Final Report

Automated Construction Data Management System

by

Bob G. McCullouch

Joint Highway Research Project

Project No.: C-36-67FF

File No.: 9-11-32

Prepared for an Investigation
Conducted by the

Joint Highway Research project
Engineering Experiment Station
Purdue University

In cooperation with the
Indiana Department of Transportation

The opinion, findings and conclusions expressed in this
publication are those of the author and not necessarily
those of the Indiana Department of Transportation

Purdue University
West Lafayette, Indiana

January 8, 1991

TABLE OF CONTENTS

LIST OF TABLES	iii
LIST OF FIGURES	iv
ABSTRACT	v
Chapter 1 Introduction	1
Chapter 2 Work Activities	7
Connecticut DOT System	10
Executive Reporting System	14
Chapter 3 System Features	16
Hardware Configurations	17
BAMS Integration	18
Computerized Specs	22
FHWA Guidelines	24
User Ease	25
PC Computing	25
Miscellaneous Features	26
Portable data collectors	26
Asphalt/Concrete plant tie-in	26
RF tags to record quantity installed	27
Bar code usage	27
Lab equipment RS232 interface	28
Laboratory Information Management System (LIMS)	28
Graphics Interfaced Transportation Information System(GITIS) Interface	28
Electronic signature control	28
Document scanner	29
Material computer code lookup program	29
Electronic clipboard capability	29
Initial Capabilities	30
Future Capabilities	30
Chapter 4 System Costs	31
Software Development	31
Hardware	33
Software	35
Communication	36
Miscellaneous	39
Chapter 5 System Benefits	40

Chapter 6 Recommendations	45
Hardware Configuration	45
Outside Consultant	45
System Development	46
Misc.	48
Costs and Benefits	49
Chapter 7 Conclusions	52
References	53
Appendices	54

LIST OF TABLES

Table

1.1	Construction Program: Past and Future	3
1.2	Current INDOT Construction Personnel	5
1.3	Documented Construction Supervisory Costs	5
2.1	CDOT Codes File Maintenance	13

LIST OF FIGURES

Figure

1.1	INDOT Construction Program	4
2.1	INDOT Integrated System	8
3.1	INDOT Hardware Option 1	19
3.2	INDOT Hardware Option 2	20
3.3	INDOT Hardware Option 3	21

ABSTRACT

Project engineers and managers involved in construction spend a disproportionate amount of time collecting and processing construction data. This processing of data typically causes the construction manager to be distracted from the more important task of supervising and controlling the project. The amount of construction data will most likely continue to expand in the future creating more of a burden on the construction manager. So reducing the volume of data most likely will not occur. New innovative data management systems that utilize the latest in computer and automatic identification technologies should be developed. This report describes such a system for use by INDOT. The goal of the system is to create a "paperless" environment for INDOT personnel that are involved with the construction program. This system will provide better data organization and flow resulting in reduced paperwork processing time and providing more time to devote to managing the construction process.

Chapter 1

Introduction

INDOT construction supervision personnel spend a considerable amount of time processing construction data (construction data includes Material & Test data); sometimes to the extent that it distracts them from their main task of directing and supervising the construction process. Based upon existing trends of increased construction activity without parallel increases in INDOT personnel, data management will continue to expand, making more demands on their time. Not much can be done to reduce the amount of construction data generated and managed, but a new, innovative automated data management system should be developed to solve this impending problem.

A recent survey, explained later in this report, reveals that out of the 44 responding DOTs, 31 either have such a system or are in the process of designing and developing one. For example in the neighboring states: Illinois is in a conceptual study phase to in-house design a system; Ohio is at the preliminary study phase with an outside consultant to have an operational system by October 91; Kansas has hired a consultant to design a system which will be operational within two years; Michigan has an operational system; and Wisconsin has a system that has been operational for three years, both were designed in-house.

Perhaps the most mature system is found in Connecticut. In 1985 a \$5 billion rehab program began that burdened their existing construction data management system. To deal with this problem, CONDOT, contracted with a consultant to design and develop a system. After spending two years and \$10.8 million, the system went on-line in the summer of 1988. The \$10.8 million paid for the \$8 million software development, \$1.8 million for PC work stations, and \$1 million for main frame enhancements. Some other background information on the CONDOT system includes the following:

Before the new construction rehab program started in 1985, approximately \$80 million was spent each year on highway construction.

CONDOT spent \$750 million this year on construction for approximately 250 projects

The last two years approximately \$ 1 billion spent each year.

150 - 200 personnel have been added making the total number approximately 400. Approximately 40% of the projects are managed by consultants, so for this year from the previously mentioned numbers, CONDOT will supervise approximately \$450 million in construction with approximately 400 personnel.

What about INDOT's construction program? What has the past been like? What is the current situation? And what will most likely happen in the future? A look at some statistics may help answer these questions.

Table 1.1 Construction Program: Past and Future

<u>Year</u>	<u>Construction \$</u> (millions)	<u># of Projects</u>	<u># Const. Employ.</u>
1987	260	600	734
1988	308	299	734
1989	338	434	724
1990	506	608	724
1991	560	450	---
1992	540	415	---
1993 & beyond	450+ **	400**	---

** Difficult to project

This 724 compares with the 400 from Connecticut DOT.

Over the last five fiscal years(1987 - 1991), the construction volume has increased from \$260 million to \$560 million, while the number of INDOT supervisory personnel has decreased from 734 to 724. Figure 1.1 is a graphical form of these numbers. Statistics in themselves can be misused and may not reflect what actually is the case so this reduction in personnel may have been warranted and

Figure 1.1 INDOT Construction Program

necessary. But it should point out that existing personnel may be approaching a strained condition because of their work load.

Tables 1.2 and 1.3 display more information about INDOT construction supervision.

Table 1.2 Current INDOT Construction Personnel

PE & supervisors:	316*
Inspectors:	
- Certified(EA1)	165
- Intermediate	162
- Entry Level	<u>81</u>
Total	724**

* The breakdown on this is:

Project Engineers	- 155
Project Supervisors	- <u>161</u>
	316

** Total does not include temporary inspectors, central office construction staff, and some administration personnel at the district level.

Table 1.3 Documented Construction Supervisory Costs

1987	- \$14.875 million	- 3.7%	of const.	budget
1988	- \$16.562	"	- 4.2%	" " "
1989	- \$16.947	"	- 5.8%	" " "
1990	- \$17.685	"	- 4.5%	" " "

An informal survey of INDOT PEs revealed that on an average, about five hours each day is spent on managing construction data. This five hours is comprised of 3 1/2 hours by the PE or PS and 1-1/2 hours by the inspector. So, for a five day work week approximately 25 hours is spent on paper work for a project. When a PE or PS is assigned to multiple projects, the percentage of time spent on paperwork is going to be higher.

Just because 31 other states have developed or are developing a data management system isn't enough impetus for INDOT to have one. But two realities should not be overlooked either. One is that with transportation facilities continuing to deteriorate, and heavier use is expected, more construction will be needed to keep pace with the demand. Secondly, because of a shrinking work force and the likelihood of tighter state budgets, less INDOT personnel will be available to manage construction projects. With these realities, tools such as this system needs to be developed for INDOT.

Current literature reveals that there is a movement underway in the construction industry towards computer integration of the construction process. Several articles on this topic are listed in the Reference section.

Chapter 2

Work Activities

The Long Range Data Processing Committee (LRDPC) established several work activities in order to reach the goal of defining a system. Each of these will be explained and described in the following paragraphs.

Computerized controls have been developed for several INDOT activities. Current INDOT computer programs are: BAMS, with on-going work in the PES, LAS, and the CAS modules; the Maintenance Management system, the Accounting system; the Materials and Test system; the Construction records system; and the Roadway Management system currently under development. Each of these are designed for a specific purpose and operate in a stand-alone basis. Because of this, "islands of automation" currently exist in INDOT. An effort needs to be made to link these islands together for sharing information. Figure 2.1 illustrates this type of linking and data sharing.

The new system will be designed to assist and service the INDOT personnel supervising construction. In order to determine what features should be a part of the system, interviews were conducted with personnel at the field, district, and central office levels. Their input helped define those features found in the next section.

INTEGRATED DATA SYSTEM

RMS - Roadway Management System
BAMS - Bid Analysis Management System
MMS - Maintenance Management System
CRS - Construction Record System
M&T - Materials & Test System

Figure 2.1 INDOT Integrated System

A large portion of paperwork is spent filling out various INDOT forms. One way to reduce this work would be to consolidate or eliminate some of the forms. A study of the forms requirements and their paths was made to determine if this was possible. A database was compiled containing the form types and their routing paths. A copy of this database is found in Appendix A. The committee decided that a formal review and recommendation on forms should be performed closer to the system design and implementation phase.

Another activity was to survey other state DOT's. A survey was sent to the other 50 (District of Columbia included) DOTs with forty-four returned. Of the forty-four, thirty-one indicated that either a system was operational or in some stage of development. These states were contacted by phone in order to collect more information about their system. A copy of the cover letter, mail survey form, and the phone survey form is included in Appendix B.

Information collected from the phone survey included what the system does, what data is tracked, system features, in-house developed or consultant used, software and hardware utilized, and development costs and other costs. Most states, with a few exceptions, have decided to automate in stages. For example, construction records may be computerized first then materials and test information would be next. Software varied from a database package like dBase III+ to a higher more powerful language like C.

IBM PCs or compatibles were the machines used and those that transferred files electronically were equipped with modems. In-house development costs have averaged a couple hundred thousand dollars(\$100,000 - \$400,00), while outside consultant costs are higher, with Connecticut's at \$8 million. A complete summary on each state is found in the Appendix C.

Connecticut DOT System

From the survey, Connecticut's system appeared to be the most comprehensive and mature one. So on July 11 and 12 a trip was made by two committee members for the purpose of observing and evaluating the system. The following describes some of the main features of the system and general impressions.

In 1984 the state of Connecticut embarked on a \$5 billion Infrastructure renewal program. Due to the magnitude of construction activity and a limited supervisory staff, CONDOT was faced with the problem of how to manage the information. So to deal with this problem several management systems were identified and developed. These systems are the Construction Management and Reporting (CMR) system, the Preconstruction Management System(PCMS), the Executive Reporting System (ERS), and the Financial Management Information System(FMIS). The CMR and the ERS were demonstrated. The PCMS system is scheduled to go "on-line this fall and the FMIS is under development.

The Construction Management and Reporting system was developed and brought on-line three years ago. It is used on all projects. The Executive Reporting System is used in the central office by upper management. An overview for each of these two systems is now provided.

The CMR is a PC stand-alone and interactive terminal system. Each project office is connected to the central office UNISYS main frame via dedicated phone lines. At each work station the user can access the CMR system as well as the following software used for local data processing. These software are:

Lotus 123 - Used for computational purposes(e.g. rebar calculations, cost+ accounts, etc.)

Multimate Advantage II - Used for correspondence. Allows for electronic message capability to all installations.

Earthworks II - Used for volumetric computations (concrete & earthwork) - commercially available

Microsoft windows - Used for miscellaneous applications.

Exit to DOS

The system is menu driven and was developed with the software AUTOMENU.

CONDOT buys the hardware and installs it. They have purchased equipment for approximately 300 installations. Zenith equipment is used and each installation has a PC(XT compatible), monitor, printer, and modem. At today's prices a similar setup should cost no more than \$3000. Also, CONDOT repairs, maintains and moves the equipment. Extra security measures such as window bars and extra locks are installed at the project offices to protect the equipment from theft. FHWA is tied into the system. Any field consultant can access the system as well.

The construction menu option is shown below. This shows the capabilities of the CMR construction module.

Construction Menu

1. Contract
2. Construction Order
3. Sub / Contractor
4. Daily Inspector
5. District
6. Item
7. Payment Estimate
8. Section
9. Testing
10. Construction Order Request
11. Federal Voucher Request
12. Daily Inspector Report Request
13. Print Reports
14. Main Menu
15. Signoff

Enter Selection:

The system is ID and password protected. Each user must have one to access the system. Basically there are three operation modes in which a user can operate:

- A - Add information into the system
- I - Inquiry, which is to look at the data
- M - Modify the data

When the user is issued an ID number and password, his system operation mode is determined and assigned to the applicable fields. A sample of the fields is shown in the below table 2.1.

Table 2.1 CDOT Codes File Maintenance

CFS105
AWG

TABLE 1 (MAIN AND SECONDARY MENU OPTIONS)

<u>MAIN MENU</u>	<u>CONSTRUCTION</u>	<u>NON-CONSTRUCT</u>	<u>REPORTING</u>	<u>OTHER</u>
MANPOWER :	CONTRACT :I 3	MP CONTRACT :	IR/POSS CLM:	PRINTER :NTRPR3
CON STAFFING:	CONST ORDER:* 3	CON RESRCE :	CON ACTIVITY:	DIR INPUT FLG:
FINANCIAL :I	CONTRACT/SUB:I 3	MP RECONSIL :	CORR BY CON:	TEST APPROVAL:
CONSULTANT :	INSP REPORT:* 3	CON STAFFING:	FIN ACT BAL:	ACCPT CONTRCT:
PERSONNEL :	DISTRICT :	CON ASSGNMT :	SPEC CORR :	CONTR S OR P :
PRE-CONSTR :I 3	ITEM :I 3	POSITION NM :	ACC WRK ZNE:	DIST ENGRN :
CLAIM/DISP :I 3	PAYMENT EST:* 3	EMP INFO :	EMP/POS LST:	
TOWN/LOC INQ:I *	SECTION :I 3	WORK ORDER :I 3	CC SER RTNG:	REPORTING
CORRESPOND :I 3	TESTING :* 3	PROJECT MOD :I 3	MP ANAL RPT:	*NOT IN USE :
CONSTRUCTION:Y	CO REQUEST :* 3	BUDGET INQ :I 3	AVIL-INSP :	*NOT IN USE :
ON-LINE RPTG:* 3	FED VOUCHER:* 3	CONSULT CO :	AVAIL-P.E. :	NON-CONSTRUCT
CF/CONV PGMS:	IR REQUEST :* 3	CONSULT SEL :	POL DIST :	SUBCON CONV:
POLIT DIST :	PRINT RPTS :* 3	CONSULT SUP :	VLD BUD LIS:	ITEM CONV :
CON COMMENTS:	*NOT IN USE:Y	CONSULT EMP :	PRJ MOD ST :	CODES FILE :
SIGNOFF :Y	*NOT IN USE:Y	MAIN MENU :Y	*NOT IN USE:	*NOT IN USE:
		SIGNOFF :Y		

Some miscellaneous features include the following. The only report that is submitted in the field is the daily report. Once

the daily report is entered it can only be revised by another daily report. At the bottom of each screen are fast path features that give the user quick access to other parts of the system. The pay estimate is performed overnight and only lists items to be paid during the pay period. Only major correspondence items leave the field office. A paper copy of all correspondence is only kept at the field office. The program does track testing data between the field and the testing labs (District & Central). CONDOT's data processing department performs the long term maintenance of the system.

Executive Reporting System

This is an information overview system for use by upper management. It is a PC based system that utilizes Oracle database and Easel software and a touch screen. Information used by the system is updated every night. This system is visually operated by using colors and the touch screen. Colors are used to indicate project condition based on certain parameters.

Red - A problem exists.

Yellow - Conditions exist that warrant caution.

Green - Conditions are OK.

The system does have graphic capability for representing data.

Each user can customize his work station and choose which projects

to monitor.

The last major work activity was to evaluate the various system options. This included hardware configurations, software requirements, development options, associated costs for each option, and expected benefits. This information is described in the following chapters.

Chapter 3

System Features

Computerizing or creating a "paperless" environment for construction records and material and test data is the goal of the proposed system. Currently, underway is the construction records program which is providing for electronic record keeping on a project. This program may provide the initial step toward this goal, but in its present form it needs enhancing. Also, the software being utilized may not allow for the following features.

General capabilities will be the automation of construction field data. Initially this will encompass the capture, storage, and transfer of daily field generated data, materials and test data, and processing reports and contractor payments.

The foundational feature that undergirds the system will be data integration. Data that is collected and used in this system should be stored in a format that is accessible from other INDOT computer systems; those existing systems that were mentioned earlier in the report and future systems. Therefore the hardware configuration should have the capability to allow for this sharing of data between the various systems. Possessing this overall perspective of system inclusion will be one the most important features of this system.

Hardware Configurations

Based on the previously mentioned premise of data integration, data will need to be stored on a central database that is accessible from other systems. This will require the configurations to center around the main frame which contains the centralized database. Because of this requirement, there are three viable configuration options. These options are:

1. Main Frame based system - All storage and processing is handled on the main frame. PC acts as a terminal. Data accessibility is controlled at the main frame by specifying user access codes. Communication costs are high because it is on-line and interactive .
2. Main frame is used as a storage device with processing required for managing the database and communicating with users. Data resides at the main frame while the major processing is done at the PC level. PC acts in stand-alone and terminal environments. Stand-alone provides the user with additional computer capabilities. By processing the data at the PC, this lessens dependency on the main frame and its availability. With batch loading to and from the main frame, communication costs can be greatly reduced. This can be scheduled on a daily basis so that next day information is available.

3. Main frame is used as a storage device. At the district level a mini system will reside where data is received from the projects, stored temporarily, processed, and eventually stored on the main frame. The PCs in the field do not communicate with the main frame but go through the mini in the district. This lessens dependency on the main frame, so that in case it is down users can still operate.

Figures 3.1, 3.2, and 3.3 on the next three pages portray these hardware configurations.

BAMS Integration

Since BAMS will play a key role in INDOT computerization it should be integrated into the proposed system. This integration should allow for data transfer in and out of BAMS and for a coordinated processing effort between the two systems.

Two states, Colorado and Minnesota, have developed a PC BAMS integrated version. Both have PC database programs that can link into BAMS and transfer data in and out of BAMS. A brief description of each is provided below.

- Colorado PC BAMS version

CASpc, a dBase III+ project data management software developed in-house, has BAMS tie-in capability. It is a

Figure 3.1 INDOT Hardware Option 1

Figure 3.2 INDOT Hardware Option 2

Figure 3.3 INDOT Hardware Option No. 3

daily recording system with monthly uploading into BAMS CAS module and automated LAS download. It allows bypassing CAS entry. It transfers data in and out of BAMS through communication software. Colorado spent \$100,000 on this development.

- Minnesota DOT (MINDOT) has integrated the BAMS CAS by downloading through a flat file format into a PC database system. All processing is handled at the PC level. The transfer is made by floppy. This system was developed in-house at a cost of about \$100,000.

One possibility is that BAMS integration may be too difficult and expensive, so instead, incorporate BAMS functions into the new system. Several states have done this.

Computerized Specs

One of the system capabilities identified by the committee is to have the specifications in electronic form. This means that the standard specs, supplemental specs, and special provisions will be stored and maintained in electronic form and made accessible to users. Because of the various types of users, the main frame provides the platform for spec storage. However, the user should have at the PC level the ability to manipulate, process and use the specs. An expert system software may need to be utilized for this

capability. With this format many desirable features are possible for specification users. A list of these potential capabilities is summarized and provided below.

- Capability of selecting and sorting spec sections at either the main frame or PC levels.

- Specs shall be indexed to provide a partial or complete listing when specified by date. The effective date of application for each spec section will be a part of the indexing.

- The spec sections should be linked to the bid items at the design stage.

- Spec file shall be linked to the contract file so that the applicable spec for each line item is available.

- Applicable spec sections should be tagged to contract items. This itemized listing should be a part of a master file and be available to any user.

- Supplemental specs and special provisions can be added at any time but should be dated with effective date.

- Supplemental specs should be formatted in a manner so

that the user will be made aware of the changes to it.

- User inquiry capabilities should be so that various ways of sorting and retrieving is available (e.g. material type, payment basis, construction procedures, etc.).

- Once a contract is awarded, no change can be made to the original line items and specs except through special authorization. All changes should be by Extra Work Agreement procedures and line item number with assigned appropriate spec sections.

FHWA Guidelines

Since this system will be used on projects that fall under the jurisdiction of the FHWA, certain established FHWA guidelines will need compliance. These guidelines are summarized below.

- Provide for adequate backup and recovery of records to protect against information loss. Protection procedures should be in place to prevent both human and system failures.

- Prevent unauthorized alteration or erasure of electronic records.

- DOT requirement of validating equipment reliability when records are created.
- Accurate audit trail must be present.
- Adequate data storage backup in place.

User Ease

Another important feature is the "user friendliness" of the system. This can be enhanced with the following:

- Screen menus
 - Pull down capability
 - Menu bypass capability
- Help screens
- Input error checking and correction capabilities
- User security controls, for limiting access by users.

PC Computing

Computing capability should be available to the user at the PC level. Capabilities provided would give the user local computing capability and allow for user developed personalized applications. At a minimum, the following software should be available: spreadsheet capability (lotus), database manager (paradox), electronic mail, word processing, and volumetric

calculation capability for earthwork and concrete calculations.

Miscellaneous Features

The features mentioned in this section are applications of some of the latest technologies in data management. These features could be a part of the initial system or phased in so that ultimately a "paperless" system could exist. A short description of each is provided.

Portable data collectors

Utilizing hand held data collectors in the field would automate the data collection process. The portable device can be used in the field to record testing, inspection, or delivery information. Once stored on the device, the data can be uploaded into a PC for processing. Arkansas is planning on using such a device that costs \$300.

Asphalt/Concrete plant tie-in

Batch plant data such as batch numbers and weights can be recorded and transmitted electronically, eliminating most of the time and labor required in the manual process.

RF tags to record quantity installed

Radio Frequency (RF) systems can be utilized to track and record hauled construction quantities. Hauling units are affixed with tags that store hauled weight and number of trips. This information is inscribed on the tag by passing the unit over a scale and RF scanner that writes it on the tag. The hauling unit essentially has a portable database attached to it from which data can be retracted and uploaded into the data management system. This would eliminate the need for an inspector to count and measure quantities.

Bar code usage

INDOT forms that have reoccurring fields of data that are keyed into the computer could probably benefit from using bar codes. Bar coded labels could be attached to testing samples and used to identify and track them through the testing process. Also, bar coded menu tablets can be utilized to quickly enter data into the computer. For example, the material code lookup program could be expedited by using bar codes for entering search parameters. Using bar codes can significantly improve data entry speed and at the same time reduce data entry error. The only equipment required would be a reader or scanner and software that can print the bar codes on the documents.

Lab equipment RS232 interface

Lab and testing equipment can be equipped with RS232 ports so that data can be captured electronically into a computer system. This would eliminate manually recording the information and keying it into a computer.

Laboratory Information Management System (LIMS)

LIMS is a commercially available software package developed for laboratory automation support. These packages can operate in a mini or PC environment.

Graphics Interfaced Transportation Information System(GITIS) Interface

The data captured by this system can become a part of GITIS by developing an interface. This should become a component of the design.

Electronic signature control

Signature authorization is required to process many of the INDOT forms, especially for contractor progress payments. Technologies are available that provide this capability electronically. One is the use of a plastic magnetic stripe card

that is scanned when authorization is required. Another, which is new, is by utilizing touch screen technology signatures can be recorded onto electronic documents.

Document scanner

Utilizing document scanners could be one way to quickly enter paper documents into electronic form. Certain forms and processes may lend themselves to this technology.

Material computer code lookup program

One of the features identified and requested in the field is the ability to retrieve material codes electronically. Currently to locate the correct code involves a lot of searching through manuals. Performing this task on the computer would be a big time saver. A bar coded menu tablet could be utilized.

Electronic clipboard capability

This is another new technology tool and is really in its infant stage. With this device, field personnel can use it to record information electronically much like they would with a clipboard and paper. An ideal application is drawing sketches that are used in the final construction report as backup on material quantity locations.

Initial Capabilities

All of these capabilities or features listed above can be components in the system but it may too complex and unnecessary initially. The system is conducive for a staged development and implementation so that these can gradually be added. But to have a productive, useful system, certain features are necessary. These are the automation of construction records and material and test data, a basic computerized spec capability, and establishing a BAMS tie-in to the field level PC.

Future Capabilities

Following the initial stage, these other technologies can be utilized to enhance and further automate the process. Further capabilities such as an Executive Reporting System and a complete computerized spec capability can be brought on-line. Also a tie-in to the Roadway Management System should be established. One possible future module is to use the system for capturing constructability data and transferring it to design for incorporating into future projects.

Chapter 4

System Costs

System cost will depend upon several factors. These are costs for software development, hardware, software, communication, system and hardware maintenance, information services staff support, and training. Each cost factor will be analyzed.

Software Development

Developing the software could be the largest initial cost. Basically three options exist with some variations possible for each one. These three are:

1. Consultant
2. In-house developed
3. Hybrid - In-house + consultant

Each option has its pluses and minuses, so the one chosen will depend upon several factors. Descriptive specifications for each option would need developing to ensure system capabilities. One constraint that will affect development is that information services is deficient in personnel and overloaded with projects;

and because of prioritization of data processing projects development start-up could be delayed. Whichever option is chosen the developer must look toward future hardware developments and software capabilities.

An outside consultant may provide expertise and experience that potentially could produce a better product. Consultants usually have the manpower to devote to a project so that development time could be shorter. On the flip side, costs will be higher. For example, Connecticut paid Andersen Consulting of Hartford \$8 million. Andersen was contacted to get a preliminary cost for converting CONDOT's system to INDOT's IBM platform and the figure was \$3.3 million with a required development time of 13 months. If this option is chosen, then INDOT information services would need to be involved to supervise the development.

Using in-house personnel to develop a system would be less expensive but other factors must be considered. The availability of information services personnel to work on a project of this magnitude may be limited. This may cause a longer time period for development. Experience in this type of system development may be less than the consultants. But long term support for the system may be better than a consultant because of INDOT's thorough knowledge on the system.

The third possibility is to have a mixture of in-house and

outside consultant to supplement the development effort. The consultant could provide additional expertise and experience while INDOT personnel would have more control over the final system makeup. This combination may also reduce costs.

Hardware

The key hardware component in the system will be the PC work station. Equipment included in the work station will be:

PC-AT (minimum), A 386 machine may be needed by the time the system is ready for implementation.

Monitor

Printer

Modem

At today's prices this setup could be obtained for around \$3000. Therefore for a 300 project hypothetical case the hardware cost will be:

$$300 \times \$3000 = \$900,000$$

With a bulk purchase this cost could be less.

Currently INDOT is in the process of upgrading their main frame capability. The proposed system will bring additional demands to it. The committee is recommending hardware option 3.

In option 3 the PC communicates with the mini system at the district so there should be no need for increased communications capabilities. All of the PC communications is performed through the mini system at the district level. Estimated additional data storage requirement on the main frame will be approximately 500 megabytes a year. This type of data should reside on the main frame for a couple years before it is dumped onto some permanent storage media. So, for this time period an additional 1 to 1.5 gigabytes of main frame storage may be needed by the system.

Hardware configuration option 3 utilizes hardware at the district level for storing, processing, receiving, and sending data. The committee determined that potentially a hundred remote users could be accessing the system but initially it would be around fifty. In order to define hardware, these requirements were communicated to IBM representatives. IBM reps stated that a mini system would have the capability and more specifically the AS 400 C20 system. Not only can this hardware support external users via phone lines but it can locally support around fifty(50) network users. Cost for this system is approximately \$55,000 which includes a state discount. Included in this price is the hardware, software, and communication capability for the off-site users and to the main frame at the central office. This system will be utilized in each of the six districts, so total estimated cost for this aspect of option 3 is:

$$\$55,000 \times 6 = \$330,000$$

Software

If the software chosen for development is not within INDOT's inventory then costs will be incurred for this. Software will be needed at the PC for the system and localized computing capability and at the mini for database management and communication. No software will be needed for the main frame.

PC software costs will depend on what software is to be utilized. Software that could be used for local computing includes: spreadsheet, database, electronic mail, word processing, and miscellaneous engineering calculation capabilities. Software will be required for the construction data system.

In order to have local computing capability on the PC the above mentioned software will be required. Costs for these will depend upon individual vendors and their licensing agreement which may vary significantly. The Connecticut system has this feature so officials there were contacted for cost information. After talking with them and a couple of vendors, it was determined that an accurate cost cannot be determined at this time. The following is just a rough estimate because the cost is affected significantly by the individual vendor agreements and what software is really needed.

Spreadsheet -	\$300
Database -	\$300
Engineering Calcs -	<u>\$ 50</u>
Total =	\$650

Software for the construction data system will either be Paradox or a higher language. INDOT currently has Paradox but it will need a compiler if it doesn't have one. A compiler will cost approximately \$500. It is assumed that INDOT possess a higher level language, so there should be no cost for this.

Word processing and electronic mail capability can be provided by the mini economically. Other software needed at the mini is PC communication and emulation. The cost for these capabilities is approximately \$11,000 per mini station. Included in the mini system hardware cost is the operating system and communications to the main frame.

Hardware option 3 will utilize the main frame as a storage device. INDOT has in-house software for a corporate database on the main frame. So there should be no cost for software on the main frame.

Communication

Transferring data from the field to the district or to the central office main frame will have associated costs. This cost will be dependent on the frequency, duration, and distance of transmission. The options available are: business telephone line with modem, dedicated data line, and the integrated digital services network. A cost analysis of each follows.

Business line with modems

Installation cost(jack) = \$100

Monthly line charge = use in-place line

Toll call rate = depends upon uploading and downloading frequency. If batch, then say \$50/month.

With this setup then the total communication costs per installation is approximately \$50/mo.

If 300 projects is used as a hypothetical number then INDOT's yearly cost (assuming each project runs a year) for maintaining communication links for the system will be :

Installation cost= 300 x \$100/install. = \$30,000

Monthly charges = 300 x \$50/mo. x 12 = \$180,000

Total = \$210,000

The installation charge could probably be eliminated by training INDOT personnel that install the PC to install an extra phone jack if it is needed.

Dedicated data line (24 hour service)

Point-to-point service w/ average distance from
Indy 100 miles:

Installation fee = \$720

Monthly service = \$450

So for a 300 project hypothetical case, the yearly
system communication costs will be:

Installation cost = $300 \times \$720$ = \$216,000

Monthly service = $300 \times \$450 \times 12 = \underline{\$1,620,000}$

Total = \$1,836,000

This cost will probably prohibit an on-line interactive
system like CONDOT's. Therefore, the system design
should utilize a daily or periodic batch transfer of data
with communication costs close to the first option.

Integrated Services Digital Network(ISDN)

Due to the location of the installations around the
state, this option is not available because the network
is only accessible at certain locations.

Miscellaneous

Costs from other sources will happen. To maintain, service and update revisions into the system, information services staff support will be needed. One from that department may be needed on a part time basis. Successfully implementing the system in the field will require a training program. This could involve developing a training manual and conducting training sessions for system users. Securing the hardware at the remote project locations with extra locks, window bars and other precautions will be another cost.

Chapter 5

System Benefits

The adoption of a system will accrue many benefits to INDOT. Most of these are hard to quantify but nevertheless will occur. These are: decisions are based on complete information; the quality of information is consistent; eliminates duplication of effort in recording and saving data; offers a better construction claims recording system; better defined audit trails making it easier to track information; easier forecasting and trend analysis; improved accessibility to test results; increased credibility in data, FHWA tie-in; consultant tie-in; paperwork processing time reduction; supervision cost reduction; and frees PE from paperwork burden.

Also because valuable data will become easily accessible and retrievable the following will be possible:

- More accurate future cost estimates
- Tracking and processing constructability data
- Improved estimated quantities capability
- Improved project duration estimates
- Better tracking of roadway and structure status for construction and maintenance planning
- Contractor performance records

- Ability to tie-in to FHWA database of information

To quantify some cost savings, the committee has identified the following impacted areas and their estimated savings. Savings will occur in: postage; paperwork; form printing and storage; permanent record storage; management inquiries, and quality of the constructed project. The savings calculated here are annual and would be expected from the complete automated system.

Postage: \$60,000

Because information will be transferred electronically, some savings in postage will occur. A survey of various INDOT offices revealed that approximately \$60,000 a year savings could result.

Paperwork processing:

This is divided into cost savings for eliminating positions and time savings costs.

Position elimination - \$239,400

Because the construction and materials & test data will be in electronic form some of the current positions that manage this data in paper form can be eliminated. The

following ones have been identified:

District M&T clerks - (1 per district)	= \$76,050
Central M&T clerk -	= \$15,600
District Construction clerks -	= <u>\$87,750</u>
	\$179,400
Adding fringes \$60,000 -	= <u>\$239,400</u>

Time Savings cost - \$1,742,260

The following \$ savings are due to expected reductions in time for processing paperwork from various personnel.

District M&T clerks =	\$ 79,560
(1 per district @ 30 hr/wk)	
District Testing Engr.=	\$ 6,240
(1 per district @ 1 hr/wk)	
District Const. Final clerk =	\$ 65,520
(1 per district @ 20 hr/wk)	
District Const. Final clerk =	\$ 42,120
(1 per district @ 10 hr/wk)	
Project Engr. & Proj. Sup. =	\$1,540,500
(316 @ 2 hr/day during const.)	
District Const. Engr. =	\$ 6,240
Central Finals =	\$ 2,080
(1 @ 5 hr/wk)	
	<hr/>
	\$1,742,260

The accounting department is currently installing a new computer system which will reduce their personnel requirements. It is felt at this time that no further reductions can or will occur in this department as a result of this new construction system.

Form printing & storage: \$37,000

Currently \$65,000 a year is spent on construction forms and \$7000 on printing them. The \$37,000 is based on eliminating the printing cost and reducing the paper form cost by \$30,000 which is an guesstimate.

Permanent record storage: \$17,000

Permanent construction record is on microfilm now. This would be changed to computer data storage. There would be costs for computer storage so maybe there would be no savings for changing processes. But there would be savings in personnel since it will be done electronically. This is where the \$17,000 comes from.

Management inquiries: \$40,000

This is the cost for retrieving management information

from construction records. Currently this is done manually by utilizing clerks and secretaries to retrieve it. This cost is due to personnel savings for this activity.

Quality: Undetermined

Because construction personnel will have more time to supervise construction, the quality in the constructed project should improve. Quantifying this in terms of \$ savings would be purely subjective.

States that have developed and are using this type of a system have documented some time benefits. In Connecticut a pay estimate would take a PE 1 week at 75% time, now it is performed in 1 to 2 days. Stated earlier in the report was that on an INDOT project about five hours per day is spent on paperwork. Of this five, 3-1/2 was spent by the PE. In comparison a PE in Connecticut spends about 1-2 hours a day on paperwork, a time savings of a couple hours a day when compared with INDOT. In New Jersey, by the manual method, it would take 1.5 hours to produce a daily report, 1.5 hours to produce a weekly report, and four hours to produce a monthly estimate. With the automated system these same reports are produced in 10 minutes, 15 minutes, and 20 minutes respectively. Missouri DOT says their system is saving \$.5 million a year with improved accuracy.

Chapter 6

Recommendations

The goal of this committee was to define an automated system for managing field generated data. A topic of much discussion was how detailed this definition should be. The committee agreed upon a description that would be comprehensive in nature , yet prescriptive in describing features that encompasses a wide range of capabilities, while avoiding establishing strict specifications. So the following recommendations attempt to comply with these definition guidelines.

Hardware Configuration

Hardware option 3 is the one being recommended by the Long Range Data Processing Committee. This option provides the lowest data communication costs and the least dependency on the main frame. It gives the construction personnel more control and accessibility over construction generated data.

Outside Consultant

The committee recommends that if money is available a consultant should be hired. One price received is \$3.3 million for the construction data system within a 13 month period. This is a

very short development time so it would provide a system very quickly. But with the recent state budget "belt tightening", this money may not be available. So for this contingency the committee is proposing the next alternative.

System Development

After studying other DOT systems and talking with Information Services personnel, the committee is recommending a two pronged development. One part is to come up with a short term solution for automating construction field data and secondly developing a mature system incorporating the features described in the report. There are several reasons for doing this.

Based on other state systems, in-house development time for a comprehensive system may take a couple years. The need is now. Currently a construction field system is operational at selected project sites. This is the Paradox construction records program mentioned earlier. The short term solution is to take this system expand it and enhance it to perform the initial features described in the report. The long term solution could evolve from this initial one or after exploring the Paradox capabilities it may be decided to use a higher level language and outside consultant to develop. If this happens the short term system could act as a bridge to the other system by providing support and relief to INDOT field personnel. The short term system could also serve as the

blueprint or scaled down model.

This initial system will start with the existing Paradox construction records program. User ease capabilities such as pull down screen menus, help screens, input error checking, and security controls will be added. Material and test data will be incorporated and either a BAMS tie-in capability developed or some of the appropriate BAMS functions included. A basic computerized specification module will be developed with the full capabilities listed in this report available in the long term system. Data communication links with the District and the INDOT main frame corporate database will be generated so that a complete intact field data system exists. A complete review of system forms will occur as well.

This initial system can be performed and coordinated through an conditionally approved JHRP project at Purdue University. The project would last approximately 18 months and a field system could most likely be implemented sometime within 12 months after approval date. The implementation would occur in one district on new projects to adequately test it. At the same time it will also be available to the other five districts for their use and feedback. INDOT would incur a minimum cost because the development cost is covered in the JHRP project.

To design and test this system some software and maybe a PC at

the district office may need to be purchased. This shouldn't exceed more than \$7,000 (includes cost for a Paradox compiler). Development of the initial system would be supervised by the Long Range Data Processing Committee and be coordinated with the committee involved in the construction records program and the Information Services department. One person from Information services has been working on the construction records program so this individual should be the one to work on this project. An estimated one day a week for the 18 month period should be budgeted for this information services individual.

The long term system solution may evolve from this Paradox based one or it may be that another type of development is necessary. This system would attempt to eliminate the "islands of automation" by bringing systems and hardware together. Computerized specs, an Executive Reporting System, BAMS capabilities and some or all of the miscellaneous features will characterize this system.

Misc.

Other recommendations from the committee are the following. PC hardware should have 386 capability because of trends in software and hardware. A formal training program should be developed for system users. This may involve day long sessions at the district or central office for construction personnel. INDOT

needs to make this investment so the system stands a better chance of being accepted. A system improvement depository should be established for incorporating user suggestions and revising the system. And the Long Range Data Processing Committee should continue to function until the system is field implemented to help insure system capabilities.

Costs and Benefits

To make this system operational statewide would require the costs described beforehand. This is a summary of these costs based on 300 installations.

Startup Costs:

PC work stations =	\$900,000
PC software (300 @ \$650) =	\$195,000
District hardware & software =	\$330,000
Mini software (6 @ \$11,000) =	\$ 66,000
Training costs (estimated) =	\$ 10,000
Extra Security(300 @ \$200) =	<u>\$ 60,000</u>
Total startup cost =	\$1,561,000

Annual Costs:

Communication =	\$210,000
Maintenance (300 @ \$200)=	\$ 60,000
Miscellaneous (supplies, etc.) =	\$ 10,000
Information Services Support =	<u>\$ 8,320</u>
(1 day/week= 8*52*\$20)	
Total annual costs =	\$288,320

The annual quantified savings are now summarized. By no means is this an exhaustive determination. The main ones were investigated.

Postage	= \$ 60,000
Position elimination	= \$239,400
Form printing & storage	= \$ 37,000
Permanent Record storage	= \$ 17,000
Management inquiries	= <u>\$ 40,000</u>
Total annual savings	= \$393,400

The annual cost savings do exceed the estimated annual costs but what about recovering the startup costs(\$1.5 million) and the additional development cost for the complete system? The only known development cost for the complete system was that submitted by the consultant. Using the other option this development cost is unknown at this time. To answer the question you have to place

value on time saved by utilizing this system. The number calculated(\$1,742,260) represents this value. Even though INDOT will not reap this in real money its construction operations and personnel will benefit significantly.

Chapter 7

Conclusions

Development and implementation of the system will require a considerable amount of effort, coordination, and cooperation. But before this system can become reality it has to be perceived by INDOT management as necessary and a priority. Two realities should not be overlooked. One is that with transportation facilities continuing to deteriorate, and heavier use expected, more construction will be needed to keep pace with the demand. Secondly, because of a shrinking work force, less INDOT personnel will be available to manage construction projects. These realities should demand the development and utilization of an Automated Construction Data Management System by INDOT.

REFERENCES

- Agai, E. S. (1988). "Automation is Management." Computing in Civil Engineering: Microcomputers to Supercomputers, Edited by K. M. Will, Proceedings of the Fifth Conference Sponsored by the Technical Council on Computer Practices of ASCE, Alexandria, Virginia, March 29-31 1988, ASCE, New York, NY, 537-541.
- "Application of Small Computers in Construction" (1985). Task Committee on Application of Small Computers in Construction of the Construction Division. Journal of Construction Engineering and Management, 111(3). ASCE, New York, NY, 173-187.
- Choi, K. C., and Ibbs, W. C. (1990). "Costs and Benefits of Computerization in Design and Construction." Journal of Computing in Civil Engineering, 4(1). ASCE, New York, NY, 91-106.
- "Construction Industry Software Inventory" (1988). Constructor, 1988 Computer Primer. Washington, DC.
- Ibbs, W. C. (1986). "Future Directions for Computerized Construction Research." Journal of Construction Engineering, 112(3). ASCE, New York, NY, 326-345.
- Murdick, R. G., and Ross, J. E. (1975). Information Systems for Modern Management. Prentice-Hall, Inc., Englewood Cliffs, NJ.
- Rounds, J. L., and Warning, G. (1987). "Impact of Computerizing Mid-sized Construction Companies.." Journal of Construction Engineering and Management, 113(2). ASCE, New York, NY, 183-190.
- Teicholz, P. (1989). Trends in Technology for Architecture, Engineering and Construction. Director of Center for Integrated Facility Engineering, Stanford University, CA.
- Tenah, K. A. (1984). "Management Information Organization and Routing." Journal of Construction Engineering and Management, 110(1). ASCE, New York, NY, 101-118.

Appendices

Appendix A
INDOT Form Database

FORM	FREQUENCY	1	2	3	4	5	6	7	8
TD 434	WEEKLY	A2	C2						
IT 651	WEEKLY	A2	B2	C2					
IT 665	WEEKLY	A2	B2	C2					
IT 667	WEEKLY	A2	B2	C2					
IT 668	WEEKLY	A2	B2	C2					
TD 453	ONE PER LOT	B2	B1	D1,C2,A1					
TD 497	WEEKLY	B2	C2	B2					
TD 452	ONE PER LOT	B2	C2,B1						
IT 576H	ONE PER LOT	B2	C2,B1						
IT 600	ONE PER LOT	B2	C2,B1						
IT 576H(alt.)	ONE PER LOT	B2	C2,C1						
IT 600(alt.)	ONE PER LOT	B2	C2,C1						
IC 727	AS NEEDED	C1	B2						
IC 94	AS NEEDED	C1	B2						
IC 672	ONCE	C1	B2,D1						
IC 664	AS NEEDED	D4	B1	A1	B1	C1	D4		
CERTIF. LETTER	ONCE	D1	B2,E1						
CON. STAT. LETTER	AS NEEDED	D1	C2	B1					
TEST REPORT	AS NEEDED	D1	C2	B1					
QUAL. SUM. LETTER	AS NEEDED	D1	C2	A2					
CORRESPONDENCE	AS NEEDED	D1	A234						
TD 350	VARIES	B2	C2,B1						
TD 409	VARIES	B2	C2,B1						
TD 455	VARIES	B2	C2,B1						
IT 576	VARIES	B2	C2,B1						
IT 600	VARIES	B2	C2,B1						
IT 625	VARIES	B2	C2,B1						
IT 652	VARIES	B2	C2,B1						
IT 620	VARIES	B2	C2,B1						
TD 392	VARIES	B2	C2,B1						
TD 441	VARIES	B2	C2,B1	B1					
TD 441(alt.)	VARIES	B2	C2	C3,D1,B3,B1					
IT 607	VARIES	B2	C2						
YELLOW CARD	VARIES	B2	A2	B1					
TD 393	ANNUALLY	B2	C2,A2,B1						
TD 444	ANNUALLY	B2	C2,A2,B1						
TD 523	ANNUALLY	B2	C2,A2,B1						
IC 689	AS NEEDED	B1							
IC 599	AS NEEDED	B1							
IC 690	AS NEEDED	B1							
IC 739	AS NEEDED	B1							
IC 655	AS NEEDED	B1							
IC 656	AS NEEDED	B1							
IC 401	AS NEEDED	B1							
IC 612B	AS NEEDED	B1							
IC 699	AS NEEDED	B1							
IC 627	AS NEEDED	B1							
IC 654	AS NEEDED	B1							
IC 632	AS NEEDED	B1							

F	FREQUENCY	1	2	3	4	5	6	7	8
IC 607	AS NEEDED	B1							
IC 614	AS NEEDED	B1							
TD 256	AS NEEDED	C2	A1,A2	C2	B1,B2,C1,D1				
TD 427	AS NEEDED	C2	B1,D1						
LAB TEST RES	AS NEEDED	C2	B1						
IC 124	WEEKLY	B1	C1	D2					
IC 636A	ONCE	B1	C1	D2					
IC 686	ONCE	B1	C1	D2					
M 232	AS NEEDED	B1	C1	D2					
M 232A	AS NEEDED	B1	C1	D2					
CR 2	AS NEEDED	B1	C1	D2					
5395	ONCE	B1	C1	D2					
23331R	AS NEEDED	B1	C1	D2					
IC 103	DAILY	B1	C1	D2					
IC 100	BIWEEKLY	B1	C1	D4					
IC 733	TWICE	B1	C1	D2	D3				
IC 626(LO \$)	AS NEEDED	B1	A1	B1	C1	B1			
IC 626(HI \$)	AS NEEDED	B1	A1	B1	C1	D2	C1,B1		
IC 626(LO FED\$)	AS NEEDED	B1	A1	B1	C1	E1	C1	B1	
IC 626(HI FED\$)	AS NEEDED	B1	A1	B1	C1	D2	E1	D2	B1,C1
IC 683	AS NEEDED	B1	C1						
IC 686	AS NEEDED	B1	C1						
IC 625	AS NEEDED	B1	C1						
I 1A	AS NEEDED	B1	C1						
IC 102	AS NEEDED	B1	C1						
IC 126	AS NEEDED	B1	C1						
IC 149	AS NEEDED	B1	C1						
IC 225	AS NEEDED	B1	C1						
IC 226	AS NEEDED	B1	C1						
IC 604	AS NEEDED	B1	C1						
IC 647	AS NEEDED	B1	C1						
IC 662	AS NEEDED	B1	C1						
IC 642	ONCE	B1	C2	D1					
IT 625	AS NEEDED	B1	C2	D1					
TD 250	AS NEEDED	B1	C2	D1					
TD 3200	AS NEEDED	B1	C2	D1					
TD 402	AS NEEDED	B1	C2	D1					
TD 424	AS NEEDED	B1	C2	D1					
TD 433	AS NEEDED	B1	C2	D1					
IT 530	AS NEEDED	B1	C2	D1					
IT 571A	AS NEEDED	B1	C2	D1					
TD 426	AS NEEDED	B1	C2	D1					
IT 652	AS NEEDED	B1	C2						
IT 530	AS NEEDED	B1	C2						
IT 628	AS NEEDED	B1	C2						
IC 117	MONTHLY	B1	C1	D2,E1					
IC 639	AS NEEDED	B1	C1	D2,E1					
IC 644	AS NEEDED	B1	C1	C4					
IC 644	AS NEEDED	B1	C1	C4					
IC 648	WEEKLY	B1	D1	C1					
PR 47	ONCE	B1	D1	C1	D2				
PR 3191	MONTHLY	B1	D1	C1	D2	E1			

FL	FREQUENCY	1	2	3	4	5	6	7	8
IT 611	MONTHLY	A1	B1	C2	D1				
TD 366	AS NEEDED	A1,A2	C2	B1,B2					
TD 451(VIRGIN)	AS NEEDED	A1,A2	C2	A1,A2,D1,B1					
TD 451(RECYCLE)	AS NEEDED	A1,A2	D1	A1,A2,C2,B1					

Coding under numbers indicates path of form or piece of paperwork. Commas between locations indicate that this goes to each location from the previous location.

Key:

A1: Contractors
 A2: Producers
 A3: Manufacturing
 A4: Suppliers
 B1: Project Office
 B2: Field Testing
 C1: District Construction, Maintenance, or Traffic
 C2: District Testing
 C3: District Development
 C4: Subdistrict
 D1: Central Office Testing
 D2: Central Office Operations Support
 D3: Central Office Design
 D4: Administration
 E1: Federal Highway Administration Construction

FORM	TITLE	Frequency
434	Notification of Shipments of Pretested Stock	?
651	Bin Analysis and Mix Comparison Record	Asphalt
651-A	Aggregate Blending	Asphalt
665	Bin Proportions and Batch Weights (Batch Type)	Asphalt
667	Drum Mix Plant Calibration	Asphalt
668	Request for use of Blended Agg for Bitum Mixt	?
455	Bituminous Mix Analysis for Quality Assurance	Freq QA
491	Weekly Liquid Asphalt Sample Log	Weekly
452	Random Sampling for Mix Analysis	Freq QA
678H	Aggregate Inspectors Test Report	Frequent
600	Bituminous Mix Analysis	Frequent
678H(alt.)	?	?
600(A)	Record of Bituminous Inspection in ___ District	?
24	Construction Record Status Report	Frequent
672	Wile Acceptance Agreement	Rarely
664	Payment of Portion of Retainage Percentage	Once/Contr
CERT 1 - LETTER	?	?
CON. ST. - LETTER	?	?
TEST REPORT	?	?
QUAL. SUM. LETTER	?	?
CORRESPONDENCE	?	?
250	Daily Summary of Moisture Determination Tests	Const
321 d	Daily Summary of In-Place Density Tests 1-6 41	Const
409	Nuclear Moisture-Density Test Summary for Soils	Const
465	Nuclear Density Tests for Quality Assurance Specs	Const
576C	Aggregate Inspectors Test Log at ___ Plant	Const
610	--- Listed Twice ---	?
625	Daily Summary of Soil In-Place Density Tests	Const
626	Field, Slump, and Air Content Report	Const
628	Water/Cement Ratio Report	Const
322	Insp Rpt of Metal Cul, Underruns, End Sect ect.	Request
417	Field Report on Concrete or Bituminous Cores	Being Replc
44(alt.)	?	?
601	Inspector's Report of Cond or Clay Pipe or Tile	Request
YELLOW CARD	?	Temporary
323	Certification of Concrete Plants	Annual
444	Report of Inspection (Bituminous Mixing Plant)	Annual
520	Insp of Scales and Meters for Batch and Drum Plant	Annual
639	Frequency of Test Record for Concrete Tests	Seldom
639	Materials Weigh Tickets	?
630	Frequency of Test Record for Compaction Tests	Seldom
633	Concrete Plant Inspector's Daily Check List	Frequent
635	Project Encls Record for Transmittal of Payrolls	Frequent
636	Letter to Rural Route Mail Patrons	Seldom
401	Construction Record (Stations Out/Fill)	Frequent
612B	Construction Record (Pipe and Cond Structures)	?
639	Check List for Construction Record	?
603	Const Record to Accompany Final Estimate (PE)	1/contract
627	?	?
654	Record of Construction	1/contract
632	Completion Date & Liquidated Damages Data	1/contract
607	?	?
614	?	Frequent
255 A/D	Job-Mix Formulae for Asphalt Mixtures	Being Replc
427	Letter of Cert by District Materials & Tests Engr	Final/Once
LAB TEST RES	?	?
124	Weekly Report of Contract Working Days	1/week
636A	?	Seldom
686	Release From Signing Responsibility	1/Contract
M 232	Preliminary Report of Overhead Structure	?
M 232A	Bridge Measurement Report	?
CR 2	Report on Contractor's Performance of Contract	1/Contract
5395	Consultant Evaluation Form	?
23331R	Pavement Marking Record	?
103	Daily Report on Construction Contracts	Daily
100	Salaried Employee's Service Report	Frequent
733	Eval of Plans, Progr Const Record, Final Const Rec	2/Contract
626(LO \$)	Change Order	Frequent
626(HI \$)	?	?
626(LO FED\$)	?	?
626(HI FED\$)	?	?

IC 683	Weighmen's Daily Report	Frequent
IC 689	Daily Utility Inspection Record	Freq/Util
IC 625	Salvaged Construction Material Record	Frequent
IC 640A	Aggregate or Bituminous Mix	Freq/Bitum
IC 102	Requisition for Supplies	?
IC 126	Final Description and Elevation of Bench Marks	Seldom
IC 149	Property Release	Seldom
IC 226	Pile Driving Records	Freq/Bridge
IC 228	Pile Orders	Freq/Bridge
IC 604	Grade Sheets	Frequent
IC 647	Moisture Determination for Mulching Material	Frequent
IC 562	Report of Crop Damage	Rarely
IC 611	Const Record: Compar of Est - Original and Final	1. Contract
IT 625	? -- Listed Twice --	
TD 251	? -- Listed Twice --	
TD 320	? -- Listed Twice --	
TD 402	Tabulation of Field Settlement Observations	?
TD 421	Tabulation of Field Piezometer Observations	?
TD 439	Settlement Stakes	Seldom
IT 537	Sample of Material	Frequent
IT 571a	Flexural Strength Report	?
TD 426	Sketch of a Typical Piezometer Installation	?
IT 553	? -- Listed Twice --	
IT 582	? -- Listed Twice --	
IT 625	? -- Listed Twice --	
IC 117	Monthly Progress Report	1. Month
IC 609	Recommendation for Acceptance	1. Contr
IC 642	Notice of Opening Pavement for Traffic	Once/Perm
IC 645	Notice of Closing Road to Traffic	Rarely
WE 343	Contractor's Weekly Payroll Affidavit	Weekly
PP 47	Statement of Material Used Involving Federal Funds	Rarely
PR 139	Federal-Aid Highway Constr Contractors EEO Report	Frequent
IT 611	Material Record	Many Month
TD 580	Proposed Source of Mtls for Bituminous Mixtures	Several
IS 451 (VIRGIN)	Composition of Mixtures for Qual Assurance Specs	Several
TD 451 (RECYCLE)		

Appendix B
State Survey Form

PURDUE UNIVERSITY

SCHOOL OF CIVIL
ENGINEERING

May 17, 1990

Dear Sir:

Currently I am performing a study for the Indiana Department of Highways to develop and design an Automated Construction Data Management System which would also include material data testing. Ultimately, the system will emulate a "paperless" environment for recording, processing, and tracking data. Such a system will assist the construction engineer by freeing him/her from the paperwork shuffle allowing more time to be devoted to the construction process.

I am conducting a survey of state highway or transportation departments to determine if a system is in existence or is being considered for development.

Indicate on the enclosed form if your department has, or has not done work, or has knowledge on this type of system. Please return the form to me by June 1. Your response is very much appreciated.

Sincerely,

Bob McCullouch, Ph.D.
Assistant Professor

BM/no

Enclosure

Automated Construction Data Management System
Survey Form

State: _____

☐

YES, such a system has been or is
being considered for development.

Contact:

Name: _____

Address: _____

Phone: _____

☐

NO, A system of this type does not
exist or is not being
considered for development.

Return to:

Bob McCullouch
Department of Civil Engineering
Civil Engineering Building
Purdue University
West Lafayette, IN 47907

Phone: 317-494-0643

State: _____

Contact:

Phone number:

Phone Survey Information

1. Find out what stage the system is at:

Conceptual
Design
Test
Operational

2. Ask for a description of the system and an explanation on how it was developed and works.

- Data tracked
- Data paths
- Hardware used
- Software

Appendix C
State Survey Results

June 13, 1990

Alaska PRM(Project Records Management). Used for producing monthly estimates. Also have an automated weigh system(RF vehicle tag for recording weights). Weigh station at borrow pits.

Arizona System conceptually designed but not operational because of budget constraints. LIMS - Lab information Management System. Off the shelf software. Capabilities described in the Illinois report on page I-8. Most of these systems are stand alone and mini based. Features include: portable data collector(storing field generated data); bar codes for contract number, contractor name, material type, other standard info.; instrument interface(RS232 capability). Function summary and data flow chart should be created in this study. Need committee help in this area. Arizona consolidated forms, INDOT should consider doing it. Page III-1 describes the system capabilities, good summary! Communication system is explained in report. Leased telephone line cost versus Integrated Services Digital Network(ISDN). Staff support is essential for system development and maintenance.

Arkansas Computerized estimating system. Operational for two years. PC based with no main frame tie-in. Copied Arizona's system. Currently developing a material & test program. Have a spreadsheet program for load tickets. Plan to use a PSION organizer (32K) (\$300) portable data collector by inspectors for recording delivery data. Offered certain engineering programs.

California Contract Administration System(CAS). It is a progress payment system, main frame. Materials & Tests is considering developing a system. Considering developing a PC based construction system.

Colorado Heavy BAMS user. Does not like the CAS module. Has developed a CAS-PC version for

downloading and uploading into the LAS module. Recommends pooling with other states to develop an automated field system.

Connecticut

System operational since 1987. Costs estimated at \$8 to \$9 million for hardware and software, based on a \$7.5 billion construction program. Their CMR (Construction Management Recordkeeping) system was developed by the consultant Anderson of Hartford, CN. Tracks basically everything with most information coming from the inspector's daily report. Field PC's with terminal emulation inputs data to a UNISYS main frame. The custom design was written in COBOL. Still use a lot of hard copies since certain departments are not tied into the system. Materials and testing was previously available and is accessed through interface with the main frame. Currently developing an Executive reporting system. Initially looked at BAMS but did not like the system.

Florida

Will call back.

Illinois

Conceptual stage. Sent copy of study team final report. Four (1 engr. & 3 DP) man team currently defining what to automate, started in April. Data to be processed and tracked includes: daily reports, automate engineering paperwork. System will include an engineering calculation program (lotus 123), word processing, and electronic bulletin board. Software used: dataease(PC), lotus 123, communications software. Do not plan on transferring into main frame. Materials & tests have an automated system which will not be tied into. Looked at Kentucky's system.

Iowa

Currently in the conceptual (brainstorming) stages of a system. Waiting for the CAS module of BAMS but will probably go to a customized system. Desire to ultimately document all contract pay items on a daily basis with totally automated progress payments. Would later include materials. Mentioned that Wisconsin has an automated pay system but no material system and Michigan has in-depth material approval computerized but still uses a hand payment system. Iowa

would like to combine these systems.

Kansas

System is in the developmental stage. A consultant is on board, Arthur Anderson and IBM, with in-house personnel overseeing. This phase will establish the specification for the Construction Management System with the system being developed over a period of 2 years. Data will include contract administration data of all types including pay quantities, change orders, testing and materials, etc. Intent is to have field input data electronically transferred to the central office main frame. Currently have a few Zenith 268's available and would like to stay with them. Hope to have a customized system. Have looked at BAMS and are somewhat leery of it (do not really want it). Have looked at Colorado's Infotec system and do not like it at all. Have also consulted with Ohio on their plans.

Kentucky

Operational system. PC stand alone system, dBase III+ compiled programs. Contractor's bid disk downloads data in. Data tracked: daily item quantity records, working days, change orders. Produces contractor pay estimate. Tracks quantities and \$. Material & test data is on a separate system. Main frame processes the pay estimates, so a dual system exists and some of the same data is rekeyed.

Louisiana

Pavement management system.

Maine

Do not really have a system. Field engineers have stand alone PC's for their use with Lotus 1-2-3 and dBase III software. Reports are formatted and shared with other field engineers. Maine does use BAMS as their bidding system. A consultant has been hired to automate their lab testing and will utilize UNIX mini computers.

Maryland

System has been operational for 2 to 3 years. While operational, the system is constantly changing and improving with a consultant on board. Used on most major projects, approximately 70-80 at the present time. Data tracked includes, pay quantities, workmen and equipment with the primary document being the Inspector's Daily Report.

Hard copy reports are then sent to the home office for processing of monthly payments. PC's are used in the field with no common data base. Software program is dBase III designed by GAI Consultants, Pittsburgh, PA. Program does not include materials and testing nor does one exist -- a common complaint by the field personnel.

Michigan

Operational system. PC stand alone system. dBase III + software and AT&T 386 equipment? Processes project records for quantities, pay estimate, tested materials verification. No tie-in to main frame, so data is not transferred. Currently used in 54 field offices.

Minnesota

Operational system went full scale July '89. Includes 300 state projects at \$500-\$600 million. Costs for the in-house programming are "roughly" estimated at \$100,000. Minnesota's CARS (Contract Administration Record System) primary purpose is for contractor payment. Contract information is downloaded from the BAMS system and goes to the district or project office where estimated quantities and work items are tracked. Through the individual pay items a document is computer generated and signed by both the contractor and engineer and sent to the central office to make payment. Over 100 PC systems are in use. The software is a Metafile developed program (which may be too small) expected to be upgraded in the future. In-house design took approximately 12 months to write and minor changes have been made. Next step is to computerize the common construction report forms. Analysts are also currently looking at materials and tests.

Mississippi

No answer.

Missouri

Operational system just implemented this month. Approximately 18 months to develop by on board personnel. Expect system is saving \$0.5 million per year with accuracy being dramatically improved. System is still in the beginning stages. Primary data includes daily reports, pay items, change orders and weekly reports. Project engineer fills out

the report and sends it to the regional office computer clerk who inputs the information into the PC data bank. The floppy disk then goes to the Resident Area and a bi-weekly payment estimate is prepared. Attempting to get modems to electronically transfer to pay offices. The custom system is written in dBase III. Missouri looked at the BAMS construction module, however, it did not include everything they desired and would have had to have been tailored. Their system is designed around Connecticut's system.

Nevada

Conceptual stage.

New Hampshire

System is in the developmental stage, anticipating 3 years to totally implement. Currently 8 months into the development and having difficulty obtaining dedicated time from the computer personnel. Data tracked includes record keeping data with screens and prompts similar to the currently used record books. PC's in the field transfer information to the home office main frame by use of a modem. In-house design is written in 'C' language. Tried Lotus 1-2-3 and dBase III with no good results. Working towards a fully automated system with full tie-in with central office main frame and available CAD system. Materials and testing is not currently implemented but will be included upon completion of record keeping system. Stated Connecticut has the best system, being able to allocate \$7.5 million to have a consultant design and develop the completed system.

New Jersey

ACES(Automated Construction Estimate System). dBase III+ compiled programs for producing monthly estimates. Daily reports and inspector's report entered into PC at field office. Equipment: PC 286 or better w/ 2 bernoulli boxes(20MB). Self contained system used only at the project site.

North Carolina

Conceptual stage. Would like const. diaries, daily reports, field reports entered into an automated system. PC based linked to main frame w/ customized software. Consulting firm - GAI Consulting, Monroesville, PA.

North Dakota

System operational for approximately 5 years. Took one year to work out the bugs and have made yearly changes to enhance the system. North Dakota's program and sample disks are sold to the state's consultants. Primarily a record keeping process which includes progress reports, progressive payment estimate and goes through the contractor payment. Field engineers input project data which is stored on a floppy disk. Payment estimates are sent in for processing. A total of 32 PC's are in the field with 640 K memory and 10 MB hard drives. Program is an in-house custom design in dBase III. Materials and tests are not part of this system and have their own stand alone system. They appear to have several systems in operation which do not interface each other. Currently they are looking for an earthwork package to compute dirt quantities, etc.

Ohio

Currently at the survey stage. Hired McDonnell Douglas. Studying forms in order to eliminate some from the paper trail. New system will not be restricted to complying with existing formats. System features: daily dairy, inspectors report, testing data, maintenance operation. Lap top PC utilization. Penn has a similar system. Conn spent about \$7 million to develop such a system. System cost is \$440,000 for this phase. Phase II is software development. Goal is to have an operational system by Oct. 91.

Oklahoma

No phone number given.

Oregon

Currently have several databases used by field project managers. Those databases are: Aggregate sources data base- contains historical data of qualifying tests as well as ongoing contract testing; automated contracts payment system - partially automates the monthly progress payments to the contractor; MBE/DBE certified minority list; Qualified Products list; Certified Technician list. Systems currently being developed are for electronic forms and a pavement management system. In the future these databases will be tied together to create a Automated Construction/ Maintenance Management system.

Pennsylvania	Documentation system. Field inspector's daily report inputted. dBase III+ system with a PC in the field office. Password coded. Currently working on developing networking data transfer. Currently using modems to transfer to district office. A M&T system is currently being developed. The M&T system will not have a main frame tie-in and should be operational by mid 91. A consultant developed both systems.
South Carolina	Construction system tie-in to BAMS. Features to be incorporated are inspector diary, lab reports, & material reports.
South Dakota	Conceptual stage. Formed a task force that will visit other states to obtain ideas(ND,NEB,WI). Materials & Test data, pay estimates, & construction record keeping will comprise the system. In-house developed.
Texas	An operational system since 1973, upgraded in 1981. Primarily for contractor payment with some material management. PC's are used in the field and a main frame in the central office. The two are not linked together. Stated the AASHTO subcommittee is sending out a questionnaire concerning automated systems. Kansas and Ohio are collaborating as a forerunner to the improvement of the BAMS system. They are spending approximately \$1.5 million and are looking for other states to include. Texas is a big advocate for automation.
Vermont	System operational for 3 years. Estimate good implementation at approximately 50%. Main challenge is in training the personnel. The system is primarily a field bookkeeping system including quantities paid, bi-weekly quantities and daily reports. Information is input by computer in the field and computer generated reports (paper) are mailed to the home office for processing. Hardware is strictly PC's. The bookkeeping software is a custom, in-house developed Basic system. Materials section has a separate system.

Stated Connecticut has the best system in the Northeast.

West Virginia

No answer.

Washington

Have several separate systems in different stages. The CAPS (Contract Administration Payment System) is in its 3rd version with the latest version running for over 2 years. System is strictly an automated payment system with field input made into an automated ledger with the payment automatically generated and sent to the contractor. The CCIS (Construction Contract Information System) is a main frame/micro computer system. Initial training was completed this week with testing to be done in 4 or 5 field offices through the summer. Field data such as time, change orders, subcontractors, etc. is input in the field and sent electronically to the home office. Currently in the process of developing a materials and tests program (LIMS) to make a paperless lab - consultant is designing. CAPS uses a Normal data base and is an in-house design by MIS personnel. CCIS and LIMS uses a SMART II data base and is developed by consultants with assistance by MIS personnel due to the main frame.

Wisconsin

Three year old operational system. Enter daily work items and monthly estimate produced. Item record account. Equipment: 386 PC, 386 zenith laptop, modem(used for hookup to main frame). Electronic transfer info to central office. Provides display write word processing and Lotus 123 support. Software used: Advanced revelation database software a relational system. Cost is \$500 for the development copy and \$100 for the runtime copy. Communications software is FTterm2. Have virtually no communication problems. Signature approval for payment released is provided by paper. 140 PE are using the system.