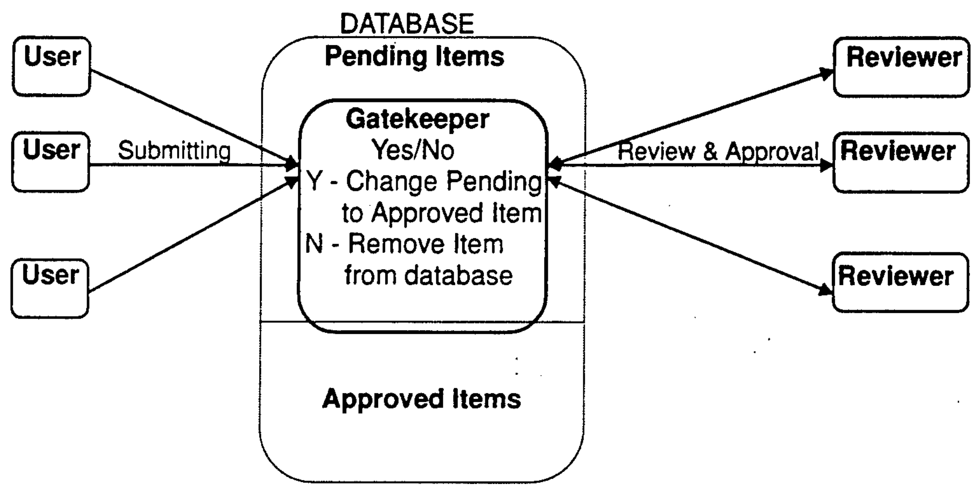



**Figure 12. Centralized gatekeeping.**

The centralized gatekeeping approach has many advantages. Since the gatekeeper is solely responsible for the data in the system, he/she will ensure that the appropriate people review the submitted items and the database is kept up to date. The single point of contact for coordination and communication will also keep the information flowing smoothly. The gatekeeper can also perform other administrative duties such as providing technical support, upgrading and maintaining system hardware and software, etc. The biggest problem from this approach is the cost. It is estimated that it will take a qualified individual at least half time, if not full time, to perform all these functions.

***Distributed gatekeeping.*** In the distributed approach, each reviewer will also serve as the gatekeeper for the system. The submitted item will be distributed automatically to appropriate reviewers depending on predetermined criteria. For example, all items generated by the Construction Division will be sent to a construction appointee for review. This person will automatically be notified by some electronic means such as e-mail or during log in. After reviewing the item, the appointee will perform the gatekeeper function by changing the pending item to an approved item if he/she approves it. Otherwise, he/she will delete the item from the database. Figure 13 further illustrates the distributed gatekeeping approach.

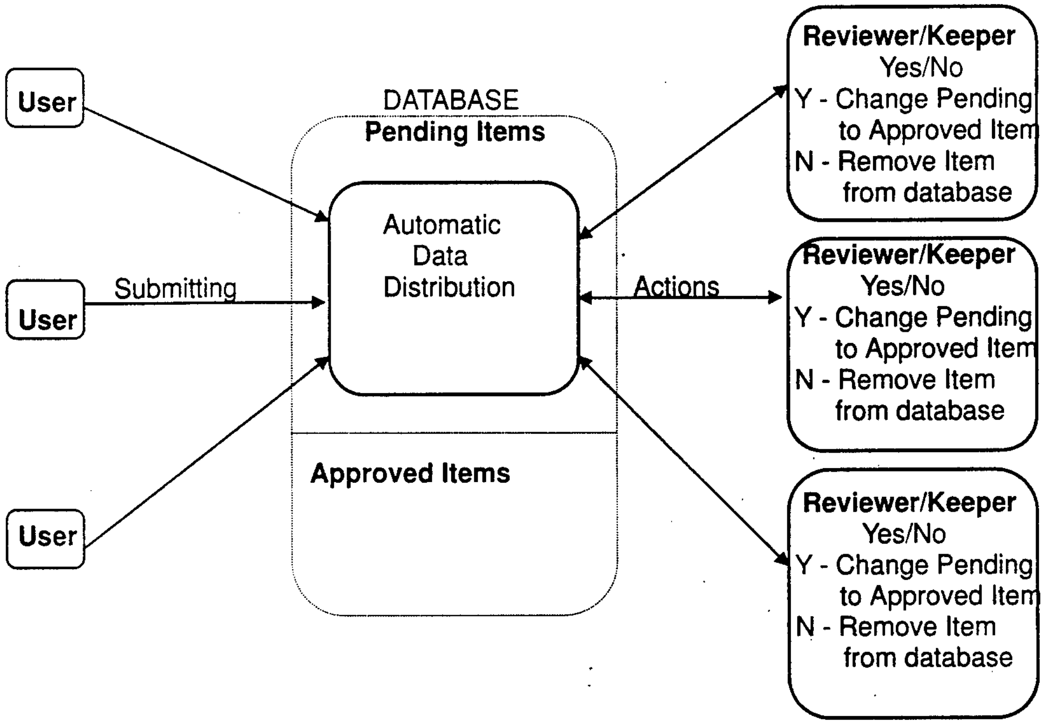



**Figure 13. Distributed gatekeeping.**

The advantage of this system is that it will not require a full time employee to perform the gatekeeping function. However, submitted items might not be reviewed promptly and the database might not be updated, since no one is responsible and accountable for the system database. Users will not know where to get support. Some minor system administration will still be required.

For the implementation of the OKBank system in the Vicksburg District, it is recommended that the centralized approach be used at least for the initial phase. Because the system is new, there will be problems and questions. A single gatekeeper who is responsible for the system will be more effective under these circumstances. After the organization becomes used to its existence and feels comfortable about it, the distributed approach can and should be used. When the distributed approach is used, some services are still required to keep the system running properly. However, these services are periodic and can be supported by personnel from an existing office such as Information Management.

### *System Integration With Business Practices*

The best automated system in the world will not and cannot make itself useful unless the organization provides mechanisms for integrating the system into its day-to-day operations. Since the OKBank is designed for use in all phases of the project life cycle and each phase has its own unique requirements, it would be difficult to suggest a detailed system integration. However, a general system integration is recommended. At a minimum, each major division that is responsible for a phase within the project life cycle should be required to review the OEs that are applicable to their own phase. For example, Planning Division should review all experiences occurring or gained during the planning phase of previous projects. At what point during the planning process the review should be done is for the Planning Division to decide. Figure 14 further illustrates the recommended system integration.

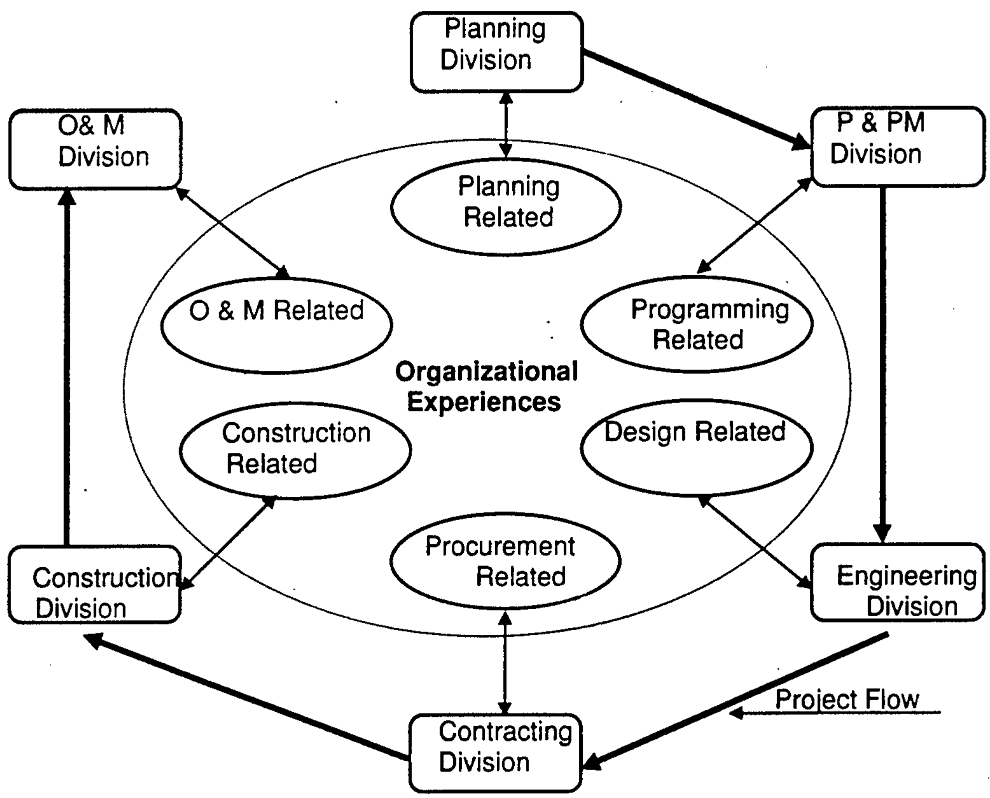



**Figure 14. Integration of the OKBank System with business practices.**

In the case of Vicksburg District, this requirement can be integrated with policies or procedures governing the processes involved in each phase of the project life cycle. For example, the Engineering Division is responsible for the design phase of any project. The design phase includes a design review process. As part of the design review process, the design team member is required to complete a Design Team Review Checklist. The review of design-related experiences contained in the OKBank system should be added to this checklist as a task to be completed. This addition will ensure that the design team member will review the OEs gained during the design phase of previous projects.

Other major divisions responsible for other phases such as Planning, Contracting, and Construction will have similar checklists of requirements. The review of applicable experiences contained in the OKBank system should be added to the checklist of each of these major divisions as an item to be completed.

## Conclusion

This investigation has indicated that one way for an organization to improve its performance is for the organization to learn from the knowledge and experiences of its members. This practice is even truer for organizations responsible for civil works projects, which are usually large and complicated. Each phase of the life cycle of these projects has unique requirements and involves many stakeholders. In addition, many civil works organizations have heavily relied upon the experiences and knowledge of the veteran employees for maintaining the organization's success. Recently, budget reductions have forced these organizations to lay off many veteran employees and more are leaving voluntarily. For the organization to effectively learn from all of its members, especially from veteran employees while they are still employed, a systematic approach for capturing, storing, and retrieving knowledge is required. This research suggested that an automated system is the best mechanism for use in this approach.

It would be a big challenge to develop an automated system to capture and share the organizational knowledge from all project participants, across multiple disciplines, and throughout all phases of the project life cycle. Such a system should be able to capture, store, and allow for retrieval of knowledge at multiple access points in time and space. Fortunately, the Internet is available. The Internet and related technologies have made the development of the OKBank prototype system possible. The OKBank prototype system will allow organizations such as the Vicksburg District to do more with less by tapping into one of its most vital resources, the organizational knowledge bank.

Without question, organizations such as the Vicksburg District will benefit from the OKBank system. The only question is the cost-benefit ratio of such a system. In the past, many similar systems have been developed. Most of them, however, operated on standalone platforms. The high cost per user of these standalone systems has discouraged many organizations from implementing them. The Internet platform has solved some of these cost concerns. The Internet allows the system to be used by as many persons as allowed by the organization without any additional software cost per user. There will be no updates beyond those provided to the operating system. The training cost will be minimal because very little training is required to use the OKBank system. Best of all, organizations such as the Vicksburg District can start reaping the benefits of the OKBank system immediately.

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# Appendix A: Sample Questionnaire

**Project Development (Planning & Programming)**

Name: ____________________ Organization______________ Phone No.______

Purpose: The questions below are designed to capture some of the organizational experiences on the Red River Levees project by interviewing key players in all phases of the project life cycle. The questions will be slightly different for each phase of the project.

1. When planning and programming for Levee projects on Red River, what are the few problems (repetitive or major problems) that you or your office have encountered, and that you would not want to see happen again? Are there positive experiences or success stories that you would like to share?

Examples: problems with site analysis, problems with the overall project schedule, problems with the landowners or with the right of ways, what items are often forgotten in preliminary project scope, what items are often needed but usually missed when project documentation/need statements are developed.

Examples of good work practices: where to obtain the best soil for the levee, when is the best time for turfing, etc.

Situation

background:

solution:

references:

2. What information/data would you like to see in the system that might benefit you?

3. Other remarks:

## Distribution

Chief of Engineers
ATTN: CEHEC-IM-LH (2)
ATTN: CEHEC-IM-LP (2)
ATTN: CECC-R
ATTN: CEMP-C
ATTN: CEMP-CE (2)
ATTN: CEDMP-E
ATTN: CEMP-ES (2)
ATTN: CERD-L

US Army Engr District
ATTN: Library (40)
ATTN: Civil Engineers (40)

US Army Engr Division
ATTN: Library (11)
ATTN: Civil Engineers (11)
ATTN: Civil Construction/Civil Con-Ops (11)

Defense Tech Info Center 22304
ATTN: DTIC-O (2)

127
3/97