The Pennsylvania Bridge Maintenance Management System

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ABSTRACT

A Bridge Management Work Group has been organized to develop, as well as to test and implement the concepts and requirements of a total bridge management system (BMS) for Pennsylvania, using highway planning and research (HPR) funding. An electronic data processing (EDP) contractor will develop the software using other sources of funding. The system is scheduled to be fully operational by April 30, 1987. The objectives of the bridge maintenance management portion of BMS are to (a) utilize standardized bridge maintenance activities and costs, (b) store activity needs on a bridge-by-bridge basis, (c) rank activities and assign a priority to bridges for maintenance programming, (d) transfer programmed projects to the maintenance division's programming and scheduling system, and (e) store cost of completed work. The work group has the responsibility for development of a comprehensive system that (a) integrates and utilizes data from the existing structure inventory records system (SIRS) and other data bases, (b) enhances and expands the SIRS data base, (c) systematically evaluates the deficiencies and associated costs, (d) records maintenance and construction-cost history, (e) stores physical attributes of each bridge for the semiautomatic structural analysis to determine load rating, and (f) yields a spectrum of information designed to enable cost-effective management of the bridge system.

A seven-member Bridge Management Task Group was convened by Pennsylvania Secretary of Transportation Thomas D. Larson in 1983-1984 to consider the development of a bridge management system (BMS) for the Commonwealth of Pennsylvania. In its report, the group unamimously agreed that the development of such a system was feasible and a very important and urgently needed tool for better management and engineering of the state's large and antiquated system of bridges (1).

Highway planning and research (HPR) funding was secured for a work group of nine to develop the concepts, technical requirements, pilot test, and guide statewide implementation of a total BMS under Research Project 84-28. This funding covered a 12-month period from August 1, 1984 to July 31, 1985. The work group consists of five Pennsylvania Department of Transportation (PennDOT) employees and four consultants. Richard M. McClure, chairman, Pennsylvania State University; David A. VanHorn, vice-chairman, visiting scientist from Lehigh University; John M. Kruegler, consultant, formerly with FHWA; Oliver J. Weber, consultant, formerly with Bethlehem Steel; Ronald C. Arner, District 3-0 bridge engineer; Hasmukh M. Lathia and Jeffrey J. Mesaric, Fiscal and Systems Management Center; Kantilal R. Patel, Bureau of Bridge and Roadway Technology; and Jonathan D. Oravec, Center for Program Development and Management. Heinz P. Koretzky, chief, Bridge Management Systems Division, Bureau of Bridge and Roadway Technology, served as the project coordinator/manager.

The work group prepared a report that formed the basis for a request for proposal to develop software for BMS (2). The electronic data processing (EDP) contractor is to provide the development, testing, implementation, and training on the use of EDP software. Software development by the EDP contractor is being performed using other sources of funding.

The formulation of a bridge maintenance management subsystem and its integration with PennDOT's maintenance operations and resources information system (MORIS) is an important component of the overall BMS development effort.

HPR funding has been approved for the work group to continue development of BMS under Research Project 84-28A. This funding will cover a 21-month period from August 1, 1985 to April 30, 1987. The complete development of BMS, including all software and implementation is scheduled for completion during this period. At the end of this time, BMS will be operational statewide.

CURRENT SYSTEM

In the past, bridge maintenance has been generally treated as an incidental component of highway work similar to storm sewers, guide rail, and other appurtenances. Although the needs for repairing and preventively maintaining a roadway and associated features are apparent, bridge maintenance needs are more elusive. Potential problems must frequently be sought out by a trained inspector. When found, the repair treatment or, for that matter, its urgency or effect on the structural safety of the bridge, is often not obvious to the highway maintenance manager. Therefore, it is understandable that highway maintenance management systems use obvious and generalized broad activities to describe bridge work. Bridge maintenance activities included in Pennsylvania's

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current highway maintenance management system (HMMS) include the following:

- General maintenance: deck repair, structure (repair), preventive maintenance (cleaning), preventive maintenance (joint sealing), and preventive maintenance (spot painting).
- Betterments and contract maintenance: bridge painting, deck rehabilitation, structural rehabilitation, deck repair, and structure repair.

Although these activities detail the extent of bridge maintenance definition in PennDOT's current maintenance management system, many more activities are available that more definitively describe roadway work.

It is a common perception that the maintenance repair and betterment budget is heavily weighted toward providing a roadway surface that satisfies the public's expectations for riding quality, skid resistance, and year-round utility. Bridge repairs generally result in the expenditure of relatively large sums of money in a small concentrated area. Frequently, the traveling public can detect no significant change in appearance between the original and the repaired facility.

The lack of sufficient data to be able to perceive, quantify, and assign a priority to the maintenance and betterment needs of the overall highway system has in large part resulted in the allocation of funds to those areas where the needs are most visible. This, coupled with past revenue crunches related to the fuel crisis and recessionary periods, has resulted in a large backlog of bridge maintenance and betterment needs. It has also resulted in an ever-increasing magnitude of need on each bridge. In many cases, degradation of the bridge advances to the point that extensive rehabilitation or replacement becomes necessary by the time construction funding is available.

THE PENNSYLVANIA BRIDGE PROBLEM

Pennsylvania has 100 percent of the bridges on the state highway system and about 95 percent of the local (nonstate) highway system that are 20 ft or greater in length on the structure inventory record system (SIRS). Also, 100 percent of the 8- to less than 20-ft long bridges on the state system have been inventoried and recorded. However, few of these 8- to 20-ft span bridges on the local (nonstate) system have been inventoried primarily because there is no federal requirement to do so. There are approximately 52,000 highway bridges in Pennsylvania that are 8 ft or greater in length.

As of November 1985, SIRS has identified more than 7,000 bridges 20 ft or more in length as having federal sufficiency ratings less than 80 and being categorized as structurally deficient or functionally obsolete (3). A structurally deficient bridge is defined as one that has identified structural weaknesses or inadequate waterway. A functionally obsolete bridge is a bridge that has inadequate deck geometry (usually too narrow), is improperly aligned with the roadway, has insufficient vertical clearance, or has inadequate load-carrying capacity to serve today's traffic needs. Those bridges with span lengths 20 ft and greater, and a sufficiency rating less than 80, are generally eligible for federal rehabilitation funds. Those with a sufficiency rating less than 50 are generally eligible for federal replacement funds.

A summary of the bridge situation in Pennsylvania is given in Table 1. The actual number of bridges ≥20-ft long eligible for replacement or rehabilitation exceeds that shown because the inventory for the local system is still in progress.

TABLE 1 Pennsylvania Bridges and Needs

	Number of Bridges			
	Length, ≥20 ft	ft²	Length, 8 to <2 ft	ft²
State system	15,100[a]		9,500	2,360,000
Local and other systems	6,700[a]		Unknown	
Eligible for replacement	4,250	13,900,000	820[b]	262,000
Eligible for rehabilitation	3,100	13,700,000	1,450	409,000

Source: PennDOT's SIRS files, November 2, 1985.

[a]Total 109,900,000 ft².
[b]State system.

PENNSYLVANIA DEPARTMENT OF TRANSPORTATION ORGANIZATION

PennDOT has decentralized and streamlined its operations. It was reasoned that because the 11 engineering districts are most aware of the needs within their geographic areas, they are in the best position to most directly, efficiently, and responsibly serve the public. The districts are authorized to do so, with the Central Office Bureau of Maintenance administering top-level managerial control and providing policy and procedures, and quality assurance checks for the department.

The Commonwealth's 67 counties are divided among the 11 engineering districts. In each district, the district bridge engineer is the focal point for all bridge activities. This includes responsibility for the ongoing biannual inspection program on all department bridges 8 ft or more in length. Some of these bridges are on former state routes that have been turned back to the municipalities. Because of the large and long-term financial responsibility of a bridge and very limited budgets, most municipalities have not been willing to accept bridge ownership.

A bridge maintenance coordinator working for either the district bridge or district maintenance engineer is responsible for bridge maintenance activities within each district. The coordinator assists in the development of the annual PennDOT force and contract bridge maintenance programs. In addition, he prepares repair sketches and provides technical guidance and quality assurance reviews of the department force work. He is the focal point for communications between PennDOT's District Office and county maintenance offices on bridge maintenance matters. Refer to Figure 1 for a flow diagram of bridge maintenance and minor improvement activities.

EXISTING STRUCTURE INVENTORY RECORDS SYSTEM

PennDOT's current computerized SIRS is an on-line system that has been in use since 1982. Each bridge file has space for recording more than 200 data items including those mandated by FHWA (4,5).

Limited capability exists for defining the maintenance needs of a bridge in the current SIRS. The data are totally inadequate for either costing or programming purposes. The second and third digits of Data Item 182 are available to generally define the type of maintenance work that is needed. Coding is as follows:

- Second digit: Safety improvement, approach improvement, deck improvement, and various combinations of above.

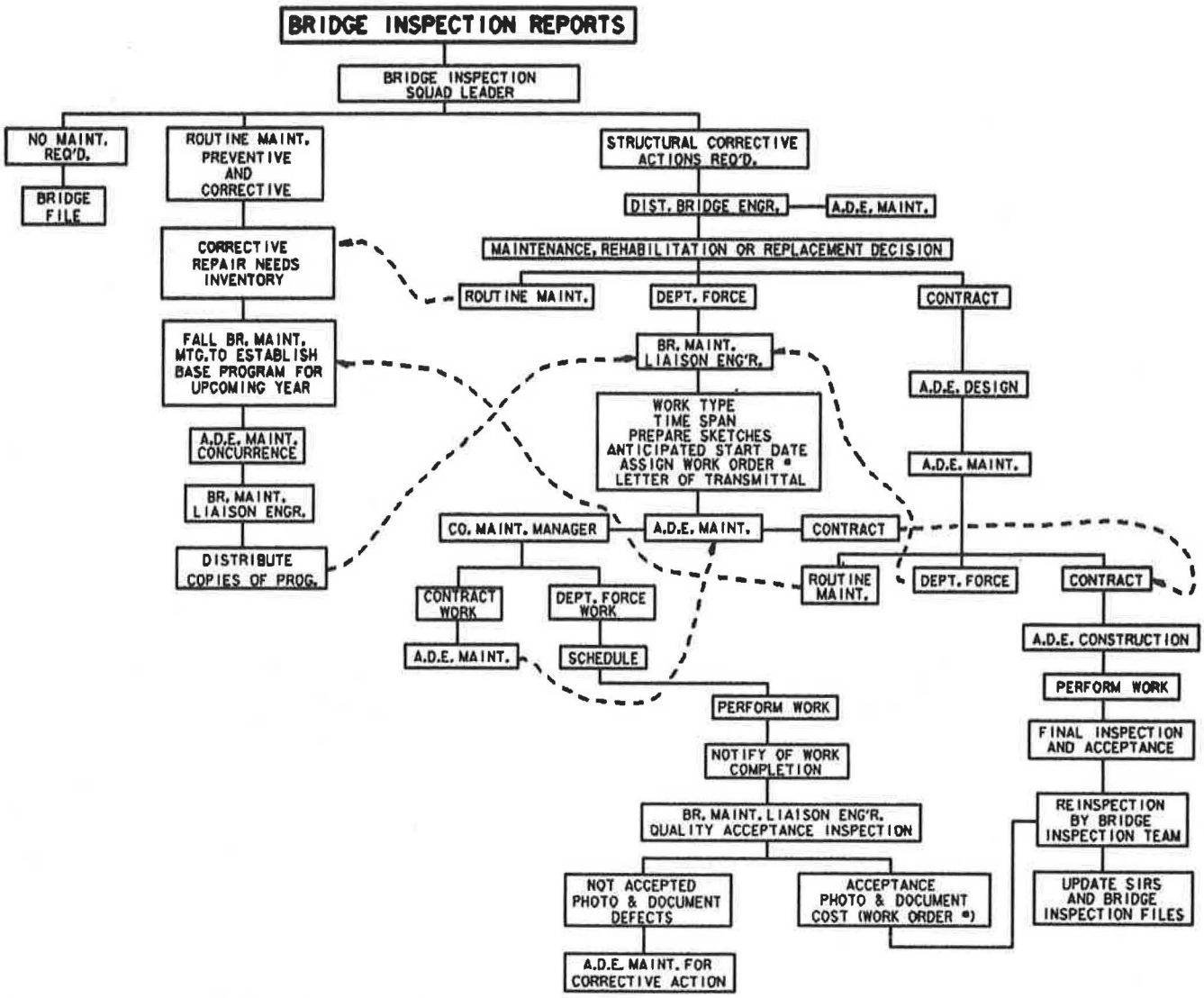

FIGURE 1 Flowchart of bridge maintenance and minor improvements.

• Third digit: Superstructure improvement, substructure improvement, waterway improvement, and various combinations of above.

The priority or urgency of the repair work is coded under Data Item 183. The available coding is as follows:

1. Emergency--within 6 months,
2. Emergency--within 12 months,
3. Priority--within 2 years,
4. Routine structural--can be delayed until funds are available, and
5. Routine nonstructural--can be delayed until programmed.

Because of the inadequacies and severe limitations of SIRS, detailed repair needs inventories must now be maintained manually. Several of the districts have begun storing some of the data on a personal computer. Sorting through the manual listings to select work for implementation by either a contractor or department forces is tedious and time consuming. Besides the inefficiency, there is the chance that structurally important or other urgent repairs will be overlooked.

AUTOMATED MANAGEMENT SYSTEMS

The need to improve the managerial control of its extensive 45,000-mi and 25,000-bridge state highway system, has prompted PennDOT to accelerate development of numerous automated systems. These systems will improve work efficiency and enable the department's declining work force to do more and to make more informed decisions. Electronic data processing development work is now underway on integrated but separate roadway and bridge management systems. Both systems are scheduled to be operational by late 1986. Figures 2, and 3 show the overall roadway and bridge management systems, respectively.

A maintenance management system is also being developed. It will integrate and enhance the existing maintenance planning, equipment, materials and personnel systems. The resulting system will be MORIS, the maintenance operations and resources information system mentioned earlier. More detailed discussion will follow.

BRIDGE MANAGEMENT SYSTEM

The BMS that is now under development will expand the existing SIRS data base, provide a data base for

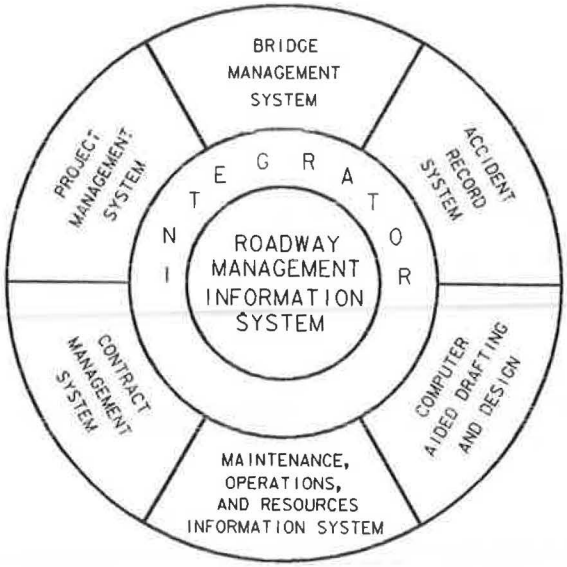

FIGURE 2 Diagram of the roadway management system.

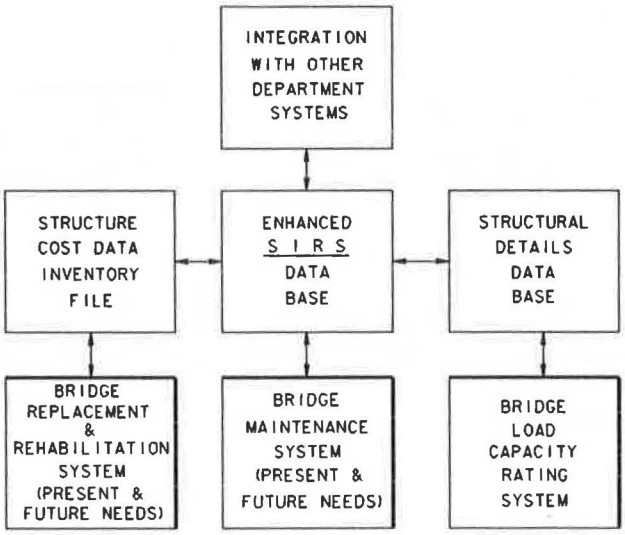

FIGURE 3 Diagram of the bridge management system.

storing structure cost data and automate the estimation of maintenance and rehabilitation or replacement needs based on a generalized scope of work definition by the user. Prioritization models are being developed to assist management in selecting and ranking bridges for maintenance as well as for major improvement.

Integration of BMS with other department systems will enable any data that are common to more than one system to be updated automatically after they are changed in the source system. The project and contract management systems and MORIS will keep BMS updated on the status of planned improvements. This will enable bridge and maintenance managers to coordinate their maintenance efforts consistent with any planned major improvements to the bridge.

BRIDGE MAINTENANCE MANAGEMENT

In formulating the concepts of a BMS, it was readily apparent that the available SIRS data related to maintenance was very general and sketchy. For PennDOT to be able to realistically assess its bridge maintenance requirements on an individual or even on a broad basis, detailed needs must be determined and quantified for each bridge.

A listing of potential bridge-related maintenance activities has been developed in consultation with the districts and the Central Office Bureau of Maintenance. This listing of 9 approach-roadway and 67 bridge-maintenance activities forms the base of the bridge maintenance portion of BMS. It is a comprehensive tabulation of common types of repairs. Activity titles are specific and descriptive. They should give the bridge inspector and the maintenance foreman a descriptive indication of the deficiency and the work that is needed to repair or remove it.

A maintenance needs form has been developed for the bridge inspector as a checkoff type of listing and as the reporting document. When a repairable deficiency is found, the inspector will review the listing, select the proper activity, circle the general location, estimate a quantity, and assign an urgency factor. The coding for the urgency factor will be the same as that currently used in SIRS. It will reflect the inspector's judgment as to how soon the maintenance activity should be completed (Figure 4).

It is anticipated that the bridge maintenance needs data will be collected as a part of the bridge inspection process. Therefore, these data will be entered into BMS's on-line individual bridge files at the same time that the inspection data are updated, that is, promptly after the inspection is completed. Figure 5 shows the general format of the BMS on-line screen where this information will be stored. Once in the computerized system, it can be extracted in any format that is required by bridge and maintenance management to satisfy their particular planning, programming, or other needs. The system is also planned to automatically notify management of any activities that have been coded an O (for critical safety deficiency) for their further evaluation and priority implementation.

BRIDGE MAINTENANCE PRIORITIZATION

The maintenance work backlog that exists far exceeds that which the PennDOT can physically and financially handle. Therefore, it is important that guidance be provided to the district and county offices to assist them in selecting the best candidate bridges for maintenance work as well as which activities to perform first. This will help ensure that those deficiencies deemed to be the most critical to the safety of the bridge and hence to its users are brought to the attention of the districts' management

A simple prioritization procedure has been developed. It considers the effect of the most structurally critical maintenance activity need on the bridge, as well as the individual bridge's impact on the road system. The components of the procedure include activity ranking, activity urgency, bridge criticality, and bridge adequacy.

Activity Ranking

The bridge maintenance activities themselves vary in their importance to and effect on the structural integrity of the bridge. Activities such as repairing stringers or repairing abutment underscour would generally be performed on a priority basis, and activities such as applying protective coatings and constructing abutment slopewalls would tend to be deferred.

As a general rule, activities that most directly,

D-488FB

COMMONWEALTH OF PENNSYLVANIA
DEPARTMENT OF TRANSPORTATION

STRUCTURE INVENTORY RECORD

BRIDGE INSPECTION REPORT

MAINTENANCE NEEDS

STRUCTURE NO. _____

INSPECTED BY: _____

DATE: _____

		ITEM NO.	LOCATION	UNIT	EST. QUANTITY	PR
APPROACH ROADWAY	PAVEMENT (PATCH/RAISE)	RDPAVMT	N F	S.Y.		
	PAVEMENT RELIEF JT. (REP/REPL)	RDRLFJT	N F	S.Y.		
	SHOULDERS (REPAIR/RECONSTR)	RDSHLDR	N F	S.Y.		
	DRAINAGE-OFF BRIDGE (IMPROVE)	RDDRAIN	N F	EA.		
	GUIDE RAIL-(CONNECT TO BRIDGE)	RDGDERL	N F	EA.		
	LOAD LIMIT SIGNS (REPLACE)	RDLDSGN	N F	EA.		
	CLEARANCE SIGNS (REPLACE)	RDCLSGN	N F	EA.		
	CUT BRUSH TO CLEAR SIGNS	RDBRUSH	N F	EA.		
	APPROACH SLAB (REPLACE)	A744201	N F	S.Y.		
CLEAN/FLUSH	DECK	A743101		E.B.		
	SCUPPER/DOWNSPOUTING	B743101	123450	E.B.		
	BEARING/BEARING SEAT	C743102	123450	E.B.		
	STEEL-HORIZONTAL SURFACES	D743102	123450	E.B.		
DECK	BITUM. DECK W. SURF (REP/REPL)	BITWRGS	123450	S.Y.		
	TIMBER DECK (REP/REPL)	B744301	123450	S.Y.		
	OPEN STEEL GRID (REP/REPL)	C744302	123450	S.Y.		
	CONCRETE DECK (REPAIR)	D744303	123450	S.Y.		
	CONCRETE SIDEWALK (REPAIR)	E744303	123450	S.Y.		
	CONCRETE CURB/PARAPET (REPAIR)	F744303	123450	S.Y.		
DECK JOINTS	RESEAL	A743301	N1230F	L.F.		
	REPAIR/RESEAL	A744101	N1230F	L.F.		
	COMPRESSION SEAL (REP/REHAB)	B744102	N1230F	L.F.		
	MODULAR DAM (REP/REHAB)	C744102	N1230F	L.F.		
	STEEL DAMS (REP/REHAB)	D744102	N1230F	L.F.		
	OTHER TYPES (REP/REHAB)	E744102	N1230F	L.F.		
RAILING	BRIDGE/PARAPET (REP/REPL)	RLGBRPR	N1230F	L.F.		
	STRUCT MOUNT (REP/REPL)	RLGSTRM	N1230F	L.F.		
	PEDESTRIAN (REP/REPL)	RLGPEDN	N1230F	L.F.		
	MEDIAN BARRIER (REP/REPL)	RLGMEDB	123450	L.F.		
DK DRAIN	SCUPPER GRATE (REPLACE)	DRNGRAT	123450	EA.		
	DRAIN/SCUPPER (INSTALL)	B744401	123450	EA.		
	DOWNSPOUTING (REP/REPL)	C744402	N1230F	EA.		
BEARINGS	LUBRICATE	A743501	N1230F	EA.		
	STEEL (REP/REHAB)	A744501	N1230F	EA.		
	STEEL (REPLACE)	B744501	N1230F	EA.		
	EXPANSION (RESET)	C744502	N1230F	EA.		
	PEDESTAL/SEAT (RECONSTRUCT)	D744503	N1230F	EA.		
TIMBER	STRINGER (REP/REPL)	A744601	123450	EA.		
	OTHER MEMBERS (REP/REPL)	B744601	123450	EA.		
STEEL	STRINGER (REP/REPL)	A744602	123450	EA.		
	FLOORBEAM (REP/REPL)	B744602	123450	EA.		
	GIRDER (REPAIR)	C744602	123450	EA.		
	DIAPH/LAT. BRACING (REP/REPL)	D744602	123450	EA.		
RC/PS	STRINGER (REP/REPL)	A744603	123450	EA.		
	DIAPHRAGM (REP/REPL)	B744603	123450	EA.		
	OTHER MEMBERS (REP/REPL)	C744603	123450	EA.		
TRUSS	MEMBER (STRENGTHEN/REP/REPL)	A744701	123450	EA.		
	PORTAL (MODIFY)	B744701	123450	EA.		
	MEMBER (TIGHTEN/FLAME SHORTEN)	C744702	123450	EA.		

		ITEM NO.	LOCATION	UNIT	EST. QUANTITY	PR
PAINTING	SUPERSTRUCTURE - SPOT	A743201	123450	E.B.		
	SUBSTRUCTURE - SPOT	B743201	N1230F	E.B.		
	SUPERSTRUCTURE - FULL	C743201	123450	E.B.		
	SUBSTRUCTURE - FULL	D743201	N1230F	E.B.		
ABUTMENT - WING - PIER, ETC.	BACKWALL (REP/REPL)	A744801	N F	C.Y.		
	ABUTMENTS (REPAIR)	B744802	N F	C.Y.		
	WING (REP/REPL)	C744802	NLRFLR	C.Y.		
	PIERS (REPAIR)	D744802	123450	C.Y.		
	FOOTING (UNDERPIN)	E744803	N1230F	C.Y.		
	MASONRY (REPOINT)	F744804	N1230F	C.Y.		
	ABUT. SLOPEWALL (REP/REPL)	A745101	N F	S.Y.		
	ABUT. SLOPEWALL (CONSTRUCT NEW)	B745102	N F	S.Y.		
	PILE REPAIR	A745901	N1230F	EA.		
EROSION CONTROL	STREAMBED PAVING (REP/CONSTR)	A745301	UPUNDN	C.Y.		
	ROCK PROTECTION	B745301	UPUNDN	C.Y.		
	SCOUR HOLE (BACKFILL)	C745301	UPUNDN	C.Y.		
	STREAM DEFLECTOR (REP/CONSTR)	D745302	UPUNDN	C.Y.		
	VEGETATION/DEBRIS (REMOVE)	ECREMVG	UPUNDN	C.Y.		
	DEPOSITION (REMOVE)	ECREMDP	UPUNDN	C.Y.		
CULVERT	HEADWALL/WINGS (REP/REPL)	A745201	IN OUT	S.Y.		
	APRON/CUTOFF WALL (REP/REPL)	B745202	IN OUT	S.Y.		
	BARREL (REPAIR)	C745203	——	S.Y.		

FOR COMPLETION BY REVIEW ENGINEER

APPLY PROTECTIVE COATING

DECK/PARAPETS/SIDEWALK	A743401	DPS	S.Y.		
SUBSTRUCTURE	B743401	N1230F	S.Y.		

CONSTRUCT TEMPORARY

SUPPORT BENT	A745401	N1230F	EA.		
PIPES	B745401	LT & RT	E.B.		
BRIDGE	C745401	LT & RT	E.B.		

LEGEND

N = NEAR
F = FAR
1,2,3,ETC. = SPAN OR PIER NUMBER
O = OTHER
NLR = NEAR LEFT OR RIGHT
FLR = FAR LEFT OR RIGHT

UP = UPSTREAM
UN = UNDER
DN = DOWNSTREAM
IN = INLET
OUT = OUTLET
E.B. = EACH BRIDGE (SITE)

PR - PRIORITY CODE

0 - CRITICAL SAFETY DEFICIENCY, PROMPT ACTION REQUIRED (INSPECTOR TO HIGHLIGHT THE DEFICIENCY)

1 - EMERGENCY, WITHIN 6 - MONTHS

2 - EMERGENCY, WITHIN 12 - MONTHS

3 - PRIORITY, WITHIN 2 - YEARS

4 - ROUTINE STRUCTURAL, CAN BE DELAYED UNTIL FUNDS ARE AVAILABLE

5 - ROUTINE NON-STRUCTURAL, CAN BE DELAYED UNTIL PROGRAMMED

FIGURE 4 Maintenance needs reporting form.

Structure Identification

MTCE. DEFICIENCY POINTS

ACTIVITY DESCRIPTION	ITEM NO.	UNIT	EST. QUANT.	EST. COST	ACTIVITY LOCATION	URGENCY	PROGRAM	
							D OR C	FY

NOTES:
EST. - ESTIMATED
EST. COST - AUTOMATED BY SYSTEM USING UNIT COST TABLE
D OR C - D = WORK BY DEPT. FORCE, C = WORK BY CONTRACT
FY - YEAR OF PLANNED ACTIVITY

FIGURE 5 Bridge maintenance activity needs screen.

immediately, and positively affect the continued safety and structural adequacy of the bridge would be performed first, and those that have minimal immediate impacts would tend to be performed later.

The activities have been divided into groups based on their generalized relative importance to the current structural stability of the bridge (Table 2). Repair or replacement of steel stringers, floorbeams, girders, or truss members could be related to existing or potential fatigue damage. If the needs are indeed fatigue related, they are more important and should be given a higher ranking. This determination can be made by comparing these maintenance-activity needs with the type of fatigue-prone member that controls the inventory load rating. SIRS Data Item 178 provides space for recording the controlling member type as well as the related fatigue and load data. If the activity is fatigue related, it will be assigned as Group AF and given additional priority.

Activity Urgency

The severity of a deficiency can be a reason to increase its priority for repair. The urgency factor for each activity need is coded by the District Bridge Inspection Unit. It yields an informed, humanized assessment of how soon the work needs to be completed. As such, it is also a measure of the severity of the deficiency.

The factor is included in the current SIRS; however, it relates only to the very generalized and broad-based maintenance needs definition limitations of the existing system. In BMS, the factor will judgmentally define the promptness of action that is needed for each specific maintenance activity need. The coding legend used is shown in Figure 4.

Bridge Criticality

The importance of a bridge to the road network as well as the effect of the loss of bridge service on traffic is another factor that must be considered in deciding the order in which bridges are to be repaired. That the road system hierarchy realistically defines importance is readily apparent. That is, if a bridge on the Interstate and a bridge on the local access system have similar deficiencies, it is obvious that the Interstate highway bridge would be repaired first. However, the impact of a bridge's closure also needs to be weighed. If the detour length is excessive and hence intolerable, the priority for repair should be raised.

The assessment of the importance of the bridge will be based on the classification of the highway, its average daily traffic (ADT), and the detour length that will be imposed on traffic if the bridge were to be closed. Multiplying the ADT times the detour length results in a partial relative measure of this importance.

The factors to be considered in evaluating the bridge's criticality then are

1. The kind of highway (e.g., Interstate, U.S. numbered highway, state highway, county highway, city, borough street, and township road);
2. The department road network indicator [e.g., priority commercial network (PCN), agri-access network, industrial access (proposed addition)]; and
3. ADT x detour length.

Bridge Adequacy

The capability of the bridge to safely carry the loads that traverse the route and to continue to do so, figure in a manager's decision of whether or not repairs should be implemented. The load capacity rating indicates the current strength of the bridge. It gives no indication of what can be expected in the future. The condition rating of the most critical component of the bridge can be used to generally assess degradation. Refer to the procedure for the

TABLE 2 Maintenance Activity Ranking

	ACTIVITY	RANK
CLEAN/FLUSH	DECK	E
	SCUPPER/DOWNSPOUTING	E
	BEARING/BEARING SEAT	E
	STEEL-HORIZONTAL SURFACES	E
DECK	BITUM. DECK W. SURF (REP/REPL)	C
	TIMBER DECK (REP/REPL)	B
	OPEN STEEL GRID (REP/REPL)	B
	CONCRETE DECK (REPAIR)	B
	CONCRETE SIDEWALK (REPAIR)	C
	CONCRETE CURB/PARAPET (REPAIR)	C
DECK JOINTS	RESEAL	C
	REPAIR/RESEAL	C
	COMPRESSION SEAL (REP/REHAB)	C
	MODULAR DAM (REP/REHAB)	C
	STEEL DAMS (REP/REHAB)	C
	OTHER TYPES (REP/REHAB)	C
RAILING	BRIDGE/PARAPET (REP/REPL)	B
	STRUCT MOUNT (REP/REPL)	B
	PEDESTRIAN (REP/REPL)	B
	MEDIAN BARRIER (REP/REPL)	C
DK DRAIN	SCUPPER GRATE (REPLACE)	D
	DRAIN/SCUPPER (INSTALL)	D
	DOWNSPOUTING (REP/REPL)	D
BEARINGS	LUBRICATE	E
	STEEL (REP/REHAB)	B
	STEEL (REPLACE)	B
	EXPANSION (RESET)	C
	PEDESTAL/SEAT (RECONSTRUCT)	A
TIMBER	STRINGER (REP/REPL)	A
	OTHER MEMBERS (REP/REPL)	B
STEEL	STRINGER (REP/REPL)	A
	FLOORBEAM (REP/REPL)	A
	GIRDER (REPAIR)	A
	DIAPH/LAT. BRACING (REP/REPL)	D
RC/PS	STRINGER (REP/REPL)	A
	DIAPHRAGM (REP/REPL)	D
	OTHER MEMBERS (REP/REPL)	B
TRUSS	MEMBER (STRENGTHEN/REP/REPL)	A
	PORTAL (MODIFY)	D
	MEMBER (TIGHTEN/FLAMESHORTEN)	A

	ACTIVITY	RANK
PAINTING	SUPERSTRUCTURE - SPOT	E
	SUBSTRUCTURE - SPOT	E
	SUPERSTRUCTURE - FULL	D
	SUBSTRUCTURE - FULL	D
ABUTMENT - WING - PIER, ETC.	BACKWALL (REP/REPL)	B
	ABUTMENTS (REPAIR)	B
	WING (REP/REPL)	B
	PIERS (REPAIR)	B
	FOOTING (UNDERPIN)	A
	MASONRY (REPOINT)	C
	ABUT. SLOPEWALL (REP/REPL)	E
	ABUT. SLOPEWALL (CONSTRUCT NEW)	E
	PILE REPAIR	A
EROSION CONTROL	STREAMBED PAVING (REP/CONSTR)	C
	ROCK PROTECTION	C
	SCOUR HOLE (BACKFILL)	C
	STREAM DEFLECTOR (REP/CONSTR)	D
	VEGETATION/DEBRIS (REMOVE)	D
	DEPOSITION (REMOVE)	D
CULVERT	HEADWALL/WINGS (REP/REPL)	B
	APRON/CUTOFF WALL (REP/REPL)	C
	BARREL (REPAIR)	B

APPLY PROTECTIVE COATING	
DECK/PARAPETS/SIDEWALK	E
SUBSTRUCTURE	E

CONSTRUCT TEMPORARY	
SUPPORT BENT	A
PIPES	B
BRIDGE	B

LEGEND

A - HIGHEST PRIORITY

E - LOWEST PRIORITY

automated estimation of remaining life given in Table 3. It is based on the summation of the condition ratings for the deck super- and substructures. If any of the ratings are four or less, they individually establish the remaining life (Table 4).

By considering both the current load capacity and the lowest condition rating of the structure's components, a measure of the inadequacy of the bridge can be obtained.

DEFICIENCY POINT ASSIGNMENT

Most of the data that will be needed to define the foregoing components of the prioritization procedure are already in SIRS. The only new items are the maintenance activities themselves and their individually assigned urgency rankings. They are important components of the proposed BMS.

Having defined the major parameters that are to be considered, the relative weights to be assigned to them and their elements must be established. To be consistent with the general philosophy of the rehabilitation or replacement prioritization system (6), a deficiency point concept (7) will also be used for the maintenance activity prioritization system. However, it is readily apparent that the factors and methodology used in each system are quite different. Although it is numerically possible for a single bridge to be assigned in excess of 100 deficiency

TABLE 3 Estimated Remaining Life of Bridges with Condition Ratings More Than 4

Bridges		Culverts	
Sum of Deck, Superstructure and Substructure Condition Ratings	Estimated Remaining Life (yr)	Culvert Condition Rating	Estimated Remaining Life (yr)
27	50	9	50
26	46	8	42
25	42	7	33
24	38	6	25
23	34	5	17
22	30	4	10
21	26	3	5
20	23	2	1
19	20	0,1	0
18	17		
17	14		
16	12		
15	10		
14	8		
13	7		
12	6		
11	5		

TABLE 4 Estimated Remaining Life of Bridges with Condition Ratings Less Than 4

Condition Rating	Estimated Remaining Life (yr)
4	10
3	5
2	1
0, 1	0

points, the deficiency point assignment will be limited to a maximum of 100. The higher the point assignment on a bridge, the higher its priority; 100 points represents total deficiency, and 0 points represents no deficiency.

Table 5 summarizes the four major components of the prioritization system, defines the elements in their makeup, and indicates the initial or trial weights that have been assigned to each. As the procedure is tested, evaluated, and refined the weight assignments could and probably will change.

The maintenance deficiency point assignment for a bridge will be based on the bridge maintenance activity that has the largest sum of deficiency points for activity ranking and urgency. The bridge's deficiency point assignment and the bridge's county ranking for maintenance based on the deficiency point assignment will be recorded on the bridge maintenance activity needs screen. Therefore, when a manager views the subject screen for individual bridges, an immediate indication of the relative priority of the most critical repair need on one bridge compared to another bridge and to the worst possible case (100 deficiency points) is available.

With a deficiency point assignment stored in BMS for every bridge, listings in priority order can be easily generated using the particular parameters desired. To facilitate this reporting, user-friendly preprogrammed report generators with user-defined variables will be developed.

A listing of bridges in priority order to be repaired can be generated for review by the district and county maintenance managers and for their use in developing the annual bridge repair programs. Once programmed, the activity needs screen can be updated to reflect whether work is to be done by department force or contract and the date of implementation scheduled.

MAINTENANCE MANAGEMENT

PennDOT is developing a MORIS to assist its Maintenance Organization to plan, implement, and effectively manage activities. The system combines various existing material, equipment, manpower, and planning subsystems and further enhances their combined capabilities. Figure 6 shows an overview of the system.

It is envisioned that when the BMS is told that a certain activity or activities on specific bridges are programmed for implementation by department forces, a copy of the data will be transmitted to the planning file in MORIS. The maintenance manager can then review and transfer the data to their annual and periodic work plans within MORIS.

MORIS will generate the daily crew payroll form, filling in the bridge location identifier plus the cost function and method (Activity Number) for the work that is to be performed. It should be noted that, initially, only 35 of the 76 maintenance activities identified on the needs reporting form are being assigned cost functions. Therefore, for cost-accounting purposes, activities without a valid cost function will have to be grouped with a similar activity that has an approved cost function.

During the actual implementation of the work, labor, use and cost of equipment, and materials are tracked daily from the crew foreman's payroll. The activity, quantity, and the cost of work performed will be reported to the individual bridge file in BMS on a daily basis. A running total quantity and cost will be maintained until notification is received from MORIS that the activity is completed. The completion date of each activity and the final quantity and its cost will then be kept for historical record purposes. Figure 7 shows the general format of the BMS on-line screen where these data will be stored. Following this, the needs-inventory portion of the bridge file can be automatically updated to eliminate those programmed activities that have been completed.

CONTRACT MAINTENANCE WORK

As part of the overall BMS development, a three-digit code has been developed to detail major improvement (rehabilitation or replacement) needs and work (6). The number inserted in the first digit indicates the type of work to be performed on the deck, the second digit relates to the superstructure, and the third to the substructure. Because this code is being incorporated into PennDOT's contract management system and may be included in the project inventory and program management systems, it will also be used as a general indicator that maintenance type work is to be performed. An R or similar indicator can be placed in the digit corresponding to the bridge component where work is to be done.

Use of the aforementioned code will allow the development and implementation of contract maintenance projects to be easily tracked and BMS to be kept informed of their new status. Although this system will monitor progress of a contract maintenance project, it will not definitively indicate the type or extent of work. To determine this, the user has to manually review the plans, contract document, or the automated structure cost data file. On completion of the work, BMS will be notified that contract maintenance-type work has been completed and

TABLE 5 Maintenance Deficiency Points Assignment

Component	Maximum Deficiency Points	Element	Deficiency Point Assignment
Bridge maintenance activity rank	40	Group AF[a]	40
		A	25
		B	20
		C	15
		D	10
		E	5
Activity urgency factor	25	Code 0	25
		1	20
		2	15
		3	10
		4	5
		5	0
Bridge criticality	25		
Part A: Interstate			5
U.S. numbered highway			4
State highway			3
County highway			2
City, borough street, or township road			1
Part B: PCN			5
PCN or coal haul			5
Agri-access network			3
Industrial access			3
Part C: ADT x detour length			
≥30,000			15
≥15,000 but <30,000			10
≥3,000 but <15,000			5
<3,000			0
Bridge adequacy	25		
Part A: Lowest condition rating			
≤3			15
>3 but ≤4			10
>4 but ≤5			5
>5			0
Part B: Load capacity (individual rating)			
H configuration ≤12 tons			10
>12-19 tons			7
ML 80 configuration >19-30 tons			4
>30 tons			0

[a] AF = Group A, activity that is fatigue prone and controls the inventory rating.

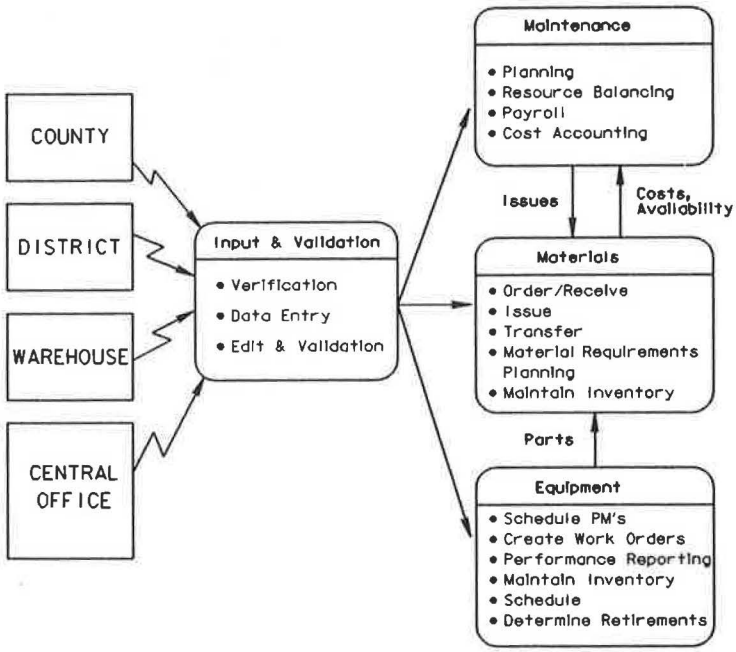

FIGURE 6 Maintenance operations and resources information system overview.

Structure Identification

DATE REPORTED	ITEM NO.	UNIT	ACTUAL QUANTITY	ACTUAL COST

FIGURE 7 Completed bridge maintenance activities screen.

its cost. To construct a more detailed historical record, the work has to be manually matched to activities and quantities, and costs determined.

PREVENTIVE MAINTENANCE AND CYCLIC NEEDS

The extent and frequency of some repetitive and age-associated preventive maintenance, routine maintenance, and minor rehabilitation needs and their effects on service life are conceptually known from generalized experience. However, this work must be blended with the other identified needs to arrive at an overall balanced program.

The repetitive need cycle or bridge age when certain bridge maintenance and minor rehabilitation needs develop can be generalized as given in Table 6. Annualized funding needs can be generated and considered in conjunction with the tabulated existing bridge maintenance needs to allocate maintenance monies.

TABLE 6 Need Cycles for Bridge Maintenance and Minor Rehabilitation

Activity	Frequency (yr)
Structural steel painting	12
Deck rehabilitation[a]	
Bridge	20
Deck, condition rating	≤5
Deck joints cleaning and resealing	5
Scuppers cleaning	1
Deck cleaning	1
Breakdown maintenance[b]	2
Timber deck replacement	15

[a] For unprotected decks or uncoated reinforcement.
[b] Carried out on bridges in poor condition until rehabilitation or replacement.

As historic activity and cost completion data are accumulated, the frequencies given in Table 6 can be revised, expanded, and perhaps categorized by highway system, level of maintenance, and so on. In addition, the effects on the service life of the bridge can be assessed, and eventually, life-cycle costing models can be developed.

SUMMARY

Various computerized highway management and information systems are scheduled to be implemented by late 1986. These will give PennDOT comprehensive and powerful tools to improve the effectiveness, efficiency, and depth of its managerial control over the Commonwealth's highway system and will help ensure that the department's limited financial and human resources are used to maximize the benefits to and safety of the traveling public.

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