Innovative Technology for Computer-Automated Bridge Inspection Process

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A procedure is presented for automated data collection and reporting of bridge deficiencies. The procedure was developed under the sponsorship of the Florida Department of Transportation (FDOT). A computer program for field data collection based on FDOT's Condensed Inspection Report (CIR) was designed for a handheld computer. The program is used to input condition ratings and generate or edit comments for each bridge element on the CIR. A text-file record of the inspection is stored in the handheld computer for subsequent uploading to an office-based personal computer (PC) system. Visual information on bridge defects can be recorded with a camcorder or 35-mm camera, or by sketch. The images are digitized and stored on computer disk with an automated system developed for the PC. The PC system uses the JetForm form program to place the images and text-file inspection record onto the cover, CIR, Comprehensive Report of Deficiencies, and Image Log forms. The complete bridge inspection reports are saved to computer disks for archiving and for printing final copies on a laser printer. This automated procedure was tested in a FDOT bridge inspection district. Field inspection time was comparable with the conventional method; office time required for completion of reports was significantly reduced.

This study presents the design of a computer-automated bridge inspection system for the Florida Department of Transportation (FDOT). The purpose of the system is to increase field inspection organization and accuracy and to speed office-based report preparation. The field system uses a handheld computer, a video camera, and computer programs to aid the collection of bridge data. The office system combines a personal computer (PC), imaging equipment, and computer programs to assist report preparation and archiving.

In order to accomplish these tasks, the study includes procedures and equipment for automating bridge inspection data collection and reporting, development of data collection and reporting software, a test of the system in a FDOT bridge inspection district, and an evaluation of the inspection procedures.

INSPECTION PROCEDURES

The proposed bridge inspection system for FDOT has two distinct parts: a field system and an office system. The field system has three tasks: to record numerical ratings of the condition of bridge components, provide an efficient method of entering narrative descriptions of bridge component defects, and visually document serious bridge component defects. The office system has four tasks: to place the bridge component condition ratings onto FDOT's Condensed Inspection Report (CIR), produce FDOT's Comprehensive Report of Deficiencies Section B narrative report describing bridge component defects, store and print photo logs of bridge component defects, and automatically integrate these sections into a bridge inspection report that can be easily archived on computer disk and printed.

The computer-automated bridge inspection system uses a portable computer programmed to be compatible with FDOT's bridge inspection reporting procedures. Past bridge inspection reports are uploaded to the portable computer from a desktop PC used to store bridge inspection data. Narrative descriptions of existing defects are edited by the inspectors. New descriptions of defects are keyed into the portable computer using a set of shorthand codes of commonly used descriptive words. Videotapes, photographs, or sketches are made of serious deficiencies and noted in the portable computer inspection program.

After all deficiencies have been documented, the inspectors enter ratings of each bridge element's condition. Descriptions of the condition of each element are displayed to the inspector before he or she enters a rating. When all ratings have been entered, the program assembles the data into files that can be transferred back to the PC at the inspection office.

On returning to the office, the inspectors download the new inspection data to the PC. A form-generation program assembles the data into a cover page, CIR, and Comprehensive Report of Deficiencies and prints these sections at the request of the inspectors. Digitizing programs request the video images, photographs, and sketches made during the inspection and convert them to formats that can be stored on the computer. Image logs containing descriptions of each defect visually documented on a bridge can then be printed at the inspectors' request.

Field work is accomplished by two-person teams. One inspector handles the portable computer while the other handles the video and photographic equipment. Tool belts and carrying cases were designed to make carrying and using the equipment easier. Small two-way radios provide communication for the inspectors if they are separated.

FIELD EQUIPMENT

Paravant RHC-44 Handheld Computer

FDOT specified that all field equipment be as lightweight and durable as possible. The Paravant RHC-44 is a lightweight

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handheld computer that uses removable battery-backed random access memory (RAM) cards that perform the same function as floppy disks in PCs. It is MS-DOS compatible and can be programmed in BASIC, C, FORTRAN, Ada, and Pascal.

Sony CCD-TR5 Handycam 8-mm Camcorder

FDOT required that the camcorder chosen for the study be durable, provide clear pictures, be as small as possible, enable mounting of lights, and be usable underwater. No one camcorder meets all of these requirements, but the Sony CCD-TR5 camcorder meets most of them.

Voice Actuated Audionic FM Transceiver

The Radio Shack Voice Actuated Audionic FM Transceiver was chosen as the communication device for this study because of its small size, economical price, and innovative design. The system has a single earpiece that functions as both a receiver and a microphone.

Tool Belts

The portable field equipment just described can be carried easily with properly designed carrying cases and used on bridges. J.A.C. Custom Pouches of Marcellus, Michigan, used high-strength, weatherproof Cordura and polypropylene to custom make tool belts and carrying cases for the field equipment. Two special carrying cases were designed for the portable computer and camcorder.

OFFICE EQUIPMENT

PC

An MS-DOS PC based at the district inspection office is required to control the transfer and assembly of inspection data into a report. Because the computer-automated bridge inspection system depends heavily on computer graphics, a PC with a fast processors, large amount of internal memory, and high-quality video and storage subsystems is necessary. Figure 1 shows a schematic of the computer configuration recommended for the computer-automated bridge inspection system.

Hewlett Packard Scanjet Plus Optical Scanner

The computer-automated bridge inspection system provides two ways to acquire images for storage on computer disk. The first of these methods uses the Hewlett Packard Scanjet Plus Optical Scanner to digitize photos and sketches. Scanned images can be saved on computer disk, displayed on a monitor, or printed.

Sigma Designs Video Image Capture Board

The second method of acquiring images for computer storage uses the Sigma Designs Video Image Capture Board. The image capture board is an expansion card that accepts standard video signals from a video camera or video cassette recorder and digitizes frames for storage or display on a computer. Video frames can be displayed in real time on a separate television monitor or at three frames per second on the computer's video graphics array (VGA) display. In either case, frames are always captured in real time. Once captured, images can be saved in Tag Image File Format (TIFF), PC Paintbrush (PCX), or several other popular file formats.

Hewlett Packard LaserJet Series II Printer with Intel Visual Edge Enhancement

To produce professional quality reports, a high-resolution printing device is needed. A laser printer was chosen for this study because of its ability to output high-resolution text and graphics at a relatively low cost. The laser printer selected for this study was the HP LaserJet Series II. The Intel Visual Edge Enhancement for the Series II is a set of add-on boards that enables the Series II to produce graphics with twice the quality and up to six times the speed of the Series II alone.

FIELD DATA COLLECTION SOFTWARE

The field data collection software, which is written in Microsoft BASIC Professional Development System Version 7.0, is designed to run on the RHC-44 handheld computer. The software can also be run on any PC to enter existing data from conventional inspections before the field work. Bridge condition ratings and narrative defect descriptions are collected with the program and organized into files for transference to an office-based PC.

FDOT's CIR for static bridges organizes a bridge into six components: substructure, superstructure, deck, approach roadway, channel, and nonstructural. These components are further broken down into elements. The field data collection program is based on the structure of the CIR. Figure 2 shows the main menu of the field bridge inspection software known as BIS. BIS has built-in routines that check the validity of data entered. The program will warn the user if the data are not acceptable. The data acquisition program is divided into three components: general input, numerical condition ration (NCR) input, and comment input and generation.

The general input section handles data that relate to the cover sheet. These are the bridge numbers, date, and identification of inspectors. The software also asks the number of bridges to be inspected. Up to six bridges can be inspected simultaneously.

The NCR input section has built-in features to ensure that all components and elements are addressed. NCRs of elements that have comments in the Comprehensive Report of Deficiencies, Section B of the report, are automatically affixed with an asterisk. The user of the report then knows to
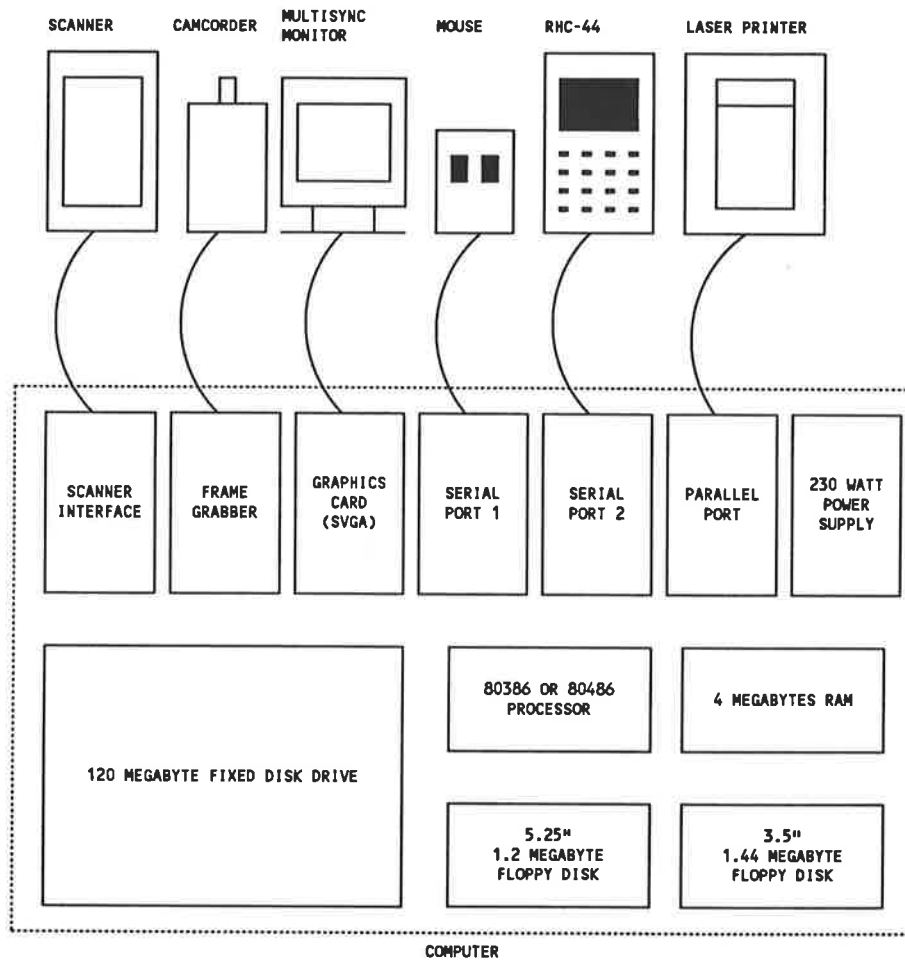
FIGURE 1   Schematic of recommended hardware configuration for automated bridge inspection system.

FIGURE 2   Data acquisition program main menu.

look for a comment. An opportunity to change the NCRs assigned is also provided.

The comment input and generation section handles the generation and editing of comments on the deficiencies. New deficiencies are described and located in a standardized format. A built-in word processors provides flexibility of editing new and old comments.

At the completion of the inspection, the data are saved in a format compatible with the Jetform software. The duration of the inspection is then calculated and written to a file named TIME.LOG. The TIME.LOG file is also used to monitor the time interval of the activities for office preparation and printing of reports. Flowcharts of the bridge inspection software are shown in Figures 3–8.

OFFICE REPORTING SOFTWARE

The office reporting software is separated into two categories: text handling software and image handling software. The text handling functions, such as data file transfer, text data editing, and text form printing, are controlled through the FDOT main menu. The image handling functions, such as video image capture, sketch and photo digitization, image editing, and image form printing are controlled from the image editing menu. The image editing menu is called from the FDOT main menu and always returns control back to the main menu.

FDOT Main Menu

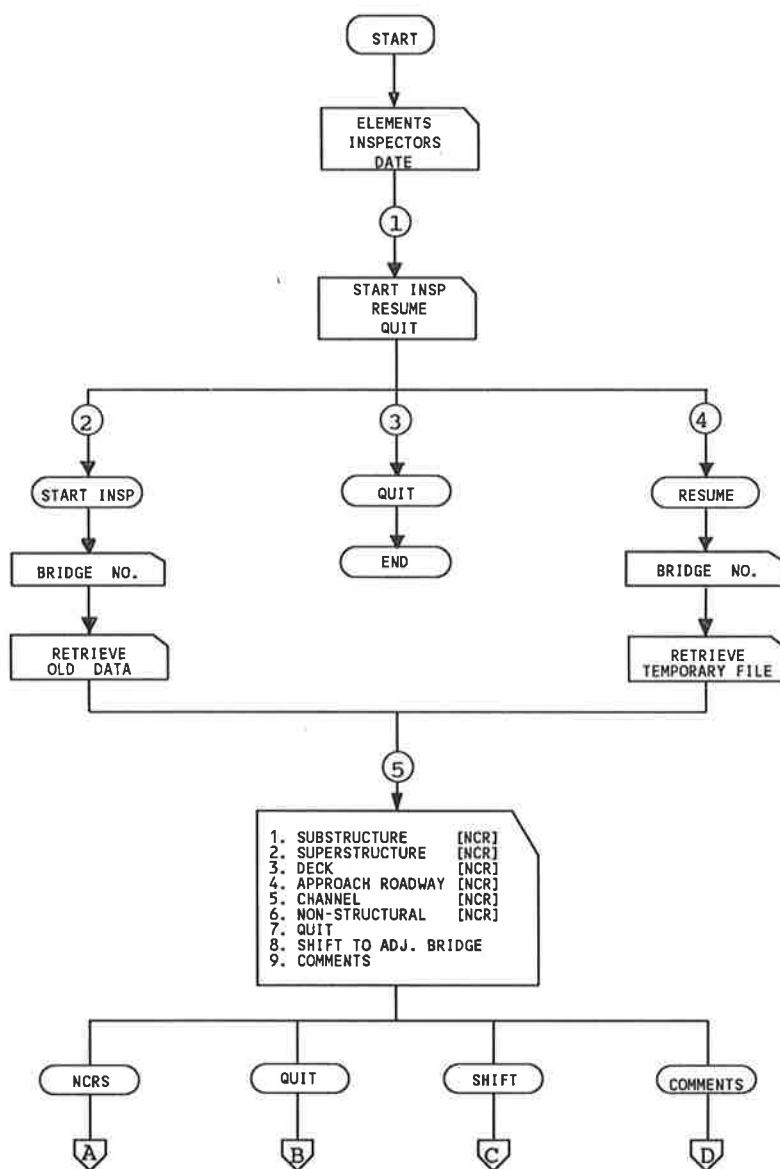All of the office reporting functions of the computer-automated bridge inspection system are accessed through the

FIGURE 3 Data acquisition flowchart, general input.

FDOT main menu. The main menu is written in Microsoft BASIC Version 7.0. The menu brings together the large variety of commercial and original programming used to create the computer-automated bridge inspection system. A flowchart of the main menu is shown in Figure 9.

Data Transfer

Before a bridge is inspected with the RHC-44, the old inspection report is transferred from the PC. After returning from an inspection, inspectors must transfer updated inspection data back to the PC. Data are transferred between the RHC-44 and the PC through a serial cable connected to RS-232 ports on each computer. The FDOT main menu automates the transfer procedure. The bridge number is used to select the appropriate inspection files to transfer.

Text Editing, Form Completion, and Printing

Once all inspection data have been transferred to the PC, two options are available for adding comments or correcting mistakes. The first option, edit inspection data, uses a text editor called QEdit from SemWare to give access to the data in their original ASCII format. QEdit allows text to be typed, deleted, inserted, and copied, among other features. The edited file is then saved in ASCII format.

The second option for editing the inspection data, view or print cover, CIR, and Section B report, uses JetForm from Indigo Software. JetForm is a professional form design and completion program that operates with Microsoft Windows. The cover, CIR, and Section B forms were designed with JetForm. Data fields for all of the necessary inspection information were placed on the forms with JetForm's design module. The data fields are accessible through JetForm's form completion module.
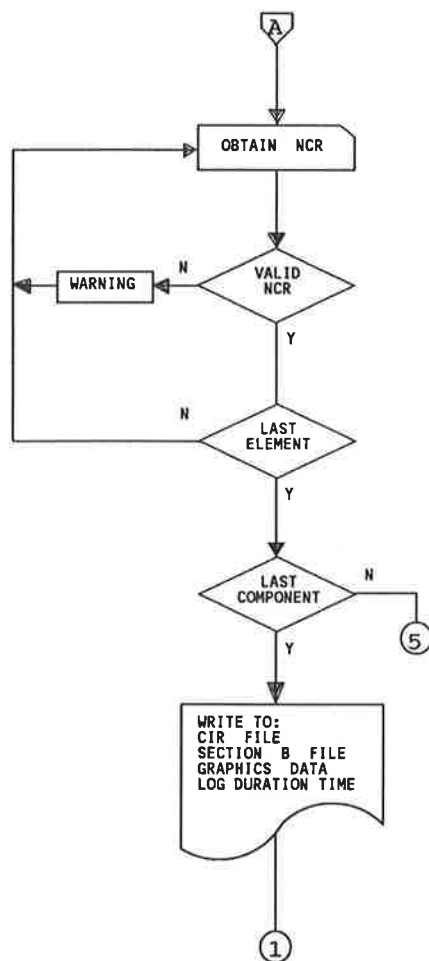
FIGURE 4   Data acquisition flowchart, NCR input.

The FDOT main menu calls the JetForm form completion module for the desired bridge. The form completion module uses the inspection data files for the bridge, which were structured to conform to JetForm's file format, to fill in the data fields on the forms. The data fields can then be stepped through one at a time or page by page for viewing or editing. The data files are updated with any changes or additions and saved to disk.

Image Editing Menu

The purpose of the image editing menu is to coordinate the commercial and original software used for digitizing, annotating, and printing bridge defect images so that the process is as automated as possible. The image editing menu is a combination of two DOS batch files and a menu program written in Microsoft BASIC. Figure 10 shows a simplified block diagram of the interactions between the programs used by the image editing menu. The image editing menu allows easy access to each of the tasks involved in digitizing, editing, printing, and displaying images. The menu is accessed from FDOT main menu.

Capturing and Converting Video Images

Images from the camcorder are captured and converted to digital form with automated software that controls the Sigma Designs Image Capture Board. The digitized video pictures are saved in .SHW files that can be manipulated and displayed with computer software.

Scanning Photos and Sketches

The scanning process has been automated by a program called ScanDOT, which was specifically written for the computer-
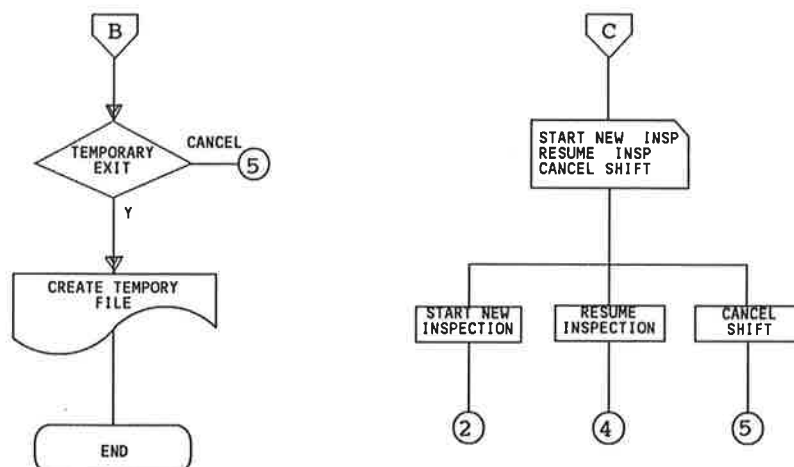

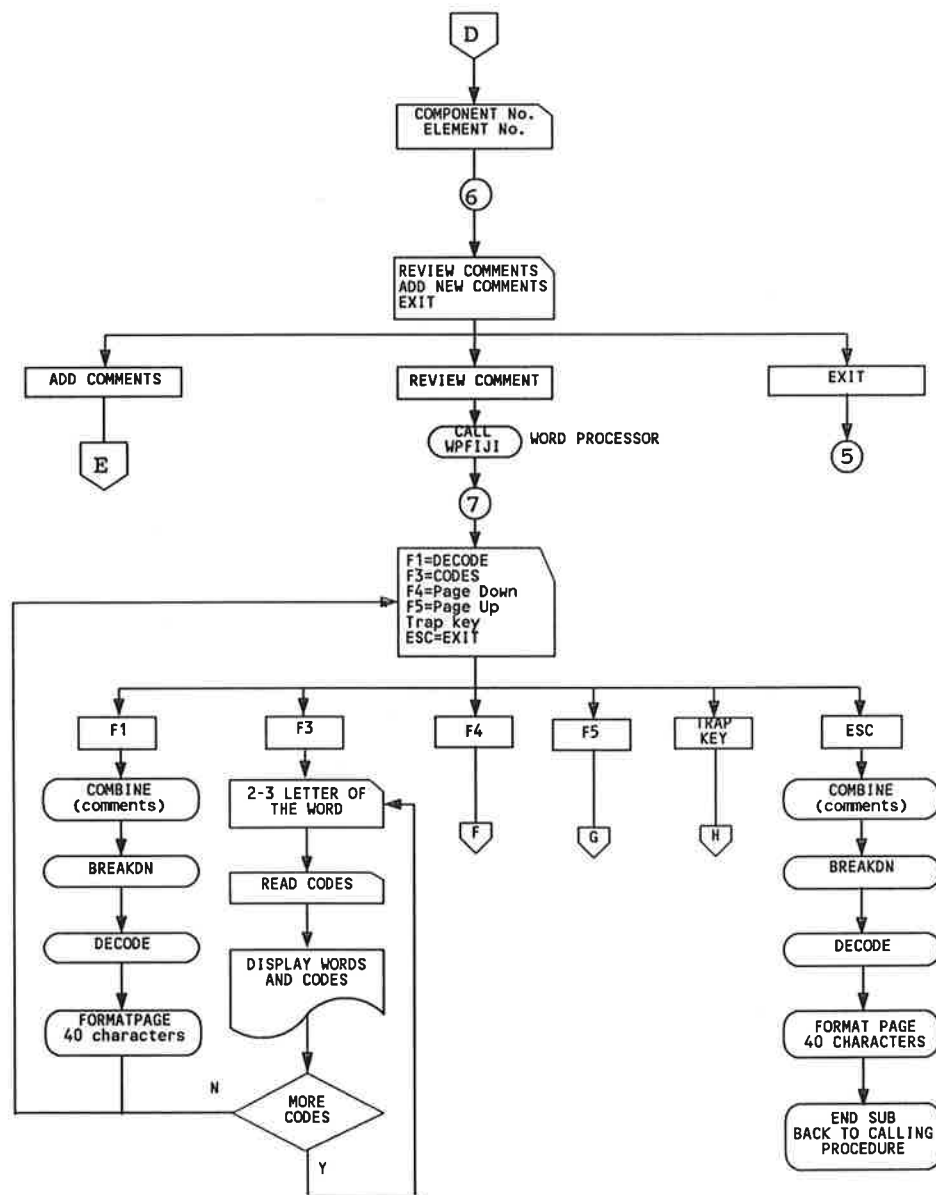**FIGURE 5   Data acquisition flowchart, quit and shift section.**

FIGURE 6 Data acquisition flowchart, comment generation by word processor.

automated bridge inspection system. ScanDOT reads the image-description file written by the bridge inspection program for a particular bridge and displays the descriptions for each image one by one on screen. The operator finds the picture or sketch matching the description, places it on the scanner, and begins the scan by pressing a key.

Video Data Base of Structures

Video images converted to the .SHW file format can be displayed on a VGA monitor by using the SHOW.COM utility program provided with the Sigma Designs Video Capture Board. A slideshow program that takes advantage of the SHOW.COM utility has been written to make the display of images easier.

Form Utilities

The image form utilities selection on the image menu allows three options for editing and printing image data and forms. The first option, view image forms, allows viewing of the forms as they will be printed with JetForm. The second option, edit image data, allows corrections of any typographical errors made in the field. The third option, print image forms, automatically prints out the finished image forms.

Manually Editing and Printing Images

PC Paintbrush IV Plus is the program used to manually edit and print photographs, sketches, and video images. The program has many sophisticated image enhancement functions if required, but is relatively easy to use.
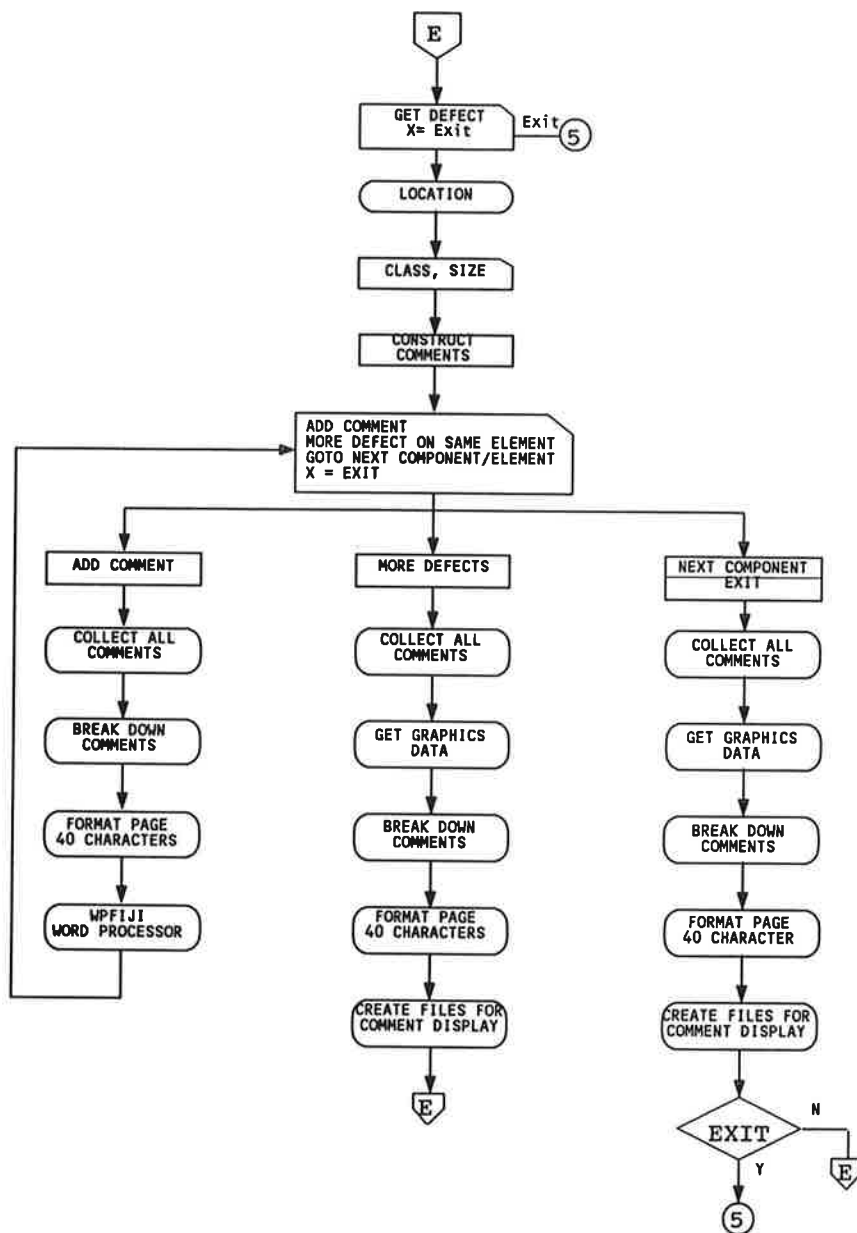
FIGURE 7 — Data acquisition flowchart, obtain defects

E
→ GET DEFECT X= Exit — Exit → 5
→ LOCATION
→ CLASS, SIZE
→ CONSTRUCT COMMENTS
→ ADD COMMENT / MORE DEFECT ON SAME ELEMENT / GOTO NEXT COMPONENT/ELEMENT / X = EXIT

Branch 1: ADD COMMENT → COLLECT ALL COMMENTS → BREAK DOWN COMMENTS → FORMAT PAGE 40 CHARACTERS → WPFIJI WORD PROCESSOR (loops back to ADD COMMENT block)

Branch 2: MORE DEFECTS → COLLECT ALL COMMENTS → GET GRAPHICS DATA → BREAK DOWN COMMENTS → FORMAT PAGE 40 CHARACTERS → CREATE FILES FOR COMMENT DISPLAY → E

Branch 3: NEXT COMPONENT EXIT → COLLECT ALL COMMENTS → GET GRAPHICS DATA → BREAK DOWN COMMENTS → FORMAT PAGE 40 CHARACTER → CREATE FILES FOR COMMENT DISPLAY → EXIT — N → E ; Y → 5

FIGURE 7   Data acquisition flowchart, obtain defects.

FIGURE 8 — Word processor editing functions

F → Pg=15? — Y → BEEP → 7 ; N → Pg=Pg+1 → LINE=(Pg-1)9+1 → ROW=STARTING ROW → 7

G → Pg=1? — Y → BEEP → 7 ; N → Pg=Pg-1 → ROW=STARTING ROW → COL=1 → 7

H → MODE — INSERT → MODE=TYPEOVER ; TYPEOVER → MODE=INSERT → LOCATE CURSOR → 7+

J → LNG=LEN(MEMO$()) → COL<LNG? — Y → INSERT CHARACTER → 7 ; N → ADD CHARACTER → 7
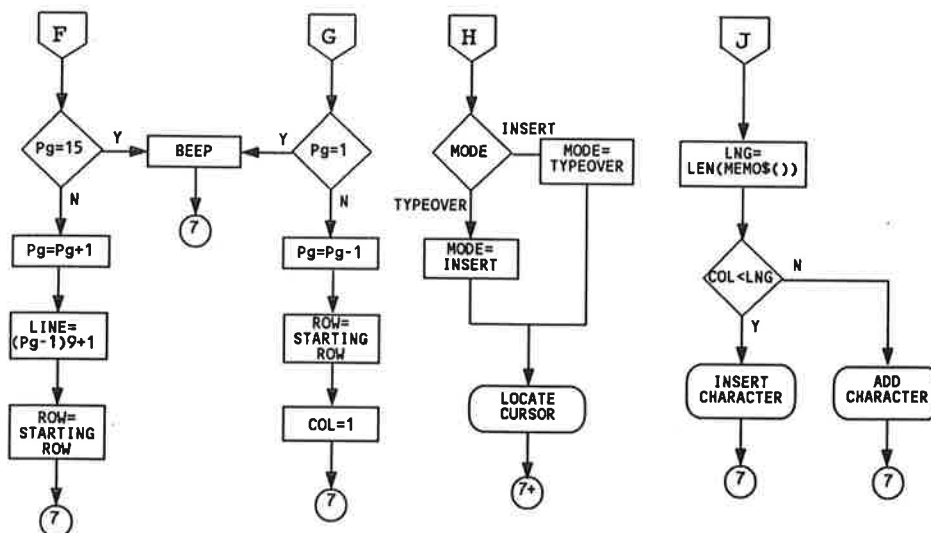
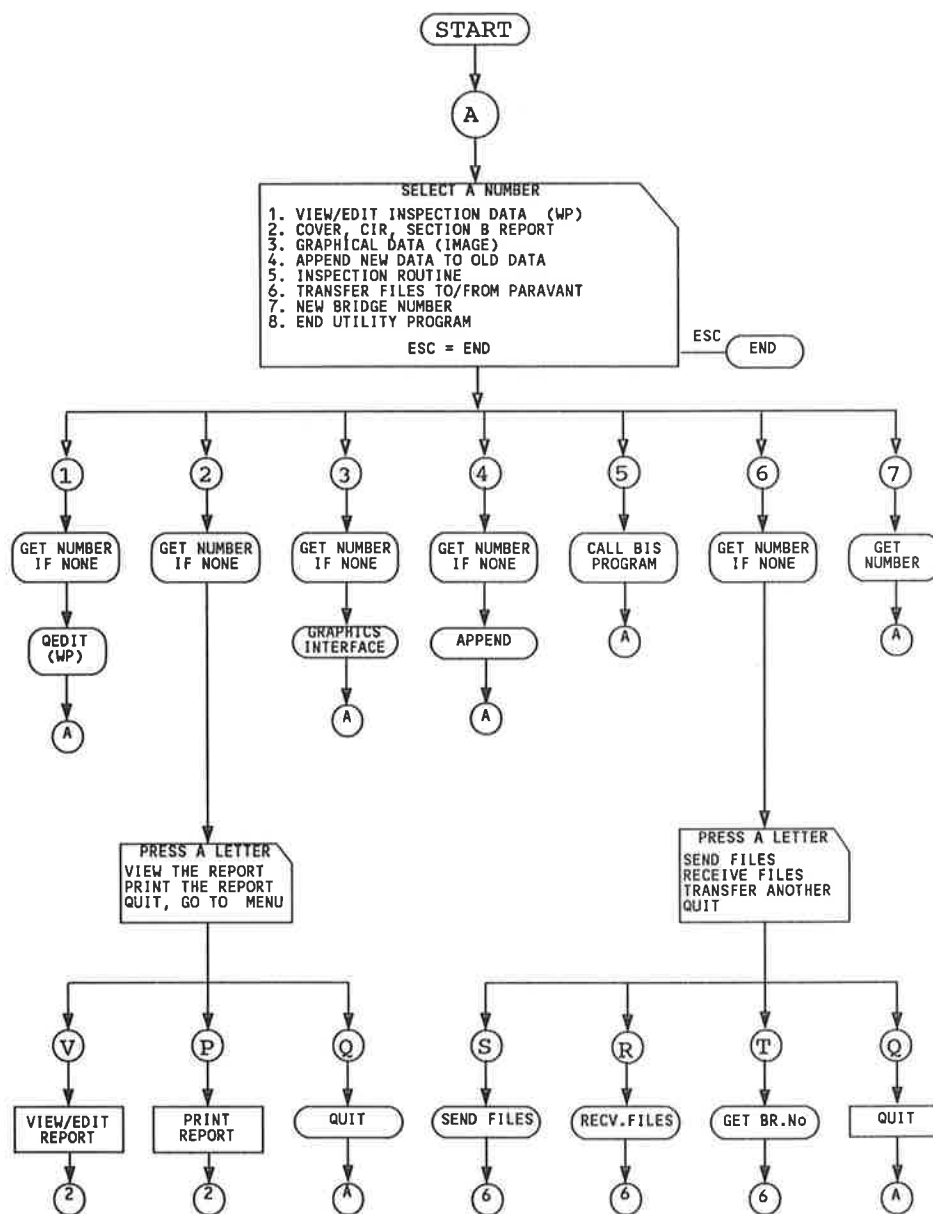FIGURE 8   Data acquisition flowchart, word processor editing functions.

FIGURE 9   Flowchart of utility program (FDOT main menu).

FIELD TESTING

Testing of the computer-automated bridge inspection system took place in FDOT's Bridge Inspection District One, which is located in the Tampa area. Experiments were undertaken 2 days a week for 8 weeks. Five bridge inspectors participated in the testing.

The field-testing procedure involved outfitting the inspectors with the automation equipment and monitoring them as they completed inspections. Completion times for the field and office procedures were recorded by the field and office computers. These times may be used in the future to compare efficiency and cost of the system with the conventional inspection procedure.

The field tests were conducted by two-person bridge inspection crews on actual bridge inspections. One member of

the crew used the handheld computer; the other was responsible for the camcorder.

The bridge inspectors followed their normal inspection procedure while in the field. They entered or edited narrative descriptions of defects with the handheld computer and videotaped, sketched, or photographed major defects. After recording all defects, they would review the comments and rate each element of the bridge using the handheld computer. The time to complete these tasks was recorded by BIS. The results of the inspections are presented in Table 1.

Table 2 presents a comparison of the completion times for the automated and conventional bridge inspection procedures. The overall completion times for both methods are virtually identical (Table 2). However, office times were significantly less with the automated process. Simply comparing completion times, however, does not take into account other
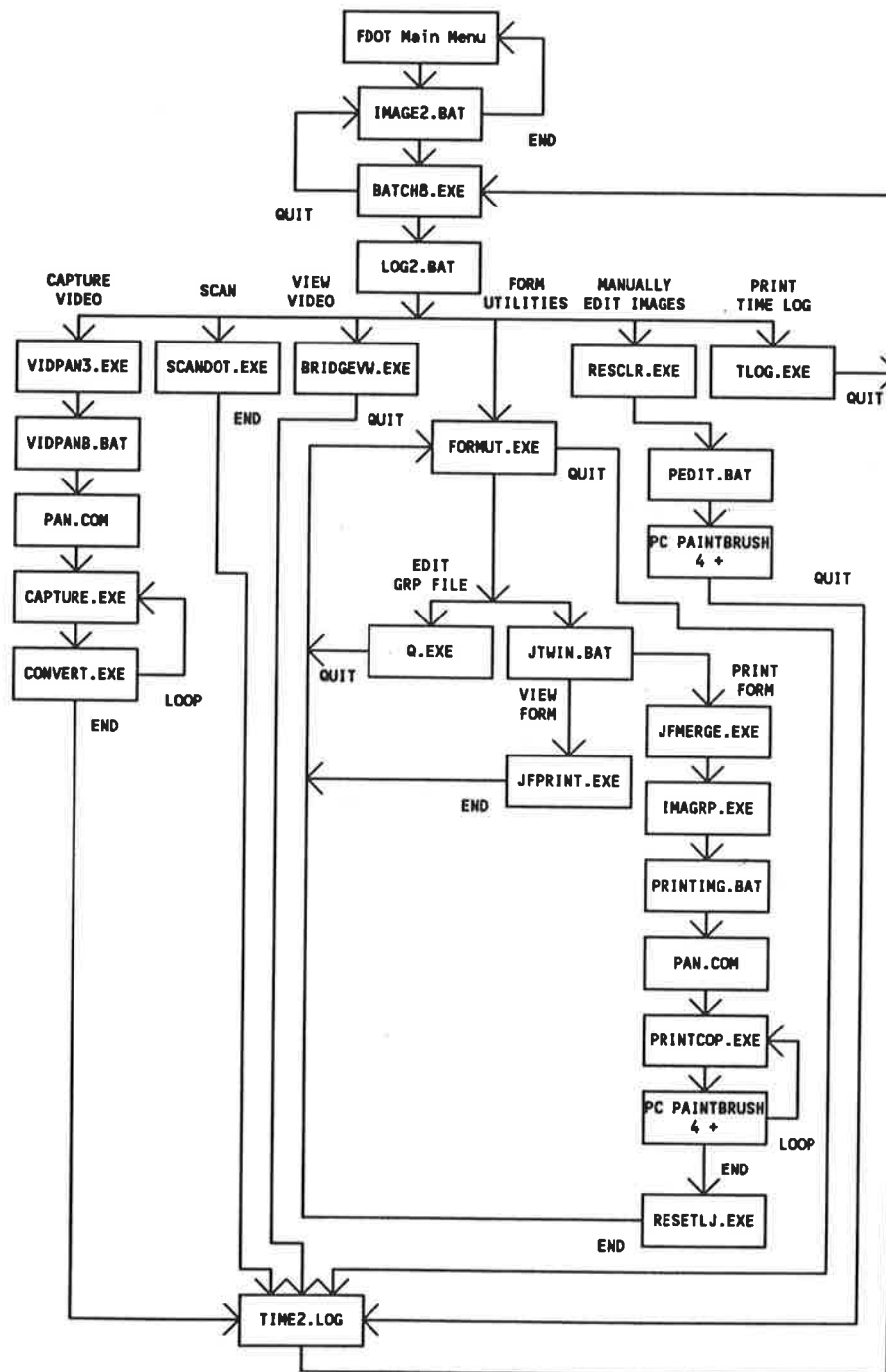
FIGURE 10   Block diagram of image editing menu program interaction.

important benefits of the computer-automated bridge inspection system.

RESULTS AND CONCLUSIONS

The computer-automated bridge inspection system was tested in FDOT Bridge Inspection District One for 8 weeks. Field data collection time averaged 56 min. This time is 26 min more than the 30 min estimated average of the current method. However, two of the five bridge inspections required less than 30 min for data collection. It is estimated that once inspectors became thoroughly familiar with the automated data collection system, they would require no more time than with the conventional method.

Report preparation averaged 24 min, a 21-min savings over the conventional report preparation method. Reports are completed by inspectors without the aid of typists. A list of other benefits from this system follows.

● Data are organized and handled efficiently by computer software.

TABLE 1   Inspection Times for Computer-Automated Bridge Inspection System

BRIDGE #	100238	100124	100216	100075	550064
DATE	05-02-90	05-09-90	06-04-90	06-05-90	06-14-90
TYPE	PRE-STRESSED CONCRETE	PRE-STRESSED CONCRETE	PRE-STRESSED CONCRETE	STEEL	STEEL
SPANS/LENGTH	3/153'	3/146'	3/135'	6/151'	6/398'
SKETCHES	2	0	2	11	1
PHOTOS	0	0	0	0	0
VIDEO	0	2	0	0	2
SECTION B PAGES	1	1	1	2	1
FIELD TIME (MIN.)	71	92	27	62	29
OFFICE TIME (MIN.)	8	38	9	42	23
TOTAL TIME (MIN.)	79	130	36	104	52

- Inspection reports have a consistent format.
- Inspection data are stored on computer disk.
- Transfer of bridge inspection reports between offices can be done electronically.
- Data are accessible through FDOT's bridge management system.
- Computer software ensures that data are complete before inspectors leave the bridge site.
- Consultant reports would more easily conform to FDOT specifications.

The following statement was made by Dewey Oliver, District One Structures and Facilities Engineer:

> It is my estimate that once this system is fully implemented, a savings in excess of $500,000 per year will be realized on in-

TABLE 2   Comparison of Average Completion Times for Typical Bridge

PROCEDURE	AUTOMATED INSPECTION METHOD	CONVENTIONAL INSPECTION METHOD
PREPARATION FOR INSPECTION (MIN.)	15	15
INSPECTION (MIN.)	56	30
PREPARING SKETCHES (MIN.)	30	30
REPORT COMPLETION (MIN.)	24	45
PROOFING (MIN.)	5	5
TOTAL TIME (MIN.)	130	125

TYPICAL BRIDGE IS LESS THAN 600 FEET IN LENGTH.

spection of state structures. If we require consultants to use the system, then we can double our savings.

Our current process allows 45 days from inspection until the report is finalized. We average 30 days in our current process. Using the automated process, this time frame could be reduced to under 5 days. In most cases we have tested so far, an inspection report preparation and report finalization have occurred in less than 5 hours.