Figure 13. Deteriorated steel and concrete.


staff are used, they may be from the Structures Division in the main office or from the regional office in which the project is located. The preferred pattern is to use staff headquartered close to the bridge in order to minimize the travel time needed for the frequent trips required to the bridge. If consulting engineers do the work, they are managed by the Structures Division with strong support from the regional office in which the bridge is located. Those managing consulting engineers at the regional level do it as a part of a variety of bridge design and construction activities. In the Structures Division, a specific unit is responsible for consultant management, including consulting engineers who design new bridges as well as rehabilitation projects. Staff managing consultants are either professional engineers or work under the direct supervision of professional engineers. Each staff member is responsible for 15-20 projects.

## CONCLUSION

In conclusion, the Department considers the bridge inspection and rehabilitation design program to be an effective way to assist with the rehabilitate/replace decision and to provide the material needed to produce reliable contract documents for construction.

Of the 150 New York State projects that have followed this procedure, only 8 bridges were reprogrammed from rehabiliation to replacement, which attests to care given the selection of bridges for the program and the prominent place of external constraints in dictating what will happen to the bridge. Some might argue that the small number of changes would indicate that the rehabilitate/replace decision point is unnecessary. It is the Department's view that the possibility of a change should always be a consideration in order to ensure that the best solution is developed for each project.

The number of deteriorated bridges in New York State and across the country make it obvious that total replacement of all these bridges is not possible. Instead, an inspection and rehabilitation design program, if properly managed, can be used to make cost-effective restorations of many of these bridges.

## REFERENCES

1. Specification for In-Depth Bridge Inspection. Structures Division, New York State Department of Transportation, Albany, Oct. 1976.
2. Manual for Maintenance Inspection of Bridges. AASHTO, Washington, DC, 1978.
3. Bridge Inspector Training Manual. FHWA, 1970.

*Publication of this paper sponsored by Committee on Structures Maintenance.*

# Pennsylvania's Structure Inventory Record System: SIRS

HEINZ P. KORETZKY, K. R. PATEL, AND GEORGE WASS

**Pennsylvania's newly implemented computerized structure inventory record system, which incorporates data in excess of federal inventory and inspection requirements, is described. These data codify and describe the actual condition of more than 16 000 bridges on the state system and more than 5000 bridges on the local system. This paper also describes the system's management, identification codes, update requirements, and security. Also provided is a general understanding of the system and its error correction, updates, and enhancement. This system produces a series of reports for use in the verification of data and the technical content of the system. The data are converted internally from Pennsylvania data to Federal Highway Administration data to satisfy frequent reporting requirements.**

This paper gives an overview of the recently implemented on-line structure inventory record system (SIRS) in Pennsylvania. The Bureau for Strategic Planning, Pennsylvania Department of Transportation (PennDOT), exercises a quality-control function over several planning information systems. This paper covers one of the information systems.

Because the Bureau of Highway Design is responsible to carry out the bridge inventory and inspection program, they are the primary users of SIRS. The primary data are gathered by the district bridge units, which are also users of the system. The Bridge Division in the central office in Harrisburg, Pennsylvania, monitors district activities that concern technical and bridge engineering data.

SIRS represents an on-line computerized bridge inventory system that provides direct data entry and retrieval. Information on bridges is collected, quantified, and entered into the on-line system through remote terminals within one day to two weeks after field collection of the raw data. Priority was given to enter bridges 20 ft and longer because such structures are defined by the Federal Highway Administration (FHWA) as bridges. This system was implemented statewide on March 15, 1982.

Federal reporting criteria require that some 88 data items be collected and reported for each structure. These data are subsequently entered into the system and a report is made (by magnetic tape) twice a year to FHWA.

Each bridge is identified in the system with a 20-digit structure number. The structure number is necessary for both the updating and inquiry modes. Most importantly, SIRS contains existing information on bridge conditions as they are at the time of inspection, disregarding planned improvements or repairs in progress.

The PennDOT coding forms list 175 items. Only 83 items are currently collected to meet federal requirements.

Because the system is the only comprehensive source of bridge data, it has a variety of uses in addition to meeting federal reporting requirements. In connection with the identification of a priority commercial network, SIRS data are now being used as a key planning and programming tool. SIRS contains technical data on the more than 16 500 bridges longer than 20 ft on the state system and the more than 9500 bridges from 8 to 20 ft.

Raw data are collected by approximately 33 inspection teams. As these data generally are updated daily, the information is changed daily. A great number of reports can be generated by the system. Twenty-five different reports are generated monthly, while more comprehensive quarterly statistics are furnished periodically to the Secretary of Transportation by the Bridge Division.

When reported to FHWA, the SIRS data are translated by the computer into a lesser volume of information through the use of a conversion program that gives data compliant with the federal requirements. SIRS replaces the previous FHWA bridge inventory file maintained on computer cards.

## SYSTEMS MANAGEMENT

This system is controlled and managed by the Bureau for Strategic Planning, which coordinates system enhancement, ensures the interfacing capability of this system with other planning information systems, and maintains system quality. The system, however, is operated jointly by three bureaus: Bureau for Strategic Planning, Bureau of Highway Design--Bridge Division, and Systems Center.

The Bridge Division provides bridge engineering support and technical and bridge engineering control; it monitors the districts' bridge safety inspection program and bridge inspection data collected by districts; and it also enters data and coordinates bridge safety inspection activities of independent government jurisdictions, such as the Turnpike Commission, the Delaware River Joint Toll Bridge Commission, and others.

Maintenance of the computer program, program testing, and program enhancement is handled by the System Center in collaboration with the Bridge Division and the Bureau for Strategic Planning.

### Structure Numbers

Inquiry into the system without a complete and correct structure number is impossible. There is a structure number for each bridge that consists of 20 digits, while the structure is identified for FHWA purposes by using a 15-digit number.

### Systems Update

The implementation of SIRS started March 15, 1982, following a halt on all activities on the FHWA (old) system in October 1981. Data collected by the 11 engineering districts after October was held until the SIRS programs were corrected and found to be functioning to the satisfaction of all parties.

The bridge data in the FHWA file were transferred internally by computer to SIRS, and districts were requested to enter all data collected in the hold period by remote terminal into SIRS, with priority given to bridges longer than 20 ft, with data entered for the federal system first, then state, then local. Two persons from each district received training in data entry by remote terminal in Harrisburg, with follow-up training visits by the instructors.

### System Security

Strict system security has been introduced since the inception of SIRS, primarily as a good practice and to prevent or discourage sabotage of the system, i.e., the possibility of loading the system with false data, purposeful deletion of structures and "phantom" bridges, and to introduce an audit trail.

Passwords are issued to qualified individuals through the Bureau for Strategic Planning, which controls the issue of such passwords. Shared passwords are not considered acceptable. Some passwords carry the authority to update bridge data and some passwords only carry the authority to inquire into the SIRS file.

## INTRODUCTION TO SIRS

PennDOT started collecting 88 structure inventory and appraisal items in 1972 to satisfy federal requirements. The federal coding form suitable for keypunching was used to enter data into the computer file that then, in the form of a computer tape, was submitted to FHWA.

Initially, data collection was directed by the Bridge Division and was for bridges on the federal-aid system. In 1978, the Surface Transportation Assistance Act expanded the collection of data to all bridges on public roads. That involved local governments that had bridges 20 ft and longer. This work involved filling out coding sheets, submission of those sheets to the central office, keypunching of data contained on those sheets, review operations, etc.

From the time data were collected in the field and coded on the forms, the full processing (that is, district office review, mail transit, keypunching, review of keypunched data, and error correction) required about six weeks or more. Regardless of those efforts, errors in coding and in keypunching were likely to occur. These errors, once stored, were not easily detectable.

Because of those reasons, in spring 1980 PennDOT implemented its desire to develop an on-line system--SIRS. An outside consultant was engaged to work with Department staff to develop the system. The system was completed by the staff of the Systems Management Center with extensive acceptance testing by the Bridge Division, District 8-0 Bridge Unit, and Strategic Planning.

The system's main purpose is to provide an on-line operation to the districts and the central office bureaus for storing, updating, and retrieving structure inventory data. The structure inventory data in SIRS contains all of the items required to satisfy FHWA and additional items for Department needs.

FHWA requires 88 items (see Figures 1-6). Those items are identified by an asterisk in the printout and on the form. SIRS has condensed those 88 items into 83, but it has provisions for additional items, which now total 175.

**Figure 1. Coding form D-491A.**

D-491A (7-81)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM
GENERAL DATA

* STRUCTURE IDENTIFICATION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| ID: | DIST | CNTY | CL | APPL | RT | SPUR | EQU | STAT |
| NEW ID: | | | | | | | | |

NOTE: Items identified with * are FHWA SI & A items and must be completed. Other items may be completed Districtwide at the option of the District Engineer. Periodically specific items will be required to be completed on a statewide basis.

DATA TYPE 01

| 10 | *11 | *12 | *13 | *14 | *15 | 16 | 17 |
|---|---|---|---|---|---|---|---|
| AGCY SUBM | LOCATION | LATITUDE DEG MIN | LONGITUDE DEG MIN | CTY/BOR CODE | FAP NUMBER | FED FND | PSU-PUC NUMBER |

DATA TYPE 02

| 19 | | | 20 | | | | *21 | *22 | | 23 | 24 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DESIGN DRAWING | | ADD | SHOP DRAWINGS | | | | YEAR | LAST RECON | | SCH | PUB |
| NUMBER | NUMBER | DRAW | NUMBER | NUMBER | NUMBER | NUMBER | BUILT | TYPE | YEAR | BUS | TRAN |

DATA TYPE 03

| *27 | A | 28 | *29 | *30 | | | | | | *32 | *33 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| OWNER/PRINCIPAL CUSTODIAN | CODE | LEG ACT NUMBER | MAINTENANCE RESPONSIBILITY | MAINTENANCE CODE 1 | 2 | 3 | 4 | 5 | 6 | SAFE FEAT | TOLL |

DATA TYPE 04

| *34 | *35 | *36 | *37 | *38 | *39 | *40 | *41 | | *42 | 43 | | 44 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| TYPE SERV | BRDG DESC | CRIT FAC | APPR RDWY WDTH | BRDG RDWY WDTH | FLRD | BRDG DECK WDTH | SIDEWALK TYPE & WIDTH LEFT | RIGHT | DETOUR LENGTH | CURVE HORZ | VERT | FIPS CODE |

**Figure 2. Coding form D-491B.**

D-491B (7-81)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM
FEATURES INTERSECTED

STRUCTURE IDENTIFICATION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| ID: | DIST | CNTY | CL | APPL | RT | SPUR | EQU | STAT |

NOTE: The first line (DATA TYPES 05, 06 and 07) is reserved for recording feature on a structure.

DATA TYPE 05

| 46 | *47 | *48 | *49 | *50 | *51 | *52 | 53 | 54 | 55 | 56 | 57 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| REF | FEATURE DESCRIPTION | ON OR UNDER | TRAF ROUTE | DIR | KIND HWY | HWY DESC | CLASS | APPL | ROUTE NUMBER | SPUR | EQUAT COUNT |

DATA TYPE 06

| 58 | *59 | *60 | *61 | 62 | 63 | 64 | *67 | | *68 | |
|---|---|---|---|---|---|---|---|---|---|---|
| STATION | NO LANE | SKEW ANGLE | MEDIAN | NAME STAT | AAR NUMBER | RAILROAD MILEPOST | MIN LAT CL LEFT | RIGHT | TTL HORZ CL LEFT | RIGHT |

DATA TYPE 07

| *69 | | | | *70 | | | | *71 | *72 | *73 | *74 | *75 | *76 | *77 | *78 | 79 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MIN VERT CL LEFT | | RIGHT | | VRT CL >10' LEFT | | RIGHT | | ROAD SECT NUM | DEFENSE MIPOINT | SECT LGTH | ADM JUR | HWY SYS | FUNC CLAS | ADT | ADT YEAR | VT SGN |
| FT | IN | FT | IN | FT | IN | FT | IN | | | | | | | | | |

DATA TYPE 08

| *47A | *47B | *59A |
|---|---|---|
| FHWA FEATURES INTERSECTED | FHWA FACILITY CARRIED BY STRUCTURE | NO LANES |

**Figure 3. Coding form D-491C.**

D-491C (7-81)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM
STRUCTURE DATA

STRUCTURE IDENTIFICATION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| ID: | DIST | CNTY | CL | APPL | RT | SPUR | EQU | STAT |

DATA TYPE 09

| 81 * | 82 | 83 * | 84 * | 85 * | 86 * | 87 | 88 * | 89 | 90 | 91 * | 92 | 93 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| D L | S L | STRUCTURE TYPE MAIN FHWA DEPT APPROACH FHWA DEPT | #SPAN MN AP | STRUCT LENGTH | M SP LENG | DK TP | W.S | G M | STEEL TYPES 1 2 3 4 | PH VUL | CUM TK TRAF | DATE EST |

DATA TYPE 10

| 95 | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| SPANS, NUMBER AND LENGTH (MAIN AND APPROACH) | | | | | | | | | | | | | | | | | | | |
| NO | LENG | NO | LENG | NO | LENG | NO | LENG | NO | LENG | NO | LENG | NO | LENG | NO | LENG | NO | LENG | NO | LENG |

DATA TYPE 11

| 96 | 97 | 98 | 99 | 100 | 101 | 102 | 103 | 104 | 105 | 106 |
|---|---|---|---|---|---|---|---|---|---|---|
| REL JT | FRM | RBR | EXP JT TYPES 1 2 3 4 | BEARING TYPE 1 2 3 4 | FLD SPL | LT PROB SUPER | F'CI | F'C | STRANDS 1 2 3 4 | TENSION 1 2 3 |

DATA TYPE 12

| 107 | 108 | 109 | 110 | 111 | 112 | 113 | 115 | 116 | 117 | 118 | 119 | 120 | 121 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| DRAP | VAC PROC | V LOC 1 2 | V TYPE 1 2 3 4 | UTIL | CNT L L | FLD SPL | ABT N F | FND N F | PIER TYPE 1 2 3 4 | PIER FD 1 2 3 4 | SP CAP | TIE | L PR SUB |

**Figure 4. Coding form D-491D.**

D-491D (7-81)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM
UTILITY, HYDROLOGY AND POSTING DATA

STRUCTURE IDENTIFICATION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| ID: | DIST | CNTY | CL | APPL | RT | SPUR | EQU | STAT |

UTILITY OCCUPANCIES

DATA TYPE 13

| | 125 | 126 | 127 | 128 |
|---|---|---|---|---|
| REF | NAME OF COMPANY AND ADDRESS | LICENSE NUMBER | DATE APPROVED | FEE |

HYDROLOGY AND NAVIGATION

DATA TYPE 14

| 130 * | 131 | 132 | 133 | 134 | 135 | 136 * |
|---|---|---|---|---|---|---|
| STREAM NAME | DRAIN AREA | VERT CLEAR | DESIGN FLOOD MAGNIT FRQ ELEV VEL | MAX ELEV W.S. YEAR | FISH | Y/N VERT CL HORIZ CLEAR |

POSTING

DATA TYPE 15

| 139 * | 140 | | | 141 | 142 | 143 | 144 | 145 |
|---|---|---|---|---|---|---|---|---|
| C/P A | WEIGHT LIMIT COMB | 1ST DT POSTED | LAST DT POSTED | DT CLOSE ALL TRAF | REASON | FLD COND | SPEC COND | IMPACT |

**Figure 5. Coding form D-491E.**

D-491E (7-81)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM
INSPECTION REPORT AND PROPOSED IMPROVEMENTS

STRUCTURE IDENTIFICATION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| ID: | DIST | CNTY | CL | APPL | RT | SPUR | EQU | STAT |

INSPECTION

DATA TYPE 16

| 150 * | 151 | 152 | 153 | 154 | | | 155 | 156 | | | 157 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| DATE INSP | NEXT INSP | INSP TP | BY | INSP ENG | MAN-HOUR RIG | OFF | CRAN HR | INSPECTION COST ENG | RIG | OFFICE | NAME CONSULTANT |

DATA TYPE 17

| 158 | 160 | 161 * | 162 * | 163 * | 164 | 165 * | 166 * | 167 * | 168 * | 169 * | 170 * | 171 * | 172 * | 173 * | 174 * |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| HIRED BY | APPR SLAB | APPR RDWY | DECK | SUP STR | PAINT | SUB STR | CHAN | CUL RET | REM LIFE | STRC COND | DK GM | UND CLR | WATER WAY | APPR ALIGN | SAFE LOAD |

DATA TYPE 18

| 175 * | | | | | 176 * | | | | | 177 | 178 | | | | 179 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| INV RATING LOADS 1 | 2 | 3 | 4 | 5 | OPR RATING LOADS 1 | 2 | 3 | 4 | 5 | RATE METH | TYPE MEM | CAT | LOAD TYPE | STRESS RANGE | AASHTO SPECS | AASHTO MANUAL |

PROPOSED IMPROVEMENT

DATA TYPE 19

| 181 * | 182 * | 183 | 184 * | 185 * | 186 * | 187 * | 188 * |
|---|---|---|---|---|---|---|---|
| YEAR NEEDED | TYPE WORK | PRIORITY | TYPE OF SERVICE | IMPROVEMENT LENGTH | DESIGN LOAD | ROADWAY WIDTH | NUMBER LANES |

DATA TYPE 20

| 189 * | 190 * | 191 * | | 192 * | | | | |
|---|---|---|---|---|---|---|---|---|
| DESIGN ADT | YEAR ADT | ADJ ROADWAY IMPROV YEAR | TYPE | ESTIMATED COST PROPOSED IMPROVEMENT ENG | DEMO | SUBSTR | SUPSTR | OTHER |

**Figure 6. Coding form D-491F.**

D-491F (7-81)

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM
REPAIR AND PAINTING RECORD

STRUCTURE IDENTIFICATION

| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|
| ID: | DIST | CNTY | CL | APPL | RT | SPUR | EQU | STAT |

REPAIR DATA

DATA TYPE 21

| 196 | | 197 | 198 | 199 | 200 | 201 |
|---|---|---|---|---|---|---|
| REF | YEAR | DRAWING NUMBER | TYPE WORK | REPAIR COST | PGM | REPAIR DESCRIPTION |

PAINTING DATA

DATA TYPE 22

| 203 | | 204 | 205 | 206 | 207 | 208 | 209 | 210 |
|---|---|---|---|---|---|---|---|---|
| REF | YEAR | TONS STEEL | EST AREA SURFACE | NUMBER COATS | GALLONS PAINT | COLOR NUMBER | TYPE CLEANING | PAINT COST |

These additional items are comprised of bridge-engineering-related items such as rating, maintenance, painting, utilities, inspection costs, etc. These are mainly to satisfy the needs of bridge engineers for record data, maintenance activities, and bridge history. The forms for collecting and entering data to SIRS are now identified as D-491, and they are broken down as follows:

1. D-491A--general data;
2. D-491B--features data;
3. D-491C--structure data;
4. D-491D--utility, hydrology, and posting data;
5. D-491E--inspection and proposed improvement; and
6. D-491F--repair and painting.

The above forms were designed to produce a mirror image of the data shown on the screens, which helps reduce transfer errors.

Data can be updated during workdays by cathode-ray tube (CRT) terminals located in each district office bridge unit, the Bridge Division, and the Bureau for Strategic Planning.

This system is designed to store data on every bridge in Pennsylvania. The fact that the system was designed to accept a broad spectrum of bridges has caused the amount of data to be collected and stored to seem rather large. As the user becomes more familiar with the system, they realize that there will always be items that are not applicable to a given bridge. This, in effect, reduces the amount of data stored for each bridge.

Off-line reports are created by SIRS for many different uses. For example, 26 different bridge statistics reports are printed on demand (Figures 7 and 8) and are used by the Bridge Division in its reporting activities. Some reports are produced nightly for quality control and historical purposes. Other reports are created less frequently and are used as references for field work or specialized informational purposes. Still others are given to PennDOT bureaus, FHWA, and other agencies that rely on SIRS for statistical studies. Also, special reports can be generated through Mark IV programming with the Bureau for Strategic Planning and the Bridge Division, which have the capability to generate such programming.

The system has several self-checks, such as the following:

1. Errors in coding are highlighted on screens, and the system does not accept these items unless coding is corrected to conform to coding given in the coding manual, and
2. If two or more items are not compatible, cross-check errors are printed out and a message to this effect appears on screen; this alerts the person entering or updating the data and makes the correction of those types of errors easy.

Once these errors are corrected, the data in SIRS are practically error free. Errors that may be in the system and that cannot be corrected by the error-update messages could be of a technical or engineering nature. These are difficult to detect and can only be discovered through constant vigilance by district bridge units and with spotchecks, systems review, and/or on-site monitoring by the central office's Bridge Division engineers.

The system has another check that prevents the user from entering (i.e., adding) a structure if the minimum mandatory items are not entered. Those key items are as follows:

1. Agency responsible for preparing the inventory and type of service (i.e., highway over highway, highway over stream, railroad over highway, etc.), and
2. Ownership (maintenance responsibility of highway system, classification, structure length, etc.).

The sufficiency rating is calculated overnight by the computer and the revised rating is displayed on the screen the next day with an indicator (letter P for replacement, letter H for rehabilitation, and blank if structure does not qualify for replacement or rehabilitation) that tells the user if the structure qualifies for replacement or rehabilitation in accordance with FHWA criteria. Through the use of Mark IV programs, listings and statistics are generated for planning and programming purposes. These lists show defective bridges, classification of defects and conditions, and they can provide bridge listings in any order of sufficiency rating or listings by using other parameters. The system has the capability to print structure data as displayed on the terminal screen.

Future enhancements are discussed regularly and jointly between the staff of the involved bureaus (Bridge Design and Strategic Planning). Enhancement currently in various stages of implementation are as follows:

1. Historical bridges (a new requirement by FHWA)--completed;

**Figure 7. Sample report 1.**

01/03/83
PROGRAM ID: P5140410

PAGE 1
REPORT ID: SIR41001

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM

TABLE A1 HIGHWAY BRIDGES (20 ' AND GREATER)

| HIGHWAY BRIDGES CARRYING | NUMBER OF BRIDGES IN SIRS FILE | M A I N T E N A N C E R E S P O N S I B I L I T Y | | | | | | | TOTAL (COL 2 THRU COL 8) |
|---|---|---|---|---|---|---|---|---|---|
| | | DEPT OF TRANS | TURNPIKE COMMISSION | RAILROAD COMPANY | LOCAL GOVERNMENT | COMBINED AGENCIES | UNKNOWN | OTHER PRIVATE | |
| | COL 1 | COL 2 | COL 3 | COL 4 | COL 5 | COL 6 | COL 7 | COL 8 | COL 9 |
| FED AID STATE SYSTEM | 10,415 | 9,621 | 428 | 189 | 39 | 123 | 1 | 14 | 10,415 |
| FED AID LOCAL SYSTEM | 247 | 1 | 0 | 5 | 230 | 11 | 0 | 0 | 247 |
| OFF FED AID STATE SYSTEM | 5,419 | 5,237 | 69 | 82 | 12 | 12 | 0 | 7 | 5,419 |
| OFF FED AID LOCAL SYSTEM | 5,119 | 254 | 60 | 21 | 4,695 | 70 | 7 | 12 | 5,119 |
| TOTAL | 21,200 | 15,113 | 557 | 297 | 4,976 | 216 | 8 | 33 | 21,200 |

2. Security of defense-related items as recommended by FHWA--completed;
3. Introduction of priority commercial network designation--completed; and
4. Two new screens for overload rating and posting.

Enhancement to SIRS is coordinated by Strategic Planning. All modifications are tested before statewide implementation. User manuals and coding manuals are also updated.

Districts are instructed to gather additional data on a two-year cycle. The first instructions that asked for 10 new items and authorized 8 optional items were made effective with the inspection cycle that started January 1, 1983.

In addition to the main menu (Figure 9), which gives the listing of available screens, there are seven screens currently built into the system, with six screens that provide bridge data. The screens show the information that is generated from the D-491 forms, as follows:

1. Screen 1, form 491A--general data (Figure 10);
2. Screen 2, form 491B--features intersected data (Figure 11);
3. Screen 3, form 491C--structure data (Figure 12);
4. Screen 4, form 491D--utility, hydrology, and posting data (Figure 13);
5. Screen 5, form 491E--inspection data (Figure 14);
6. Screen 6, form 491F--repair and painting data (Figure 15); and
7. Screen 7 (Figure 16), which is used to enter the identification numbers of structures for printing data (this has the potential for printing data on five bridges at a push of a button).

To operate SIRS is a relatively easy task. Also, hands-on training is available through the Bridge Division or the Bureau for Strategic Planning.

Figure 8. Sample report 2.

01/03/83
PROGRAM ID: P5140440

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION
STRUCTURE INVENTORY RECORD SYSTEM

PAGE 1
REPORT ID: SIR44001

TABLE A5 NUMBER AND DECK AREA OF (HIGHWAY) BRIDGES (20 ' AND GREATER)

| COUNTY | NUMBER | SQ FT DECK AREA | % DECK AREA | COUNTY | NUMBER | SQ FT DECK AREA | % DECK AREA |
|---|---|---|---|---|---|---|---|
| ADAMS | 246 | 555,252 | 0.54 | LACKAWANNA | 355 | 2,000,222 | 1.95 |
| ALLEGHENY | 1,092 | 12,486,451 | 12.20 | LANCASTER | 687 | 3,254,468 | 3.18 |
| ARMSTRONG | 254 | 1,218,722 | 1.19 | LAWRENCE | 221 | 1,275,972 | 1.25 |
| BEAVER | 291 | 2,225,647 | 2.17 | LEBANON | 198 | 709,903 | 0.69 |
| BEDFORD | 429 | 1,373,250 | 1.34 | LEHIGH | 330 | 2,137,116 | 2.09 |
| BERKS | 588 | 2,926,211 | 2.86 | LUZERNE | 435 | 2,390,554 | 2.34 |
| BLAIR | 257 | 953,318 | 0.93 | LYCOMING | 446 | 1,717,699 | 1.68 |
| BRADFORD | 409 | 1,031,398 | 1.01 | MCKEAN | 226 | 629,142 | 0.61 |
| BUCKS | 576 | 3,619,742 | 3.54 | MERCER | 456 | 1,622,772 | 1.59 |
| BUTLER | 389 | 1,285,635 | 1.26 | MIFFLIN | 151 | 530,591 | 0.52 |
| CAMBRIA | 244 | 1,187,999 | 1.16 | MONROE | 307 | 1,164,772 | 1.14 |
| CAMERON | 52 | 127,335 | 0.12 | MONTGOMERY | 668 | 4,089,216 | 3.99 |
| CARBON | 133 | 780,132 | 0.76 | MONTOUR | 109 | 249,276 | 0.24 |
| CENTRE | 251 | 812,921 | 0.79 | NORTHAMPTON | 322 | 1,415,127 | 1.38 |
| CHESTER | 607 | 1,706,639 | 1.67 | NORTHUMBERLAND | 298 | 1,113,208 | 1.09 |
| CLARION | 192 | 868,608 | 0.85 | PERRY | 195 | 559,800 | 0.55 |
| CLEARFIELD | 302 | 1,044,086 | 1.02 | PHILADELPHIA | 382 | 11,144,024 | 10.89 |
| CLINTON | 181 | 1,224,957 | 1.20 | PIKE | 158 | 579,509 | 0.57 |
| COLUMBIA | 289 | 1,016,085 | 0.99 | POTTER | 190 | 297,900 | 0.29 |
| CRAWFORD | 397 | 1,403,650 | 1.37 | SCHUYLKILL | 362 | 1,161,051 | 1.13 |
| CUMBERLAND | 266 | 1,336,164 | 1.31 | SNYDER | 156 | 372,027 | 0.36 |
| DAUPHIN | 418 | 3,930,642 | 3.84 | SOMERSET | 427 | 1,075,394 | 1.05 |
| DELAWARE | 293 | 1,683,397 | 1.64 | SULLIVAN | 116 | 162,673 | 0.16 |
| ELK | 99 | 200,533 | 0.20 | SUSQUEHANNA | 282 | 613,325 | 0.60 |
| ERIE | 375 | 1,837,709 | 1.80 | TIOGA | 400 | 769,087 | 0.75 |
| FAYETTE | 333 | 950,755 | 0.93 | UNION | 149 | 376,638 | 0.37 |
| FOREST | 63 | 160,030 | 0.16 | VENANGO | 164 | 639,196 | 0.62 |
| FRANKLIN | 267 | 672,688 | 0.66 | WARREN | 210 | 677,384 | 0.66 |
| FULTON | 149 | 408,575 | 0.40 | WASHINGTON | 604 | 2,423,937 | 2.37 |
| GREENE | 320 | 666,104 | 0.65 | WAYNE | 255 | 435,592 | 0.43 |
| HUNTINGDON | 218 | 579,993 | 0.57 | WESTMORELAND | 531 | 2,085,780 | 2.04 |
| INDIANA | 313 | 1,050,139 | 1.03 | WYOMING | 132 | 402,348 | 0.39 |
| JEFFERSON | 216 | 617,828 | 0.60 | YORK | 590 | 1,847,565 | 1.80 |
| JUNIATA | 183 | 494,589 | 0.48 | | | | |
| | | | | TOTAL | 21,204 | 102,360,532 | 100.01 |

Figure 9. Sample screen of main menu.

SIRS MAIN MENU

ID _
PASSWORD

FUNCTION: (A=ADD, I=INQUIRY, U=UPDATE)

| | |
|---|---|
| MAIN MENU | (HIT PF1) |
| GENERAL DATA | (ENTER ID & FUNCTION, HIT PF3) |
| FEATURES INTERSECTED DATA | (ENTER ID & FUNCTION, HIT PF4) |
| STRUCTURE DATA | (ENTER ID & FUNCTION, HIT PF5) |
| UTIL, HYDRO & POSTING DATA | (ENTER ID & FUNCTION, HIT PF6) |
| INSPECTION & IMPROVEMENT DATA | (ENTER ID & FUNCTION, HIT PF7) |
| REPAIR & PAINTING DATA | (ENTER ID & FUNCTION, HIT PF8) |
| PRINT D491 A THRU F | (HIT PF9) |
| WALK THRU SCREENS | (HIT PF11) |

Thirty-minute training is normally adequate for data inquiry and browsing. Four-hour training, with an additional one week of practice, is normally adequate to provide a person with sufficient confidence to proceed with data entry.

UNDERSTANDING THE DATA

SIRS could not be designed to be a completely "user friendly" system, even though it has many headings that are shown on the screen and are self-explanatory. System data are designed to be used by bridge engineers, and the design and enhancement of the system was an add-on to the 88 required federal items, whose values are expressed in coding language.

To fully understand all data, the user must be familiar with

1. The six different coding forms (D-491), which are designed to be a mirror image of the six technical data screens;

**Figure 10. Sample screen 1.**

```
MODSIR01 V4300001              SIRS GENERAL DATA           03/17/82  09:22:13
ID: DIST CNTY CL APPL RT   SPUR EQU STAT
     08   22  1   0  00767 0   00 020831              FUNCTION: I
NEW                                                   (A=ADD, I=INQUIRY, U=UPDATE)
ID:

AGCY          LOCATION             LATITUDE LONGITUDE CTY/BOR  FAP    FED  PSU-PUC
SUBM                               DEG MIN   DEG MIN  CODE   NUMBER  FND   NUMBER
D08  SWATARA TOWNSHIP              40  155   76  490  000

DESIGN DRAWING ADD          SHOP DRAWINGS              YEAR LAST RECON     SCH  PUB
NUMBER NUMBER DRAW  NUMBER NUMBER  NUMBER  NUMBER      BUILT TYPE YEAR     BUS  TRAN
                                                       1970       0000

  OWNER/PRINCIPAL     LEG ACT      MAINTENANCE          MAINTENANCE CODE   SAFE
CUSTODIAN  AND  CODE NUMBER      RESPONSIBILITY         1  2  3  4  5  6  FEAT TOLL
PADOT                  1         PADOT                  11                1111  3

                    APPR  BRDG         BRDG    SIDEWALK
TYPE BRDG  CRIT     RDWY  RDWY         DECK  TYPE & WIDTH  DETOUR     CURVE    FIPS
SERV DESC  FAC      WDTH  WDTH FLRD    WDTH  LEFT   RIGHT  LENGTH  HORZ VERT  CODE
 61   D     *       050   0223  1      0265   000    000    02
ALL DATA HAS BEEN DISPLAYED.  NO MORE.  REQUEST MORE DATA OR SELECT NEW FUNC.
DELETE STRUCTURE
```

**Figure 11. Sample screen 2.**

```
                         SIRS FEATURES INTERSECTED DATA
ID _                        FUNCTION:   (A=ADD, I=INQUIRY, U=UPDATE)

      FEATURE    ON OR  TRAF        KIND  HWY                     ROUTE        EQUAT
REF DESCRIPTION  UNDER  ROUTE  DIR  HWY   DESC   CLASS  APPL  NUMBER SPUR  COUNT


           NO    SKEW            NAME    AAR      RAILROAD   MIN LAT CL   TTL HORZ CL
STATION   LANE  ANGLE  MEDIAN   STAT   NUMBER    MILEPOST   LEFT RIGHT    LEFT RIGHT


MIN VERT CL   VRT CL >10'   ROAD
LEFT  RIGHT   LEFT  RIGHT   SECT    DEFENSE   SECT  ADM  HWY  FUNC         ADT  VT
FT IN FT IN   FT IN FT IN   NUMB    MIPOINT   LNGH  JUR  SYS  CLAS   ADT   YEAR SGN


FHWA FEATURES INTERSECTED      FHWA FACILITY CARRIED BY STRUCTURE        NO LANES
```

**Figure 12. Sample screen 3.**

```
                              SIRS STRUCTURE DATA
ID _                          FUNCTION:   (A=ADD, I=INQUIRY, U=UPDATE)

        STRUCTURE TYPE
D S    MAIN      APPROACH    *SPAN STRUCT M SP DK      G STEEL TYPES PH CUM TK DATE
L L FHWA DEPT FHWA DEPT   MN AP LENGTH LENG TP W.S   M 1  2  3  4 VUL  TRAF  EST


                      SPANS, NUMBER AND LENGTH (MAIN AND APPROACH)
NO LENG NO LENG NO LENG NO LENG NO LENG NO LENG NO LENG NO LENG NO LENG NO LENG


REL            EXP JT TYPES    BEARING TYPE FLD LT PROB            STRANDS TENSION
JT FRM RBR  1   2   3   4    1  2  3  4   SPL  SUPER   F'CI F'C  1 2 3 4  1 2 3


      VAC  V LOC V TYPE      CNT FLD ABT  FND PIER TYPE   PIER FD SP     L PR
DRAP PROC  1 2  1 2 3 4 UTIL L L SPL N F  N F 1  2  3  4  1 2 3 4 CAP TIE SUB
```

Figure 13. Sample screen 4.

```
                         SIRS UTIL, HYDRO & POSTING DATA
ID _                        FUNCTION:   (A=ADD, I=INQUIRY, U=UPDATE)

                  UTILITY OCCUPANCIES                    LICENSE    DATE
REF            NAME OF COMPANY AND ADDRESS               NUMBER   APPROVED  FEE


                             HYDROLOGY AND NAVIGATION
  STREAM      DRAIN VERT      DESIGN FLOOD        MAX   W.S.           VERT HORIZ
   NAME       AREA  CLEAR  MAGNIT  FRQ ELEV   VEL ELEV  YEAR FISH Y/N  CL   CLEAR


                                      POSTING
C/P  WEIGHT      1ST DT LAST DT DT CLOSE        FLD  SPEC
 A   LIMIT COMB POSTED POSTED  ALL  TRAF REASON COND COND IMPACT


S1        S2        S3        S4        SUFF RATING        ELIG HBRR    EST/UPD
```

Figure 14. Sample screen 5.

```
 MODSIR06 V4300001      SIRS INSPECTION & IMPROVEMENTS   03/17/82  09:24:33
ID 08221000767000020831        FUNCTION: I (A=ADD, I=INQUIRY, U=UPDATE)
                                       INSPECTION
 DATE    NEXT   INSP   INSP  MAN-HOUR CRAN INSPECTION COST
 INSP    INSP  TP BY   ENG    RIG  OFF  HR  ENG   RIG  OFFICE   NAME CONSULTANT
120180

HIRED APPR APPR        SUP         SUB        CUL REM  STRC DK UND  WATER APPR   SAFE
 BY    SLAB RDWY DECK STR PAINT STR CHAN RET LIFE COND GM CLR   WAY  ALIGN  LOAD
            7    7    7         7    N    N   50    8   7  8     N     8     8

 INV RATING LOADS      OPR RATING LOADS     RATE TYPE      LOAD STRESS AASHTO AASHTO
 1   2   3   4   5    1   2   3   4   5   METH MEM  CAT TYPE RANGE  SPECS  MANUAL
236                   254
                              PROPOSED IMPROVEMENT
 YEAR     TYPE                 TYPE OF     IMPROVEMENT     DESIGN    ROADWAY   NUMBER
NEEDED    WORK   PRIORITY      SERVICE       LENGTH         LOAD      WIDTH     LANES


DESIGN      YEAR      ADJ ROADWAY IMPROV          ESTIMATED COST PROPOSED IMPROVEMENT
 ADT         ADT          YEAR      TYPE          ENG     DEMO   SUBSTR  SUPSTR  OTHER

ALL DATA HAS BEEN DISPLAYED.  NO MORE.  REQUEST MORE DATA OR SELECT NEW FUNC.
```

Figure 15. Sample screen 6.

```
                              SIRS REPAIR & PAINTING
ID _                           FUNCTION:   (A=ADD, I=INQUIRY, U=UPDATE)

                                   REPAIR DATA

           DRAWING   TYPE  REPAIR
REF YEAR   NUMBER    WORK   COST   PGM              REPAIR DESCRIPTION



                                  PAINTING DATA

            TONS     EST AREA   NUMBER   GALLONS   COLOR      TYPE      PAINT
REF   YEAR  STEEL    SURFACE    COATS     PAINT    NUMBER   CLEANING    COST
```

Figure 16. Sample screen 7.

```
  SIRS PRINT D491 A THRU F


ENTER STRUCTURE IDENTIFICATION NUMBER(S)

   DIST CNTY CL APPL ROUTE SPUR EQU STATION
1.  _
2.
3.
4.
5.
```

2. The coding manual (PennDOT publication number 100); and

3. A manual on inventory and inspection of bridges (PennDOT publication number 24), which includes the current federal inventory and coding guide and PennDOT supplements.

To understand the inventory rating, operating rating, and posting values, it is suggested that bridge engineers be consulted for an explanation. Reference can also be made to the 1978 American Association of State Highway and Transportation Officials' (AASHTO) manual for maintenance and inspection of bridges.

For bridge-design-related information, refer to the PennDOT design manual, part IV, and the 1977 AASHTO standard specification for highway bridges and the interim specifications for the years 1978, 1979, 1980, and 1981.

*Publication of this paper sponsored by Committee on Structures Maintenance.*

# Computer Model for Life-Cycle Cost Analysis of Statewide Bridge Repair and Replacement Needs

WILLIAM A. HYMAN AND DENNIS J. HUGHES

**The Wisconsin Department of Transportation (WisDOT) has developed a computer simulation model that uses life-cycle cost analysis, in addition to information on the structural adequacy and functional obsolescence of bridges, to determine the least-cost mix of bridge repair and replacement work for up to 25 000 bridges and up to 20 program periods. The mathematical structure underlying the replacement decision rule is partly based on the solution to an unconstrained cost-minimization problem suitable for assessing funding requirements for bridge work irrespective of budget constraints. The decision rule also depends on the condition, age, and life expectancy of each bridge. This paper presents a description of the computer model and the results of examining three policy directions for 4500 state-owned bridges for the program period 1982-1999. WisDOT is using these results for its State Highway Plan and to provide guidance in formulating its six-year highway investment program and its biennial budget proposal for bridge repair and replacement. The results indicate that WisDOT should probably replace between 27 and 38 bridges/year from 1982 through 1999, that the cost of repair work will increase more than 75 percent over the period, and that the average condition of the bridges will decline over the period if the Department minimizes the cost of repair and replacement work. The paper also discusses issues regarding implementation. One can learn to run the model with several days training, and in-house staff needed to maintain the model may be as little as one-quarter of a person-year annually.**

It is estimated that 105 000 bridges nationwide require replacement; about one-third of them are on the federal-aid highway system (1, p. 4). Assuming an average replacement cost of $300 000/bridge, current bridge replacement needs throughout the country total $31.5 billion. These are enormous costs. Are they believable?

Estimates of bridge replacement needs on state and federal highway systems are usually based on the number of bridges that have become structurally deficient, functionally obsolete, or closed. A bridge is structurally deficient if the superstructure or substructure requires immediate repairs or rehabilitation or if the ability to carry normal live loads is severely impaired. A functionally obsolete bridge has a narrow deck, low vertical clearances, or poor alignment relative to the roadway (2).

Is structural adequacy or functional obsolescence a sufficient criterion to determine replacement needs? Clearly not. By definition, a structurally inadequate bridge is in immediate need of major repairs, rehabilitation, or replacement, but it does not require replacement. Moreover, a functionally obsolete bridge may be in excellent condition and have many additional years of useful life even if it is narrow, has substandard clearances, or has poor alignment. Thus, such criteria as structural adequacy and functional obsolescence are not sufficient to determine replacement needs by themselves.

A more germane issue is whether repair or rehabilitation is more cost effective than replacement at various times during the life cycle of a bridge.

This paper reports the development and application of a computer simulation model that supplements information on the structural adequacy and functional obsolescence of structures with life-cycle cost analysis in order to determine the number of state-owned bridges in Wisconsin that will require replacement in each period from 1983 to the year 2000.

The computer model also estimates the number of bridges that will require different repairs, including concrete overlays, new decks, painting, joint work, and other minor repairs. The model calculates the cost of replacement and each type of repair work in each period and forecasts bridge condition. Results may be summarized by type of structure.

The Wisconsin Department of Transportation (WisDOT) is currently using the model to evaluate long-term bridge repair and replacement needs for its State Highway Plan (3) and to provide estimates of required bridge funding levels for the Six Year Highway Improvement Program (4) and the Department's biennial budget proposals. Other states and the federal government may find the model useful for similar applications.

## SCOPE OF PROBLEM IN WISCONSIN

In Wisconsin, there are close to 12 000 bridges. The state owns nearly 4300 bridges that carry traffic on or over the state trunk highway system. In addition, the state has both repair and replacement responsibility for an additional 200 bridges. The total of 4500 bridges under state responsibility has been the focus of this study.

The three most common structure types are steel deck girders, prestressed concrete, and concrete slabs. They represent 77 percent of all these bridges and 85 percent of the total deck area. The Department has ceased to build trusses and reinforced-concrete deck girders, which comprise most of the remaining bridges. Forty-eight percent of the 4500 bridges are on the highest functional systems: Interstates and principal arterials. Repair costs are concentrated on these structures, since they account for 57 percent of the deck area, and repair costs are proportional to deck size. The average size of bridges has been increasing over time as new bridges have been designed to constantly improve standards. Bridges on lower function and volume roads are more likely to be replaced in the next 20 years because they are generally much older than bridges that serve higher function and volume roads.

Indeed, structure age significantly influences system-level bridge needs. The average age of all