Development of a Microcomputer-Based System for Traffic Signal Maintenance Records

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The Houston district office of the Texas State Department of Highways and Public Transportation is presently responsible for the operation and maintenance of approximately 1,000 traffic signals within a six-county area. This number is expected to double within the next 5 years. The Texas Transportation Institute has begun the development of a microcomputer-based method of recording and analyzing traffic signal system maintenance records. Still under development, this system will eventually replace the manual method now used by signal maintenance personnel. The system will be based on the use of portable microcomputers and expert system software. An overview and benefits of the system as it is being developed are presented.

On completion of maintenance activities within the Houston district office of the Texas State Department of Highways and Public Transportation (SDHPT), the technician or engineer must fill out a standardized form (Figure 1). Although it is intended for this form to be filled out on completion of the activity at the specific signal location, many of these forms are not filled out until the end of the day. Therefore, some of the required items may not be accurately recorded. Accuracy in recording arrival and departure times is especially critical when responding to emergency maintenance activities. These signal maintenance records are used in tort liability, civil, and criminal cases involving the state-maintained traffic signals. (In 1989, the Houston district was involved in 28 cases. By law, such records must be maintained for 7 years.) The development of a microcomputer-based method of recording this information in the field would greatly enhance the accuracy of the records. The data would also be available at the end of each day. The developed system would save the district time and money, and would result in an enhanced and modern maintenance records system. Accurate maintenance records would be available in cases where such information is required in litigation.

This system is in its initial steps of development by the Texas Transportation Institute (TTI). An overview of the existing system as presently used and of the proposed system under development is presented. This research was sponsored by the Houston district of the Texas SDHPT under a study titled *Planning, Design, and Operation of Transportation Facilities in Houston*

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EXISTING SYSTEM

Frequency of Maintenance Calls

A data base has been developed by the Houston district for all signal maintenance activities completed since 1987. The frequency of total yearly calls has remained almost constant since that time period.

Year	*Total Calls*	*Number of Signals Maintained by District*	*Calls per Location per Year*
1987	8,033	732	10.97
1988	8,120	763	10.64
1989	8,621	984	8.76
1990 (6 months)	4,444	1,001	8.88

In 1989, SDHPT policy changed and the Houston district assumed maintenance of and operation of 25 percent more signals, which are located in cities between 15 and 50,000 population.

These data result in an average of 9.67 maintenance calls per location each year. Although each traffic signal is visited at least once each year for annual maintenance, it is not uncommon for problem locations to be called on two or more times each month. In a scenario of double the present number of signal locations and average number of visits per location, which could occur in 5 years, the management of a manual record system would become impractical. This assumed scenario results in an estimated 18,000 maintenance forms being completed each year.

Present Procedures

Each of the existing traffic signal maintenance records follows a manual procedure that is labor-intensive and time consuming. The steps are outlined as follows:

Step 1. On completion of the required maintenance activity, a traffic signal maintenance report is filled out in the field by the technicians or the engineer. The form is filled out as completely as possible with all available information.

Step 2. The completed forms are then returned to the crew's shop at the end of the day. Any remaining information must then be added to the report. This procedure normally involves

TRAFFIC SIGNAL MAINTENANCE REPORT

Location: | Date

County | Control | Section | Milepost | Desc.

Description Received: | Nature of Call:

Notified By: | Time Received | Time Arrived | Time of Departure

Condition Upon Arrival:

Primary Action

See Codes From Table Below

Work Performed:

Materials Used:

Condition Upon Departing:

Crew Leader

Asst. Crew Leader

Checked By:

Primary Action Codes

Equip. Codes	Activity Codes
W - Wiring (In Cabinet)	X - Change Out
C - Controller	A - Adjust
E - Other Electronic Equip.	C - Clean
D - Detector	O - Observe
B - Bulb	W - Contracted Work
L - Load Switch	Y - Preventive Maint.
M - Control Unit	F - Turned on Flash
T - Timing	K - Turned Off
I - Illumination	M - Modify
Y - Wiring(Outside Cabinet)	P - Paint
G - Associated Equip.	R - Reset
R - Relay	I - Install
F - Fuse or Circuit Breaker	
S - Signal Head	
Z - Stop Signs	

Notes:

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FIGURE 1 Existing signal maintenance report form.

matching the location (e.g., IH-10 at Mason Road) with its corresponding county, control, section, and milepost identification (e.g., 102-271-6-3.75). This location code is used as the basis for identifying the signal and is used in matching the data item with those of other data bases.

Step 3. The completed forms are then forwarded to the district office at selected time periods, usually weekly. The contents of each form are then entered into a data base using dBASE III-Plus. Although data entry is performed as accurately as possible, input errors are likely to occur. Therefore, a corresponding level of inaccuracy between the resulting data base and the actual reports exists.

Step 4. The maintenance reports then must be filed in a permanent record system. A separate file for each signal location is kept at the district office. The filing system is in numerical order according to the location code. The reports are then sorted manually according to numerical order (to make filing easier) and placed in the proper file. They must be maintained for 7 years according to the tort liability laws in Texas. An output of this process that recently began is to provide the identification of problem locations. The updated data base file is provided to TTI once all reports for the previous month have been entered. The file is then converted to standard data format (ASCII) to allow access by statistical programs. PC-SAS is used to provide any analyses as requested by the district. The present analysis provides a listing of all locations that required four or more maintenance activities during a consecutive 2-month period (Figure 2). Although the listing only provides limited information, problem locations can be identified. Signal personnel, who have responded to the same locations on multiple occasions, can also be identified.

This four-step process is somewhat time consuming and requires a lot of manual effort. The potential for errors and possible loss of valuable data increases. The turn-around time from filling out the reports in the field to entering into the data base takes approximately 14 days. If the system were redesigned to use portable microcomputers in the field, an updated and current system on a next-day basis could be provided.

DISTRICT 12 SIGNAL MAINTENANCE RECORD LISTING
4 OR MORE CALLS FOR MAY AND JUNE 1990 ONLY

COUNTY=HARRIS CONTROL=502 SECTION=1 MILEPOST=15.38

DATE1	MAJOR		MINOR	NOTIFIED	ARRIVED	DEPARTED	DESC	NATURE	ECODE	ACTCODE	NAME1	NAME2
Tue, May 1, 90	SH	225	SENS	10.18	10.75	15.75	GENOA	EMERGENCY	ASSOCIATED EQUIP.	CHANGE OUT	HJR	JHN
Wed, May 2, 90	SH	225	SENS	8.00	9.00	12.00	GENOA	ROUTINE	ASSOCIATED EQUIP.	ADJUST	HJR	JHN
Thu, May 3, 90	SH	225	SENS	8.00	11.00	11.38	GENOA	ROUTINE	ASSOCIATED EQUIP.	CHANGE OUT	HJR	JHN
Fri, May 4, 90	SH	225	SENS	6.50	7.50	8.25	GENOA	EMERGENCY	OTHER ELECTRONIC EQUIP.	RESET	DRB	
Fri, May 4, 90	SH	225	SENS	8.00	10.10	12.27	GENOA	ROUTINE	ILLUMINATION	CHANGE OUT	HJR	JHN

COUNTY=HARRIS CONTROL=508 SECTION=1 MILEPOST=40.4

DATE1	MAJOR		MINOR	NOTIFIED	ARRIVED	DEPARTED	DESC	NATURE	ECODE	ACTCODE	NAME1	NAME2
Tue, May 1, 90	IH	10	BELTWAY 8	13.00	13.42	15.50	DISTRICT	EMERGENCY	SIGNAL HEAD	OBSERVE	WAR	DER
Tue, May 8, 90	IH	10	BELTWAY 8	14.65	14.67	15.33	HUMBLE	ROUTINE	CONTROLLER	OBSERVE	B D	
Fri, Jun 1, 90	IH	10	BELTWAY 8	12.82	13.50	14.58	GENOA	EMERGENCY	ASSOCIATED EQUIP.	OBSERVE	HJR	
Fri, Jun 1, 90	IH	10	BELTWAY 8	13.00	16.83	22.67	DISTRICT	EMERGENCY	CONTROLLER	CHANGE OUT	WAR	DER
Mon, Jun 25, 90	IH	10	BELTWAY 8	8.00	9.25	15.25	HUMBLE	ROUTINE	CONTROLLER	ADJUST	JDH	WCH
Mon, Jun 25, 90	IH	10	BELTWAY 8	8.00	9.33	12.08	HUMBLE	ROUTINE	WIRING (IN CABINET)	INSTALL	B D	
Mon, Jun 25, 90	IH	10	BELTWAY 8	13.83	14.17	15.25	HUMBLE	ROUTINE	CONTROLLER	OBSERVE	B D	
Tue, Jun 26, 90	IH	10	BELTWAY 8	8.00	9.08	12.00	HUMBLE	ROUTINE	CONTROLLER	ADJUST	JDH	WCH
Thu, Jun 28, 90	IH	10	BELTWAY 8	10.00	15.17	16.00	GENOA	ROUTINE	CONTROLLER	ADJUST	DRS	

COUNTY=HARRIS CONTROL=720 SECTION=3 MILEPOST=13.41

DATE1	MAJOR		MINOR	NOTIFIED	ARRIVED	DEPARTED	DESC	NATURE	ECODE	ACTCODE	NAME1	NAME2
Tue, May 15, 90	SH	249	FM 1960	8.00	10.75	12.80	HUMBLE	ROUTINE	DETECTOR	OBSERVE	RAD	
Thu, May 17, 90	SH	249	FM 1960	8.00	13.00	14.00	HUMBLE	ROUTINE	DETECTOR	OBSERVE	RAD	
Mon, May 21, 90	SH	249	FM 1960	8.00	10.00	13.00	HUMBLE	ROUTINE	WIRING (OUTSIDE CABINET)	ADJUST	ORS	
Mon, May 21, 90	SH	249	FM 1960	8.00	10.83	12.93	HUMBLE	ROUTINE	DETECTOR	ADJUST	RAD	
Wed, Jun 13, 90	SH	249	FM 1960	13.50	14.83	15.25	GENOA	EMERGENCY	CONTROLLER	OBSERVE	ORS	
Fri, Jun 15, 90	SH	249	FM 1960	.	10.58	10.67	HUMBLE	SPECIAL	TIMING	ADJUST	NAA	
Tue, Jun 26, 90	SH	249	FM 1960	8.00	10.08	10.25	HUMBLE	EMERGENCY	SIGNAL HEAD	ADJUST	B D	

FIGURE 2 Examples of monthly listing of maintenance records.

MICROCOMPUTER-BASED SYSTEM

System Concept

A system is being developed that will use portable microcomputers in the field as the basis for gathering the information presently being handwritten. This system would allow for time and date input as provided by the computer. At the end of each signal crews' shift, the maintenance report data could be forwarded to the district office. How this transmission would be accomplished depends on the capabilities of the portable microcomputer. It would most likely be completed using telephone modem hook-ups from remote locations. Once all data have been loaded on the office microcomputer, supervisors could assess a menu of programs to view and print desired information. This access of the data is much quicker than the present manual method. Daily information on field maintenance activities would also be readily available.

Selection of Portable Computer

The initial task in designing the system was the selection of a portable microcomputer. It must have design qualities that will allow it to withstand field environmental conditions and a sufficient battery duration between recharges. Approximately 15 companies, with manufacture portable hand-held microcomputers, were contacted. Many of these companies also manufacture standard laptop computers. However, laptops were not considered for use because of power requirements and field environmental conditions. The portability or size of the unit was also a major factor in the selection process. The response from those contacted ranged from receiving literature in the mail to phone calls from sales and technical staff. All specifications were reviewed and one unit was selected to be used for the proposed system. In addition to the unit's physical requirements, the user friendliness and programming capabilities of the unit were primary considerations. The user of these units would be signal technicians and engineers.

The GRiDPad, manufactured by GRiD Systems Corporation, was selected as the portable computer to be used in the field (Figure 3). This unit is unique in that it is lightweight (4.5 lb) and that data may be entered by printing text with its attached electronic pen. In addition to its ability to run MS–DOS-compatible application software, the GRiDPad has the capability of running customized forms and user applications. Data storage is provided by removable RAM/

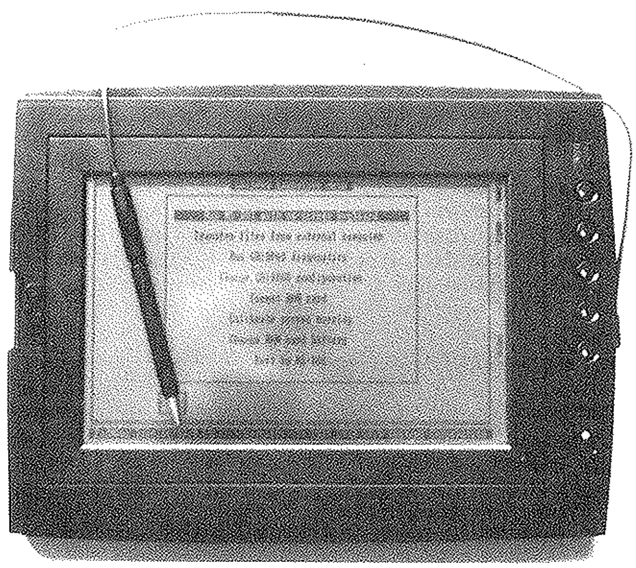

FIGURE 3 GRiDPad portable computer and attached electronic pen.

ROM data storage cards. Its serial port can be used to connect bar-code readers, printers, or other microcomputers. No other manufacturer presently markets a unit with these characteristics.

The use of pen-based portable computers, particularly the GRiDPad, was described in an article in *Business Week Magazine* (May 14, 1990). The Southern Pacific Transportation Company stated that billing errors because of sloppy paperwork can be avoided. Officials with the railroad estimate that setup costs for the GRiDPad-based system will be paid off in a maximum of 3 years with savings from error elimination. The Best Foods Baking Group also indicated that it could save $1.5 million annually in reduced billing errors, increased cash flow, and fewer loaves of stale bread with implementation of a GRiDPad system. The article also pointed out that Southern Pacific selected the GRiD unit partially because the unit uses the familiar MS-DOS operating system.

In the case of recording traffic signal maintenance records in the field, the GRiDPad is an ideal unit. Custom entry forms that are similar to those presently completed (Figure 1) can be developed. Therefore, less training of signal technicians on the operation of the system is required for its implementation. Initial purchase costs for software development are estimated at approximately $6,000. This amount includes purchase of all software and connection hardware necessary to develop the input form and a single GRiDPad for field testing. Depending on the amount and number of storage cards required, additional purchases of the GRiDPad only should be less than $3,000 each.

System Development

The proposed system to be developed for the Houston district is designed for staged implementation. As each less-complicated portion of the overall system is completed, it can be implemented in the field. (This process depends on the availability of sufficient GRiDPads being purchased by the SDHPT for use by all signal maintenance crews.) The staged objectives and the methods by which each will be accomplished are described in the following sections.

The primary goal of the first stage is the development of a data collection form to be used in the field, which would be similar to the one presently used, shown in Figure 1. This process would require most of the computer programming time as well as an understanding of the capabilities of the GRiDPad. All routines for downloading the field data to the host microcomputer would be developed and field tested. The resulting software, when used in the field with the GRiDPad, would increase the efficiency of the manual procedures presently used. Implementation of this stage will eliminate the manual step of matching the location code with the intersection name. The present manual step of entering the maintenance records into a data base (or into some other acceptable format) will be completed using programming techniques. The portable computer will also provide time and date stamping as each activity is recorded in the field.

Another set of PC-based programs will be developed to manage the resulting data base. Each maintenance record will be available for screen viewing and editing of field input errors or those times when the printed information cannot be interpreted by the GRiDPad. Programs will also be developed to provide printed output for permanent filing. These listings will be produced in order according to the county, control, section, and milepoint identification. Other listings will also be provided within the PC-based routines.

The second stage would add a major component to the proposed system that would eliminate the step of inputting the signal location. A bar code reader would be attached to the GRiDPad to automatically identify the signal location. A bar code unique to each intersection would be placed within the signal cabinet and not on the controller, because the controllers are often changed out. This process would eliminate mistakes caused by misidentification of the signal location by field technicians. The bar code concept could later by expanded to include inventory control of all traffic signal equipment. The feasibility of inventory control will be examined at a later date; present emphasis is being placed on only the portion of the project pertaining to maintenance records.

Development of the second stage requires that additional software and equipment be purchased. This equipment, which would allow production of the required bar codes, would be installed within each controller cabinet. The technology for producing bar codes has improved so that labels can be printed using a standard personal computer and printer. Costs of implementing the bar code portion have not yet been estimated. The initial expense would be the purchase of a system (software and hardware) to produce the printed bar code. Minimum costs are expected to be about $750. Second-stage development would begin only after the initial system has been successfully field tested.

A third stage has also been considered that would use these hand-held computers to assist field technicians. This activity involves working with signal controller manufacturers in developing an expert system to assist field technicians in troubleshooting of malfunctioning controllers. The expert system for diagnostics would be maintained on an office PC and accessed using a cellular telephone modem connection.

Implementation

This system is designed for implementation according to the staged development process. The first stage will be ready for implementation by the Houston district signal maintenance crews in late 1992. This time frame provides approximately 2 years for the system to be developed and field tested, and for the purchase of sufficient GRiDPad computers by the SDHPT. The second stage—use of bar codes for location, time, and data identification purposes—could begin at the same time. Expansion of the bar code system for signal inventory control could be implemented by 1993. Successful use of an expert system for troubleshooting controllers depends on the willingness of manufacturers to develop and assist in the design of such a system.

BENEFITS OF A MICROCOMPUTER-BASED SYSTEM

The benefits of using the described microcomputer-based system for maintaining traffic signal maintenance records can be expressed in terms of operational and monetary benefits.

In terms of operations, many manual steps, which are presently used to document field activities, can be eliminated. The field information, when forwarded to the host personal computer on a daily basis, can be used as a virtual real time system for determining maintenance needs. After implementation of the second stage, the record system will be almost foolproof because of the computer-based date and time-stamping routines.

Because of the possibility of litigation, the monetary benefits from the improved accuracy cannot be adequately determined. However, any lawsuit has a cap of $280,000 potential liability to the state. Because 10 hr per week are devoted to inputting the signal record into a data base and filing of the handwritten copy, the monetary benefits of the system far outweigh the cost of implementation. After an appropriate training period, the time for the signal technician to record the information on the GRiDPad should be equal to or less than the present time to record this information in a written format.

As mentioned earlier, a change in departmental policy resulted in a 25 percent increase in the number of traffic signals maintained by the Houston district. Because the number of signal maintenance personnel was not increased, the time spent at each location became critical. Development of expert system software to assist field technicians in troubleshooting of malfunctioning controllers may reduce the repair time at each location. Each maintenance crew will then be able to provide service to more traffic signals each day at reduced stress levels of personnel.

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