Managing Minnesota's Bridges

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The process that is presently used, and that is anticipated to be used in the future, to manage Minnesota's limited bridge resources is explained. Present bridge management history and policies including present inspection methods, computer tools that are available, present priority-ranking methods for bridge replacements, and the relationship between the Minnesota Department of Transportation (Mn/DOT) and local governments are discussed. Future bridge management practices including Pontis bridge management system (BMS) implementation, element-level inspections, the Minnesota case study in moving to the use of Pontis, new funding processes as a result of the Intermodal Surface Transportation Efficiency Act (ISTEA), and how these factors will tie together for managing bridge resources in the 21st century are covered. In 1994 Minnesota began the process of implementing the Pontis BMS. Before that time all bridge inspections were based on National Bridge Inspection Standards and management decisions were guided by a Minnesota priority-ranking system, (FHWA) sufficiency ratings, Minnesota published improvement guidelines, and engineering judgment. Minnesota has used computer software programs extensively to record and store field inventory and inspection data, which has substantially reduced the amount of paperwork required during each inspection. With the advent of the Pontis BMS, inspection coding is changing and new data collection software has been developed. As a result of ISTEA, Minnesota has established area transportation partnerships that develop the statewide transportation improvement program. Outputs from BMS will provide information to be used in the selection of appropriate bridge projects and bridge maintenance activities. The outputs necessary to plan a bridge preservation and improvement program include overall conditions, estimates of bridge needs, future conditions assuming certain levels of expenditure, and identification of activities with high benefit-cost ratios. This information will best be illustrated through graphs or charts. Bridge management is another tool that can be used to assist in the definition of bridge programs, so even with the introduction of system analysis, engineering judgment will continue to be a part of the process. In the future integration will occur among the various management systems (pavement, safety, etc.). Limited integration exists at this time in Mn/DOT, and preliminary thoughts on extensive integration of these systems and level-of-service goals are described.

A bridge management system (BMS) is required by the 1991 Intermodal Surface Transportation Efficiency Act (ISTEA) and FHWA regulations mandating that states use management systems in an effort to optimize transportation resources. BMS is defined as a rational and systematic approach to organizing and carrying out all of the activities related to providing programs for bridges vital to the transportation infrastructure.

Bridge Management in Minnesota

A simplified BMS has been in place in Minnesota since the late 1960s with the start of the bridge inspection and inventory system. This system has worked well for identifying bridges that are in need of replacement and rehabilitation and has provided valuable information for preservation activities; however, there has not been a way to compare the relative benefits of proposed actions, nor has there been a way to determine appropriate life-cycle costs or to trace deterioration rates.

Criteria for certain types of maintenance and rehabilitation work are currently provided in the Minnesota Department of Transportation (Mn/DOT) *Bridge Improvement Guidelines* on the basis of condition and level of service. Examples of such criteria are

- Conditions when spot painting and complete repainting are appropriate,
- Conditions when deck replacement is appropriate,
- Conditions when joint replacement is appropriate,
- Conditions when deck overlays are appropriate, and
- Conditions and functionality when railing replacement is appropriate.

Examples of painting guidelines and deck repair/replacement guidelines are shown in Figure 1.

Eligibility for the funding of bridge projects and the determination of project scope varies depending on the types of funds used as well as on the condition and geometrics of the bridge. For example, bridge projects funded through the Highway Bridge Replacement and Rehabilitation Program must meet federal requirements for sufficiency rating, whereas bridge projects funded under the National Highway System or Surface Transportation Program categories do not have such requirements. Determinations of rehabilitation versus replacement are made on the basis of a comparison of the construction cost of rehabilitation versus the cost of a totally new bridge. The policy in Minnesota is to maximize the life of each bridge and improve geometrics and load capacity when they are economically feasible.

The sufficiency rating is used as a guideline for replacement priority even if federal funding is not involved. This FHWA formula is based on geometric, traffic, and condition data relative to each bridge (*1*). A report listing the bridges on the various road systems (trunk highway, county, township, city) is generated twice each year, listing bridges by increasing sufficiency rating number. Before the development of the FHWA sufficiency rating formula, Minnesota had developed a formula called the Replacement Priority Criteria (RPC), which uses safe load appraisal rating, average daily traffic (ADT), deck geometry appraisal, structural condition appraisal, and approach roadway appraisal as well as a factor for the age of the structure. The RPC rating was used to generate a statewide ranking of bridge replacement projects and to determine eligibility for replacement funding before the development of federal sufficiency formulas and current management systems. The RPC is not currently used as a criterion for funding, but it is still generated and is shown on the priority lists described earlier.

Weaknesses in Procedures Before BMS

The procedures used before the Pontis BMS identified and ranked bridges that were in need of replacement or rehabilitation, but they did not consider the life-cycle costs of bridges, nor did they define cost-effective actions to be taken during the life of the bridge. These procedures did not consider the remaining life of a bridge or compare the expected life with those of other bridges needing replacement or rehabilitation. Additionally, they did not have the ability to forecast the annual investment needed for a defined level of bridge preservation or replacement activities.

Present Inspection Process

Minnesota state regulations require annual inspections of all structures greater than 10 ft in length. These inspections are performed by several different levels of government. The Mn/DOT district offices are responsible for the inspection and inventory of 4,600 state-owned bridges. Eighty-seven Minnesota counties are responsible for the inspection and inventory of 13,900 bridges owned by the county, township, and cities with populations of less than 5,000. Minnesota cities with populations of greater than 5,000 are responsible for the inspection of 990 bridges. Other agencies in Minnesota such as the National Forest Service, the Bureau of Indian Affairs, and State Forest Roads are responsible for inspection and inventory of 180 bridges. This makes a total of approximately 19,670 bridges in Minnesota of 10 ft or greater in length.

With the advent of the Pontis BMS and the change to element-level inspections, Minnesota began a transition phase. During 1994 all Mn/DOT districts performed element-level inspections, whereas all counties and cities recorded information by National Bridge Inventory (NBI) methods. Local governments have been trained in element-level inspections and will begin element-level inspections in 1995. The element-level inspections and an outline of how Minnesota transitioned to the Pontis BMS are explained in greater detail later in this paper.

Computer Hardware and Software

The capabilities and affordability of personal computers (PCs) have increased the use of automation in procedures that previously required manual recording. The

Guidelines for Deck Repair/Replacement by Contract

Priority guidelines are based on the premise that:

1. Overlays are placed on basically intact decks as a protective measure, or
2. Deck replacements are deferred until full deck removal and replacement is warranted.

The following general categories and procedures have been established for deck repair projects:

Category	Deck Condition	Procedure
I	0-5% Unsound (Slight Scarify, deterioration)	Spot removal and 2" low slump concrete overlay or 1 1/2 latex modified concrete overlay
II	5-20% Unsound (Moderate)	Scarify, spot removal and 2" low slump concrete overlay
III	20-40% Unsound (Severe) Only non-interstate highways < 10,000 ADT & bottom of slab sound	100% removal of surface down to reinforcing bars and minimal spot removal below reinforcing bars. Overlay with 3" of low slump concrete
IV	40+% Unsound (Critical) (20+% on Interstate of > 10,000 ADT)	Schedule new deck after usable life of inplace deck is expended. May require bituminous overlay to maintain rideability.

Guidelines for Bridge Maintenance Painting

The guidelines for bridge maintenance painting are based primarily on preserving the structural integrity of steel bridges in the most cost effective and practical manner possible:

Paint Condition	Procedures	PRIORITY	
		Contract	Mn/DOT
(% Unsound)			
0% - 5%	Sandblast isolated areas. Apply two prime coats to all areas where paint was removed.	4	1
6% - 20%	Sandblast isolated areas. Clean all structural steel. Apply two prime coats to all sandblasted areas. Apply two finish coats to areas severely exposed, one finish coat to all other areas.	3	2
21% - 40%	Sandblast isolated areas. Clean all structural steel. Place two complete prime coats and two finish coats on all members.	2	3
More than 40%	Remove all inplace paint and rust per SSPC-10, Near White Blast. Repaint with complete zinc-rich paint system.	1	4

FIGURE 1 Bridge repair guidelines.

advent of networking and modems has allowed data sharing and electronic data transfer, both of which provide increased capabilities for bridge personnel. Two PC programs have been developed in Minnesota and are being used to help in the data collection effort: the Minnesota Bridge Inventory PC System (MBIPS) and the Bridge Inspection Program (BIP).

MBIPS Program

The MBIPS program was written in 1988 as a means to allow bridge inspectors to electronically record inventory information on all bridges in their jurisdiction, obtain reports on those data, and electronically transfer the data to the central office for review. The program was written in Basic, and despite other higher-level languages and data bases available today, it has still proven to be a very effective program. Many summary reports are available from this program, both for screen viewing and as hard copy. The most comprehensive of these reports is the Structure Inventory and Appraisal Sheet, which contains 150 data elements. A sample inventory report form is shown in Figure 2. Examples of other summary reports that are available include lists of bridges by sufficiency rating, by inspection date, by con-

1994 MINNESOTA DEPARTMENT OF TRANSPORTATION - STRUCTURE INVENTORY

COUNTY JURISDICTION 09-28-1994

Suff Rating 23.2 S.D. Status

*** IDENTIFICATION ***

Br.No. ________ 2157 ____

District 3 Maint Area __

County AITKIN

City ____________________

Township LIBBY

CSAH 36 MAIN LINE
Route Number Function

Rdwy Type 2 WAY ROAD

STREAM
Name of Feature Crossed

0.2 MI NE OF JCT TH 65
Descriptive Location

Sec 01 Twp 050 Rge 24W

Reference Pt 010+00.980

46deg 50'48" 93deg 20'06"
Latitude Longitude

Detour Length . . . 16 Mi

COUNTY COUNTY
Maint Resp Owner

Nat'l Hwy System . . NO

08 RURAL MINOR COLLECTOR
Functional Classification

Year Built 1916 Rem ____

Date Open to Traffic _____

Lanes ON Br 02 UNDER __

25 1988
A.D.T. ~~Hcadt~~ Year

Rdwy Appr Width 024 024
Shld Surf

Median __ ___ Skew 00

Defense Sys NO Temp. ___

Plan Available COUNTY

*** STRUCTURE DATA ***

15 HWY/STREAM
Type of Service

Type Main Span . . 301
STEEL BM SPAN

Type Appr Span . . ___

Fract
Critl NON-APL ___ _____

Specl
Feat ~~Member~~ ~~Proc~~ ~~Date~~

~~Culvert Type~~ ~~Length~~ Ft

No Spans 01 001
Main Appr Total

Length 20.0 23.3 Ft
Max Spn Total

Sdwlk Wid Lt ____ Rt ____

Rdwy Width OVER 17.2
If Divided Nb-Eb ~~Sb-Wb~~
Deck Width (Out-Out) . . 019.0 Ft

Vert Clear Over ____ Ft ____ Ft

Vert Clear Under ____ Ft ____ Ft

Max Vert Clear ____ Ft ____ Ft

Underclear Lat Rt ____ Lt ____

Type Wearing Surface GRAVEL

Depth of W.C.& Fill . . 00.33 Ft

~~Deck Protection System-Yr~~ ____

Coated Rebar ________ ____

RAILINGS: TYPE 32 32

Condition 3 3

Base Height 3'06" 3'06"

Curb Height . . 06" 06"

Approach Guardrails 0

*** SUBSTRUCTURE DATA ***

Abut CONCRETE FTNG/PILE

Pier ~~Mater'l~~ NON-APPLY Foundat'n

*** WATERWAY DATA ***

A08/90 J/92
UW Insp Scour ~~Dr Area~~

Waterway Opening 126

Navig Cntrl/Prot NO __

Vert ___ Horiz ____

*** APPROACH PANELS ***

Near ON _ __

Far ON
Type Cond Length

*** PAINT DATA ***

Yr Pntd ____

Type . . __

Area ______

% Unsound __

*** EXPANSION * * DEVICE ***

Type . . . NN

Condition _

Yr Instl __

*** CAPACITY RATINGS ***

Design Load . UNK/OTH

Operating . . H 10.0

Inventory . . H 07.3

Posting . 10 -TON

Rating Date . . 01/88
Need New Rating NO

*** CONDITION CODES ***

443 401
Structure Area Rdwy Area

Deck CONC/CIP 05.00 6
Material %Unsd
Superstructure . . . 3
Substructure 3
Channel & Protection 4
Culvert & Wall . . N

Inspection Date 10/20/93
Insp. Freq. 12 Plan __

*** APPRAISAL RATINGS ***

Structure Evaluation 2

Deck Geometry . . . 3
Underclearances . . N
Safe Load Capacity 2
Waterway Adequacy 8
Approach Alignment 5

*** * BRIDGE SIGNS * ***

Posted Load 1 Traffic 0
Horizontal 3 Vertical N

*** IMPROVEMENT DATA ***

Prop Work REPLACE COND
Prop Structure BRIDGE

Length 51 Width 24
Proj ADT 30 Yr 2011

Appr Rdwy Work REGRADE
Bridge Cost $ 55,000
Appr Cost $ 11,000

Project Cost $ 66,000
Year of Data 1990 (I)

FIGURE 2 Structure inventory and appraisal sheet.

dition, and by route system and lists of fracture-critical, load-posted, or scour-critical bridges. MBIPS includes six different screens that allow input and editing of 200 data elements. These six screens group common data elements together.

Effort has been made recently to rewrite MBIPS by using expert system logic to enable better edit checks. Expert system logic or artificial intelligence means that technical expertise and experience in reviewing bridge data are coded into formulas to show relationships between data elements. These formulas can identify data inconsistencies that will improve data reliability. Among the benefits to be gained in using the new program will be (a) a data base compatible with Mn/DOT standards for relational data bases, (b) expert logic that eliminates some errors found in data submittals at the present time, and (c) a system compatible with Windows for ease of operation.

BIP

BIP was written in 1988 in an effort to eliminate the repetitious data and comment recording necessary during bridge inspections. Mn/DOT inspection forms contain space for recording inspection data and comments on bridge deficiencies. Bridge inspectors have found that many comments are repeated from year to year. BIP was written to eliminate the need to rewrite comments and as a means to provide summary reports on inspection data.

BIP is divided into three major parts. The first part gives general information about bridge location and type. The second part provides information about the type of elements and the conditions of elements on a bridge. The third part enables the inspector to record detailed information regarding the conditions and locations of defects. An example of an Mn/DOT NBI inspection report form is shown in Figure 3, and a Mn/DOT Pontis BMS element-level report form is shown in Figure 4. The condition portion of the form is automatically updated with the previous year's inspection data, and the inspector has to revise those values that have changed since the previous inspection. This eliminates some of the repetitious data entry previously encountered and also reduces the chance of data entry errors.

Reports available from BIP include the inspection report as well as lists of bridges that meet certain criteria. These criteria can be selected by using ad hoc selection criteria or by selecting certain data elements and the range of values for which outputs are desired.

Data Transfer

One of the largest benefits of automating bridge inspection and inventory data is the ability to transfer data between programs and between local and central data bases. To provide the ability to transfer data into the Pontis BMS, a file that is compatible with the required Pontis input file is created. With increased use of relational data bases, all data recorded and stored for bridge purposes can be exchanged with other programs.

The Mn/DOT Office of Bridges and Structures is responsible for maintaining a central bridge data base and submitting the data to FHWA. All information stored on district, county, and city computers is transferred electronically to the Office of Bridges and Structures data base. Data transfer from the counties is done via network modems and eliminates the need for the transmission of floppy disks. Data transfer from Mn/DOT districts to the Office of Bridges and Structures is done via statewide optical transmission lines. Program updates are also transferred by these methods.

The main data base remains in a flat file format on a mainframe computer. Data are downloaded to and uploaded from the local agency computers at least once per year. Statewide reports are still run by using the mainframe data base, although many options are available locally on PCs. Mn/DOT is considering moving to a relational data base such as Oracle in an effort to improve data sharing between various transportation users. Data would be stored on a network instead of on a mainframe. This would reduce costs for data storage and report generation and would eliminate the need for double entry for data such as traffic counts and accident locations.

Hardware

Computer hardware requirements change with the advent of more powerful software. With the move toward the Windows operating system, relational data bases, and higher-level programming tools such as the C language, it is recommended that a minimum configuration of an International Business Machines 486 machine with 66 MHz and 8 MB of random access memory be provided in each agency.

Many Minnesota inspectors are using laptop computers for recording field data. Both the MBIPS and BIP data collection programs can be loaded onto the laptop computer and, with the use of Windows, can be accessed simultaneously. The method most often used is to take a hard copy report to the bridge site, mark any changes from the previous inspection onto the sheet, and then enter the changes into the computer while at the bridge site or while in transit to the next bridge location.

One problem with laptop computers is that they are difficult to carry onto the bridge site. One new technology being considered is the use of palm pad- or pen-based computers. It is anticipated that the easier port-

Mn/DOT OFFICE OF BRIDGES AND STRUCTURES

Bridge No.: 1241 Bridge Inspection Report Jun 18, 1993 Sheet 1 of 1

Road System:03 MNTH	County :19 DAKOTA	Location:2.8 MI W OF FARMINGTON
Road Number:50	Load Posting(Tons) :LEGAL	Feature Crossed:DITCH
City:	Reference Point :06.724	Bridge Type :W104 113 CONC BOX CULV
Township:	Deck Area (Sq.Ft.) :	Min. Vert (Und/Und) :
Maint. Area / District: 9A	Painted Area (Sq.Ft.) :	Min. Vert (Over/Over) :
Control Section :1914	Crew No. :2	Inspection Classification :A

NO	ITEM	RATINGS				%PCT	QUANT	UNIT
	SUBSTRUCTURE	N	N	N	N			
1	Abutments	N	N	N	N			
2	Piers	N	N	N	N			
3	Bridge Seats	N	N	N	N			
	SUPERSTRUCTURE	N	N	N	N			
4	Trusses	N	N	N	N			
5	Girders	N	N	N	N			
6	Floor Beams	N	N	N	N			
7	Stringers or Beams	N	N	N	N			
8	Bearing Devices	N	N	N	N			
9	Arches	N	N	N	N			
10	Fascia Beams	N	N	N	N			
11	Diaphragms	N	N	N	N			
12	Spandrel Columns	N	N	N	N			
	DECK	N	N	N	N			
13	Structural Slab	N	N	N	N	00	0	sqft
14	Wearing Surface	7	7	7	7			
15	Curb & Walk	N	N	N	N			
16	Railing	N	N	N	N			
17	Expansion Joints	N	N	N	N			
18	Bridge Deck Drains	N	N	N	N			
19	Median	N	N	N	N			
	AREA UNDER BRIDGE	6	6	6	6			
20	Channel & Protection	6	6	6	6			
21	Fenders	N	N	N	N			
22	Roadway,Railway,Other	N	N	N	N			
23	Slopes & Berms	8	8	8	8			
	CULVERT & WALL	7	7	7	7			
24	Barrel & Floor	7	7	7	7			
25	Apron,Wingwall,Headwall	7	7	7	7			
	APPROACH ROADWAY	N	7	7	7			
26	Approach Near (S or W)	N	7	7	7			
27	Approach Far (N or E)	N	7	7	7			
	OTHER	7	7	7	7			
28	Signing	N	N	7	7			
29	Retaining Wall	N	N	N	N			
30	Guardrail	7	7	7	7			
31	Fence	N	N	N	N			
32	Paint	N	N	N	N		0	sqft
33	Plow Straps	N	N	N	N			
34	Drainage	8	8	8	8			
35	Miscellaneous	N	N	N	N			

COMMENTS

Bridge 1241 Year 93

(14) 1/4 to 3/4 inch wide cracks in bit need to be sealed.

(20) [1989] Apron washout 18 inch deep, South end, 10 inch deep North end.

(24) [1987] 50 SF spalled floor. Barrel has 1/16 inch vertical crack in walls and top along C/L of roadway.

(25) SE wing spalled, broken off at apron. South headwall 12 SF moderate spall. Light scaling on wings and headwalls. 10 SF of 1/16 inch deep scale. 6 SF of 2 inch spall on top of wingwall at SW corner. 4 SF of 3/4 inch deep spall on South headwall.

(26/27) [1991] NUMEROUS CRACKS IN BIT ROADWAY.

(28) [1988/92] No Type 2 culvert markers.

(30) 33 FT-2 inch from face to face of plate beam

INSPECTOR		YEAR	REVIEWED BY	
R EDGELL	KRJ	1990	ROGER SCHULTZ	17JAN91
N GUSTAFSON	JWH	1991	ROGER SCHULTZ	31JAN92
L KELLER	JLA	1992	ROGER SCHULTZ	20FEB93
T FLYNN	PAK	1993	ROGER SCHULTZ	07FEB94

FIGURE 3 NBI inspection data collection form.

Mn/DOT OFFICE OF BRIDGES AND STRUCTURES

Bridge No.: 6808 Bridge Inspection Report Sep 28, 1994 Sheet 1 of 2

County:50 MOWER	Road System:01 ISTH	Crosses:EB OVER TWP RD & TURTLE C
Control Section:5080	Road Number:90	Location:0.9 MI W OF W JCT TH 218
City:	Ref. Point :176.585	Load Posting(Tons):LEGAL
Township:008 LANSING	Local Bridge Num.:	Length: 243 Width: 44.2
Maint. Area / District:6B	Crew Number:	Deck Area (Sq.Ft.):
Sec: 33 Twp: 103 Rge: 18W	Inspection Class:A	Painted Area (Sq.Ft.):
Bridge Type:501 4 PREST CONC BEAM SPANS		Min. Vert. (Under):
		Min. Vert. (Over):

NO	ELEMENT	ENV	QTY	UNT	YR	CONDITIONS 1	2	3	4	5
9	Prest Conc Girder	3	2215	LF	93	85%	_%	15%	_%	
					94	85%	_%	15%	_%	
41	Rein Conc Pier Cap	3	133	LF	93	95%	5%	_%	_%	
					94	90%	10%	_%	_%	
58	Reinf Conc Column	3	9	EA	93	9				
					94	8	1			
62	Rein Conc Abutment	3	88	LF	93	85%	15%	_%	_%	
					94	80%	20%	_%	_%	
90	Strip Seal Exp Jt	3	82	LF	93	100	_%	_%		
					94	100	_%	_%		
91	Pourable Joint	3	160	LF	93	100	_%	_%		
					94	50%	50%	_%		
92	Compression Joint	1	56	LF	93	100	_%	_%		
					94	100	_%	_%		
95	Elastomeric Brg	1	4	EA	93	4				
					94	3	1			
96	Movable Bearing	3	33	EA	93	28	5			
					94	28	4	1		
98	Fixed Bearing	1	20	EA	93	20				
					94	20				
100	Conc Appr Panel	3	2	EA	93	2				
					94	2				
102	Concrete Railing	3	486	LF	93	90%	10%	_%		
					94	90%	10%	_%		
122	Conc Deck &RigidOL	3	1	EA	93		1			
					94		1			

OTHER ITEMS	93	94
180 Channel & Protection	8	7
181 Signing	1	1
182 Guardrail	3	3
183 Plowstraps	N	N
184 Drainage	1	1
185 Slope Protection	2	2
186 Curb & Walk	N	N
187 Roadway Over	N	N
188 Miscellaneous	N	N

SMART FLAGS	93	94
108 Scour	N	N
109 Traffic Impact	N	N
156 Fatigue Cracking		N
157 Pack Rust	N	N
158 Deck Cracking	1	1
159 Under Deck	4	4
160 Substruct Movmnt	N	N

INSPECTOR	YEAR	REVIEWED BY
RCP	1993	
RCP	1994	

COMMENTS

*Bridge 6808

41. All pier caps have several transverse cracks beneath them. Some small holes with rust stains, in side faces of pier caps.

9. Bottom ends of Span 4 girders, over Pier 3, have spalled off concrete. Several Span 2 girders appear to have longitudinal cracks in the bottom of their lower flanges.

96. & 98. Some bearing devices getting quite rusty.

62. Minor vertical cracks in face of each abut. (7 at east & 5 at west). Leaching cracks in end diaphragms. Utility access hole, west end, has a brick removed.

9. Concrete diaphragms at Pier 3 are cracked and breaking apart.

122. Leaching cracks with efflorescence, beneath deck at Spans 1, 3 and 4. Some rust stains at transverse cracks, beneath the deck. Some patched areas noted beneath the deck. Low slump concrete overlay placed (1980). Numerous random deck cracks have been epoxy sealed (1990). Construction joint over Pier 2 and at each end of deck have been sealed (1990). Small hole through deck was cut out and patched (1993) in the shoulder area (over river) for foundations crew.

102. Numerous leaching vertical cracks should be sealed. Concrete surface treatment on rails and posts is wearing off, mostly at the south side.

90. New waterproof expansion joints placed at Piers 1 and 3 (1980).

185. Vandals have rearranged rip

FIGURE 4 Pontis inspection data collection form.

ability of the palm pad will allow data entry directly into the computer instead of using the hard copy form. Entry of comments is a potential problem with the pen-based computers, and Mn/DOT is considering using standard comments that would provide a customized line by entering quantities and location. For example, a standard comment for abutment deterioration could be " m^2 of spalls with rebar exposed m from edge of abutment." Standard comments for each type of element would be developed.

ISTEA and Relationship of Mn/DOT to Local Governments

Local governments (cities, counties, and townships) are responsible for the inspection, maintenance, and replacement of all bridges under their jurisdiction. Mn/DOT offers technical assistance to local governments and works with the local agencies to prioritize bridge projects.

The Mn/DOT Division of State Aid for Local Transportation provides oversight and guidance for all state or federally funded bridge projects. By state law 62 percent of state gas tax funds are distributed to Mn/DOT, 29 percent of funds are distributed to counties, and 9 percent of funds are distributed to cities. State and federal funds for bridge replacements are distributed on the basis of a project selection process in which the readiness of project paperwork, past projects funded, availability of funds, and how the project meets deficient status are all considered. Special state bonding funds are available for bridges with spans of 10 to 20 ft that are not eligible for federal funding, as are matching federal funds for bridges longer than 20 ft.

The Office of Bridges and Structures provides a review of bridge plans, assistance in bridge safety inspections, and technical assistance upon request during construction for local bridges. The Bridge Management Unit provides central storage of all inspection and inventory data, checks all data for accuracy, enters data for new bridges into the data base for future updating, and distributes summary reports each year to all agencies on the conditions of bridges, updated sufficiency ratings, and eligibility for funding.

STIP Process

As a result of ISTEA Minnesota has revised the process used to develop a statewide transportation improvement program (STIP) including bridge repair, rehabilitation, or improvement. The new process is organized around eight regional transportation groups called area transportation partnerships (ATPs). ATP membership includes representatives from districts, counties, cities, townships, regional development commissions, and metropolitan planning organizations. See Figure 5 for the relationship among these various agencies in the planning process.

Guidelines have been developed to identify transportation investment goals and objectives (2). These statewide investment goals are drawn from statewide planning and policy studies as well as from previous historical funding levels and are used as an aid in determining priorities. The goals are defined by Mn/DOT Modal and Resource Management committees, as shown in the left column of Figure 5. The basic principles for making transportation investment priorities are that the emphases must be on preservation and management of existing systems over capital improvements, with safety being a key criterion involved in all investment priorities. Specific priority goals for the 1995 to 1997 STIP are as follows:

- Priority 1: preservation—maintenance of existing systems at a level that will provide for the safe movement of people and freight. This includes activities such as bridge repair tht retain or restore the existing condition without necessarily adding capacity. The goal is 30 to 40 percent of investment.
- Priority 2: management and operations—safely and efficiently manage and operate existing systems, effectively addressing critical safety and operations problems including bridge railings through minor and moderate cost improvements. The goal is 5 to 15 percent of investment.
- Priority 3: replacement—enhance economic development by replacing eligible system pieces or elements and reducing barriers such as weight restrictions, bottlenecks, and system disruptions. Replacement includes traditional categories of bridge replacement and reconstruction. The goal is 25 to 35 percent of investment.
- Priority 4: expansion—attain a competitive advantage for the state by reducing travel times and maintaining mobility. Expansion includes major construction. The goal is 15 to 25 percent of investment.

Target values for regional funding are provided as an estimate of the funding available for the Regional Transportation Improvement Program (RTIP). Targets are a flexible short-range planning estimate that offers some assistance for establishing a level of investment for solutions to transportation needs and problems within the region. Targets are used as beginning points, not the final answers, in establishing a priority list of projects for the development of the RTIP and the STIP. The flexible target funding in Minnesota is based on an economic formula that includes the region's contribution to the highway trust fund and regional income. Each

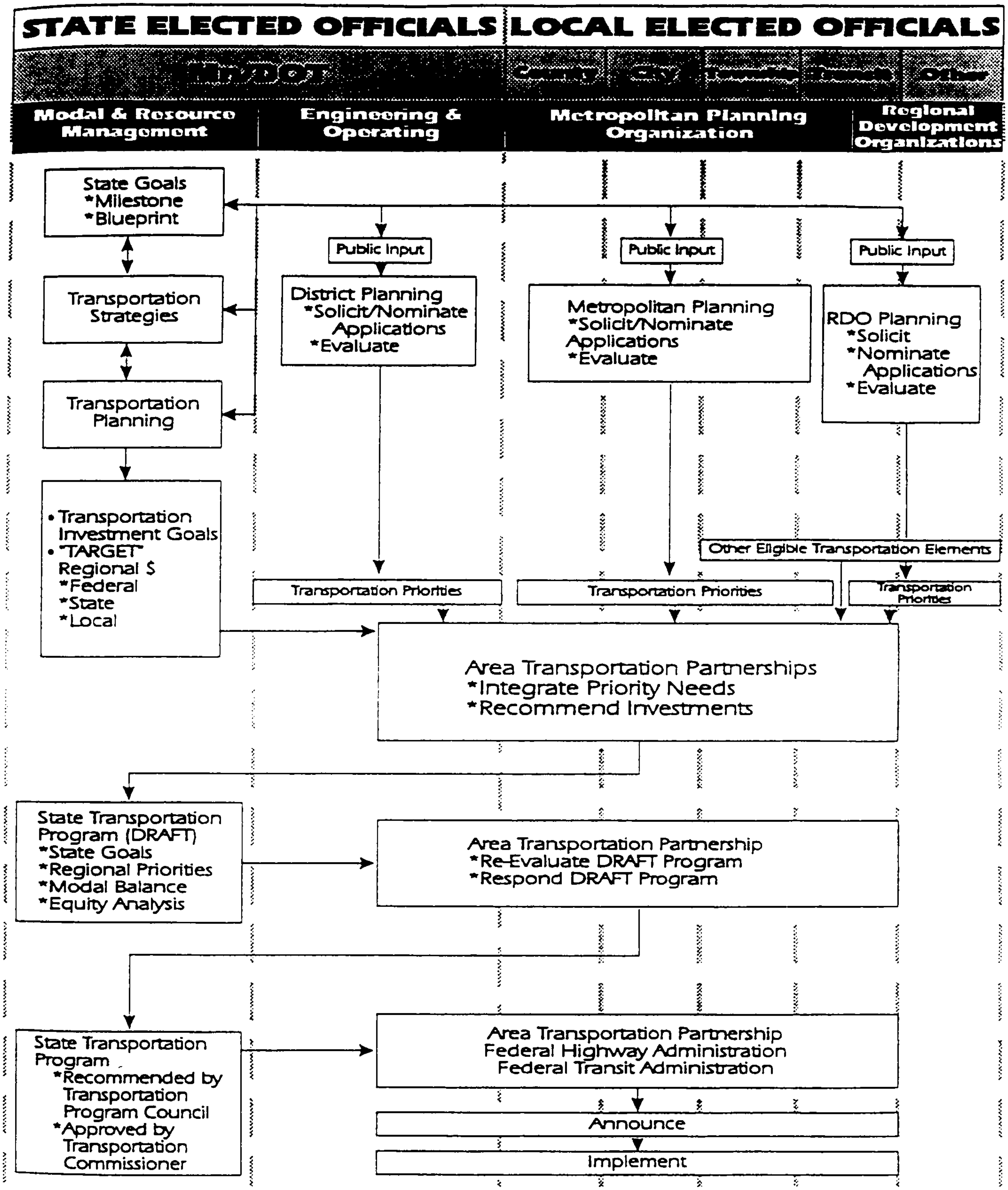

FIGURE 5 Minnesota project selection process.

region must have a target that is no less than 90 percent of the share of its contributions to the trust fund. In the future it is anticipated that the results of Minnesota's BMS and other management systems will affect the target values for the different regions.

Projects are selected on the basis of priority ranking within each RTIP and are combined into the STIP. Each agency in the ATP provides a listing of bridge projects that should be included in the federally funded portion of the STIP. ATP prioritizes the lists along with other transportation projects such as roadway improvements, transit, and safety improvements. At present bridge priority rankings are based largely on the sufficiency rating, and there is no good way to compare the benefits of bridge work to those of other types of highway work. In the future Minnesota expects to use information from the various management systems to allocate funding to the greatest area of need. To help in this process it is important for a BMS to provide accurate and realistic results for bridge improvement and maintenance, repair, and rehabilitation (MR&R) activities.

As the BMS is implemented better results and additional information including well-defined level-of-service goals will become available for determining appropriate regional funding levels and for making informed bridge decisions including needs for MR&R programs as well as the replacement programs used to a large extent today.

Pontis BMS

Minnesota has decided to use Pontis as a bridge management tool. Development of Pontis began in 1989 by FHWA and a six-state technical advisory group (*3,4*). Pontis is a computer software program that uses mathematical models to optimize bridge funding for MR&R as well as for improvements. Both the agency costs and user costs are identified, with the agency costs being limited to the actual costs required to preserve or replace a portion of a bridge. User costs are those costs incurred by the bridge user for detours or accidents due to poor geometrics or clearances on the bridge. The agency costs of various MR&R actions have been estimated by Mn/DOT bridge maintenance personnel and will continue to be updated on an ongoing basis as more accurate costs become known. The deterioration rates of various bridge elements are critical to calculating accurate benefit-cost ratios. These rates were first estimated by Mn/DOT bridge inspectors and will be updated as actual data become available.

User Costs

User costs are defined as the cost borne by bridge users traveling on or beneath the structure or increased costs to those who cannot use the bridge because of detours, load posting, or clearance limitations. The costs include travel time, motor vehicle operating costs, and accident costs. These costs will be calculated and updated as needed by Pontis rather than by local agencies. Since user costs can significantly affect the outcomes reported by Pontis, it is important to ensure that these figures accurately reflect the cost to the bridge users.

Element-Level Inspections

Pontis requires a means of recording bridge inspection information different from that used previously in Minnesota. Bridges have always been categorized into various components, and each one has been rated according to condition severity. Under the Pontis system, bridge elements are defined and ratings will include both severity and extent of deterioration. A condition rating scale between 1 and 5 is used, where a 1 is the best rating for an element and a 3, 4, or 5 is the worst rating, depending on the element (*5,6*). A sample Pontis inspection form used in Minnesota is shown in Figure 4. This rating system will enable the user to determine the amount of the element that is in either good or poor condition. Since reporting to FHWA of the conditions of the deck, superstructure, and substructure in a standard format is required by all states, a conversion program has been developed by the University of Colorado to translate element-level data to NBI condition data (*7*). Results obtained from 4,600 conversions indicate that the translated NBI conditions are slightly lower on average than the actual NBI values obtained in the field. Results vary, as shown in Table 1.

The training program for Minnesota bridge inspectors includes an explanation of element-level inspection, an overview of Pontis, a review of terminology, a review of the condition code language for all elements, and a field rating exercise. Since most bridge inspectors have already taken extensive training in bridge inspection techniques, a 1-day class has proven to be sufficient to provide the basics of element-level inspection and data recording. Experienced bridge inspectors are usually comfortable using the new inspection system within 2 to 4 weeks. Many feel that the inspection coding is easier because they are able to break the bridge into elements. Very little additional time is required for element-level coding compared with the time required for NBI coding, and any additional time is mainly due to the initial learning curve of using a new system. Based on the inspection of 4,600 bridges, the increased inspection and recording time the first year ranged from 5 to 20 percent, and that is expected to decrease after inspectors become more familiar with the coding.

TABLE 1 Actual and Translated NBI Condition Values

	-2 point diff.	-1 point diff.	No change	+1 point diff.	+2 point diff.	Errors
Deck	38%	36%	12%	4%	3%	7%
Superstructure	26%	17%	31%	13%	6%	7%
Substructure	16%	41%	29%	5%	2%	7%
Culverts	2%	10%	41%	34%	12%	1%

Element-Level Reporting

Element-level reporting requires that the inspector record data about each element found on a bridge and the quantity of the element. Because of the computerized inventory data base that Mn/DOT has kept over the past 20 years, a great deal of information about the type of material and the type of elements found on each bridge is available. For example, Minnesota's inventory data base includes information about the type of pier material, the type of pier construction, the type of expansion joints, and the type of deck protection system used. These data enable Mn/DOT to develop formulas to accurately estimate the type of elements on each bridge without checking bridge plans. Quantities are estimated on the basis of typical bridge characteristics such as average beam spacing and on the basis of known dimensions such as deck width and bridge length. Experience to date has shown that approximately 80 to 90 percent of the estimated elements are accurate when these formulas are used, and the estimated quantities are accurate approximately 65 to 75 percent of the time. The estimated elements and quantities are checked by the bridge inspector in the field during the initial element-level inspection. Mn/DOT feels that a great deal of time is saved by using estimated elements as opposed to the alternative of either fully researching plans in the office or entering all elemental data in the field during the initial inspection. On complex bridges, however, the estimated elements and quantities are not accurate, and Mn/DOT finds it beneficial to review plans to determine the elements on bridges longer than 125 m.

Bridge Management Output

The BMS provides several types of outputs that can be used for three main purposes: (a) to provide information to transportation agencies in developing cost-effective programs for bridge maintenance, improvements, and replacements; (b) to provide defensible support for target funding requests; and (c) to identify and describe bridge maintenance activities. The outputs needed for transportation agencies include historical conditions and funding levels; anticipated deterioration rates of bridges; the costs of various maintenance, improvement, and replacement activities; present conditions of the system and individual bridges; the overall cost of specific projects; a ranking of proposed projects; a listing of maintenance needs; and the overall budget required to maintain bridges at a selected level of service. Planners will need outputs that show proposed funding levels at the present time and how that level of funding affects future funding needs of the system. Charts and graphs that show proposed funding, optimal funding, and resulting bridge needs are valuable tools for accurately depicting BMS results.

Bridge Maintenance

Mn/DOT has always spent a reasonable amount of resources on bridge maintenance activities in an effort to preserve this vast infrastructure investment. At present Mn/DOT has 20 bridge maintenance crews stationed in the districts. They perform preventive maintenance, minor bridge rehabilitation, and emergency repair work. In addition to Mn/DOT bridge maintenance crews, contract maintenance is used for larger maintenance projects. A typical priority for maintenance work by Mn/DOT crews or by contract is shown in Figure 1.

Pontis BMS outputs will be used to help plan bridge maintenance activities in the future. The benefit-cost ratio of maintenance activities such as spot painting, deck overlays, and concrete patching will be provided, and suggestions for optimal MR&R activities will also be provided. The comparable value of MR&R activities versus bridge replacement will be shown. The element-level inspections used enable detailed information on the extent of problems such as deck cracking and deteriorated paint, steel, and concrete conditions to be recorded and summarized. These data can then be used to develop detailed maintenance programs for deck crack sealing, spot painting, and concrete patching.

Implementation Schedule

Pontis is a new system that requires training of bridge inspection personnel and project programmers. The first Mn/DOT bridge inspectors were trained in element-level inspection techniques during the summer of 1993. Inspections on 1,600 bridges in 1993 produced some minor changes to BIP and training techniques. In 1994 the remainder of Mn/DOT's bridge inspectors were trained. The training consisted of a 1-day class, including general Pontis overview, definition of elements, discussion of condition state language, and a field inspection of one bridge. Approximately 100 Mn/DOT bridge inspectors are now trained in element-level inspection techniques. During 1995 a total of 200 local bridge inspectors have been trained in element-level inspections, and all bridge data in the state will be coded by using element-level criteria by the end of 1996.

Minnesota Bridge Management Case Study

Minnesota has been involved with the development of BMSs since the inception of FHWA Demonstration Project 71, BMSs, in 1988. Since then Mn/DOT has systematically moved forward until today, when all inspections are being done by using element-level criteria, and the data are being used to help with bridge management decisions. Important milestones along the way are listed below:

- Late 1960s, developed bridge inventory data base and began bridge inspection program.
- Mid to late 1980s, developed PC data collection tools, MBIPS, and BIP.
- 1988 to present, involved with development and guidance of the Pontis BMS.
- 1992, determined initial element deterioration rates and feasible action costs with expert elicitation.
- 1992, involved with testing and implementation of Pontis versions 1.0 and 2.0.
- 1993, developed formulas to approximate elements and estimate quantities for use in Pontis. These estimated elements were used by inspectors in the field during the initial Pontis inspection.
- 1993, began element-level inspections with three pilot districts and inspected 1,600 bridges.
- 1994, began element-level inspection of all Mn/DOT-owned bridges and decided not to collect NBI deck, superstructure, substructure, and culvert data.
- March 1995, BMS results were provided to Mn/DOT districts to assist in developing maintenance and improvement programs and replacement programs.
- 1995, finished training all local bridge inspectors and collected element-level data on all 19,670 bridges in Minnesota.

Critical decisions made during Pontis implementation were (a) to use formulas to estimate elements and quantities in the initial inspection; (b) to first implement the program in three districts, then in the remaining districts, and lastly in local agencies; and (c) to develop a data collection tool that used previous data, especially comments, that were collected during NBI inspections. All of these decisions have proven to be cost-effective and have provided a clean transition from NBI to Pontis inspections.

How Will Minnesota Manage Bridges in 2000?

The entire scope of managing transportation resources is changing as a result of ISTEA and other management directives. As we move toward the 21st century there will be a greater emphasis on the results of the management systems used as tools for identifying programs and prioritizing projects. Additional information such as relative health indexes will be determined to assist in overall bridge rankings. Bridges will continue to compete for limited funding, and transportation agencies need to have information that will encourage adequate funding to minimize the impact of pending future bridge needs that are 5 to 10 times the size of today's needs. The construction of a large number of complex bridges in the 1950s, 1960s, and 1970s creates a need for careful management of resources to provide a safe and usable transportation system as this infrastructure system ages.

A comprehensive BMS will provide defensible background information for funding prioritization in the transportation planning process. The funding requests of transportation departments will continue to be balanced against many other needs, and a BMS that shows future needs if funding is delayed may be the tool that can be used to establish the level of funding needed to preserve the infrastructure. A comprehensive BMS will also provide data to show transportation agencies the most cost-beneficial maintenance activities to be performed and to ensure that available funding is used to the optimal benefit.

As the other management systems required in ISTEA are developed there will be a need to integrate the results of all systems into an overall planning tool. Much of the coordination of results will be done through a geographic information system (GIS), which will provide a means of linking data at a common location. Since BMSs are at the forefront of management system development, it is important that a BMS include GIS capabilities. A good GIS tool will allow easier integration of data from all management systems so that the needs of the various transportation system components can be determined and if a variety of needs exist in a certain location. A great deal of work needs to be done to combine bridge, roadway, and safety data into an overall management system that can address a variety of funding issues and needs. For integration to succeed an agency needs to have well-defined level-of-service goals. In a BMS a typical level-of-service goal may include no posted bridges on interstates, no posted bridges on market artery routes, and fewer than 5 percent posted bridges on all collector routes. When combined with level-of-service goals for other transportation sectors, the management systems will be able to identify the level of expenditure necessary to preserve or improve the transportation infrastructure.

Summary

Minnesota has developed several computer-based programs such as MBIPS and BIP and is implementing BMS tools such as Pontis that provide convenient ways of analyzing bridge data, developing reports on bridge data, and providing information on the most cost-effective solutions for improving bridge conditions. These data will be used in the planning process to prioritize bridge maintenance activities as well as bridge replacement and rehabilitation projects and provide support for funding requests. Future system improvement efforts will be in the areas of user cost determination, improved data collection, incorporation of GIS capabilities, and overall integration with other management systems.

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