SD93-10 F

SD Department of Transportation
Office of Research

Increased Efficiency Through Integrated Project Filing

Study 93-10 F

Final Report

Prepared by

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16. Abstract

Construction project documentation is vitally important to completing construction projects efficiently and effectively. Multiple functional, organizational and geographic entities must precisely coordinate activities to maximize productivity. Information is distributed widely to keep respective parties informed and this has led to duplication of effort to sort, file, retrieve, refile, copy, and merge/purge the redundant files. Individual offices within the Department maintain separate files leading to duplication, inconsistency and occasional loss. The bottom line is that construction progress may be delayed.

The first objective of the research was to assess the need for an automated, integrated project filing system for department- and consultant-prepared documents in SDDOT's central and field offices. This was accomplished by conducting surveys and interviews with SDDOT management and operational personnel to uncover operati ng procedures, problems encountered and suggestions for improvement.

The second objective was to identify appropriate technologies for integrating construction files into a single inclusive file accessible to all of SDDOT's central and field offices. This objective was accomplished by conducting interviews with other state DOT and commercial engineering organizations as well as researching what the information technology industry could offer.

The third objective was to develop a plan to effectively implement these technologies, assessing costs and benefits of advanced document management technology as applied to SDDOT. A conceptual system was designed, an estimated cost was established and operational, strategic and economic benefits of applying the system were estimated.

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PROJECT BACKGROUND

The mission statement of The South Dakota Department of Transportation is:

> The Department of Transportation's mission is to plan, finance, design construct and maintain a cost-effective state transportation system to support tourism, enhance economic development and facilitate the movement of people and products in a safe, timely manner.

The SDDOT submits approximately 900 projects worth $760,000,000 to the Transportation Commission for approval each year under the Statewide Transportation Improvement Program (STIP). In carrying out this mission, the Department has planned to complete 956 construction projects from 1993-1997.

Not only are dollars invested in South Dakota's transportation system. There are nearly 1,500 people, over 100 computer data bases, and millions of documents that must be effectively utilized to carry out the mission.

Although effective computer systems have been developed to manage data that supports the Department, 85-90% of all the information utilized by the Department's processes still resides on paper documents. The magnitude of paper these processes manage is illustrated as follows:

68,000 design drawings in redundant hard copy, microfilm and CADD formats
8,000,000+ documents filed in 3,368 file drawers
2,460,000 copies made annually on large format reproduction equipment
2,745,000 copies made annually on large-run copiers
1,100,000 copies made annually on Central Office walk-up copiers
376,000 copies made annually in field offices

The time constraints of integrated "critical path" construction processes have fostered redundant files of the same documents in most processes within Central Office and in each of the field offices. Individuals have also built personal "desk files" to assure fast access and control of their most active documents.

Distributing duplicate copies of all documents that support the construction process has made information available to those who need to be informed. However, the price paid is duplication of effort to sort, file, retrieve, refile, copy, and ultimately purge. It has led to multiple renditions of the same document which has confused which rendition is the "official" document and which is the latest configuration.

This uncertainty has forced those who must make decisions based upon accurate information to call or visit other processes to verify the most current information. As a result the effort to reference a document may be multiplied several times as personnel on both ends get involved. An even more serious situation could occur when decisions are made based upon outdated, or without consideration of information in inconvenient or unretrievable documents.

The South Dakota Department of Transportation, Division of Planning, Office of Research, believed there were technologies that could help. The Office of Data Services agreed. A research project was funded to **(1) Assess The Need** to automate and integrate the construction project files; **(2) Identify The Technologies** that were available to support the entire Department; **(3) Determine The Costs And Benefits** of implementing such technologies; **(4) Develop An Implementation Plan** for SDDOT. Our workplan is summarized in Figure 1.

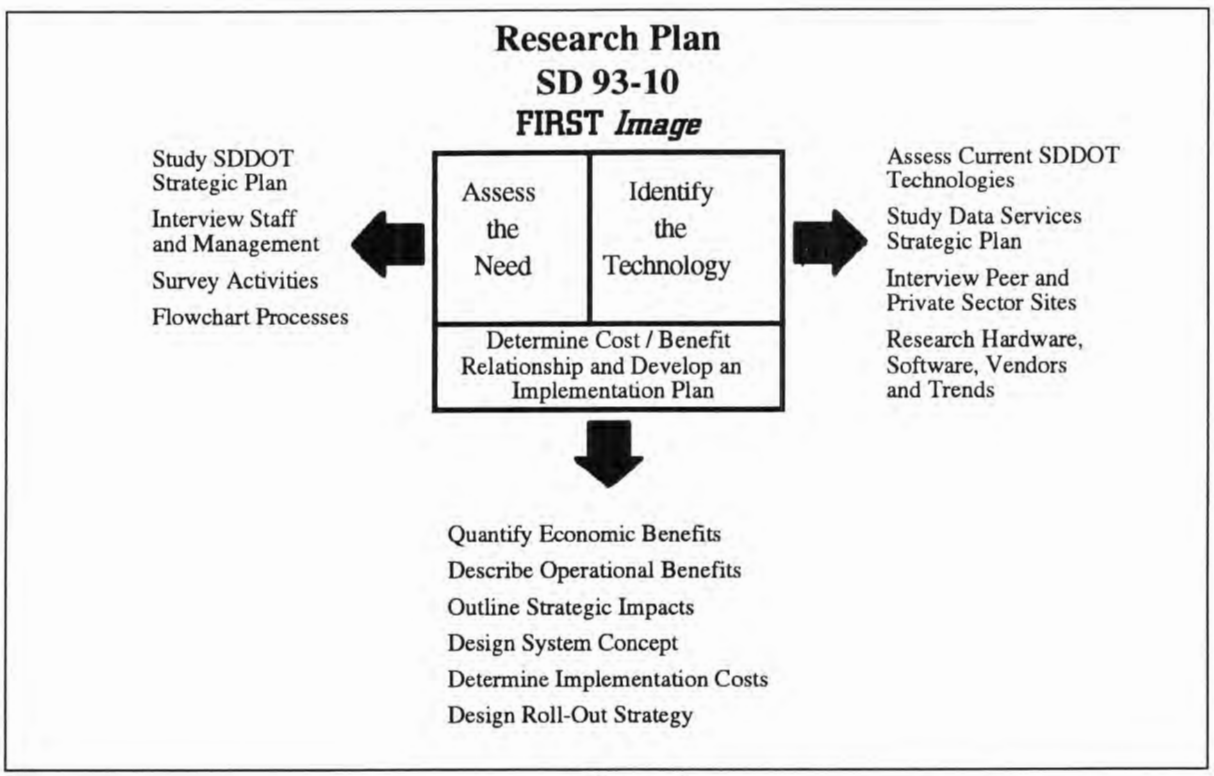

Figure 1

- Project Organization and Information Gathering from May 3 to June 18, 1993
- Process Analysis and Requirements Development from June 8 to August 20, 1993
- Draft Report on August 27, 1993
- Technical Panel review from August 30 to September 17, 1993
- Research Review Board Presentation on November 19, 1993

The directive was to address the problems from a business perspective. There were many possible technologies and many possible combinations. The key issue was to determine how those technologies would meet today's needs as well as lay the foundation to meet tomorrow's even greater needs. The research plan looked at the needs through the eyes of management as well as through the eyes of the technical and office staff as illustrated in Figure 2. Forty seven interviews were conducted and visits were made to every functional area and three field offices.

Top Down / Bottom Up Perspective

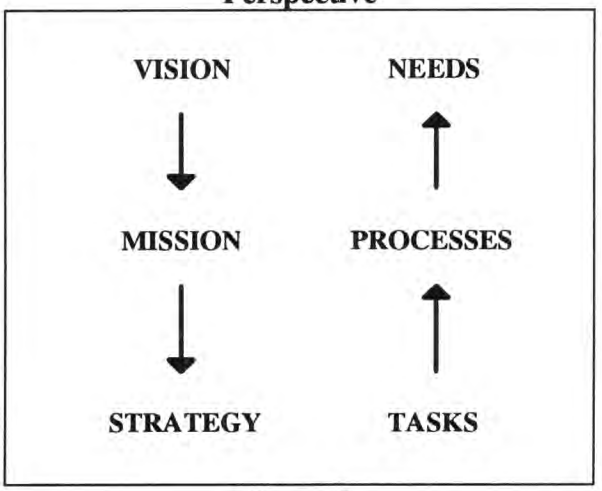

Figure 2

- Division management interviews were conducted to understand SDDOT operational vision, mission, and current strategy to carry out the mission
- Functional management, and technical and clerical staff were interviewed to understand the tasks and processes that would be necessary to realize the vision
- The disparity between the vision and the processes needed to fulfill the vision would define the global needs that technology must fill
- The research would be focused on business needs and not on technology implementation motives
- Implementation of recommended technologies would provide the opportunity to examine the current processes and structures in light of those new capabilities
- Soliciting creative ideas and securing "buy-in" would be critical to success

Our interviews with Divisional Management provided the vision to guide the research. They collectively created the following vision for SDDOT as they looked to the future:

Management Vision

- Improved information flow to facilitate decision making with better information access to foster proactivity
- More effective teamwork, empowerment, tools, and job enrichment that will attract and retain top engineers
- Protection against further loss of "intellectual assets" through retirement
- Improved project status reporting through timely information access and better management controls
- Benefit from valuable historical information locked in past project files
- Facilitate communication with external entities to maintain a professional public image
- Maintain an effective transportation system despite anticipated tax base reduction
- Facilitate increased reporting requirements of ISTEA
- Develop a transportation-based scope through cross-program information access and coordination
- Be more adaptable to rapidly changing conditions

CONSTRUCTION PROCESS OVERVIEW

The transportation construction process is made up of many sub-processes at the South Dakota Department of Transportation. The Department does not actually perform the construction of highways, bridges, or airports. It manages the process from the point of determining where the needs are to assuring that the completed projects are maintained appropriately so they will meet planned life expectancy.

The processes as shown in Figure 3, are derived from the South Dakota Department of Transportation Information Systems Plan, SD 91-14, dated September 1991, by Deloitte & Touche. We have used the same process labels to be consistent with this earlier study.

The vast majority of people in SDDOT are knowledge workers. To effectively manage the process, knowledge workers must rely heavily on accurate, timely and readily-accessible information. They must coordinate with other processes to avoid "lag time" between hand-offs. Conversely, if one process can overlap another overall cycle time can be reduced. Information access is imperative to such coordination.

SDDOT Construction Processes

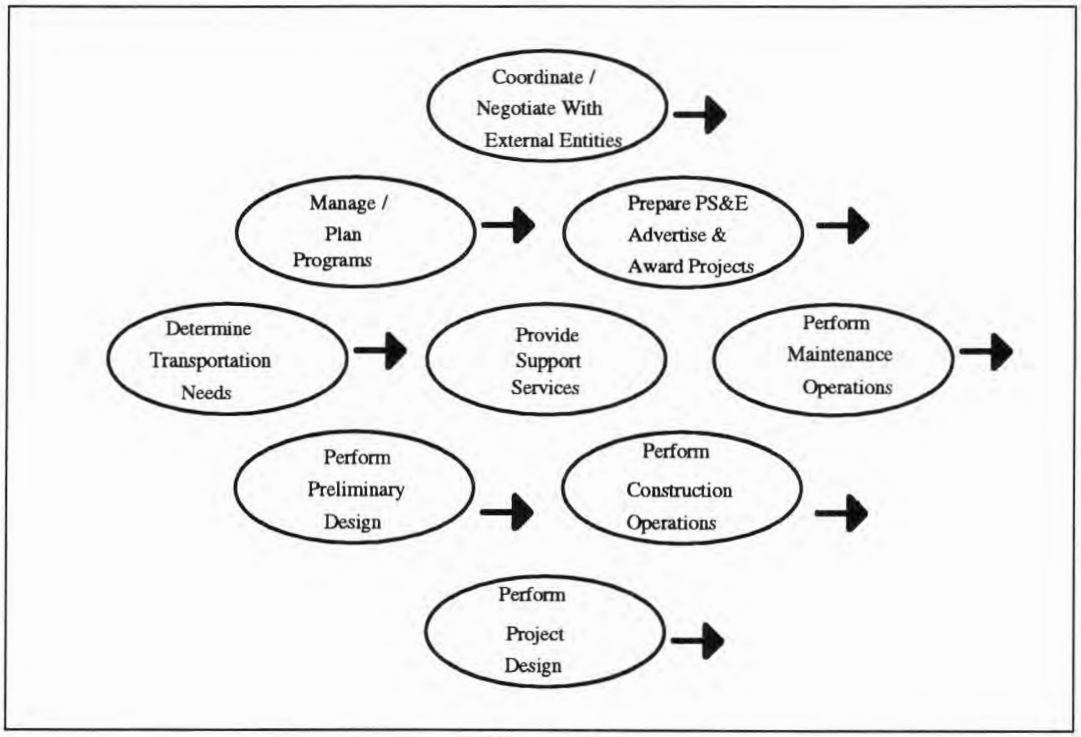

Figure 3

Several general observations were made during our research of the construction project process and are presented on the following page.

General Observations

Design Files

- Design drawings are critical to getting projects done correctly
- Most drawings are now created on CADD (Computer-Aided Drafting and Design) system(s) with design approval (redlining / mark-up) done manually from paper
- There is a belief that the drawing approval process must be handled on full size prints
- There is a strong concern about having general access to drawings prior to finalizing
- Most project activities are now carried out from reduced-size (11"x17") plans
- There has been no time available to create and distribute official "as-built" plans
- Drawings are archived on magnetic disk, aperture cards, and hardcopy media and have a 50-year retention period
- Configuration management is enforced for drawing renditions

Support Files

- Supporting document files are critical in completing projects according to schedule and to effective timing of project cycle processes
- Support documents reflect the variances, agreements, details and legalities of projects
- Support documents are distributed widely in an effort to keep entities informed of events
- There is no configuration management system for project documents and this leads to multiple renditions
- There is a 50-year retention period for some project documents

The following two pages overview the construction process cycle. The process is depicted in sequential steps to simplify presentation. However, many of these steps actually take place in parallel.

Simplified
Construction Process Overview

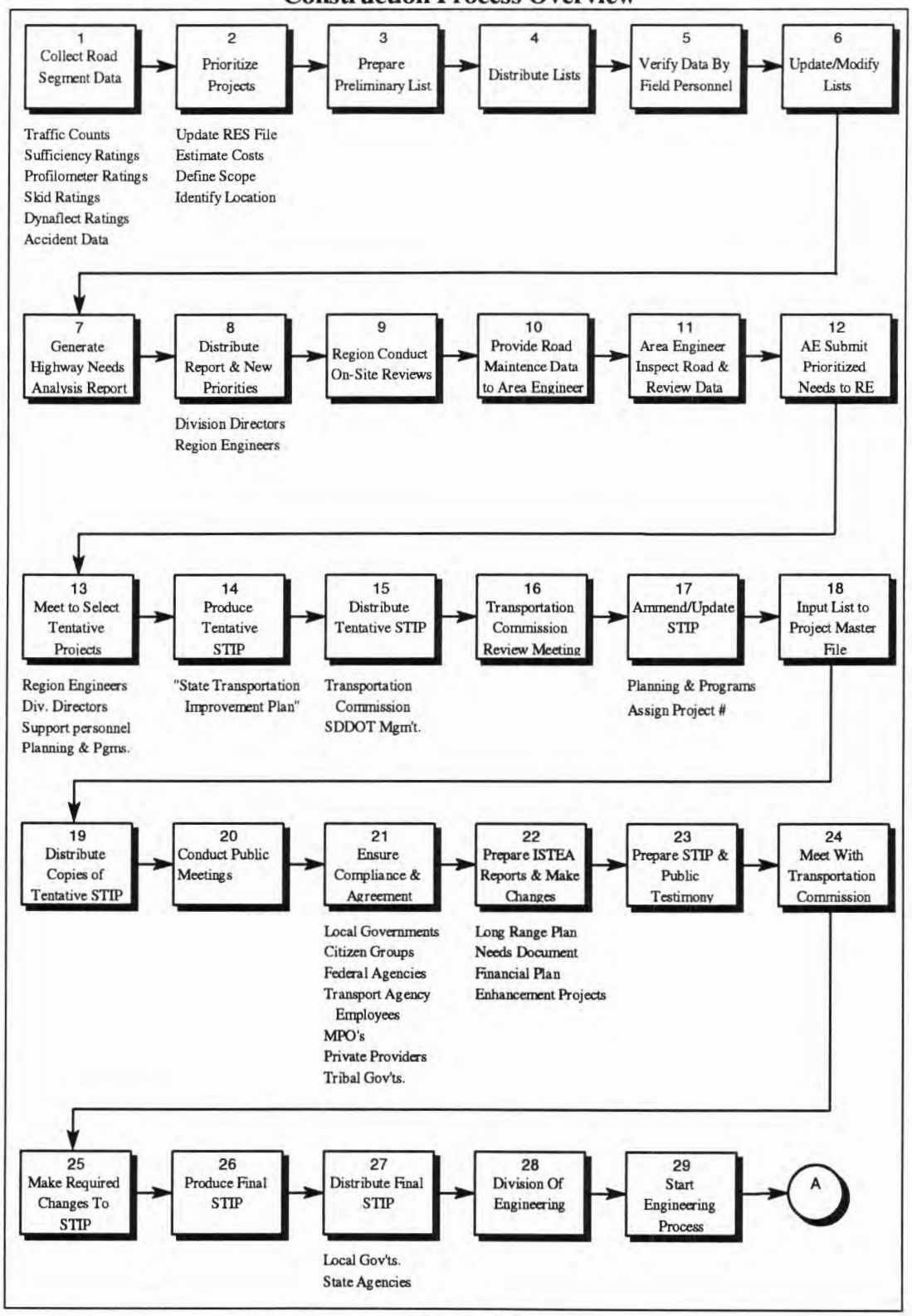

Figure 4

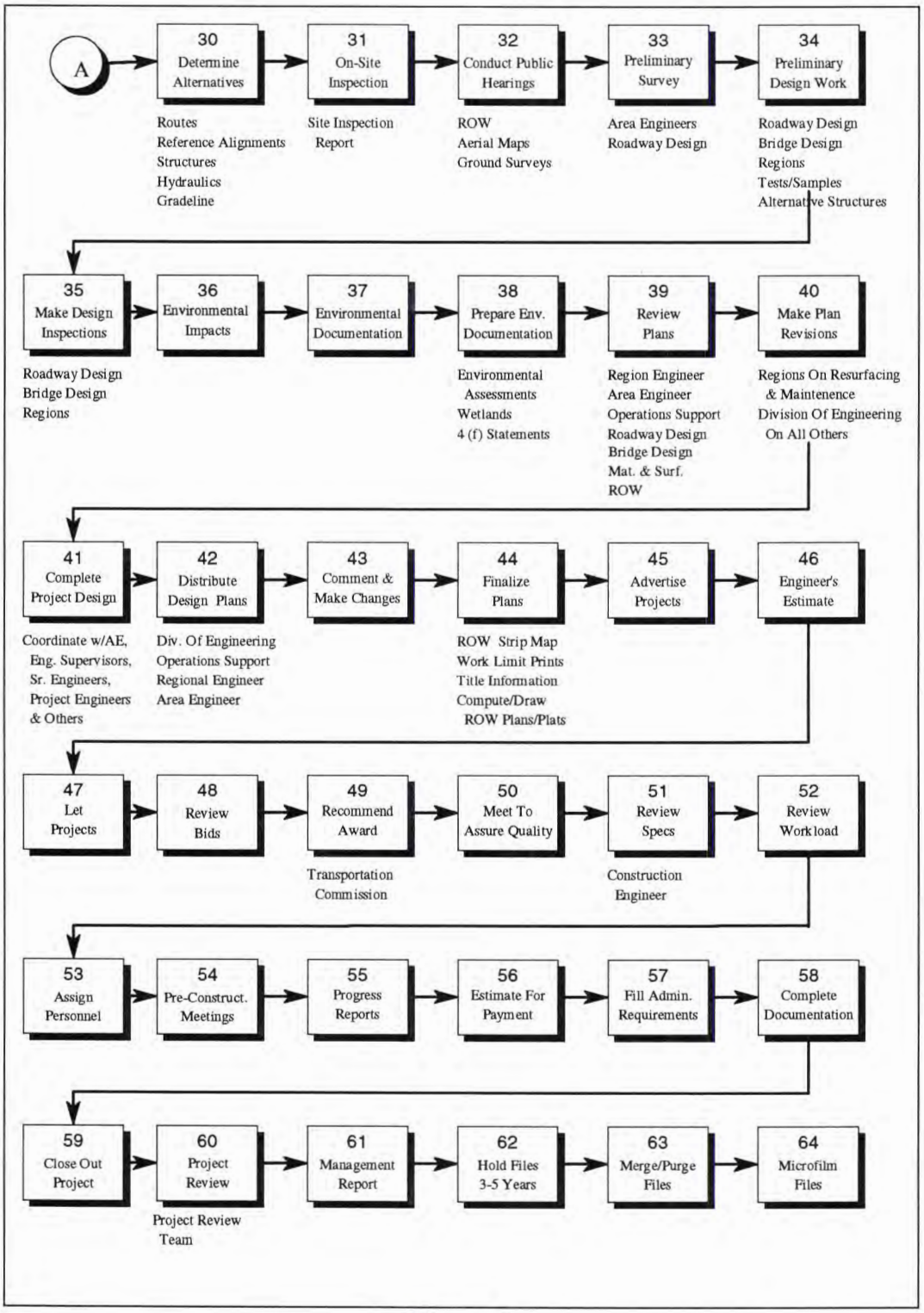
A
30 Determine Alternatives
Routes
Reference Alignments
Structures
Hydraulics
Gradeline
31 On-Site Inspection
Site Inspection Report
32 Conduct Public Hearings
ROW
Aerial Maps
Ground Surveys
33 Preliminary Survey
Area Engineers
Roadway Design
34 Preliminary Design Work
Roadway Design
Bridge Design
Regions
Tests/Samples
Alternative Structures
35 Make Design Inspections
Roadway Design
Bridge Design
Regions
36 Environmental Impacts
37 Environmental Documentation
38 Prepare Env. Documentation
Environmental Assessments
Wetlands
4 (f) Statements
39 Review Plans
Region Engineer
Area Engineer
Operations Support
Roadway Design
Bridge Design
Mat. & Surf.
ROW
40 Make Plan Revisions
Regions On Resurfacing & Maintenence
Division Of Engineering On All Others
41 Complete Project Design
Coordinate w/AE, Eng. Supervisors, Sr. Engineers, Project Engineers & Others
42 Distribute Design Plans
Div. Of Engineering
Operations Support
Regional Engineer
Area Engineer
43 Comment & Make Changes
44 Finalize Plans
ROW Strip Map
Work Limit Prints
Title Information
Compute/Draw ROW Plans/Plats
45 Advertise Projects
46 Engineer's Estimate
47 Let Projects
48 Review Bids
49 Recommend Award
Transportation Commission
50 Meet To Assure Quality
51 Review Specs
Construction Engineer
52 Review Workload
53 Assign Personnel
54 Pre-Construct. Meetings
55 Progress Reports
56 Estimate For Payment
57 Fill Admin. Requirements
58 Complete Documentation
59 Close Out Project
60 Project Review
Project Review Team
61 Management Report
62 Hold Files 3-5 Years
63 Merge/Purge Files
64 Microfilm Files

Figure 5

Determine Transportation Needs

The Determine Transportation Needs process and the Manage/Plan Programs process are closely interrelated. They team to compile the intelligence necessary to determine where the greatest needs for transportation improvement exist throughout the State. They lead the definition and refining of those needs to the point that they get prioritized and programmed into the Statewide Transportation Improvement Program (STIP) for funding.

The process starts with the Transportation Data Inventory Office. Their primary role is to collect and assimilate the data necessary to identify and prioritize transportation improvement projects that eventually end up as the STIP. They assess the needs across the state, maintain roadway, traffic and structure inventories, develop maps and initially define the long-term project plan.

Most of the data collection is automated, however special studies are maintained in hard copy. The files maintained do not relate directly to specific construction projects. As a result, subsequent processes that are project oriented can not use the Roadway Environment System (RES) data effectively and must get Data Inventory involved to answer questions.

Bridge inspection reports are maintained for structures that are not in the state trunk system. There are 4,600 structures in that category and two thirds of the structures do not have any plans that still exist. A significant amount of communication with local government authorities and consultants surround these structures and the associated files.

Although organizationally under a different office, accident records are also used in determining transportation needs. Data from the accident reports are keyed into a mainframe data base for manipulation. Hard copy reports are produced for reference. Descriptive information on the records themselves is valuable, but can not be computerized. The file is used to respond to inquiries from many external entities as well as entities within SDDOT.

Specific Process Needs

- A more on-line, user friendly system on a single computer platform
- A more structured data collection process to handle the growing volume of data
- More time left for processing data after the collection of data
- A system that facilitates staff backing up one another
- Ability to collect data and information without going to the "custodian" of the particular file
- Effectively handle the many project-related information requests received from within SDDOT and from external entities

Manage / Plan Programs

The Manage/Plan Programs process addresses highway, local government, railroad, aeronautics and rural transit. The process takes needs that are identified in the Determine Transportation Needs process and works them through to the "program" phase which includes them in the official priority scheme and inclusion in the STIP. It is here that the scope is defined, the costs estimated and the alternatives scrutinized.

Files are maintained on prospective projects and they contain all the background information that supports their consideration for inclusion in the STIP. Individuals generally have specific responsibilities, but they do form informal teams as needed. Reports on prospective projects are distributed to the region and area offices on a monthly basis. In the meantime, calls are continuously received from throughout SDDOT for information.

Approximately ten percent of the projects are considered "special" for reasons such as significant environmental impact, broad scope, politically sensitive, lack of inclusion in the state trunk system, or entanglements with local or tribal government issues. Most of these projects will result in a file being built in the Office of the Secretariat. Ninety percent are considered regular projects and are handled normally through the process.

There is an annual cycle in the programming of projects. From January until October there are precise timetable milestones that must be met. Projects are brought to the point of being officially identified in the STIP and a Preconstruction Engineering Management System (PCEMS) number is assigned to a project. The PCEMS number is also referred to as the Project Control Number (PC #). This identifying number is input to the Project Management System (HY-21) and the PCEMS system which starts the project accounting and tracking cycle.

Specific Process Needs

- Compatibility between all the various data bases and files used
- Better system continuity in maintaining the pre-PCEMS project files
- Ability to search effectively for historical roadway segment data
- Provide project-structured traffic statistics, soils and design data in a "help yourself" system
- Effectively manage Non-State Trunk System road and bridge files for 40 years
- Ensurance that data on Region maintenance projects is fed back to update planning files
- More effectively support local government construction programs

Perform Preliminary Design

When a construction project is programmed by the Manage / Plan Programs process it moves into the Perform Preliminary Design process. The preliminary design process includes performing location and environmental studies, a number of preliminary engineering activities, project scheduling, project definition refinement and design testing. There are a number of distinct activities that occur within the process and there is an interdependent relationship formed with other processes. Those processes include Perform Project Design and Coordinate/Negotiate With External Entities as shown in Figure 4.

Critical Path Processes

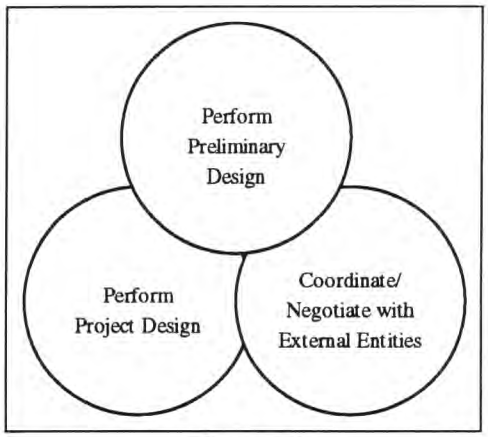

Figure 4

The functional areas involved in these three interrelated processes include Materials & Surfacing, Project Development, Right of Way, Road Design, Bridge Design, in addition to the region and area offices.

Coordination among the three processes is critical to success in carrying out the STIP. Teamwork is critical to presenting a consistent, accurate image to the public. Information sharing is imperative to meeting deadlines, minimizing reworks, and maximizing Department resources.

Coordination across processes is challenging in itself, but this is complicated even further by the miles that may separate the process activities. Information must flow horizontally and vertically between the three processes within Central Office. It must also flow geographically between Central Office, the region office and area office involved in each project. Information is originated in any one of these locations and is typically disseminated widely.

Wide distribution of hard copy project information would appear on the surface to facilitate coordination and teamwork. In actuality, it often presents problems of knowing which copy is the most up to date, whether all necessary parties were copied in on a particular event and which process "has the ball" at the time. Also, the multiple main and personal "desk" file copies that are built in every entity multiply file maintenance labor five or ten fold.

PCEMS, a highly-sophisticated computerized project management system, schedules the multitude of processes that must be completed throughout the pre-construction phase. Although PCEMS is felt to be a good system, only a few individuals use it in an on-line fashion due to what is perceived as user unfriendliness. Users would also like more project detail than what is currently contained in PCEMS with ad hoc inquiry and reporting capability.

Project status reports are generated periodically and distributed to the work centers involved. When a project has fallen behind in a PCEMS-scheduled activity, reports are distributed for that particular work center requiring explanations for the delay. In many cases, the reasons noted on the report indicate that a prerequisite activity was not completed by another work center process. It could actually be that the information showing the activity had been completed was not yet received, not yet circulated, or somehow misplaced. Precision coordination is demanded by these three processes or slippages, reworks and time wasting oversights can occur. Information sharing and access is critical.

Specific Process Needs

- Easy access to project detail that PCEMS and Project Master System provide
- Ability to effectively browse old project files, diaries, cost estimates and test reports by date, activity, structure design, location, source, dollars, etc.
- Single retrieval reference for design, hydraulics, et.al., for a given structure
- Better flow of information between Central Office and consultants, cities and counties to reduce field trips and conferences
- More effectively meet increasing environmental regulations that can complicate design and get plans to point where Right of Way can get started on property acquisition sooner
- Better control and information access to county secondary road projects
- Ability to effectively audit for project test and certification completeness and controls to ensure other processes don't use preliminary or revised plans erroneously
- Bring old bridge drawings into CADD system in rehabilitation projects

Coordinate / Negotiate With External Entities

Most of the functional areas in SDDOT have involvement with entities outside the Department in one way or another. Right of Way (ROW) is probably the unit that is most clearly identified with external involvement as they deal with land owners in the property acquisition process. They also must deal with local government and utilities in the process.

ROW is notified by Roadway Design via a ROW Strip Map that properties will need to be acquired once preliminary design activities have determined a centerline for the construction. This initiates action on a number of fronts and begins the paper documentation process starting with a request for incidental funding approval from the Federal Highway Administration (FHWA). Contact is also made with any local entity that may participate through the appraisal, acquisition and relocation processes and paper is generated on both ends to document the agreements. The various documents and agreements circulate through SDDOT for formal approvals.

Books are assembled for each property that must be appraised in the acquisition process. They include all the maps, sketches and photographs relative to that property. A Certificate of Title for each property is requested from courthouses and a formal contract is signed with abstractors. ROW staff believed that effective access to old appraisal and acquisition files could greatly facilitate the process. An estimate stated during interviews was a 10% improvement in productivity could result from more effective document access.

The appraisals are next approved by the Transportation Commission and a project folder is developed for each relocation required. Relocation costs must be established and old relocation documents are valuable in the cost estimating process. All the documents accumulated on the appraisals and relocations are reviewed with the Federal Highway Administration (FHWA). Sometimes documents get lost among the large quantities of paper that is being distributed in multiple directions and requires retracking and/or redoing the entire step.

During the process a status report is generated on paper for each acquisition. This takes 1 1/2 hours per week to complete. Having the ability to review acquisition and relocation status information would be very helpful. It is critical that the regions have copies of agreements for properties in their respective areas prior to their visits to landowners in the field. Professional image can be damaged and revisits necessary if there isn't consistency of information. Inconsistency could even foster the need for condemnation action on properties.

Much of the ROW activity is carried out by individuals and the files are maintained as personal desk files. There is a significant amount of collaboration within the functional area and information sharing is important. At various stages the files or individual documents are routed to supervision and management for approvals. At conclusion of the acquisition process the files are audited to ensure that all the required steps have been taken and all the required documentation has been filed. Files are retained for three years after the construction is completed.

Acquisition, relocation and condemnation proceedings can cause delays in starting construction. Completeness, accessibility and timeliness of information documenting the activities is critical to ensuring that this part of the process flows smoothly. It is also critical to other interdependent activities.

Local Government Assistance and Air, Rail and Transit work with local governmental authorities through the entire construction project process. The local government entity does or contracts for much of the planning, design, and construction on their own. SDDOT programs the projects if there are federal funds involved. They are also there to help with all the issues surrounding ROW activities, environmental impacts, hydraulics, materials, needs analysis, etc. In that capacity they generate and receive large amounts of paper to document all the required activities. Most personnel work independently on their own projects.

Air, Rail and Transit projects have been broken off as a separate division to enhance effectiveness in meeting the new intermodal transportation orientation of SDDOT. They must work closely with local government entities. They manage leases and grant licenses for state-owned properties and must interact with railroad companies in that regard. The files are used exclusively by this function within Air, Rail and Transit.

In the construction process there is a lot of coordination with the railroads and utility companies as well as with cities and counties. This can get very entangled, especially in urban locations. Information on utility locations and the agreements in effect with each company or local government is critical to avoiding bottlenecks and misunderstandings that can impact construction efficiency.

Specific Process Needs

- Improve property acquisition efficiency
- Better coordination between Central Office and the field
- Consistent and timely information presented to external entities
- Ability for other processes to inquire into local government project files on their own for status information
- Better access to topographical data and utility locations
- Multi-characteristic access to utility files by company, location, project, etc.
- Provide better information to utility companies to reduce their approval times
- Provide ready access to historical project files

Perform Project Design

There is a large overlap in activities between the Perform Preliminary Design and Perform Project Design processes. Road design receives a lot of information from other processes, such as the planning process, or the soils, tests and surveys activities within the Engineering Division.

The personnel involved in this process often work together in design teams and may collaborate on several projects at any one time. There is a significant amount of coordination necessary with all the other critical path processes such as Coordinate/Negotiate With External Entities. Roadway Design has developed a PC-based program to maintain larger amounts of detail than PCEMS on specific projects. They feel that this gives them better control of all the entities and activities that are involved in the design process.

Design plans are in process for extended time periods. What began as a preliminary grade lines is expanded and refined, adjusted many times and ultimately approved for construction. The design team must depend on a lot of research, field test data and on-site reviews to move through the approval process. Roadway Design must work hand in hand with Bridge Design on many projects.

Most of the design drawings produced today are on the Intergraph Microstation CADD system. As plans are being worked they are closely controlled. There is a strong belief in the engineering groups that they must control who has access to design drawings while they are in process. There is a concern that decisions could be made on preliminary plans that would be incorrect.

Engineering has considered automating the design approval process through CADD conferencing. A strong opinion was expressed in our interviews that redlining and mark-up of large drawings on a CRT screen would not be practical because the full perspective is difficult to achieve.

Specific Process Needs

- Manage and control the large amount of correspondence generated and received
- Acknowledgement that all entities in this process have received plans
- Effective access to old design plans
- Retrieval of project files by multiple categories, descriptors and relationships
- Make preliminary plans accessible without risk of premature decisions being made
- Tie together multiple projects in a geographic area over an extended period of time
- Provide a high level of coordination between Central Office, field and outside entities

Prepare PS&E, Advertise And Award Projects

The primary role of this process is to facilitate moving a construction project through all the steps that lead to bid letting. Project Development initially sets a project up on the PCEMS system so that costs can be tracked from that point on. Work Authorizations are created for every step in the process and the Project Management System (HY-21) data base is updated on a regular basis with charges and work to be performed.

A large amount of paper is generated throughout the approval and bid letting process. Coordination is extremely important between Central Office processes, region and area offices, outside agencies and FHWA. Environmental issues are major efforts that must be documented and taken into account in all design work.

There is an extensive list of requirements that must be met throughout the project development process. Keeping on top of what is required and what requirements have been met is a major effort. Any one of the requirements or approvals that are late can hold up the final bid letting. There is a lot of telephone calling to get the status on project activities and to track down missing paperwork throughout the Department.

The PCEMS system is critical to managing all the steps from the initiation of a project to the bid letting. Every month a multi-project scheduling run is made which attempts to reconcile activities for a project and "flag" any that have fallen behind. Exception reports are sent to work center managers for updating as to why the activity did not occur and what action will be taken to get it back on schedule.

Specific Process Needs

- Access to old project files and cost information
- Communicate and coordinate effectively with internal and external entities to acquire/assemble plans, work authorizations, approvals, agreements and permits
- Universal availability of documents that can support more parallel process activities
- Ensure that all potential impacts have been reviewed and addressed
- Ability to search for project documentation by multiple descriptors when a PCEMS number is not known

Perform Construction Operations

The SDDOT does not actually perform the construction operations, but they manage and support the actual construction. This requires close coordination between the field offices and Central Office, contractors, utility companies and local government entities.

Construction begins with contract award and a work schedule. Everyone involved gets copies of final plans which are usually 11"x17" in size. There is little change made to original plans once construction begins and any "as-built" changes may be created only for regional use. This can cause serious problems in later maintenance or modification projects on that same construction.

There are Construction Change Orders (CCO's) issued and approved during construction. Much of the responsibility for project construction is in the hands of the area office project engineer.

Bridge inspection reports are generated in the field offices and ultimately feed into the STIP for programming. Smaller maintenance projects are handled exclusively in the regions and there is a concern with the information generated from those projects not being fed back into the Central Office that might impact subsequent construction at that site.

Weekly Progress Reports are generated weekly on what has been done on a given project. Correspondence and contractor payroll documentation also is sent from the field to Central Office.

At the conclusion of construction there is a final cost analysis and Final Data Sheet created. Projects are finaled out and the files are maintained at both the area office and at Central Office for three to five years. There is an extensive file purging and merging process and then files are sent to Internal Services for temporary filing and subsequent microfilming.

Specific Process Needs

- Better coordination and information access across all the entities involved in construction
- Ability to retrieve information in current and past project files by highway attributes
- Efficient access to utility files
- Universal availability to all construction documentation during the process
- Effective conferencing on design issues that arise during construction
- Better feed back on the quality of the construction for better planning
- Consistent information when dealing with external entities

Perform Maintenance Operations

Maintenance operations are largely managed in the field offices. If the projects are under a certain dollar limit, it is handled by the area offices and does not get programmed into the PCEMS system. The field will also design small grading and road widening projects. The plans are sent through the approval process as described for Perform Project Design.

There was a view expressed during our area office interviews that Central Office could benefit more by having access to area office project file information than the converse. That view was confirmed during interviews in Central Office. A serious problem can result when Central Office modification or rehabilitation projects are planned without information housed in area office files.

There is a vision that all overlays, seals, crack treating can be designed in the region and the work done at the area level.

The Perform Maintenance Operations process does not have the volume of paper or the precise coordination seen in most other SDDOT processes. Much of what is generated in this process would be valuable to other processes. Interest was expressed in our interviews for more automation in the collection of construction and maintenance data with use of laptop or pen computers. It was stated that an automated process would save time, improve accuracy and make construction-site data more likely to be included in Central Office design files.

Data Management

The South Dakota Department of Transportation manages most of its data processing resources in the Office of Data Services, under the Division of Finance. The large mainframe-based applications such as PCEMS and Project Management System reside on the State's mainframe. These systems were given high marks by users during our interviews because of the breadth of data these systems manage.

Users also stated that these systems were difficult to use in an on-line mode. In addition, mainframe charges are tied to use so there has been no real incentive to expand use. As a result, only a few people use them in other than a batch mode with periodic reports. They universally wanted more timely access to the data to facilitate planning and decision making. They wanted to be able to retrieve data by other than a PCEMS or project number.

There has been a gradual migration from mainframe-based processing to network-based processing and stand-alone processing. The migration has been driven by greater flexibility, more friendly user interface and lower costs. In 1991, Data Services developed an Information Systems Plan to address integration and formulate a long-range strategy for the future. Because there is a migration, not wholesale implementation of network-based systems, Data Services has to manage an overall information management system that does not totally integrate.

Several decisions are being made now that will impact final design and implementation of an automated, integrated project filing system.

Data Services Decisions Underway

- Network operating system choice between Microsoft NT and IBM OS-2
- Actual implementation of a windows-type operating system
- Network architecture decision between client-server and peer-to-peer
- Need for, implementation of, and integration with an Executive Information System
- Need for, implementation of, and integration of a Geographical Information System
- Need for integration of CEAL and IGRDS design systems
- Speed with which to move from batch programs to real-time programs
- Need to accelerate the PC workstation upgrade cycle

SDDOT
Tentative Wide Area Network Configuration

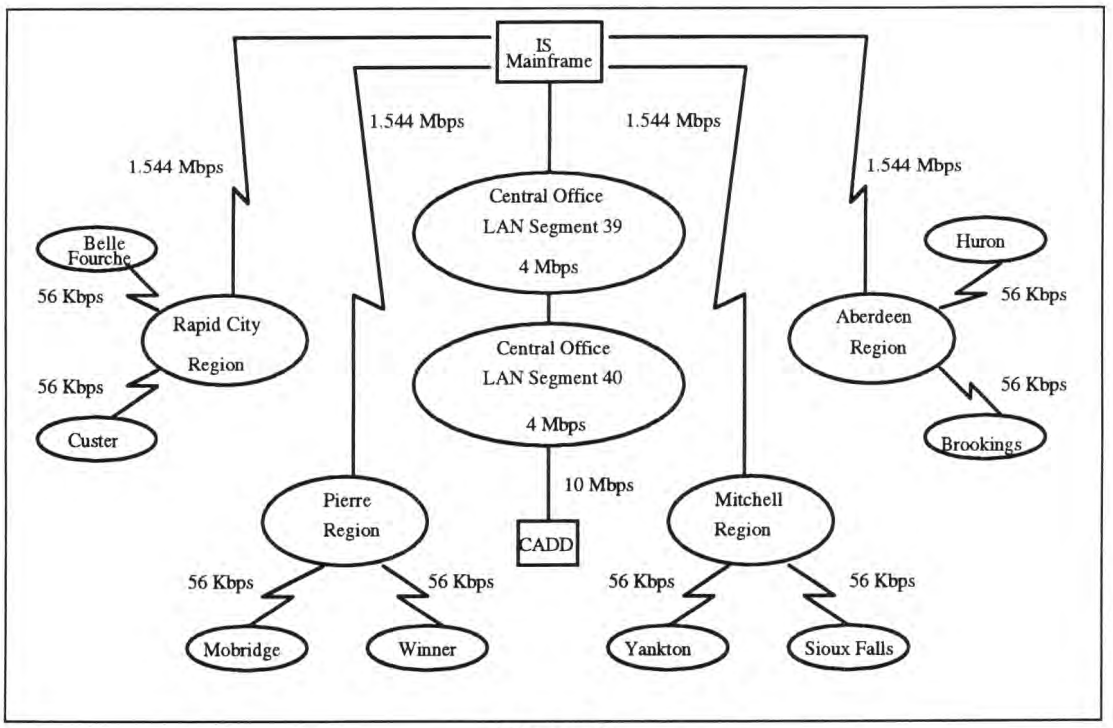

Figure 5

Data Services Environment

- Mainframe is State Information Systems' IBM 3090 200J mainframe
- Tempus Link communications software for data transfer between PCs and mainframe
- INS SDLC Gateway 1.04
- Attachmate Extra channel attached gateway; DOS and Windows
- LAN Manager 1.0 in Central Office; PC LAN in region offices
- 27 servers: 4, 8, 16 meg; File, Print, Mail, Gateway, Bridge, and Network Manager
- 250 nodes on Central Office IBM Token Ring Network
- 324 PCs: 108 XTs, 69 286s, 100 386s, 47 486s (most 386's & 486's are CADD; Data Service's 76 machines are not included in totals)
- Microsoft Windows 3.1 client software (limited personal copies)

Central Office
CADD Output Environment

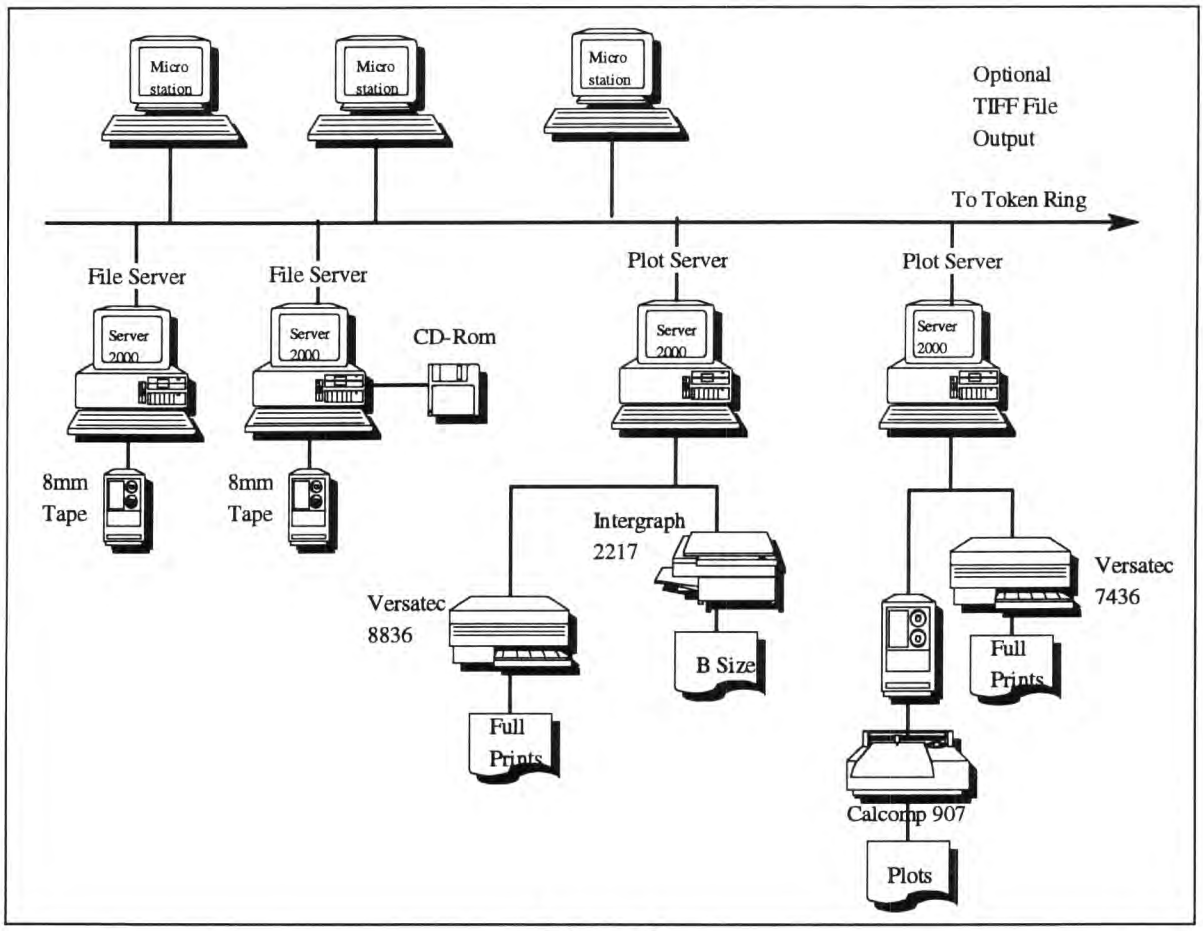

Figure 6

CADD Issues

- Intergraph Microstation can output an optional TIFF file directly to the Ethernet network to any compatible device or through the gateway to the Token Ring network to any TCP/IP compatible node
- IGRDS is not compatible with the CEAL system in the field offices
- Most CADD-generated drawings are distributed as reduced-size 11"x17" prints and serve the purposes for most uses except for complex or heavily detailed drawings
- Intergraph has announced an open systems platform that will be compatible with Microsoft NT Operating Environment for late 1993

Central Records Management

The central document file is managed by Internal Services in the Division of Finance. In essence, this office serves as the final repository for project file documentation not as an active file management service. Project files are maintained in hard copy by each process at both Central Office and in the field for at least three years after project close out.

Project Development provides about 70% of all documents that currently end up in the permanent project files because of the legal nature of what they document. Approximately 10% is received from Operations Support. Three years after a project is closed out the files in each process area are supposed to be purged and merged and sent to the central file at Central Office. Because of the magnitude of this activity, file purging is sometimes postponed for several years after the three-year close out retention period. An estimated 2,352 hours annually are devoted to close out activities in the area offices alone. The whole Department could spend twice that figure.

Internal Services maintains the project files in paper for a period of time and then they are microfilmed. Letter-size are filmed on 16mm microfilm on a high-speed Kodak camera and indexed on a PC by project descriptors that will permit retrieval. Materials and Surfacing, Finance and Accident Records have their files microfilmed separately. 4,870 retrievals are made to roll microfilm per year on a Canon reader-printer. About 75% are to accident records to support hazard studies. A Xerox 18"x24" reader printer is used for aperture cards. A Space Saver sliding open shelf filing system was recently installed to better manage the hardcopy project files prior to microfilming.

Full size drawings are copied to 11"x17" size and are sent out to the Springfield correctional facility for microfilming. Originals are returned to the design area that originated them. The 35mm film rolls are then sent to the State Records Center for processing. The finished rolls are loaded into aperture cards by Internal Services and indexed by project number. This process can take several months to complete.

Internal Services also operates the Central Quick Copy facility. They use engineering printers, xerographic copiers, and offset printing systems. These include a Xerox 5080, Xerox 7085, Mita DC-8585 and Multigraphics System 7 to produce over 4,340,000 copies annually. They also operate a blue line printer that produces 60,000 prints per year. A large portion of this copying is for distribution to potential project contractors and other external entities during the bid letting process. An even larger share is distributed throughout the SDDOT organization and ends up in files to be managed. At $.05 per copy, this is $217,000 annually.

There are approximately 250-300 retrievals to the hardcopy project files per year. It usually takes less than a minute to locate the file, but an engineer from Roadway Design may have to walk from the opposite wing of the third floor to the central files on first floor to get to the file. That trip takes 1 1/2 minutes each way. The total retrieval time is really close to 4 minutes. If the information resides on aperture cards, it will take another 3 minutes.

Financial Services

Financial Services handles all the transfer of moneys between FHWA, SDDOT and contractors in the construction process. They receive pay estimates, correspondence, vouchers, contracts and agreements and must process them and appropriately apply the funds. They maintain most of the documentation they need to fulfill their role and seldom need to go to another functional area for answers. Documents are used mostly by specialized individuals as opposed to the whole workgroup. As such, retrieval from a close-at-hand file cabinet is estimated at 30 seconds by the staff.

Much of the documentation received is used to update the Pay Estimate and Project Master computer data bases. These systems allocate and disburse funds and keep Department personnel udpated on how funds are being applied to projects. However, for audit trail these input documents must be maintained and readily accessible.

Project reports are run every four weeks off the mainframe computer and nine copies are sent to the area , region, Auditor, accountant who will bill FHWA, the contractor and one to the project file. The area office uses the pay estimate to create input for the next pay estimate. Voucher copies are filed in the voucher file, project file and a copy is sent to the auditor.

There are 50,000 vouchers cut per year. Only vouchers that originate in the office (payments to contractor, contract payment for utility relocations) are stored in the project file. Project files contain a copy of Construction Change Orders (CCOs), Pay Estimates, Agreements, correspondence, and any information that affects contract financials. Files are retained until a project is finaled with FHWA or as space is required. This could take many years to complete. Files are ultimately sent to Internal Services where they are microfilmed as a separate file.

Internal Audits

Internal Audits performs project audits. This requires researching Central Office files as well as field office, contractor and consultant files. A random list of audits can be generated by the computer and field trips are made to external locations. Spreadsheets are used extensively to profile projects. It would be very valuable to have the ability to perform some pre-audit functions before traveling to an audit site.

Internal Audit makes sure that rules were followed for a project. The audit section performs the audits on site and rarely makes copies for their own files. They ensure that the appropriate meetings were conducted, reviews and inspections done, tests performed, receipts filed, permits obtained, CCOs appropriately generated, payments accurately made, etc. Operations Review also audits projects, but from a more technical perspective.

In their audits they occasionally find that documents are misfiled. The average time to locate a misfiled document is eight hours.

Specific Needs

Data Management

- Design a platform to support CADD conferencing and plan approval automation
- A user-friendly systems interface for users
- Establish a comprehensive project management data base
- High speed communication lines to all field locations and coordinate desktop computing power across the network
- Interoperability of all heterogeneous computing platforms
- Accelerated PC upgrade program to take advantage of today's technology
- Computing environment that can grow with the needs of the Department

Central Records Management

- Elimination of redundant project file indexing for microfilm retrieval
- Ability to provide flexible retrieval of project files housed in Internal Services
- Ensure that users have confidence in the accuracy of the project files

Financial Services

- More effectively monitor the quality of activities as opposed to only the quantity

Internal Audits

- Do more of the audit function from an automated project file to focus on issues before making the on-site audit.

NEEDS SUMMARY

- Fast retrieval of project file documents
- Timely filing and availability of all project documentation
- Retrieve all information without having to call or travel to "custodian" of that file
- Effectively research old project files, cost estimates, utility locations and test reports
- Search for project file documents by roadway segment descriptors
- Search for project files by date, activity, structure design, source, dollars, etc.
- Effective file access that facilitates concurrent processes to shorten cycle times
- High level of coordination and teamwork between all project entities
- Monitor for completeness of project tests, requirements, certifications
- Friendly user interface
- Reduced file maintenance activities
- System with a high level of flexibility
- File integrity for 50 years
- Audit design revisions and accuracy
- Single, authoritative source of project documentation

TECHNOLOGIES

In implementing an automated, integrated records management system vendors and integrators have used a wide variety of components and system configurations. The technology is a rapidly advancing technology and "break through" announcements occur on a regular basis. Basic components such as workstations have become genericized while software capabilities and integration support have become the elements that differentiate one offering from another.

Software customization, which is always required for a system needing to meet the complexity requirements and long-range strategic needs of organizations like SDDOT, can be a significant part of the cost and effort involved in implementing a successful system. Some systems are designed to be customized from the beginning. They often consist of "tool kits" that allow an integrator, value-added reseller or user to customize the system to meet very specific requirements.

The user's current system platform, resident capabilities, human resources and long-range technology plan must be major considerations when designing a system. Automated file systems no longer stand alone and must integrate "seamlessly" into the organization. Systems that were sold and installed as closed, "canned" systems just 24 months ago are no longer acceptable to the purchaser.

It is critical to build the correct long-range plan and system platform strategy. The technologies described here have the potential to impact the ways in which SDDOT conducts business. A concerted analysis should be carried out to ensure that the foundation established will support the Department well into the next decade. A high-level management commitment should be made to support the long-term investment in the technology as well as involve all of the Department in designing the system that will support on-going needs.

Systems today are highly customizable and offer multitudes of options. Vendors have significant latitude to customize the costs and levels of support for a particular client. Effort and expertise to integrate a system into a given computing environment can also have a major impact on the design and costs of a system.

Specific system design and recommendation of a software system and integration vendor are outside the scope of this research project. The system description contained in this report should be considered conceptual as stated in our workplan for SDDOT SD93-10. We have attempted to profile what the industry can currently offer in meeting the needs identified by our research of SDDOT and the various industry vendors.

Issues of speed, performance, features and price will vary from one vendor to another. In general, the capabilities of this type of technology have increased significantly each year as needs are creatively addressed by new hardware and software components. In addition, hardware costs

have paralleled the microcomputer industry with approximate 15% decrease in price annually for comparable functionality. Price/performance should continue on a favorable course for users such as SDDOT well into the future.

Conceptual System Design

The recommended system will operate in a client-server environment on SDDOT's wide area network. Figure 9 is a graphical illustration of the Pierre campus environment.

Recommended Central Office Environment

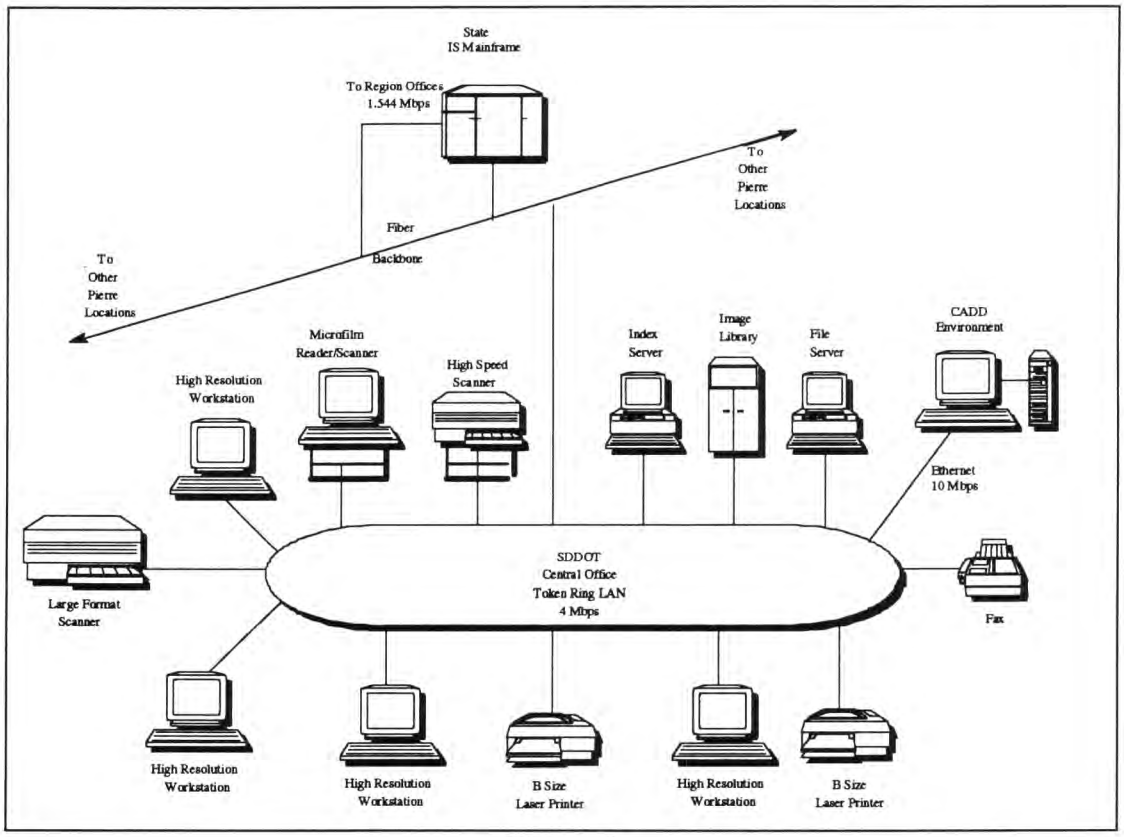

Figure 9

The processing power resides in a file server that operates on the IBM Token Ring Network at the Central Office. In some vendor products all server functions are performed by the file server. In other sytems the server responsibilities are spread across multiple special-function servers. Many factors must be considered in determining the design that will provide the best cost/performance for SDDOT.

The main software is a Relational Data Base Management System (RDBMS) that allows image retrieval by multiple retrieval characteristics. The application software has scanning and capture, viewing and manipulating, mark-up and enhancement, storing and archiving and retrieval

modules. The Graphical User Interface (GUI) is Microsoft Windows and the network operating environment is Windows NT or IBM OS-2.

The system has the capability to incorporate all the various types of documentation currently found in the construction project files spread throughout SDDOT as shown in Figure 10. Paper business documents and reduced-size drawings can be scanned into the system centrally on a high-speed multi-function scanner as well remotely from the field offices. Text, spreadsheets, graphs, reports, E-Mail, and Fax are input directly in electronic form bypassing the paper handling steps. Full size drawings can be scanned on a large format scanner. CADD drawings can be directly input in raster form.

Capture Options

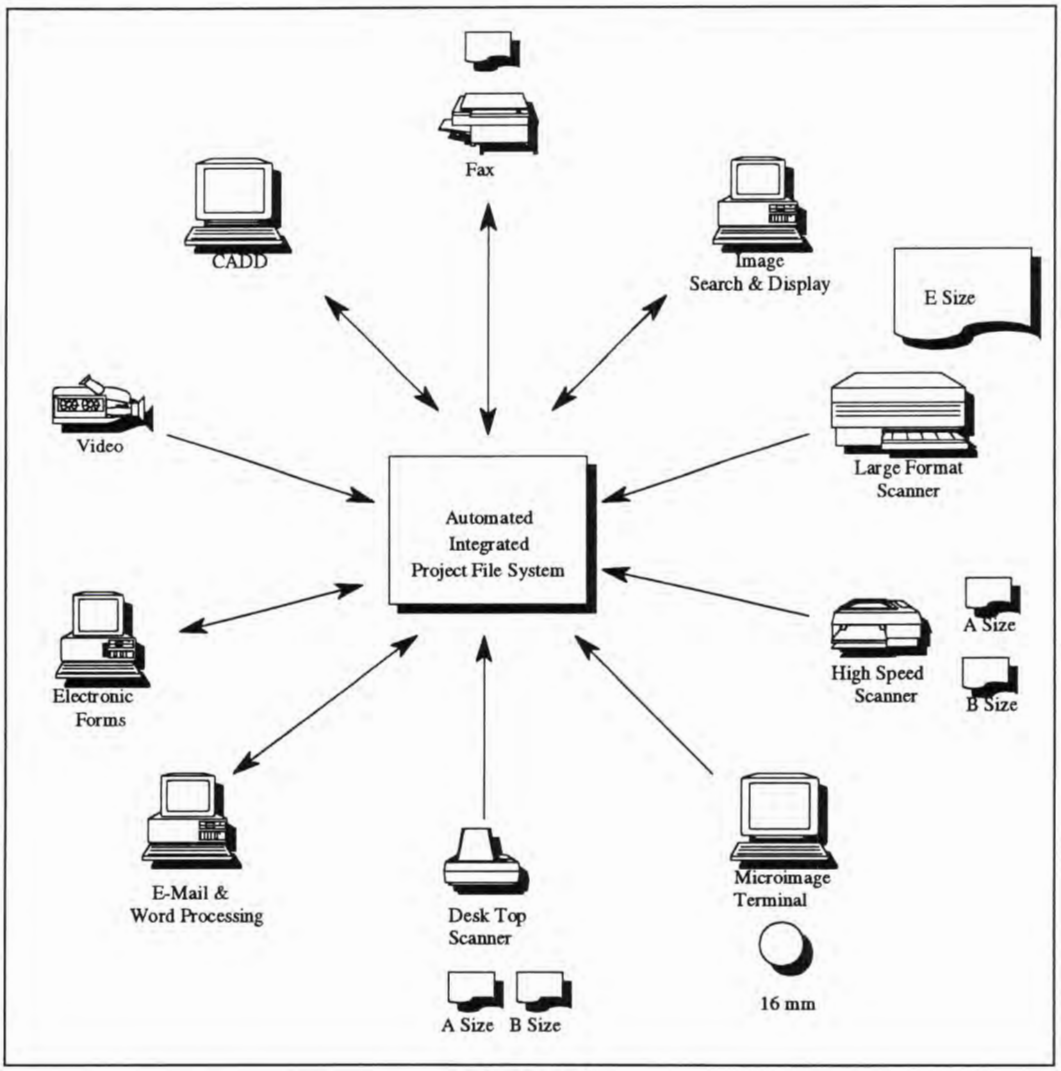

Figure 10

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System Flow Diagram

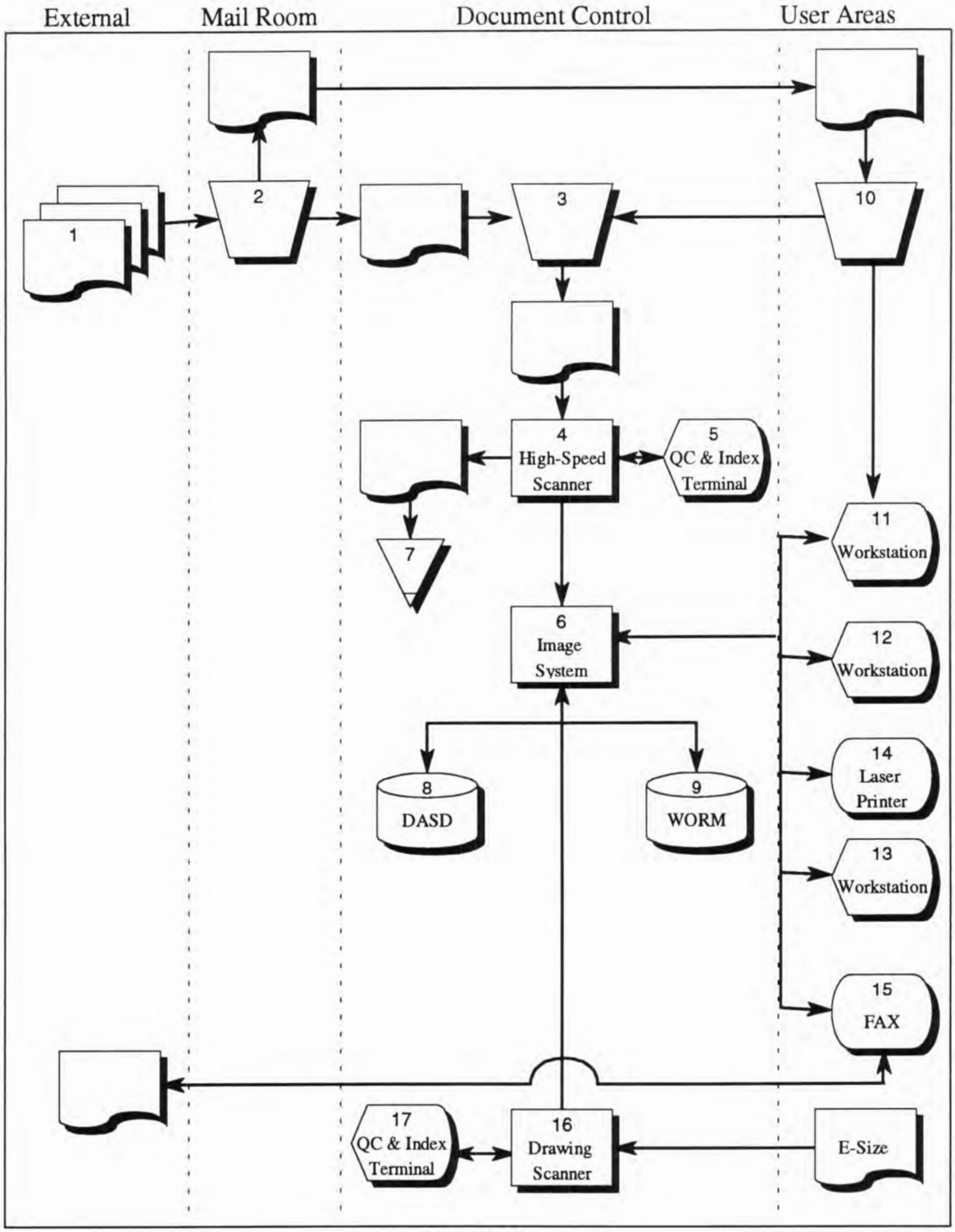

Figure 11

System Flow Description

1. Documents are received from outside SDDOT or from functional areas not on the Automated Project Filing network. These would primarily be 8 1/2"x11" and 11"x17" documents.

2. Documents are received in the Central Office mailroom where they are separated into two batches. Those clearly related to construction projects are put in one batch. Those not related to construct projects and those the technician has any question about are put in a second batch.

   Documents clearly project related are sent directly to the Document Control Area. The other Documents are forwarded as currently done via internal delivery to the respective addressee user areas. The user will make decisions about the disposition of the document as will be explained under Step 10.

3. The technician in Document Control prepares the documents for scanning.

4. The documents are then scanned on a high-speed scanner. Both sides are captured simultaneously and are stored in a temporary file on the scanner server. During scanning a capture date is automatically assigned as well as an Image Control Number (ICN).

   If desired, the high-speed scanner can also be equipped to microfilm for long term archive storage. The ICN is physically imprinted on the document, on the microfilm and associated with the bit mapped (scanned) image in the electronic file. In the event of disaster any media can be linked back to a particular record on the system index file.

5. The technician performs a visual check of the scanned images on a display monitor attached to the scanner server to ensure they are of acceptable quality. At the same time, he/she assigns a routing code to the image to direct the system to route it through the network to the appropriate user or user area.

   If a PCEMS Number and/or Doctype code is written on the document, the technician will key that data to link the image to that project folder in the index.

6. The image is next moved to the System Controller for processing. This consists in some systems of a single file server and in other systems there may be an image server and an index server on the network for specialized functions.

7. The original paper document is filed in the sequence it was scanned for subsequent batch storage off site.

8. The image is initially written to the Direct Access Storage Device (DASD). It will be held in a suspense file until the user inputs

the PCEMS number for that image(s) to link it to a specific project. That user procedure will be explained under Step 10.

9. After a PCEMS number is linked to the image suspense file the image is moved to a permanent file on DASD for the early and most active use period for the image. After that time period the image is moved to permanent Write-Once-Read-Many (WORM) optical disk media. Many systems handle this aging of images automatically based upon rules that the client establishes.

10. The user reads the mail in his/her in basket. If they determine that a document pertains to a construction project, they write the PCEMS Number in the margin. They also determine the document type and indicate a Doctype code in the margin. If not sure, they inquire into the index file on their workstation by what they know of the document to determine what PCEMS Number and Doctype code is appropriate.

    They can retrieve by any data element currently included in the Project Management System (HY-21) data base, except for financial and project status data. They also can retrieve images using Boolean Search Logic (=, ≠, >, <, or, and) when an exact number is not known for effective file browsing.

    After reading and acting on the document the user puts it in the out basket to be sent to the Document Control section for scanning. With the PCEMS Number and Doctype on the face of the document the technician can link the image to the project folder by keying them to the index.

11. The user points to an icon on his/her workstation screen to pull up any images dropped into their "electronic in basket". He/she views the image and determines what project it relates to. They then key the PCEMS Number to link the image to that particular "electronic project folder", point to the "File" icon on the screen, and file it to the system. If not sure of the PCEMS Number for the project, they inquire into the index file by what information they know and retrieve the appropriate PCEMS Number.

12. A user on the network can perform a number of tasks from their workstation. They can retrieve images from their "electronic mailbox" as previously described. They can retrieve images from the automated project file by keying into the keyboard the information they know about the document they need.

13. A user can retrieve images, place them in an "electronic folder" and route them to an individual or group on the network. Another option is to tag a "sticky note" to the image which stays with the image until deleted to inform others who retrieve the image of their comments. Some systems allow searching and retrieval of images based upon any word in the message attached to the image.

E-Mail messages can also be incorporated into the system automatically in many software systems. The sender or receiver can decide whether or not to link an E-Mail message as a project document using the same indexing facility as described for text.

A user can request a microfilm file from their workstation. They would send a message to Internal Services to retrieve a particular project file. Internal Services would locate the file, selectively scan the images and send them via the network to the requestor's mailbox. The user could view the images on their screen, and if desired, could direct the images to the image system. They would input the PCEMS Number and click on the "file" icon on their screen to send the images to be filed.

The user can type a letter that is filed directly as an ASCII record in the image file and associate it to a project file with a PCEMS Number. They can also create spreadsheets, charts and graphs and file them automatically. They can package their letter, spreadsheet and graph and sent it to an individual or group on the network.

An electronic forms facility can be integrated into some systems that would provide an electronic format for documents that have a standard format. Test and certification reports may fit this capability. In essence, the user would fill in the blanks and the report would be available to anyone on the system when sent to file.

Additionally, they can be routed to an individual or group with notification back to the sender if anyone on the list had not retrieved the document. This can be powerful when approvals or precise timing is required for the next project activity.

14. They can send the images to the B-size laser printer nearby to print hard copies.

15. They can fax selected images to destinations outside the network. Faxes can also be directly captured into the system. Faxes would be routed to the intended person or area and they would decide whether to index and file the fax to a project folder.

16. Full size drawings, maps and plans are scanned on a large-format scanner. They would go through compression routines to reduce their file size for storage and transmission efficiency. Existing drawings are "scanned on demand" when they become activated.

    E-size drawings and maps represent large files when scanned to the system. Many systems now break large document files into "tiles" for managing. When a user requests a full size drawing image, an "overview" image is sent of the whole drawing for viewing. The user can zoom and scroll around the image. If a higher resolution view is required, the user outlines the section needed on the overview image and the individual tile is sent for detail viewing.

17. The same quality control procedures are performed on drawing and map images as described in step 5.

Additional Functionality

There are four additional capabilities we recommend be considered for implementation after SDDOT staff and management are accustomed to electronically managing project files.

- CADD Integration

Drawings generated on CADD can be output as a TIFF file on the network or on 8mm tape for automatic integration into the project file system. Most imaging systems work more efficiently with raster files rather than vector files. When it comes to transmitting images on the network the industry says "raster is faster". Also, the files in the image system are not meant to be manipulated or updated as with vector files on a CADD system.

Some imaging systems have the facility to break large CADD files into "tiles" of 512x512 bits for manageability. If the CADD files were used for reference only, an "overview" file of the entire drawing can be scaled to the size of the user window (display) to reduce the amount of data being transferred. If that low resolution, full size image is not sufficient for the task the user selects a section to view at higher resolution. That section is then sent at a "scaled-to-window" size at a higher resolution for detailed viewing. The file size sent is approximately 25 KB for VGA and 50KB to 100KB range for 19" high resolution monitors. Monitor size and resolution is considered to be two of the most important factors to imaging success. A 19" screen can display several windows simultaneously for enhanced compare/contrast of images or data screens and to display a larger portion of a drawing.

Non-destructive markup, redlining and CADD conferencing can then be considered as a part of the construction plan approval cycle via the network. This fits better in Phase Two for a number of reasons. (a) There are some integration issues that will have to be addressed with the integrator of the system and your CADD vendor. (b) A strong concern was expressed from the design groups about making preliminary drawings available to other processes that might cause inaccurate decisions. (c) There also was a strong view that plan approvals could not be effectively performed from a workstation monitor. (d) With the experience of Phase One, the various impacts of imaging will be qualified and quantified.

- Video Files

Video road segments could be linked to project files using Object Linking and Embedding (OLE) capability. Most client-server imaging systems are based on the Microsoft Windows environment and incorporate OLE as a part of the system. A video frame location can be linked to an image identification to be able to view a short video segment during an image retrieval session.

These would be large files and their impact could be better measured after SDDOT has some experience with traditional image files and their network impacts. A number of integration issues

will require additional time to research as this is a new technology to both imaging vendors and video road logging vendors.

- OCR/ICR

OCR provides automatic indexing by interpreting characters in specific document locations and capturing them for the index. This technology has great application where the forms being captured are turn-around documents produced in-house. Currently, the technology can produce a 98%-99% accurate read rate on various type fonts for selected data fields on a fixed document format. This means that 1-2% of the characters will have to be keyboarded into the system in an error-correction step. If the field being scanned is 50 characters, then 5-10 characters per page will have to be keyed.

ICR goes one step further and interprets the characters and converts them to machine code that can then be processed by a computer system. This technology is powerful for technical, scientific or legal documentation where the user needs to retrieve by any word in the body of the text.

Read rates here are far less than OCR and the error correction process can be very labor intensive. However, when coupled with full-text indexing to provide retrieval of images by any word in a document ICR is a powerful tool.

A separate full-text data base can co-exist on many systems with a traditional RDBMS to index only certain documents. That would seem to be the best application of OCR/ICR for SDDOT. Also, the cost to implement the technology on the high-speed scanner-microfilmer described in the conceptual system is high.

The technology can be more feasibly incorporated into a desktop scanner and 386 processor where special documents can be input to the system at slower speeds. The cost of a production-grade OCR/ICR system is in the $30,000-$45,000 price range.

- Full Text Indexing

This technology is used primarily for "needle in a haystack" retrieval applications. The legal profession and other abstract filing needs can be addressed by being able to retrieve by any word contained in the body of the text. Most imaging vendors have the ability to incorporate a full text search capability on text generated on word processors that are input directly to the imaging system. The characters are already in ASCII form. That can be included in Phase One and would address all correspondence produced in-house.

The challenge comes in getting the scanned images converted to ASCII form so that each word can be indexed. Accuracy rates on mixed documents, consisting of faxes, xerographic copies, varying formats and typefonts, can be as low as 50%. That means that 1,500 or more characters would have to be keyed in an error-correction step for every document. If the documents are extremely high value and abstract in nature, the cost can be justified. The approximate costs for a

hybrid ICR/full text index product is between $3,000 and $12,000 per user depending on the size of the system.

Our research into the project files did not uncover such documents. Perhaps letters from the public that are dealt with by the Secretary's Office would be good candidates. The cost and effort, as stated earlier, would have to be analyzed.

- Workflow Software

This capability provides for the automatic routing of image folders to workstations on the network according to routing rules established by SDDOT. The routing can be changed relatively easily in many systems to adapt to the way business may change in the future. Images are routed and the sender or management can inquire into the status of a particular folder along the routing steps. In addition, some have automatic notification to sender of any incomplete steps.

In setting up the routing, the sender can request a response back from each function. Although workflow software makes the greatest impact in operations with predictable routing patterns, it could be effective for SDDOT in the project development and plan approval processes.

Because this technology has the greatest potential to radically change the way business is done, we suggest it is better considered for Phase Two. It would be recommended that the Department consider a re-engineering effort prior to implementing workflow.

The field offices are remotely located on the wide area network. The 4 Mbps Token Ring network at Central Office is stepped down to a 1.544 Mbps communication link to four region offices. Each region office has one area office resident on the region premises and will be serviced by the same 1.544 Mbps service and LAN as the region.

The planned communication link from the four regions to each of their respective two remote area offices is via a 56Kbps communication link. It has not been decided as yet what LAN will be installed in each area office. Figure 12 illustrates the field environment and communication links.

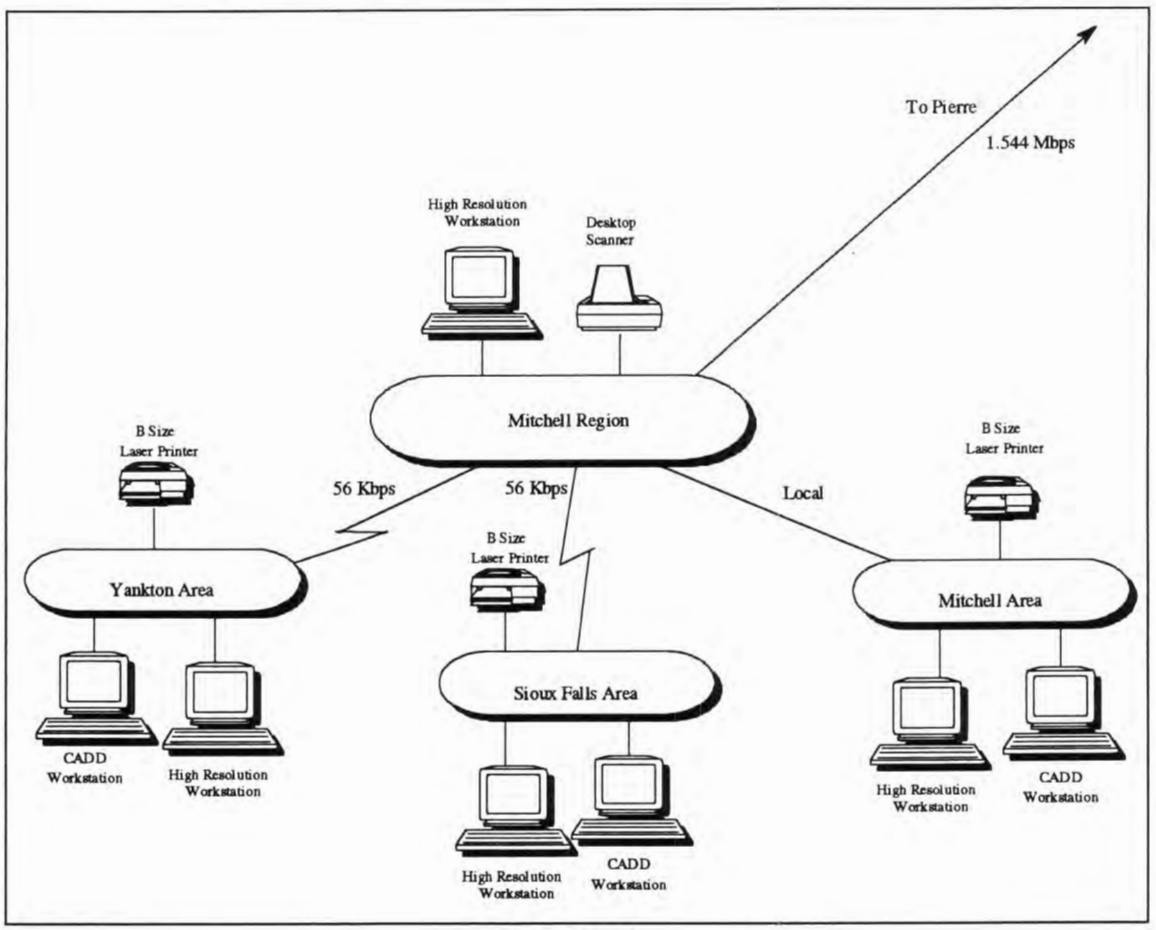

Figure 12

CADD work is done in each of the area offices on the CLM CEAL system. Currently this system is incapable of reliably transferring CADD design intelligence to the Intergraph Microstation CADD system at Central Office. The Department has not decided whether the transfer of files from one system to the other is a requirement.

There are four region offices located throughout South Dakota. Three area offices report to each region. One of the three area offices in each region shares the same building as the region office.

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Field Office
System Flow Diagram

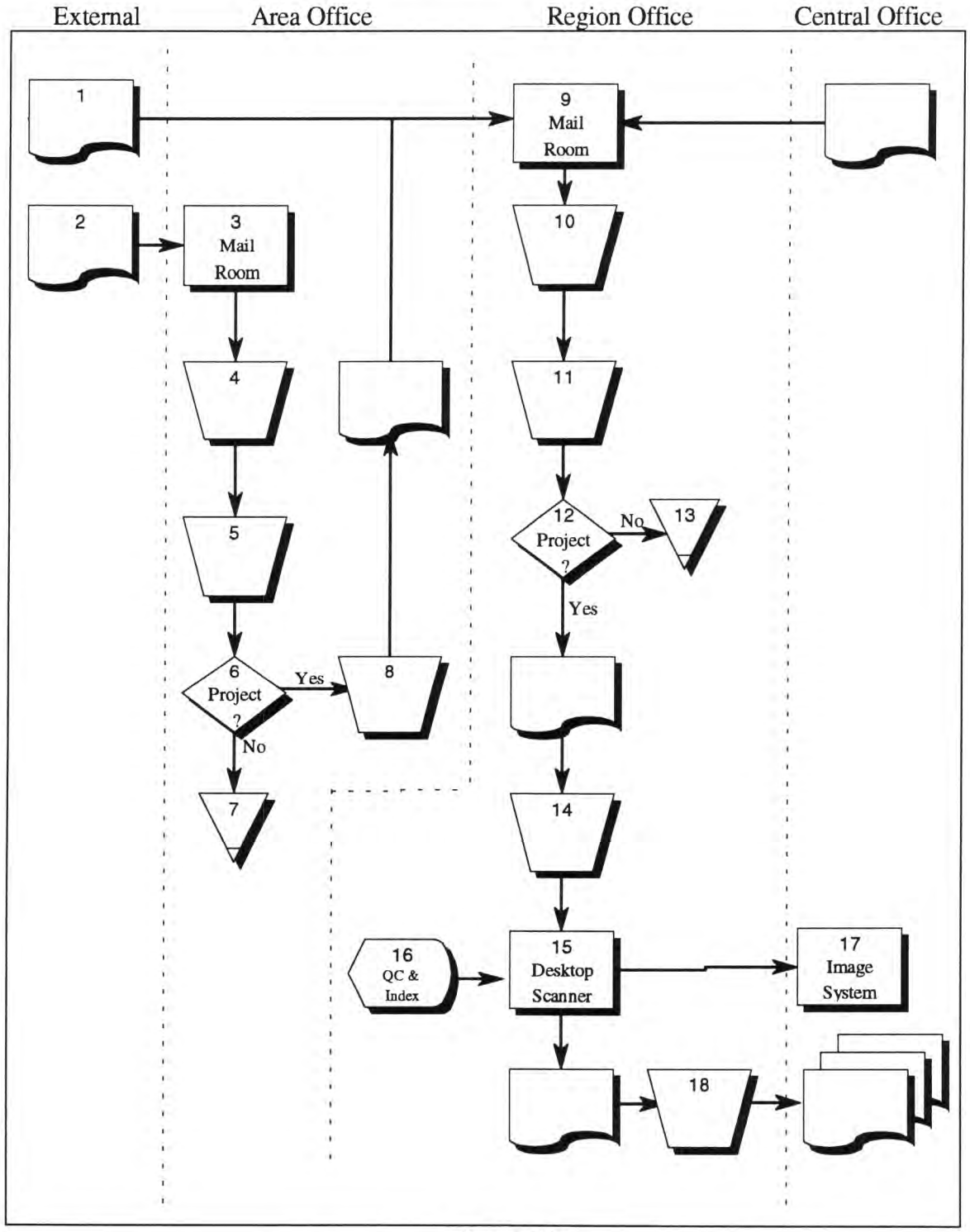

Figure 13

Field Office
System Flow Description

1. Documents are received at the Region Office from outside SDDOT.
2. Documents are also received from the external entities at the Area Office.
3. Documents are received at the Area Office mail room.
4. Documents are routed as usual to the addressee or Area Engineer if not specifically addressed.
5. That individual takes appropriate action on the documents.
6. If the documents are project related, the most appropriate person writes the PCEMS number on the border of the document along with a Doctype code.
7. If they are not project related, they are filed as before.
8. Based on the low daily volume of filing reported by the area in our survey, project documents are then sent to the region office for scanning into the project filing system with as a group.
9. The batch of documents are received in the region office mail room along with documents received from the other area offices in the Region and are set aside for scanning.
10. Documents received from outside the region that have not come through the area office are distributed to the addressees as usual.
11. The addressee, or the Region Engineer, takes the appropriate action on the document.
12. If the document received from outside is project related, it is routed back to the mail room for capture into the system along with those sent from the area offices.
13. If it is not project related, it is sent to file.
14. The documents are prepped for scanning.
15. Documents are scanned on a small desktop scanner.
16. The images are checked for quality and the PCEMS number and Doctype is entered.
17. The images are transmitted to Central Office to the project file imaging system.
18. The documents are batched in scan sequence and forwarded to Internal Services for archiving.

Capture Components

- Desktop Scanner

Desktop scanners are used in low volume environments where the input volume on a daily basis is in the hundreds of documents. They are relatively low in cost and operate much like a desktop copier. There have been some introductions recently of multi-purpose devices that serve as a scanner, copier, and fax. These devices are new and have not been promoted as part of any imaging vendor's integrated solution yet. They are designed with windows in mind so they should be compatible with current offerings. There seems to be potential for these devices in an SDDOT area or region office.

Desktop scanners carry a price tag of between $1,000 and $30,000. Rated scan speeds are in the 20 letter-size page-per-minute range with small-capacity automatic feeders. They can handle up to 11"x17" and resolutions up to 400 dpi.

- High-Speed Scanner

High-speed scanners are designed to handle the volumes that are typically associated with centralized systems. Throughput on these units are in the 100 letter-size page-per-minute range in a duplex mode. They range in price from $50,000 to $100,000 and require a fast server and software to handle the data rates the scanners produce.

SDDOT currently has a Kodak Imagelink Microimager in Internal Services that can be configured to scan and digitize documents as well as microfilm them simultaneously. It can also be equipped to OCR forms, ICR full pages and feed full text indexing systems. The upgrade cost is approximately $50,000-65,000.

- Multi-Purpose Scanner

There are some recent offerings that can serve not only as scanners, but also copiers and fax machines. They are not readily available and tested in most systems integrations. There seems to be a market for such devices and SDDOT field offices may be candidates. These devices range in price from $3,000-$8,000.

- Large Format Scanner

Large format scanners are used for scanning full-size drawings and maps up to E Size. Resolution is the main consideration here as opposed to speed. Resolutions are up to 800 dpi and scanning speeds are around 20-30 E-size drawings per hour. These units cost from $15,000-$75,000.

An alternative to scanning the hard copy drawings and maps is via an aperture card scanner.

These units are faster and scan at approximately 100-300 E-size frames per hour. This is an alternative at SDDOT, but the quality of the aperture cards in file is questionable as scanning input. They cost in the $50,000 range.

When there are large quantities of drawings and maps to be converted service bureaus are often used. Services vary from production of an unformatted magnetic tape to delivery of optical media formatted for the particular system is question. Prices vary also from $4 to more than $10 per drawing.

- Fax Machines

Most top performing imaging systems incorporate a fax-in and fax-out capability. Standard fax devices that output or receive Group III or Group IV records can be used as either a direct input device or as a network output device. Prices are between $1,000 and $5,000. A fax modem board for the PC is available for about $200 each.

- Workstation For Word Processing and E-Mail

Letters, reports, spreadsheets and E-Mail messages can be directly input to most commercially-available high performance systems as either ASCII (machine code) records or TIFF (Tagged Image File Format) bit-mapped records. ASCII formats (Word Perfect) and vector files can typically be manipulated and stored more efficiently than TIFF records.

- Microimage Retrieval Terminal

There are a few microfilm retrieval terminals that offer the capability to selectively digitize a film image and send the record on the network to an imaging system. Selection of the film roll and location of the correct image is handled by an operator at the request of a remote user. SDDOT currently has a terminal on order that has this capability.

- CADD

Some systems have the ability to import raster files from CADD systems. Many earlier CADD systems were proprietary in nature and there can be compatibility problems. However, if the system can output a TIFF record there is a good chance it can be directly imported into the imaging system. The Intergraph Microstation CADD system in use at SDDOT is able to output a TIFF file to Transmission Control Protocol and Internet Protocol (TCP/IP) compatible network devices.

- Color Images

Image systems have the ability to store digital color images. However, the file sizes are very large to store, manipulate and transmit. A 256-color system will require 3,760,000 bytes (30,000,000 bits) at 200 dpi for an 8 1/2"x11" document. New algorithms are being developed to compress color files to a more manageable size, but it will be some time before file size is manageable in a business document-based imaging system.

- Video

Many systems available today are based upon a Microsoft Windows environment. As such, Object Linking and Embedding (OLE) capability is part of the system. Video objects can be linked to files in the imaging system and retrieved as part of the image file.

- Image Search & Display Workstations

The image search and display workstation can be used to retrieve and display images. In addition, they can serve as an input component. When image records are retrieved and displayed, the user has the option in most systems to attach an electronic "post-it" note to the image. Subsequent retrievals of the image file will display that add-on message until no longer needed.

Document Indexing

Indexing of images was briefly described in the previous section. We would like to go into more detail in this section. There are four or more types of indexing that can be utilized in most systems. We have considered them all as options for SDDOT.

- Key Parameter Indexing

One type of indexing is to enter significant index parameters via a workstation keyboard. Because key entry is labor intensive most systems using this method build indexes on just a few parameters. In some systems this can be facilitated by use of light pens or image scraping techniques to grab a number or word off the displayed image and input them to the index. We believe this would not serve the complex retrieval needs identified for the Department.

- Image Enabling

A second technique is to associate a single index element to an application data base that already exists. This is called "Image Enabling" an application. We considered this in light of the extensive applications already supporting the project process such as PCEMS and the Project Management System, HY-21. Because these two data-intensive applications are mainframe

based, would cost additional money to expand access and CPU cycles, and are categorized by users as hard to use, we looked for other alternatives.

- Full-Text Indexing

A third method is to index on every word in the body of a document as briefly outlined in the previous section. Full text indexing can be extremely powerful in technical document-based systems. A document can be retrieved by any word in the body of a document. Text generated on SDDOT word processors can be indexed on every word in many systems that are available. That would apply to about 25% of all documents that end up in the project files. The overhead associated with indexing on every word for scanned documents would have to be measured in terms of the value derived.

- Data Base Pointer Indexing

What we recommend is the fourth option. What looks feasible at this point is to duplicate an existing data base on the image system and add image pointers to it. The data is already in existence and the data capture is already handled by another system. All the user must do is provide the linkage. This is illustrated in Figure 14.

Index To Image Linkage

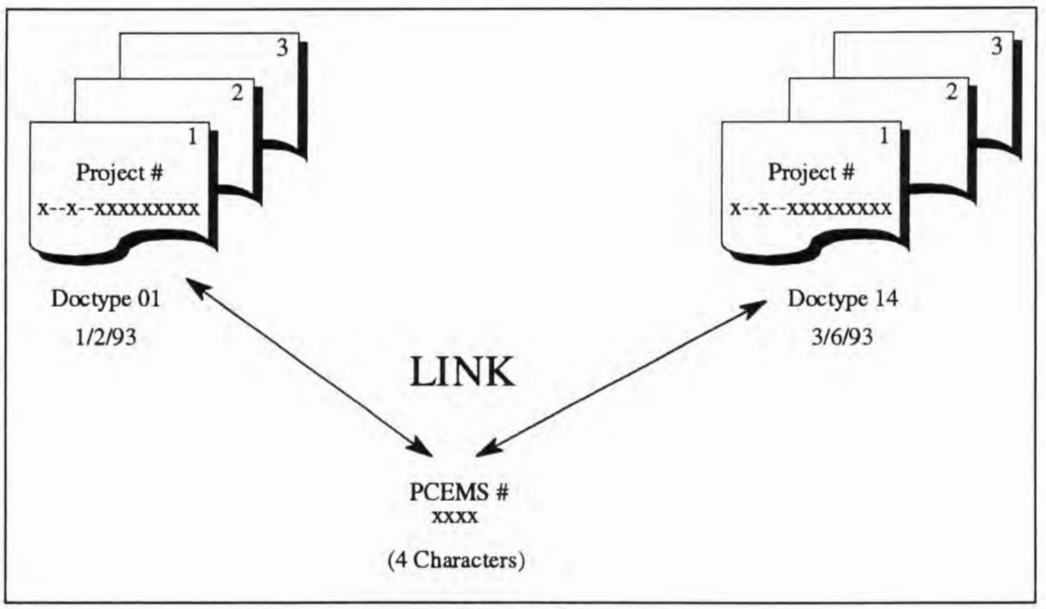

Figure 14

We recommend loading the Project Management data base (HY-21) into the automated project file index. Only the project descriptive data elements are "stripped" from the file. The financial and scheduling elements remain intact in the feeding system to avoid confusion. The index is then

built on all the general descriptive data now residing in HY-21. As new projects are added, the project file index is updated. The only data entered to the system when documents are captured, as outlined in the System Flow section, is a PCEMS Number and a Doctype code that associates an image to the index. The capture date is automatically input by the system.

Most imaging systems use a Relational Data Base Management System (RDBMS) as the indexing system. Users could then retrieve specific images or the list of images associated with a PCEMS number by any descriptor in the index. In this case, they could retrieve by any general descriptive data in the HY-21 data base. Such descriptors as MRM, highway number, region, area, county, function class, year programmed, location, structures, etc. could be used as retrieval handles.

In addition, the Doctype code can be used as a retrieval handle alone or in combination with any of the HY-21 descriptors. Images could be retrieved by a Soils Test Report at a particular MRM number, or between two MRM numbers, as an example. The capture date can also be incorporated in the search argument to limit the range of the search within date frames.

Image Storage

As stated earlier, some systems provide for the automatic "aging" of images and determines where they should be stored on the system media. Images are written to magnetic disk immediately after scanning to permit rescanning if necessary. Once accepted, the images are stored on magnetic disk for a period of time while there is heavy activity. DASD is the fastest storage media.

After the appropriate time the images are moved to optical media for permanent storage. The cost is less and the media is more permanent. Images could be sorted into a "family" sequence to block the image file by common characteristics such as region, area, county, etc. The optical disks would be housed in a jukebox with multiple read/write heads to provide fast access. This "aging" process is described in Figure 15.

Image Migration

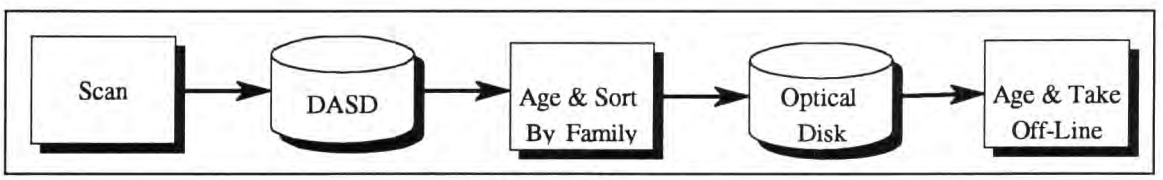

Figure 15

Disk platters can be taken off line after an extended time and reactivated if necessary. Optical media has been certified by manufacturers to last for 30 years. Recently, a manufacturer announced 100-year life for their media. The Federal Government and many state governments are forcing the archival permanence of optical disk media. Most experts believe that documents reproduced from the media will be legally acceptable in all courts of law within the next year or two.

Image Display

The monitor on which images are displayed to a user is critical to success of an imaging system. Making the transition from paper to a displayed image of paper is many times a significant adjustment in itself. Displays used in full time retrieval and processing of images must meet readability and screen size requirements.

At SDDOT, there are other factors that compound the importance of the display monitor:

- There are a multitude of document types that are being integrated into the system
- There will be some poor quality originals over which SDDOT has no control
- 11"x17" reduced-size drawings will be a prime document being viewed
- Initially the monitor will be used for image retrieval by multiple users in a functional area
- The reviews of the initial users will determine the rate of acceptance by subsequent users

There are two major types of monitors in the imaging world and each user location must be analyzed to select the most cost effective display:

- VGA Monitor

The standard VGA monitor in the 14" to 15" size permits about half of the 8 1/2"x11" document image to be displayed on the screen at one time. Scrolling or panning through the image is necessary to view all parts of the image. The VGA monitor has approximately 60-72 dots per inch (dpi) to generate the image. This type display is acceptable in those cases where the user casually references images and is typically looking at sections of a document for specific information.

- High-Resolution Monitor

Users that retrieve and display images for two or more hours during a day should be equipped with a large screen, high-resolution monitor. The other factors listed above could dictate use of high-resolution monitors in themselves. These monitors are 19" or larger in size and have a resolution of 120-150 dpi. They can display a full 8 1/2"x11" document image. Some can display two full documents side by side. They also are capable of displaying an 11"x17" or larger drawing through software techniques that size the image to the screen size. The size and resolution should make viewing of reduced-size drawings practical for reference purposes.

We recommend SDDOT include high-resolution 19" monitors for most uses and especially during the first phases of system implementation.

NETWORK MODEL

The ability of the network bandwidth to transmit large image files within a 1-2 seconds along with other network traffic has a significant impact on system acceptability to users. The scope of this project is to assess whether the current SDDOT network platform is capable of supporting the additional traffic that large image files would add to the network with acceptable response time.

Moving image files can have unique impact on a network. Novell, the largest network system vendor, has established a test environment at their research facilities in an attempt to better estimate the impact of image traffic on a particular network. Here, they attempt to duplicate a client's environment to gain insight before full implementation. Most image system and network vendors have stated that actual impacts can only be tested when the pilot system is actually installed in an actual operational environment.

Based on the factors we are able to consider in our feasibility analysis, we believe the WAN that is planned is capable of supporting the estimated network traffic. A diagram depicting the SDDOT network bandwidth remaining after image traffic is considered is included as Figure 16:

SDDOT WAN
Bandwidth Used With Imaging

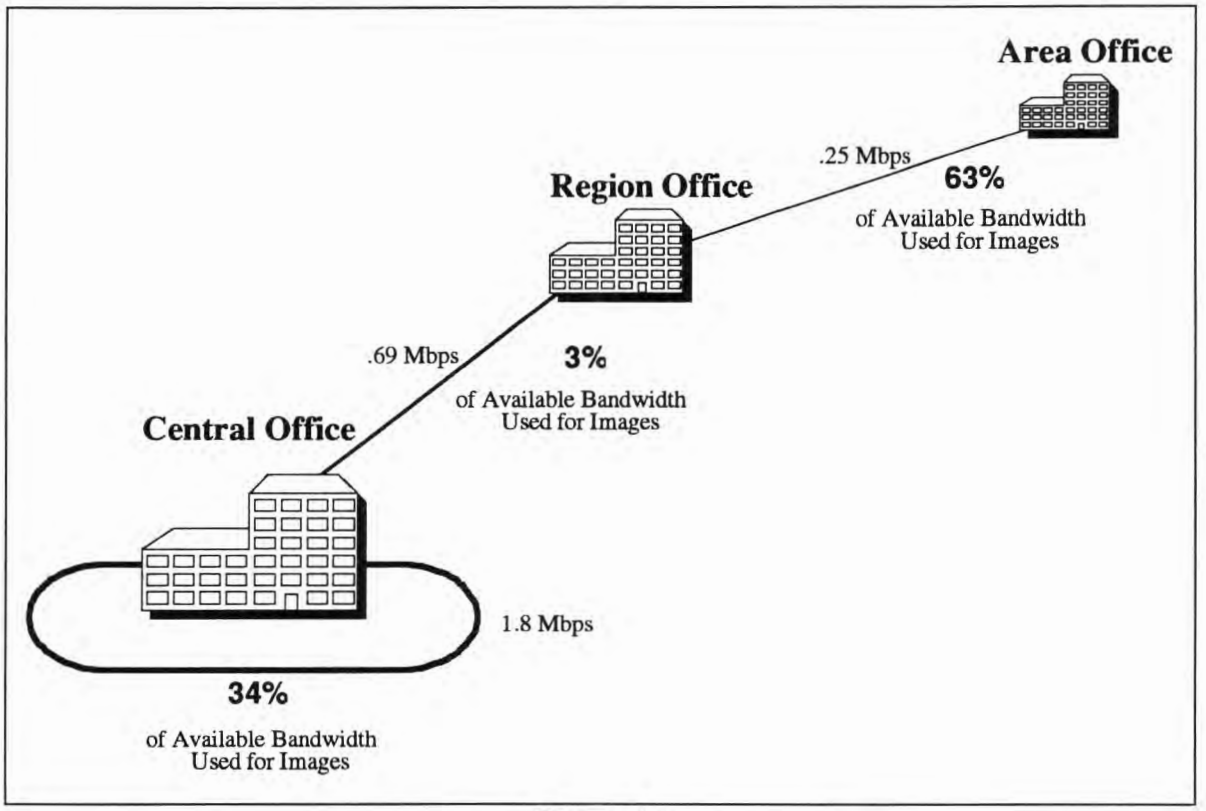

Figure 16

Our only reservation is the area office link. The volume of retrieval and filing activity reported by Huron on the survey seem unusually low when compared against the file drawers they maintain. We have recontacted the lead administrative support person and she is confident the figures are reasonably correct as reported. With those figures they would use 63% of available bandwidth.

An industry rule of thumb is to plan for 3x current image traffic requirements. Image volume will certainly grow as users gain an appreciation for the value of the information that is available to them. We calculate there is an approximate 3x growth capability in the SDDOT WAN as planned with the exception of the area office link.

In addition, there are other applications planned by Data Services that will demand network resources. Those applications must also be considered in addition to the resources needed by existing applications and imaging. The unpredictability of image transmission on any given network is another reason to plan for excess capacity.

We have made the following assumptions in our analysis of image traffic on the SDDOT network and the network's ability to handle the traffic:

Network Model Assumptions

- File retrieval and file input volumes reported on the survey forms by functional areas
- Personal "desk file" retrievals are 2x the reported main file retrievals
- A Data Services estimate that 10% of the available LAN bandwidth is currently being used
- 50% of rated LAN bandwidth is realistically available during production periods
- The rated bandwidth of the Central Office LAN is 4 Mbps, the rated bandwidth from Central Office to the regions is 1.544 Mbps, and the rated bandwidth from the regions to the areas will be 56Kbps
- An A-size raster image averages 400,000 bits (50,000 bytes), a B-size raster drawing image averages 800,000 bits (100,000 bytes) and an ASCII text record averages 32,000 bits (4,000 bytes)
- Peak retrieval periods are 2.5X the flat average
- Peak retrieval periods are 9:00am-10:30am and 2:00pm-3:30pm

Image retrieval and image routing data for the Central Office, region and area offices is shown on the following tables:

Central Office Model

Image Retrieval

Retrievals Per Day	Document Type	Compressed Bits Per Image	Images Per Retrieval	Total Bits Per Day	**Total Peak Bandwidth Needed in bps	Total Bandwidth Available in bps	Bandwidth % Used
747	ASCII Text	32,000	5	119,520,000	10,375		
1,494	A-Size Raster Document	400,000	5	2,988,000,000	259,375		
1,464	B-Size Raster Drawing	800,000	2	2,342,400,000	203,333		
3,705				5,449,920,000	473,083	1,800,000	26.28%

Table 1

- "Desk file" retrievals are estimated at 2x reported main file retrievals and are included in above daily figures
- ASCII text retrievals are estimated at 1/3 total reported source document retrievals
- **Peak retrieval periods = 2.5x average volume

Image Routing

Docs Routed Per Day	Document Type	Compressed Bits Per Image	Images Per Document	Total Bits Per Day	Total Bandwidth Needed in bps	Total Bandwidth Available in bps	Bandwidth % Used
381	ASCII Text	32,000	2	24,384,000	2,117		
1,746	A-Size Raster Document	400,000	2	1,396,800,000	121,250		
308	B-Size Raster Drawing	800,000	1	246,400,000	21,389		
2,435				1,667,584,000	144,756	1,800,000	8.04%

Table 2

- Equals total daily file inputs from survey
- Peak period multipliers apply with Central Office routing schedule

Central Office to Region Model

Image Retrieval

Retrievals Per Day	Document Type	Compressed Bits Per Image	Images Per Retrieval	Total Bits Per Day	**Total Peak Bandwidth Needed in bps	Total Bandwidth Available in bps	Bandwidth % Used
31	ASCII Text	32,000	5	4,960,000	431		
61	A-Size Raster Document	400,000	5	122,000,000	10,590		
20	B-Size Raster Drawing	800,000	2	32,000,000	2,778		
112				158,960,000	13,799	694,800	1.99%

Table 3

- Includes retrieval traffic for 3 area offices in addition to region traffic
- "Desk file" retrievals estimated at 2x reported main file retrievals are included in above daily figures
- ASCII text retrievals are estimated at 1/3 total reported source document retrievals
- **Peak retrieval periods = 2.5x average volume

Image Routing

Docs Routed Per Day	Document Type	Compressed Bits Per Image	Images Per Document	Total Bits Per Day	Total Bandwidth Needed in bps	Total Bandwidth Available in bps	Bandwidth % Used
8	ASCII Text	32,000	2	512,000	44		
82	A-Size Raster Document	400,000	2	65,600,000	5,694		
25	B-Size Raster Drawing	800,000	1	20,000,000	1,736		
115				86,112,000	7,475	694,800	1.08%

Table 4

- Includes traffic for 3 area offices in addition to region traffic
- Pre-construction vs. construction period shifts traffic direction at region by 90%
- Peak period multipliers apply

Image Retrieval

Retrievals Per Day	Document Type	Compressed Bits Per Image	Images Per Retrieval	Total Bits Per Day	**Total Peak Bandwidth Needed in bps	Total Bandwidth Available in bps	Bandwidth % Used
30	ASCII Text	32,000	5	4,800,000	417		
60	A-Size Raster Document	400,000	5	120,000,000	10,417		
15	B-Size Raster Drawing	800,000	2	24,000,000	2,083		
105				148,800,000	12,917	25,200	51.26%

Table 5

- "Desk file" retrievals estimated at 2x reported main file retrievals are included in above daily figures
- ASCII text retrievals are estimated at 1/3 total reported source document retrievals
- **Peak retrieval periods = 2.5x average volume

Image Routing

Docs Routed Per Day	Document Type	Compressed Bits Per Image	Images Per Document	Total Bits Per Day	Total Bandwidth Needed in bps	Total Bandwidth Available in bps	Bandwidth % Used
2	ASCII Text	32,000	5	320,000	28		
14	A-Size Raster Document	400,000	5	28,000,000	2,431		
4	B-Size Raster Drawing	800,000	2	6,400,000	556		
20				34,720,000	3,014	25,200	11.96%

Table 6

- Estimated 20 documents/day sent to the regional office during construction period and 20 documents per day received from region during pre-construction
- Includes images routed both ways from region office to area office
- Peak period multipliers apply during pre-construction period

Routing Traffic

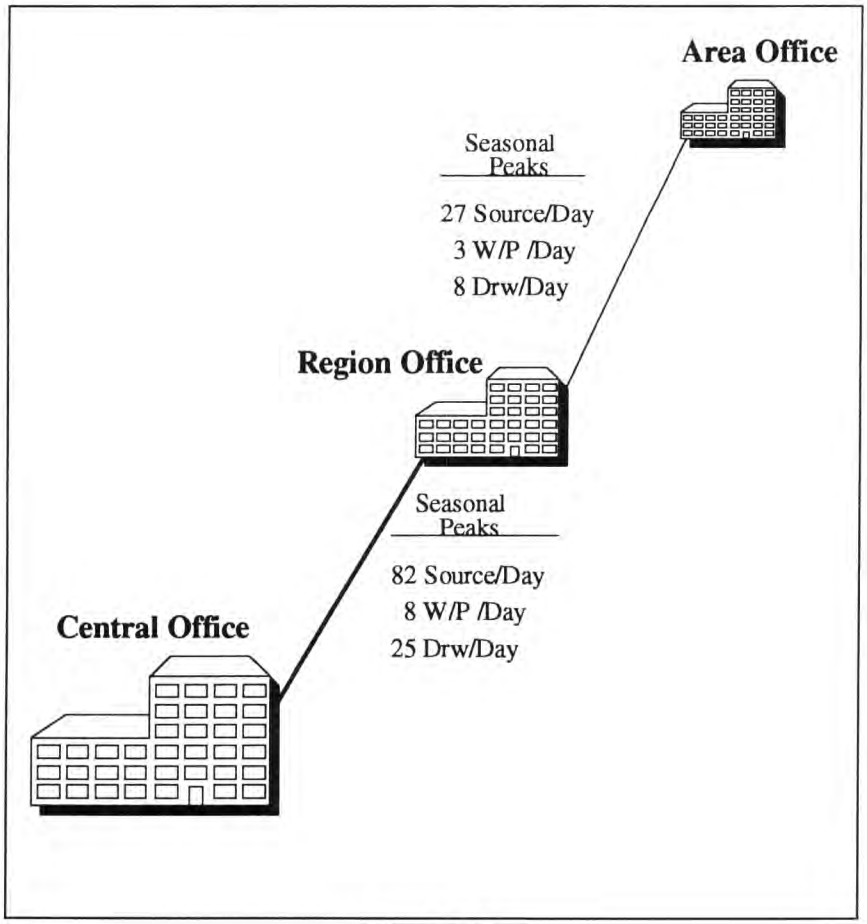

Figure 17

- 90% of total received by region is from Central Office during pre-construction period
- 90% of total received by region is from three areas during construction period
- Region traffic is 2x because each of 3 areas get 1/3 of what goes from/to region
- Peak period multipliers apply because recipient will recall the routed images during peak periods

SDDOT BENEFIT OPPORTUNITIES

Strategic Benefits

We believe the automated, integrated project filing system described will offer many benefits that will assist the South Dakota Department of Transportation in meeting strategic goals outlined in the SDDOT Strategic Plan document. Following are the strategic benefits:

- Contribute to the efficiency, effectiveness and adaptability in meeting ISTEA management systems requirements
- Increase productivity across the Department in anticipation of reduced revenues and increased numbers of projects
- Facilitate collaboration with Metropolitan Planning Organizations (MPO's) and tribal governments and consistently present a professional image of SDDOT to the public
- Provide a higher level of service and teamwork with other state agencies that are closely involved in construction issues
- Facilitate correlation of planning, engineering, construction and maintenance information on a project basis across the SDDOT enterprise
- Attract and keep top personnel through state-of-the-art technology
- Safeguard against loss of intellectual assets with a highly-controlled information management system
- Improve project status tracking through automatic and ad hoc reports
- Provide an information system with the flexibility to adjust to any future Department re-engineering needs

Operational Benefits

The system as described offers many operational benefits. Intellectual assets, the knowledge and expertise of SDDOT personnel, can be distributed to all those who can profit by it. Highlights of the operational benefits are:

- Save engineers and technical personnel over 18,000 hours per year in file maintenance activities
- Save managers at all levels a total of over 12,000 hours per year from "information conduit" activities
- Reduce the number of physical meetings due to universal access to information
- Reduce cycle times and facilitate concurrent engineering
- Provide a file retrieval capability by all the project description data elements now contained in the Project Master File (HY-21) and file browsing capability through and, or, boolean logic
- Expedite the project development process by automating and managing the various approval processes in parallel
- Provide a control mechanism to ensure that the latest, most complete documents are the ones being used to make decisions
- Deliver information across South Dakota's geographic expanse in a matter of seconds
- Reduce the number of new drawings by having efficient access to old design plans
- Provide a highly-responsive information base to support litigation actions
- Availability of tests and certifications is facilitated with electronic forms generation and routing

Engineers and technical staff do most of the filing and retrieval of documents in the project files because of the technical nature of the information. The following table illustrates the time devoted to such activities by engineers and staff.

Annual Main File Retrieval Activity
(In Hours)

YEAR	ENGINEERS ANNUAL RETRIEVAL HOURS	STAFF ANNUAL RETRIEVAL HOURS	ENGINEERS ANNUAL REFILING HOURS	STAFF ANNUAL REFILING HOURS	TOTAL HOURS
1994	10,420	3,473	4,631	2,315	20,839
1995	10,941	3,647	4,863	2,431	21,881
1996	11,488	3,829	5,106	2,552	22,975
1997	12,062	4,020	5,361	2,680	24,124
1998	12,666	4,221	5,629	2,814	25,330

Table 7

Based Upon:

- 3 Minute Per Retrieval For Engineers And Staff
- 2 Minute Per Refile For Engineers and 1 Minute For Staff
- Main File Only; Does Not Include Personal Desk Files
- 5% Growth in Volume Per Year

- Refiles would be totally eliminated.....6,946 Hours Saved Per Year
- Estimate retrieval time would be cut by 50%.....6,947 Hours Saved Per Year
- Estimate retrievals in response to other functional areas cut by 20%.....4,168 Hours Saved Per Year

18,061 Total Hours Saved Per Year

We estimate, based on our interviews and the time estimate questionnaire submitted by 18 supervisors and managers, that they spend at least 15 percent of their time on transferring status or historical information vertically and horizontally. The time estimate results are included in the Appendix.

Management/Supervisory
"Information Conduit" Activities

JOB GRADE	NO. OF MANAGERS	INFO CONDUIT HRS./DAY	TOTAL HRS./YR.
E22 & E23	8	1.2	2,410
T19 & T20	26	1.2	7,831
T18	47	1.2	14,156
TOTAL	81		24,397

Table 8

Based Upon:

- Average supervisor/manager spends 15% of their time in such information exchange activities
- Average supervisor/manager is the valve through which staff seeks information both vertically within his/her group and horizontally across functional groups because information is not universally accessible

- Estimate that 50% of "Information Conduit" activity (.6 hours per day or 3 hours per week) can be saved.....12,199 Hours Saved Per Year

- This represents only a 7.5% productivity increase

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Economic Benefits

The following section covers the economic benefits the automated project filing system described is estimated to return to SDDOT. The figures are based upon survey forms filled out by each functional area that we covered in our research and SDDOT job classification and wage data. The estimated operating efficiencies and additional capabilities not available with the current methods of project file management are based upon vendor research, user interviews, published industry averages and personal experience.

Annual Savings Summary
(When Fully Implemented)

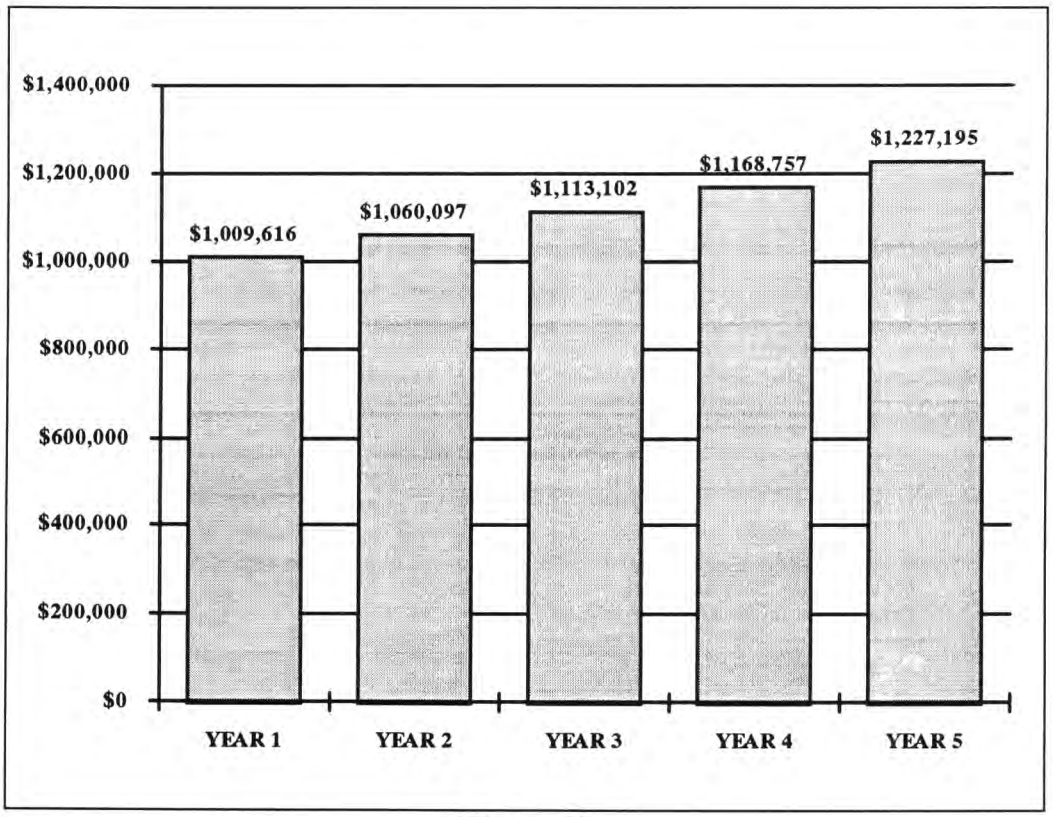

Figure 18

- Annual savings is the equivalent of 25 $40,000 employees including fringe benefits
- Anticipating a 5% annual growth in volume

The following graph summarizes the cost estimates for the various file related activities for 1993. It also summarizes the savings estimates when the automated project filing system is fully implemented.

Annual Savings
Factors
(When Fully Implemented)

ACTIVITY CATEGORY	CURRENT COSTS	YEAR 1 SAVINGS	YEAR 2 SAVINGS	YEAR 3 SAVINGS	YEAR 4 SAVINGS	YEAR 5 SAVINGS
Document Filing	$168,272	$84,136	$88,343	$92,760	$97,398	$102,268
Document Retrieval	301,593	150,297	157,812	165,702	173,988	182,687
Document Refiling	143,879	143,879	151,073	158,627	166,558	174,886
Document Copying	319,285	159,643	167,625	176,006	184,807	194,047
Document Mailing	130,000	86,666	90,999	95,549	100,327	105,343
File Close Out	28,623	28,623	30,054	31,557	33,135	34,791
Internal Services File Retrieval	11,721	11,721	12,307	12,922	13,569	14,247
Management / Supervisory Information Conduit Activities	689,302	344,651	361,884	379,978	398,977	418,925
TOTAL	$1,792,675	$1,009,616	$1,060,097	$1,113,102	$1,168,757	$1,227,195

Table 9

- Detail on how these estimates were calculated are contained in the Appendix
- Appendix A contains the master data sheet from which all estimates are calculated

Supervisors and managers are typically the most knowledgeable and most highly paid members of the Department workforce. A 7.5 % increase in productivity due to a 50% reduction in information conduit activities, results in significant dollar savings.

Management
"Information Conduit" Time Savings
(When Fully Implemented)

YEAR	ANNUAL E20 HRS.	ANNUAL T20 HRS	ANNUAL T18 HRS.	TOTAL	CUMULATIVE
YEAR 1	$42,000	$118,760	$183,892	**$344,652**	$344,652
YEAR 2	44,100	124,698	193,087	**361,885**	706,537
YEAR 3	46,305	130,933	202,741	**379,979**	1,086,515
YEAR 4	48,620	137,480	212,878	**398,978**	1,485,493
YEAR 5	51,051	144,354	223,522	**418,927**	1,904,420
TOTAL	**$232,077**	**$656,224**	**$1,016,119**	**$1,904,420**	

Table 10

Based Upon:

- A 7.5% productivity increase (.6 Hrs./Day) for the average supervisor/manager

- Other management time savers provided by an effective information management system:
  - Fewer decision upgrades due to information accessibility
  - Documents or files are dropped in the manager's in-basket to be reviewed at the most appropriate time for the manager
  - Comments added to document images forwarded to manager reduces call-backs for clarification
  - Automatic delivery confirmation of documents routed by manager reduces follow up calls to determine status

FINANCIAL INVESTMENT

Moving SDDOT from a paper-based project filing system to an automated, integrated, centralized system can provide the benefits outlined in the BENEFIT OPPORTUNITIES section. It requires that SDDOT management make a commitment for the long term.

The Department is in the process of upgrading all the personal computers throughout the central and field offices to take advantage of desktop computing, client-server resources and advanced network architectures. The approved SDDOT Information System Plan calls for upgrading 80 workstations per year at a cost of $3,100 each. There are 177 XT and 286-class machines in SDDOT that are scheduled to be replaced with 486SX machines. The total cost is $548,700.

The incremental benefits that an automated, integrated, centralized project filing system can deliver significantly improves the return-on-investment for 177 new workstations.

The following assumptions are made in the cost estimate table, Table 11, on the following page:

System Cost Assumptions

- Workstation costs reflect only incremental cost of 19" high resolution monitor over VGA (17" would be about $300 less per unit, but 19" is industry standard and recommended)
- Year numbers parallel implementation timeline in Implementation Strategy section of this report
- License cost is approximately 12% of the purchase price after the first 12-month warranty period
- Second jukebox added in year 3
- Jukebox capacity is approximately 50 Gigabyte (GB) with 2 drives
- Costs reflect 15% reduction in technology cost per year minus 5% inflation per year

SDDOT
Cost Estimates

	PILOT SYSTEM						*PHASE - ONE SYSTEM*								
COST ELEMENT					**YEAR - 1**			**YEAR - 2**			**YEAR - 3**			**TOTAL**	
	SEATS			**SEATS**			**SEATS**			**SEATS**			**SEATS**		
		LOW	**HIGH**		**LOW**	**HIGH**		**LOW**	**HIGH**		**LOW**	**HIGH**		**LOW**	**HIGH**
Hardware/Software	14	$258,000	$354,000	66	$224,000	$314,000	80	$244,800	$342,700	17	$91,000	$127,400	177	$817,800	$1,138,100
Licenses/Support								44,400	62,160		72,500	101,500		116,900	163,660
Systems Administrator		22,500	25,000		22,500	25,000		47,250	52,500		49,613	55,125		141,863	157,625
Systems Technician		15,000	17,500		15,000	17,500		31,500	36,750		33,075	38,588		94,575	110,338
TOTAL		$295,500	$396,500		$261,500	$356,500		$367,950	$494,110		$246,188	$322,613		$1,171,138	$1,569,723

Table 11

The following costs are presented to give an approximate cost relationship between the various components that make up a 14-seat pilot system. Every integrator and VAR can configure a system in a multitude of ways to accomplish the same end. Software costs are typically about 25% of the total cost. The integration costs can also vary considerably with each vendor.

Pilot
System Components

	Cost Range
• Software	$60,000 - $80,000
• File Server	4,000 - 5,000
• Index Server	4,000 - 5,000
• Image Server	4,000 - 5,000
• Jukebox & Drives (Approx. 50GB & 2 Drives)	50,000 - 75,000
• Desktop Scan Server	2,000 - 3,000
• Desktop Scanner	4,000 - 6,000
• High-Speed Scanner Server/Integration	24,000 - 31,000
• High-Speed Scanner Upgrade	50,000 - 65,000
• Printer Servers (4)	8,000 - 12,000
• Laser Printers (4)	20,000 - 28,000
• High Resolution 19" Display/Controller (14)	*28,000 - 39,000
TOTAL	$258,000-$354,000

* Note: Workstation cost used is incremental cost of high-resolution monitor cost versus VGA monitor cost approved in the Information Systems Plan.

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ACTIVITY	YEAR - 1 MONTHS												YEAR - 2 MONTHS																YEAR - 3 MONTHS							
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
1.0 PROOF OF CONCEPT PHASE																																				
1.1 Install Pilot Hardware/Software	x																																			
1.2 Load HY-21 Sample Data Set	x																																			
1.3 Train Appropriate Test Personnel		x																																		
1.4 Scan Sample Documents		x	x																																	
1.5 Scan Sample 11x17 Drawings		x	x																																	
1.6 Test PCEMS # Index Link		x	x																																	
1.7 Test W/P Text Input				x	x																															
1.8 Test E-Mail Input				x	x																															
1.9 Test Fax Input					x																															
1.10 Evaluate Concept Feasibility						x																														
2.0 PILOT PHASE																																				
2.1 Select Pilot Region and its 3 Areas				x																																
2.2 Install Pilot Hardware					x																															
2.3 Install Network Components					x	x																														
2.4 Load Total HY-21 Data Base						x																														
2.5 Determine How Far Back To Scan				x																																
2.6 Train Appropriate Pilot Personnel							x																													
2.7 Scan New Let Projects For Region 1							x	x																												
2.8 Scan Internal Services Files For Region 1							x	x	x	x	x	x	x																							
2.9 Scan Mailroom Receipts for Region 1							x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.10 Purge And Scan Back Files For Region 1										x	x	x	x	x	x																					
2.11 Input W/P Text for Region 1													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.12 Input E-Mail For Region 1													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
2.13 Input FAX For Region 1													x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.0 PRODUCTION PHASE -1																																				
3.1 Scan Preliminary Design Files for Region 2																		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.2 Implement Electronic Forms																		x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.3 Train Appropriate Region Personnel																		x																		
3.4 Scan Documents for Region 2, 3 & 4																				x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x	x
3.5 Test Scanning of Full Size Drawings																									x	x										
4.0 PRODUCTION PHASE-2																																				
4.1 Start Scanning in the Planning Process																														x	x	x	x	x	x	x
4.2 Add Workflow Capability to Software																														x	x	x	x	x	x	x
4.3 Integrate CADD																																	x	x	x	x
4.4 Integrate OCR/ICR for Select Documents																																			x	x
4.5 Scan at Area Office level																																	x	x	x	x

1.0 Proof of Concept Phase

The Proof of Concept Phase of the implementation plan is intended to test the feasibility of the major aspects of the conceptual system before impacting any user areas. The successful systems integrator should be a vital part of this phase so specifications and requirements are properly documented and work can begin on incorporating the capabilities into the operational system.

1.1 A representative set of hardware is set up by the integrator. Representative software is installed that will permit testing of scanning, storage, indexing, retrieval, printing and faxing.

1.2 SDDOT must provide a sample data set from the HY-21 data base to test the ability to load the data elements into the relational data base.

1.3 The people who will head up the implementation effort are trained in all aspects of document preparation, scanning, quality control, indexing, printing and faxing.

1.4 The staff will begin scanning representative documents that will be included in the system. These will be primarily 8 1/2"x11" documents and smaller.

1.5 11"x17" reduced-size drawings are scanned to determine quality levels that can be produced at different scan densities. The user acceptability of viewing reduced drawings on both 15" VGA and 19" high resolution monitors is tested.

1.6 The indexing of document images is validated. Here, the time to key the PCEMS number is determined in addition to the ease with which a person familiar with the documentation can determine what PCEMS number is associated with an image.

1.7 Text generated in a word processor system is tested as input to the system. Also, the indexing scheme to the appropriate PCEMS number is validated.

1.8 E-Mail is routed to the system and captured in a test environment.

1.9 Faxed documents are routed to the system and captured in a test environment. The fax-out facility is also tested.

1.10 Based on testing as many aspects of the system as possible, a determination is made what is needed to move to the next phase, the Pilot Phase.

2.0 Pilot Phase

2.1 The most appropriate region is selected to serve as the pilot. Region and area management and staff attitudes should be a major consideration.

2.2 Actual specified hardware is installed in the Central Office and Region Office that will support the system. The components and their locations for the Pilot Phase are shown following this implementation strategy description.

2.3 The network components needed to move images and files from/to Central Office and the pilot region and area offices is installed and tested. In addition, the network operating environment, either Microsoft NT or IBM OS-2, must be installed.

2.4 The balance of the HY-21 data base is loaded into the system index server.

2.5 A decision is made on how far back SDDOT should go in scanning files into the system. There is great value in the old project files if easily accessible. The cost for scanning and microfilming into the system would be comparable to the current process, but the value of the information would be greatly increased through enhanced retrieval capability.

Back file conversion is facilitated by the microfilm file. As microfilm retrievals are made they are transmitted from the microfilm reader-scanner to the imaging system for inclusion in the permanent image file. The most active files are thus converted first.

2.6 Central Office, region and area office personnel are trained by the vendor in system operation.

2.7 Depending upon timing, new let project files are scanned into the system so that subsequent file activities can be tested during the pilot.

2.8 All Internal Services files for the pilot region and area offices are scanned and indexed.

2.9 Documents are scanned when received in the mailroom for the pilot region and area offices and follow the process as described in the Central Office Systems Flow section of this report.

2.10 Region and area files that are pulled for daily reference are scanned in the region instead of being refiled into the paper files so that the most active files are being captured first.

The present closed file purging and merging process is continued. Files are sent to Internal Services as is currently done where they are microfilmed and scanned in one pass on the high-speed scanner. A PCEMS number is keyed to each document image or to the entire

folder. The time and cost of this process is about the same as the microfilming and indexing cost under the current procedure.

2.11 Staff starts inputing word processor text files directly into the system at both the region and area offices for the pilot region.

2.12 E-Mail is captured and routed to the system at the recipient's discretion.

2.13 Fax documents received are routed to the system and images are faxed out.

3.0 Production Phase-1

3.1 The Central Office preliminary design files are next focused upon for the second region to be brought up on the system. Documents received in the mailroom for the second region are sent through the system as described for the Pilot Phase.

3.2 Electronic forms capability is implemented for the pilot region and tested by those with experience as a result of the pilot.

3.3 Appropriate region 2 personnel are trained. In all probability this later training will be conducted by the integrator as a separate charge. SDDOT may want to perform the training by Central Office staff or with pilot region staff who have extensive experience and strong teaching skills by this point.

3.4 The start up process for the remaining two regions is a duplicate to what was described for the Pilot Phase.

3.5 A decision must be made on whether the full-size drawings and maps that are filed separately need to be scanned into the system. This decision would be based up upon the users' satisfaction with the reduced-size scanned images for all their purposes. In addition, SDDOT may want to wait until the next phase when direct CADD input is implemented.

4.0 Production Phase-2

4.1 Scanning is moved up in the construction process cycle to include planning files. PCEMS numbers should be assigned as soon as feasible so that planning files can be effectively used by all the other processes that are now PCEMS number oriented.

4.2 Automatic, rule-based image routing is implemented to facilitate the distribution of information and to automate the multiple and extensive approval processes within the construction project process.

4.3 Direct CADD input is tested and implemented if found acceptable. This may involve integrating a different vendor into the system solution due to the many additional unique features that may be needed in a comprehensive engineering document management and design approval process. By this time all staff and management will have had extensive experience with images in lieu of paper documents and may be more receptive to redlining and mark-up of design drawings via a workstation monitor.

4.4 OCR/ICR is tested for special documents and integrated into the system if desired.

4.5 Scanning at the area offices can begin if it is deemed necessary for turn around and/or control purposes.

We recommend starting the pilot in the preconstruction processes with the following functional areas:

Pilot Implementation

	Functional Area	Seats
•	Project Development	2
•	Roadway Design	2
•	Bridge Design	2
•	Right of Way	2
•	Materials & Surfacing	2
•	Operations Support	1
•	One select region	1
•	Three areas that report to the select region	2
	TOTAL	14

CONCLUSIONS

The following return-on-investment graph illustrates the cumulative economic result if SDDOT implements an automated, integrated project filing system. The Return figures reflect the savings shown in Table 9, page 60. The Investment figures reflect the costs shown in Table 11, page 63.

The figures take into account investment and return factors starting with the current paper-based system at the beginning of Year 1 and concluding with a fully implemented system of 177 workstations in Year 3. The realization of savings is 25% in Year 1, 50% in Year 2, and 100% in Year 3. The payback is less than 2 1/2 years.

Return on Investment

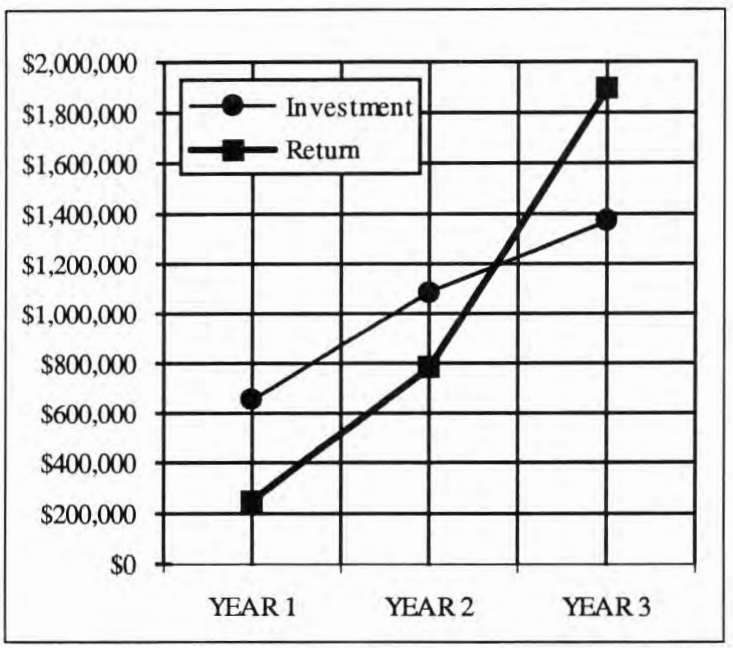


Table 12

- **SDDOT should implement an automated, integrated project filing system**

  - The investment will quantifiably pay for itself in approximately 2 1/2 years
  - Over $1,000,000 will be saved each year when the system is fully implemented
  - Over 18,000 hours of technical staff time will be saved per year when fully implemented
  - Over 12,000 hours of management time will be saved per year when fully implemented
  - Over 500,000 copies will be eliminated per year when fully implemented
  - Parallel processing and concurrent engineering will be greatly facilitated to shorten cycle time and minimize reworks
  - Elimination of information flow bottlenecks will eliminate process flow bottlenecks

- The value locked in old project files will be released to aid new project activities
- SDDOT size makes it ideal to lead the other state DOTs into automated, integrated project filing

- **The benefits are long-term and SDDOT senior management must make a long-term commitment to realize the benefits outlined in this report**

  - Strategic and operational benefits when quantified over time will outweigh the direct economic savings identified in this report
  - Benefits will be even greater as labor costs rise and technology costs continue to decline
  - SDDOT will not be able to attract and keep top engineers without state-of-the-art tools
  - The automated information platform will foster new ways of conducting business
  - Image-level control and multi-characteristic retrieval will provide greatly-enhanced litigation support

- **56 percent of the hardware investment has already been approved by management**

  - 177 desktop workstations at a cost of approximately $548,700 over three years has been approved for client-server computing applications
  - Desktop access to documents, plans, text, fax, and electronic forms will greatly enhance the value derived from this investment
  - The historic investment in the Project Master data base (HY-21) will be extended to provide relational, multi-characteristic document retrieval at no additional cost

- **Successful implementation will require that all levels of SDDOT management support the resulting technology-driven culture change**

  - The human element must be methodically addressed
  - Windows and image retrieval training should be coordinated for maximum benefit
  - The system should be implemented in well-planned phases
  - Each phase of implementation must be successful and publicized throughout SDDOT
  - Recognize that private knowledge is often the basis of power and personal value

- **SDDOT should form a Joint Application Development (JAD) Team to carry out the second phase of the analysis**

  - All ideas, problems, needs, attitudes, and trends must be objectively considered from all processes affected across the Department
  - There must be a high level of user involvement in the final design
  - User expectations must be accurately managed
  - There must be a capable program manager appointed to lead the project
  - The system platform must be as open as feasible and adhere to all established industry standards

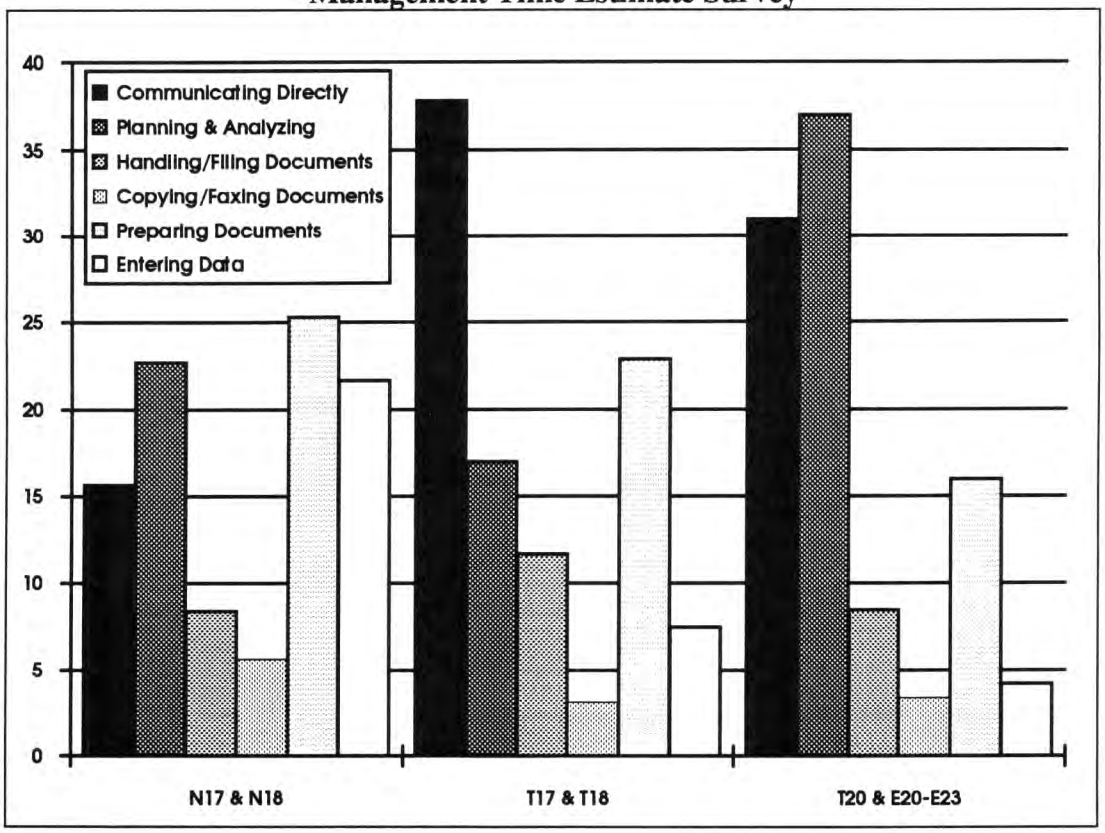
Master Data Sheet

DIVISION NAME	PROCESS NAME	SQ. FT. FILES	NO. OF DR'WRS.	PGS. PER FILE	SOURCE DOC. INPUT PER MO.	W/P DOC. INPUT PER MO.	DRW'GS. INPUT PER MO.	SOURCE DOC. RET. PER DAY	DRW'G. RET. PER DAY	COPIES MADE PER DAY	TOTAL DRW'GS. FILED	DESK FILES ?	AVE. FILE RET. TIME
Planning	Data Inv.	600	200	30	3,000	300	0	10	20	25	1,500	Yes	7.5
	Plan. & Pgm	328	88	75	770	296	122	62	25	260	1,565	Yes	1
	LGA	438	154	350	7,000	920	1,700	220	100	570	4,800	Yes	5
	Accident Rec	150	36	50	2,000	130	100	80	5	70	650	Yes	2
	Admin.												1
Engineering	Mat. & Surf.	214	186	685	8,400	2,800	37	43	13	171	1,075	Yes	7.5
	Bridge Des.	600	406	210	750	130	1,700	50	50	250	36,903	Yes	5
	Road Des.	700	98	325	1,000	900	55	10	25	500	10,000	Yes	2.5
	Proj. Dev.	140	62	59	570	1,400	2,100	12	113	320	400	Yes	10
	ROW	450	54	30	5,000	775	100	20	20	100	5,000	Yes	3
Operations	Huron Area	200	150	200	130	120	30	30	5	100	40	Yes	2
	Other Areas	2,200	1,650	2,200	1,430	1,320	330	330	55	1,100	440	Yes	2
	Const. Supp.	240	50	200	5,000	150	20	40	10	100	300	Yes	1.5
	Prop. Mgmt.	72	23	15	180	80	40	20	4	100	480	No	1.5
	Pierre Reg.	92	33	150	1,000	100	300	2	5	75	100	No	0.5
	Other Reg'ns	276	99	450	3,000	500	900	8	15	225	300	No	0.5
Air, Rail, Tra	Rail. Prop.	62	43	20	150	300	600	10	3	4	600	No	1
	Aeronautics	60	10	200	1,000	200	200	20	100	50	3,800	Yes	5
Finance	Fin. Svcs.	64	26	225	3,600	20	0	150	0	100	0	No	0.5
	Internal Svcs	171											
													Average
	CENTRAL	4,289	1,436	2,474	38,420	8,401	6,774	747	488	2,620	67,073		
	FIELD	2,768	1,932	3,000	5,560	2,040	1,560	370	80	1,500	880		
	TOTAL	7,057	3,368	5,474	43,980	10,441	8,334	1,117	568	4,120	67,953		3.11
	Note:	171 Sq. Ft. of files in Internal Services represents the new rolling file system at a cost of $20,000											
		450 Sq. Ft. of file space in ROW includes rolling file system and other cabinets scattered throughout ROW											
		Data for Pierre Region and Huron Area offices are extrapolated to determine data for the remaining regions and areas											

APPENDIX B

A survey was completed by 18 supervisors and managers at Central Office. Following are their estimated percentages of time spent on various activities in an "average" day:

Management Time Estimate Survey



- Direct Communication - Time spent in "information conduit" activities would be cut and access to all documentation would make other communications more effective
- Planning & Analyzing - Time would be saved because current and historical project information is readily accessible
- Handling & Filing Documents - Redundant personal files and file maintenance activities are reduced because files are under control
- Copying/Faxing Documents - These tasks are done at a touch of a workstation keyboard
- Preparing Documents - Time would be saved because of electronic forms and access to valuable information that minimizes "re-inventing the wheel" each time

Current Project Filing System
Cost Projection

YEAR	DOCUMENT FILING	DOCUMENT RETRIEVAL	DOCUMENT REFILING	DOCUMENT COPYING	DOCUMENT MAILING	FILE CLOSE-OUT	ANNUAL TOTAL
1994	$168,272	$302,593	$143,879	$319,285	$130,000	$28,623	$1,092,652
1995	176,686	317,723	151,073	335,249	136,500	30,054	1,147,285
1996	185,520	333,609	158,627	352,012	143,325	31,557	1,204,649
1997	194,796	350,289	166,558	369,612	150,491	33,135	1,264,881
1998	204,536	367,804	174,886	388,093	158,016	34,791	1,328,125
TOTAL	$929,809	$1,672,017	$795,022	$1,764,251	$718,332	$158,160	$6,037,592

- Average midpoint for engineer salary & benefits of $24.98 per hour (30% fringe)
  Note: The fringe benefit percent is conservative and could be as much as 40%
- Average midpoint for support staff salary and benefits of $12.18 per hour (30% fringe)
- Wage and benefit increase of 5% per year

Current Project Filing System
Cost Projection

YEAR	DOCUMENT FILING	DOCUMENT RETRIEVAL	DOCUMENT REFILING	DOCUMENT COPYING	DOCUMENT MAILING	FILE CLOSE-OUT	ANNUAL TOTAL
1994	$168,272	$302,593	$143,879	$319,285	$130,000	$28,623	$1,092,652
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TOTAL	$929,809	$1,672,017	$795,022	$1,764,251	$718,332	$158,160	$6,037,592

- Average midpoint for engineer salary & benefits of $24.98 per hour (30% fringe)
- Average midpoint for support staff salary and benefits of $12.18 per hour (30% fringe)
- Wage and benefit increase of 5% per year

Current Main File Retrieval Activity
(In Dollars)

YEAR	ANNUAL ENGINEER RETRIEVAL COSTS	ANNUAL STAFF RETRIEVAL COSTS	ANNUAL ENGINEER REFILING COSTS	ANNUAL STAFF REFILING COSTS	ANNUAL TOTAL LABOR COST	CUMULATIVE LABOR COSTS
1994	$260,292	$42,301	$115,682	$28,197	$446,472	$446,472
1995	273,307	44,416	121,466	29,607	468,796	915,268
1996	286,972	46,637	127,539	31,087	492,235	1,407,503
1997	301,321	48,969	133,916	32,642	516,847	1,924,350
1998	316,387	51,417	140,612	34,274	542,690	2,467,040

Based Upon:

- Average midpoint for Engineer of $50,170 including 30% fringes ($24.98/Hr.)
- Average midpoint for staff of $24,470 including 30% fringes ($12.18/Hr.)
- 251 days per year
- 5% growth per year
- Main file only; does not include personal desk files

Walk-Up Copying
Cost Detail

	ANNUAL		STAFF COSTS		TOTAL	
	NUMBER OF	COPY	(TIME)		ANNUAL	CUMULATIVE
YEAR	PAGES	COSTS	ENGINEERS	STAFF	COSTS	COSTS
1994	1,034,120	$51,706	$215,097	$52,482	$319,285	$319,285
1995	1,085,826	54,291	225,852	55,106	335,249	654,534
1996	1,140,117	57,006	237,144	57,861	352,011	1,006,545
1997	1,197,123	59,856	249,002	60,754	369,612	1,376,157
1998	1,256,979	$62,849	$261,452	$63,792	$388,092	$1,764,249

Based Upon:

- Copy cost of $.05 each for materials and equipment/service
- 50% of copies are made by Engineers; 50% are made by staff
- Each copy takes an Engineer 1 minute; staff .5 minute
- Engineer time worth $.416 per minute; staff worth $.203 per minute

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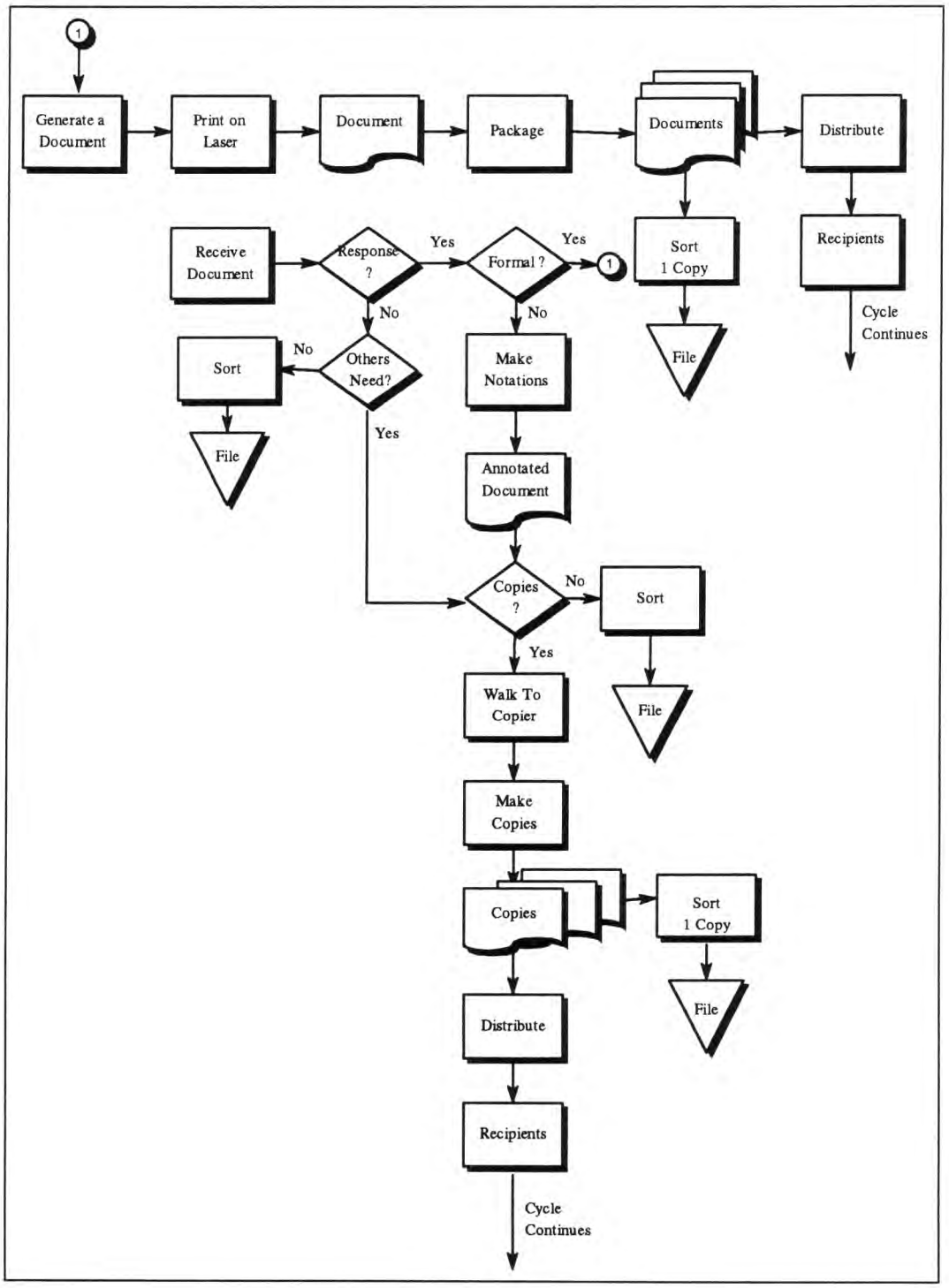
- Conservatively, 50% of copies could be eliminated - saving $159,643+ per year
- 50% fewer copies being distributed throughout SDDOT has an immense ripple impact in time and cost on the Department
- 50% less copies to distribute, sort, file, retrieve, sift through and around to locate what is really sought, and to purge when out of space
- 50% less copies that confuse what is the "real" up-to-date file that often prompts a call or visit to others who are believed to be the custodian of the "real" file
- Reduced copy proliferation simplifies maintaining the "official" project file

The Paper Proliferation Cycle



APPENDIX G

Annual Main File Retrieval Activity
(In Volume)

YEAR	ANNUAL RETRIEVALS BY ENGINEERS	ANNUAL RETRIEVALS BY STAFF	ANNUAL REFILING BY ENGINEERS	ANNUAL REFILING BY STAFF	TOTAL RETRIEVAL ACTIONS
1994	208,393	69,464	138,928	138,928	555,713
1995	218,813	72,937	145,874	145,874	583,499
1996	229,753	76,584	153,168	153,168	612,674
1997	241,241	80,413	160,827	160,827	643,307
1998	253,303	84,434	168,868	168,868	675,473

Based Upon:

- 1,107 Total Retrievals Per Day In 1993
- 251 Days per Year
- 5% Growth per Year
- 75% of Retrievals by Engineers; 25% of Retrievals by Support Staff
- 50% of Refiling done by Engineers; 50% of Refiling done by Support Staff
- Main File only; Does not include Personal Desk Files

APPENDIX H

Regional
File Close-Out Costs

YEAR	HURON	BROOKINGS	ABERDEEN	YANKTON	WINNER	RAPID	AVERAGE HOURS	TOTAL COST
1994	140	170	375	30	120	340	196	$28,623
1995	147	179	394	32	126	357	206	30,054
1996	154	187	413	33	132	375	216	31,557
1997	162	197	434	35	139	394	227	33,135
1998	170	207	456	36	146	413	238	34,791

The area offices in the graph above responded to our question on how much time it took to perform the file close-out activities every year. There was a fairly wide swing across the offices. Some of this could be explained by how large the area was, how many projects they averaged and how complex the projects were.

One thing that was universal, no body wanted to do it.

APPENDIX I

Following is a list of organizations that have products with potential application in the conceptual system we described. The industry is made up of software developers, Value-Added Resellers (VARs), Systems Integrators (SIs), computer systems manufacturers, and service companies. Products from multiple sources are incorporated into solutions that are delivered by the final integrator.

Hardware components have become commoditized to a large extent. The factors that differentiate one system solution from another are often based upon software functionality and integration services. The following list of companies could fall into any one or all of the vendor descriptions outlined above. This list is a starting point for SDDOT vendor research and is not intended to be an inclusive list or endorsement.

Non-Inclusive List
of
Potential Systems Vendors

- **Cimage Corporation -** Ann Arbor, Michigan
- **Digital Equipment Corporation** - Merrimack, Hew Hampshire
- **Filenet Corporation** - Costa Mesa, California
- **IBM Corporation** - White Plains, New York
- **Intergraph Corporation** - Huntsville, Alabama
- **Kefile Corporation** - Nashua, New Hampshire
- **Metafile Information Systems** - Rochester, Minnesota
- **Optika Imaging Systems** - Colorado Springs, Colorado
- **Plexus Software - Dallas, Texas**
- **Sigma Imaging Systems** - New York, New York
- **Viewstar Corporation** - Emeryville, California
- **Wang Laboratories** - Lowell, Massachusetts

APPENDIX J

Peer Group Researched

As part of the research work plan we contacted several state departments of transportation and other engineering-oriented private sector businesses to determine the state of the art for managing project files. In general, no other state DOT has addressed automating and integrating the construction project files.

Most of those we talked with were very interested in technology to automate the project files, but were looking at investigating the application of such technologies in the next 3-5 years. The larger states believed their file sizes and the critical path nature of those files would require a structured and committed task force to carry out the research in their departments.

- **Caltrans**

  Caltrans has implemented an imaging system to store, preserve and retrieve their bridge books. They have converted approximately 200,000 aperture cards, 100,000 drawings on 35mm microfilm drawings and 700,000 8 1/2"x11" documents to an imaging system. They are using an Intergraph system that contains an Informix data base management system. The images are stored on four Kodak jukeboxes.

  Caltrans had a study done in 1986 that indicated that the bridge books were the best application with which to start an imaging program. The construction project files were too complex and too hard to quantify the benefits. Also, Caltrans is decentralized across 12 autonomous districts. They have no direct CADD integration, but plan to do so in the future.

  They have implemented an imaging system for the accounting process to assist in managing receivables and payables as it regards construction projects. They are looking at a third application to manage consultant and contractor contracts. They hope some day to be able to address the main project files.

- **Florida DOT**

  Florida DOT is in the process of testing imaging technology for the management of full-size drawings after approximately 1 1/2 years of investigating the technology. The Design Division has placed an equipment order with Intergraph to begin storing drawing images on optical media. They went out to bid to have some of their drawings converted from aperture cards and hard copy to begin the process. They have approximately 1,000,000 drawings. Florida has top engineering management directives to move into electronic imaging.

FDOT has 7 autonomous districts. Each has their own project files. There is a central project file, but is an "after-the-fact" file. Their vision is to have a centralized drawing file with electronic delivery to the remote sites. They plan on displaying drawing images on 19" CADD monitors, 14" PC monitors and 15" PC monitors. They will be using "tiling" technology to send overview images at low resolution and then following with high resolution tiles of drawing sections. They are not sure if they will move to CADD conferencing in the near future. They plan to move from the engineering drawings and maps into project development in the future.

The Construction Division recently went to bid to design a system to manage the data and documentation in the field offices that support construction management. Pen computers was considered to be one of the technologies that will be applicable.

Florida DOT is very interested in our research project at SDDOT.

- **North Carolina DOT**

North Carolina DOT has installed an IBM Image Plus/2 system for accounting records. The personnel in the project file are have been to numerous demonstrations of imaging technology, but as of yet have not moved aggressively in that area.

They have been implementing a Geographic Information System (GIS) for several years. Their plan is to be able to tie the construction project files into a GIS data base for retrieval.

- **Texas DOT**

Texas DOT is in the process of implementing imaging for litigation support. There are several large construction projects that are in litigation now where access to critical correspondence and documentation will be instrumental in their defense. In Texas there has been a startling increase of incidents over the past 5 years where contractors are requesting additional compensation during construction due to situations or claimed DOT errors. DOT must be able to support its case if they feel additional compensation is not warranted.

Texas has committed to spending the money to convert litigation-critical documents to five standalone imaging systems for each of the litigation actions. Each of their districts are pretty much autonomous. They are just starting to look at how imaging could be used for their drawings. They believed that tackling the project files would be a gigantic project due to the size of Texas DOT.

They are using OCR/ICR technology to scan and interpret every word to build a full-text index. They index is intended to serve the purposes of litigation. They feel they will have to develop a different index for images that support the general construction process.

Texas DOT is very interested in our research project at SDDOT.

- **Michigan DOT**

Michigan DOT is not doing anything in the way of imaging for project files. They have concentrated in the construction area and have developed a Construction Project Record Keeping System (CPRKS) that tracks construction, feeds data to Lansing and provides information retrieval capability. It is a PC-based system, but has an interface to handle pen-based computers. The system does not store or manage documents.

- **Florida Power & Light**

FP&L is considered to have a "state-of-the-art" technical document imaging system. The initial application is for vendor documentation (P.O.s, specs, photos, manuals, documents). They intend to scan 100,000 drawings at 200 dots per inch (dpi) up to size G. To date they have converted about 10,000 drawings.

They are using an Intergraph system and are sending "overview" images and tiled images over high-speed fiber cable, T-1 and 56kbps lines. They are displaying images on 15" VGA monitors and Intergraph high resolution monitors. Their transmission speed to remote locations on the LAN is only about 1-2 seconds slower that speeds on the LAN. They report that transmitting the raster image is faster that transmitting the vector file of the same drawing.

- **Walt Disney World**

Walt Disney World is moving toward implementing a technical document image management system. They currently have 100 CADD seats on their system and 400 non-CADD terminals. They have approximately 500,000 drawings of which 100,000 are CADD generated. They estimate that it would cost about $2 per drawing to convert full-size hard copy drawings to an imaging system. That cost, $1,000,000, has inhibited the progress toward imaging.

They believe, however, that it costs them $1,000 to redraw a drawing if it were destroyed. That is one of their major justifications for converting hard copy drawings to a raster file that can be "vectorized" and also stored as a raster image in a storage and retrieval system.