TRANSPORTATION RESEARCH
CIRCULAR

Number E-C052 July 2003

Maintenance Management 2003

Presentations from the 10th AASHTO–TRB Maintenance Management Conference

July 13–17, 2003
Duluth, Minnesota

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSPORTATION
RESEARCH
E-CIRCULAR

Number E-C052, July 2003
ISSN 0097-8515

Maintenance Management 2003

Presentations from the 10th AASHTO–TRB Maintenance Management Conference

July 13–17, 2003
Duluth, Minnesota

Hosted by
Minnesota Department of Transportation

Sponsored by
Transportation Research Board
American Association of State Highway and Transportation Officials
Federal Highway Administration

TRB website:
www.TRB.org

Transportation Research Board
500 Fifth Street, NW
Washington, DC 20001

Preface

This publication contains papers presented at the Tenth AASHTO–TRB Maintenance Management Conference held in Duluth, Minnesota, July 13-17, 2003. The objective of this series of conferences is to provide a forum every three to four years for the exchange of new ideas and developments in the maintenance and operations management of transportation facilities. The conference was hosted by the Minnesota Department of Transportation, and jointly sponsored by the Transportation Research Board, the American Association of State Highway and Transportation Officials, and the Federal Highway Administration of the U.S. Department of Transportation. It was integrated into the Annual AASHTO Highway Subcommittee on Maintenance meeting and includes topics corresponding to the AASHTO Subcommittee Task Forces on pavements, roadsides & environment, traffic services & safety, bridges and snow & ice, and the Focus Groups on customer satisfaction, contract maintenance, work force development, equipment and maintenance management.

The views expressed in the papers contained in this publication are those of the authors and do not necessarily reflect the views of the Transportation Research Board, the National Research Council, or the sponsors of the conference. *The papers have not been subjected to the formal TRB peer review process.*

ACKNOWLEDGMENTS

Technical Program

The technical program was developed through the joint efforts of Chairman, Vice-Chairman, Secretary and Task Force and Focus Group Leaders of the AASHTO Highway Subcommittee on Maintenance, and members of TRB Maintenance Section (A3C00).

AASHTO Highway Subcommittee on Maintenance

Chairman:	David Sprynczynatyk, *North Dakota Department of Transportation*
Vice-Chairman:	Gary Hoffman, *Pennsylvania Department of Transportation*
Secretary:	Jim Sorenson, *Federal Highway Administration*

Task Force Leaders

Bridges:	Pete Weykamp, *New York State Department of Transportation*
Traffic Services & Safety:	Mark Wikelius, *Minnesota Department of Transportation*
Pavements:	Steve Varnedoe, *North Carolina Department of Transportation*
Roadside & Environment:	John Lorentson, *Alabama Department of Transportation*
Snow and Ice:	Ed Fink, *Colorado Transportation Department*

Focus Group Leaders

Customer Satisfaction:	Jim Lilly, *Minnesota Department of Transportation*
Contract Maintenance:	Joe Graff, *Texas Department of Transportation*
Work Force Development:	Bob Peda, *Pennsylvania Department of Transportation*
Equipment:	Francis Allred, *Alabama Department of Transportation*
Maintenance Management:	Larry Orcutt, *California Department of Transportation*

TRB Maintenance Section (A3C00)

Chairman:	Lee Smithson, *AASHTO SICOP Coordinator*
Members:	Dean M. Testa; Andrew V. Bailey, II; James E. Bryden; Larry Galehouse; Ronald L. Purvis; Joseph S. Demko; Glenn R. Hagler; Wilfrid A. Nixon; James S. Kalchbrenner; Imad L. Al-Qadi; David W. Fowler; John Philip Broomfield; Arunprakash M. Shirole
Staff:	Frank Lisle

Contents

PART 1

Contract Maintenance

Development and Application of the Expanded Version of the Florida Maintenance Rating Program

KELLY L. SMITH
CURT A. BECKEMEYER
Applied Research Associates Inc.

ROBERT BOURDON
DAVID MYZIE
VMS, Inc.

In October 2001, VMS, Inc. was awarded a 5-year highway asset management contract with the Miami–Dade Expressway (MDX) Authority. The contract calls for the routine maintenance of approximately 32 centerline miles of roadway and associated roadway features on five major expressways in the Miami metropolitan area —State Routes 112, 836, 874, 878, and 924—beginning in July 2002. As part of the MDX project, VMS was asked to monitor and report the quality of its maintenance using an expanded version of the Florida Department of Transportation's maintenance rating program (MRP). Through the work of one of its consultants, VMS replaced the pass–fail field rating approach of the Florida MRP with a 1-to-5 scale field rating system acceptable to the Authority. This expanded MRP applies to the same 36 roadway features included in the Florida MRP, and it likewise produces rolled-up, 0-to-100 scale management-level ratings. Its advantage over the Florida MRP is a more accurate and definitive account of the levels of maintenance quality being provided to each feature. Trial use of the expanded MRP on the MDX project occurred in February 2002, whereby a trained, independent 2-person team evaluated features at 30 randomly selected 0.1-mile roadway segments. A baseline survey to establish the existing condition of the roadway (prior to VMS taking over maintenance responsibilities) was performed in June 2002 and a second formal evaluation was performed in October 2002. This paper discusses the development of the expanded Florida MRP and its implementation and use in VMS's MDX asset management project.

In October 2001, VMS, Inc. was awarded a 5-year highway asset maintenance contract with the Miami–Dade Expressway (MDX) Authority. The thirteenth such contract of its kind for VMS, it calls for the routine maintenance of approximately 32 centerline miles of roadway and associated roadway features on five major expressways in the Miami metropolitan area —State Routes 112, 836, 874, 878, and 924—beginning in July 2002. The locations of these five highway facilities are shown in Figure 1.

As part of the MDX project, VMS was asked to monitor and report the quality of its maintenance using an expanded version of the Florida Department of Transportation's (DOT's) maintenance rating program (MRP). Originally developed and implemented in 1985, Florida's MRP has been and continues to be a tremendously useful tool for ensuring that maintenance features on the State highway system are kept at an acceptable and uniform level.

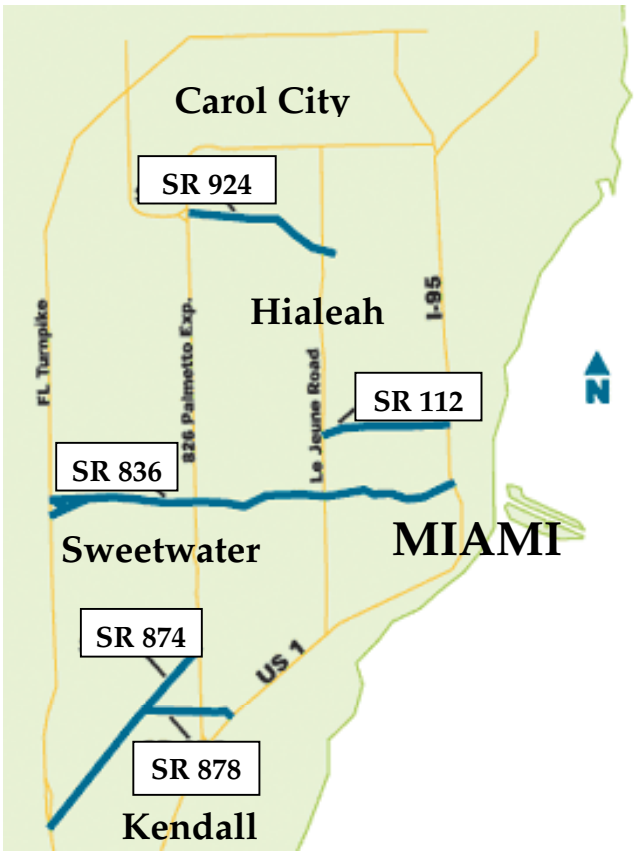


FIGURE 1 Florida highways included in VMS's MDX asset management contract (*1*).

Expansion of the MRP for use in the MDX project primarily entailed transforming the pass–fail rating criteria for 36 separate maintenance features/characteristics into a 1-to-5 scale rating approach. Under the current Florida approach, each maintenance feature/characteristic is assigned either a pass or fail rating based on one of two possible distinct conditions, whereas the expanded approach allows one of five possible ratings—1, 2, 3, 4, or 5—to be made, with the lowest rating (1) representing very poor condition and the highest (5) representing excellent condition.

This paper describes how the Florida MRP was expanded and discusses the preliminary results and experiences of its application in the MDX asset maintenance project.

OVERVIEW OF FLORIDA MAINTENANCE RATING PROGRAM

The Florida MRP system consists of a quantifiable process to determine the levels of service (LOS) of various maintenance activities performed on any of five highway facility types—rural limited access, rural arterial, urban limited access, urban arterial, and special facilities. Three times each year, a random number generator program is used to select 0.1-mile (0.16 km) sections on each of the facility types contained within a maintenance unit (*2*). The number of samples required for the population (centerline miles) involved is determined using statistical formulas designed to provide accuracy within 3 percent at a confidence level of 95 percent.

The quality of maintenance is evaluated by two-person teams in each of eight districts. Assessments are made using pass–fail ratings that indicate conformance or nonconformance with

established agency-wide LOS criteria, which in turn is reflective of long-term, end-result performance.

Maintenance Elements

The Florida MRP is divided into five asset groups or maintenance elements, which represent portions of the highway system that serve similar functions (*3*). The five maintenance elements are as follows:

- Roadway,
- Roadside,
- Traffic Services,
- Drainage, and
- Vegetation and Aesthetics.

Maintenance Features and Characteristics

Each maintenance element is comprised of multiple maintenance features and characteristics that represent specific maintainable items. The features and characteristics evaluated in the Florida MRP are as follows (*3*):

- Roadway
  - Flexible pothole
  - Flexible edge raveling
  - Flexible shoving
  - Flexible depression/bump
  - Flexible shoulder/turnout
  - Rigid pothole
  - Rigid depression/bump
  - Rigid joint/cracking
  - Rigid shoulder/turnout
- Roadside
  - Unpaved shoulder
  - Front slope
  - Slope pavement
  - Sidewalk
  - Fencing
- Traffic services
  - Raised pavement markers
  - Pavement striping
  - Pavement symbols
  - Guardrail
  - Attenuator
  - Signs ≤ 30 ft^2
  - Signs > 30 ft^2

  - Object markers/delineators
  - Lighting
- Drainage
  - Side or cross drain
  - Roadside or median ditch
  - Outfall ditch
  - Inlets
  - Miscellaneous drainage structure
  - Roadway sweeping
- Vegetation and aesthetics
  - Roadside mowing
  - Slope mowing
  - Landscaping
  - Tree trimming
  - Curb or sidewalk edge
  - Litter removal
  - Turf condition

Each feature or characteristic is rated in the field according to whether it meets a pre-defined condition standard. Examples of condition standards for a couple features and characteristics are as follows (*3*):

- Flexible Pothole: No defect is greater than 0.5 ft^2 in. area and 1.5 in. deep. No pervious base is exposed in any hole.
- Roadside Mowing: Not more than 1 percent of vegetation (excluding allowable seed stalks and decorative flowers allowed to remain for aesthetics) exceeds:
  - 18 in.: rural limited access
  - 12 in.: rural arterial
  - 12 in.: urban limited access
  - 9 in.: urban arterial

Thus, in order for Flexible Pothole to receive a passing rating at any given 0.1-mile sample segment, there can be no potholes of the dimensions listed or with exposed pervious base, present in the entire flexible pavement surface (travel lanes and shoulder). And, in the case of a rural arterial highway, Roadside Mowing can receive a passing rating only if 1 percent or less of the vegetation exceeds a height of 12 in.

Development and Reporting of MRP Ratings

The pass–fail ratings collected in the field from multiple 0.1-mile sample segments are used with level-of-importance weighting factors to develop LOS ratings for individual facility type–DOT district combinations. The weighting factors include feature and characteristic weightings (0-to-10 scale) that reflect how important each feature or characteristic in a maintenance element is to that element, and element weightings (0-to-100 percent scale) that reflect how important each element is to the overall system.

The starting point in the MRP calculation process is identifying, for each feature or characteristic, the percentage of sample segments in which the feature or characteristic met the predefined condition standard. Applying the respective feature or characteristic weightings to these percentages results in individual MRP element ratings for the chosen facility type–DOT district combination. Applying the respective element weightings to the individual element ratings produces one overall MRP rating for the facility type–DOT district combination.

Using the centerline mileage associated with each facility type in a DOT district, an overall MRP rating for the district is computed. Similarly, by using the centerline mileage associated with each facility type for all DOT districts, an overall MRP rating for the entire state is computed.

The completed MRP results are summarized for distribution to all levels of management. The results, which are shown on a 0-to-100 scale (with 80 and above being considered acceptable), are then used to identify areas (features and characteristics, elements, roadways) that may need additional funding to return to the desired level of compliance.

DEVELOPMENT OF EXPANDED VERSION OF FLORIDA MRP

As discussed in the introduction, the MDX Authority required that VMS monitor and report the quality of its maintenance using an expanded version of the Florida DOT's MRP. The expanded version was to include all of the same features/characteristics and elements presented in the previous section, but was to utilize a 1-to-5 scale field rating approach instead of the pass–fail approach. This section describes how the Florida MRP was transformed to satisfy the Authority's requirement for the project.

Methodology

The process of expanding the MRP from a pass–fail approach to a 1-to-5 scale approach consisted of two steps. First, for each feature or characteristic, four break points in condition instead of one had to be identified. The break points would allow for the creation of five possible ranges of condition, thereby allowing ratings of 1 (very poor), 2 (poor), 3 (fair), 4 (good), and 5 (very good) to be made in the field, as illustrated in Figure 2.

The second step in the process involved developing a way to convert numerical field ratings into individual element and overall MRP ratings, using the same level-of-importance weighting factors.

To the extent possible, the condition standard established by the Florida DOT for each feature/characteristic was cast as the condition standard separating the "3" and "4" ratings. In other words, the range in conditions signifying acceptable (passing) maintenance under the current MRP was equated with ratings of "4" and "5" under the expanded MRP.

Condition Standards

For example, as seen in Table 1 for the Sidewalk feature, the break point for the pass–fail criterion is set at 99.5 percent of the sidewalk area being free of vertical misalignments or horizontal cracks greater than 0.75 in. This is the same break point for the "3" and "4" ratings under the expanded MRP.

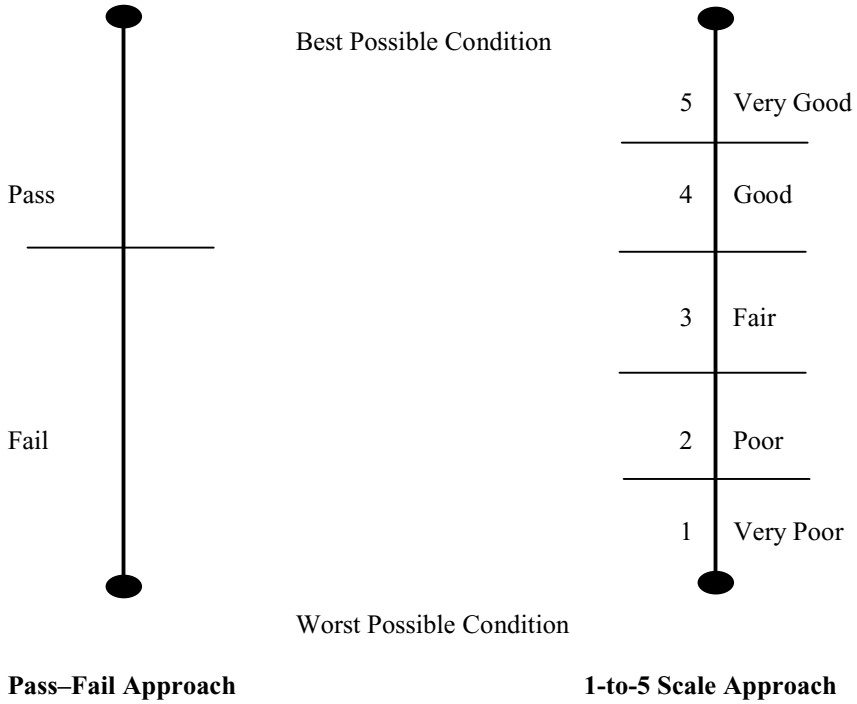


FIGURE 2 Condition ranges for 1-to-5 scale and pass–fail rating approaches.

TABLE 1 Example Illustration of Florida MRP Rating Criterion for Sidewalk Feature or Characteristic

Current Pass–Fail Criterion	Expanded 1-to-5 Scale Criterion
For "Pass" rating: At least 99.5% of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in	**For "5" rating:** 100% of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in
	For "4" rating: At least 99.5% (but less than 100 percent) of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in
For "Fail" rating: Less than 99.5% of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in	**For "3" rating:** At least 95% (but less than 99.5%) of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in
	For "2" rating: At least 90% (but less than 95%) of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in
	For "1" rating: Less than 90% of sidewalk area is free of vertical misalignments or horizontal cracks greater than 0.75 in

As another example, under the pass–fail approach, at least 90 percent of the total luminaires used in sign and highway lighting must be functioning as intended to assign a passing rating. In the 1-to-5 scale approach, at least 90 percent and less than 100 percent of the total luminaires must be functioning as intended to assign a "4" rating, whereas at least 80 percent and less than 90 percent must be functioning as intended to assign a "3" rating.

In some instances, the pass–fail criterion could not be used as the break point for the "3" and "4" ratings. For instance, for both Flexible and Rigid Potholes, the quantity criterion of zero potholes greater than 0.5 ft^2 in area and 1.5 in deep represented the highest possible level of quality—a "5" in the 1-to-5 scale approach. Although consideration was given to varying the dimensions of the pothole, it was believed that doing so would create confusion for the raters in the field and would unnecessarily slow down the rating process.

Weighting Factors

The Florida MRP features different sets of weighting factors for different facility types. For instance, on arterial highways (rural and urban), a factor of 7 is used to weight the Rigid Pavement Joints/Cracks rating toward producing a Roadway element rating. On limited access highways (rural and urban), a weighting factor of 8 is used for this feature/characteristic. Similarly, in generating an overall rating (i.e., all elements combined), weighting factors of 24 and 25 percent are applied to the Roadway element rating for arterial and limited access facilities, respectively.

For the MDX project, the feature/characteristic weighting factors associated with urban limited access highways were used. These factors are as follows:

- Roadway
  - Flexible pothole (9)
  - Flexible edge raveling (5)
  - Flexible shoving (5)
  - Flexible depression/bump (6)
  - Flexible shoulder/turnout (5)
  - Rigid pothole (9)
  - Rigid depression/bump (6)
  - Rigid joint/cracking (8)
  - Rigid shoulder/turnout (5)
- Roadside
  - Unpaved shoulder (9)
  - Front slope (6)
  - Slope pavement (6)
  - Sidewalk (0)
  - Fencing (6)
- Traffic services
  - Raised pavement markers (9)
  - Pavement striping (8)
  - Pavement symbols (7)
  - Guardrail (9)

  - Attenuator (9)
  - Signs ≤ 30 ft^2 (9)
  - Signs > 30 ft^2 (8)
  - Object markers/delineators (7)
  - Lighting (8)
- Drainage
  - Side or cross drain (7)
  - Roadside or median ditch (4)
  - Outfall ditch (6)
  - Inlets (8)
  - Miscellaneous drainage structure (5)
  - Roadway sweeping (7)
- Vegetation and aesthetics
  - Roadside mowing (7)
  - Slope mowing (6)
  - Landscaping (5)
  - Tree trimming (7)
  - Curb/sidewalk edge (6)
  - Litter removal (4)
  - Turf condition (7)

Similarly, the element weighting factors associated with urban limited access highways were used for the expanded MRP. These factors are as follows:

- Roadway (25 percent);
- Roadside (13 percent);
- Traffic Services (30 percent);
- Drainage (15 percent); and
- Vegetation/Aesthetics (17 percent).

Application of the feature/characteristic factors in the 1-to-5 scale approach is very similar to the pass–fail approach. As illustrated in Table 2, for a given MRP zone, the average 1-to-5

TABLE 2 Example Application of Feature and Characteristic Weighting Factors (for a Given Element and MRP Rating Zone)

Feature/ Characteristic	Avg. 1-to-5 Scale Rating	No. Rated Samples	Weighting Factor	Score	Possible Score	Element MRP Rating
1	3.4	23	8	625.6	920.0	
2	4.4	12	9	475.2	540.0	
3	4.8	25	6	720.0	750.0	
4	3.7	18	7	466.2	630.0	
				2287.0	2840.0	80.5

scale rating for a particular feature or characteristic is multiplied by its designated weighting factor and by the number of samples in the zone in which the feature or characteristic could be rated. This yields a certain score for the feature or characteristic, which is then summed with the scores of other features or characteristics in the element to produce the element score. By dividing the element score into the total possible element score (i.e., the score if all ratable features and characteristics received a "5" rating) and multiplying by 100 percent, the 0-to-100 scale MRP zone rating for the element is determined.

Application of the element weighting factors in the 1-to-5 scale approach is exactly the same as in the pass–fail approach. Table 3 simply illustrates how the individual element weighting factors (percentages) are multiplied by the corresponding element ratings to produce the 0-to-100 scale rating for the MRP zone.

MDX Rating Requirements

The MDX asset maintenance contract requires that VMS meet or exceed specified maintenance ratings at the feature or characteristic level, element level, and overall level (i.e., all elements combined). The specified ratings are as follows:

- Features and characteristics: MRP ≥ 70 (corresponds to 3.5 out of 5, on 1-to-5 scale);
- Elements: MRP ≥ 75; and
- Overall: MRP ≥ 80.

APPLICATION OF EXPANDED VERSION OF FLORIDA MRP

Roadway Sampling Procedure

MRP Rating Zones

To utilize the MRP process effectively, the roadway network illustrated in Figure 1 was divided into the following MRP rating zones, based on the location and length of each expressway:

- Zone 1: State Route 836;
- Zone 2: State Routes 874 and 878; and
- Zone 3: State Routes 112 and 924.

TABLE 3 Example Application of Element Weighting Factors (for a Given MRP Rating Zone)

Element	MRP Rating	Weighting Factor	MRP Zone Rating
1	80.5	25%	
2	76.4	32%	
3	92.3	19%	
4	84.6	24%	
			82.4

MRP Sample Segments

To conduct the expanded MRP surveys within the three MRP roadway zones, each zone was further divided into 0.1-mile roadway segments that serve as the basic sampling element in the MRP process. Since bridge structures are not included in the MRP evaluation process, the roadway segments were established outside the limits of individual bridge structures. Table 4 summarizes the formation of MRP rating zones and 0.1-mile roadway segments for the MDX project.

When conducting the MRP field surveys for a given zone, multiple 0.1-mile roadway segments must be evaluated to ensure statistical validity of the results. Although the highest level of statistical validity can be obtained by surveying all the segments in a zone, this approach can be very time consuming and expensive. In contrast, surveying only a handful of segments, while inexpensive and desirable from a time standpoint, may not yield an accurate account of maintenance conditions.

A minimum of 25 randomly selected roadway segments per rating zone (per inspection cycle) was selected for use in the MDX project. This number, which represents 31 percent of the total number of segments in Zone 1 (25÷80), 33 percent (25÷76) in Zone 2, and 39 percent (25÷64) in Zone 3, was expected to provide a more than reasonable level of accuracy (95 percent confidence interval) in reporting maintenance ratings.

To expedite the random selection of roadway segments to be surveyed in the field, a Microsoft Excel-based sampling program was developed. This program automatically selects 35 random segments per zone, according to route and beginning milepost. Although only 25 sample segments (minimum) per zone must be surveyed, 10 additional segments per zone are chosen to serve as alternates in the event that one or more of the first 25 segments cannot be inspected due to interference by maintenance or rehabilitation work.

Pilot Survey

To test the functionality and efficiency of the 1-to-5 scale MRP rating approach, VMS directed one of its two-person maintenance rating teams to perform a pilot survey. This survey was done in February 2002 and included inspections of 30 roadway segments on the 5 MDX roadways. Results of the pilot survey confirmed the need to have 3 MRP rating zones and to evaluate a minimum of 25 segments per zone, so as to achieve the desired precision levels for ratings. The pilot survey also indicated a need for more detailed guidelines in evaluating some features/characteristics in the field. Both of these issues were fully resolved prior to conducting the June 2002 baseline survey.

TABLE 4 Summary of MRP Rating Zones and Roadway Sampling Segments

MRP Rating Zone	Expressway	Milepost Limits	Total Length, mi	Length Exclusive of Bridges, mi	No. of 0.1-mi LE Roadway Segments
Zone 1	SR 836	0.000 to 13.048	13.048	10.396	80
Zone 2	SR 874	0.000 to 7.200	7.200	6.691	58
	SR 878	0.000 to 2.725	2.725	2.279	18
Zone 3	SR 112	0.000 to 4.132	4.132	2.879	22
	SR 924	0.000 to 5.378	5.378	5.047	42
NETWORK>>			32.480	27.292	220

Formal Surveys

To establish the approximate conditions of the MDX network prior to VMS taking over maintenance responsibilities, VMS conducted a baseline survey of the subject roadways in June 2002. This survey was performed by the same rating team involved in the pilot survey. A total of 75 roadway segments (25 segments per zone) were surveyed over a period of 7 days (June 14 through 20, 2002). A breakdown of segments surveyed along each route is as follows:

- Zone 1
  - SR 836: 25 segments.
- Zone 2
  - SR 874: 18 segments.
  - SR 878: 7 segments.
- Zone 3
  - SR 112: 11 segments.
  - SR 924: 14 segments.

The results of this survey are summarized in Tables 5 and 6. In Table 5, it can be seen that, for all three rating zones combined, only five of the features/characteristics evaluated—Raised Pavement Markers, Striping, Object Markers and Delineators, Landscaping, and Litter Removal—did not meet the MDX required MRP rating of 70.0.

In terms of individual maintenance elements, Table 6 shows that the Traffic element in MRP Zone 1 and the Vegetation/Aesthetics element in MRP Zone 3 did not meet the MDX required MRP rating of 75. Nevertheless, the overall network rating of 87.0 well exceeded the MDX requirement of 80.

In October 2002, VMS conducted its second formal MRP evaluation of the MDX network. This survey was performed by the same rating team responsible for the baseline survey and included the same number of sample segments (i.e., 25 on SR 836, 18 on SR 874, 7 on SR 878, 11 on SR 112, and 14 for SR 924).

The results of this survey are summarized in Tables 7 and 8. In Table 7, it can be seen that, network wide, all of the features/characteristics met or exceeded the MDX rating requirement of 70.0. The five features/characteristics found to be deficient in the baseline survey were improved to satisfactory levels by the time of the second formal survey. For instance, the rating for Raised Pavement Markers was improved from 61.3 to 86.0, while the rating for Landscaping was improved from 52.0 to 72.0.

Table 8 shows that all five maintenance elements met or exceeded the MDX requirement (75) for each MRP zone and all zones combined. In addition, the overall network rating of 91.0 exceeded the MDX requirement (80) and was considerably improved from the overall network rating determined in the baseline survey (87.0).

ASSESSMENT OF EXPANDED MRP APPROACH

Although the 1-to-5 scale MRP system developed for VMS's MDX asset management project has been in use for less than 1 year, the experiences of those involved in its development and its initial use have been, on the whole, very good. The expanded system has allowed raters to score

features and characteristics with more detail than the pass–fail approach and this, in turn, has helped VMS managers to better prioritize and schedule repairs.

TABLE 5 June 2002 (Baseline) MRP Survey Results: Feature and Characteristic Ratings

Element Group	Feature/Characteristic	No. Sample Segments	Avg. 1-to-5 Rating	MDX Required Rating	Avg. MRP Rating	MDX Required MRP Rating
Roadway	Flexible Pothole	75	5.0	3.5	99.7	70.0
	Flexible Edge Raveling	0	—	3.5	—	70.0
	Flexible Shoving	75	5.0	3.5	100.0	70.0
	Flexible Depression/Bump	75	5.0	3.5	100.0	70.0
	Flexible Paved Shoulder/Turnout	72	4.9	3.5	98.2	70.0
	Rigid Pothole	1	5.0	3.5	100.0	70.0
	Rigid Depression/Bump	1	5.0	3.5	100.0	70.0
	Rigid Joints/Cracks	1	5.0	3.5	100.0	70.0
	Rigid Paved Shoulder/Turnout	0	—	3.5	—	70.0
Roadside	Unpaved Shoulder	66	4.6	3.5	92.0	70.0
	Front Slope	72	4.6	3.5	92.2	70.0
	Slope Pavement	3	5.0	3.5	100.0	70.0
	Sidewalk	3	5.0	3.5	100.0	70.0
	Fence	56	4.4	3.5	88.6	70.0
Traffic	Raised Pavement Markers	75	3.1	3.5	**61.3**	**70.0**
	Striping	75	3.2	3.5	**64.3**	**70.0**
	Pavement Symbols	46	4.2	3.5	83.5	70.0
	Guardrail	49	3.9	3.5	77.1	70.0
	Impact Attenuators	7	5.0	3.5	100.0	70.0
	Signs ≤ 30 ft^2	48	4.7	3.5	93.3	70.0
	Signs > 30 ft^2	48	4.9	3.5	98.3	70.0
	Object Markers & Delineators	59	3.5	3.5	**69.2**	**70.0**
	Lighting	70	4.8	3.5	95.4	70.0
Drainage	Side/Cross Drains	27	4.9	3.5	97.0	70.0
	Roadside/Median Ditches	69	4.9	3.5	97.4	70.0
	Outfall Ditches	0	—	3.5	—	70.0
	Inlets	60	4.2	3.5	84.0	70.0
	Misc. Drainage Structures	40	4.8	3.5	96.0	70.0
	Roadway Sweeping	49	5.0	3.5	100.0	70.0
Vegetation/ Aesthetics	Roadside Mowing	73	3.9	3.5	77.8	70.0
	Slope Mowing	28	4.9	3.5	97.1	70.0
	Landscaping	10	2.6	3.5	**52.0**	**70.0**
	Tree Trimming	75	4.0	3.5	79.7	70.0
	Curb/Sidewalk Edge	21	3.9	3.5	78.6	70.0
	Litter Removal	75	2.4	3.5	**47.2**	**70.0**
	Turf Condition	74	3.9	3.5	77.6	70.0

TABLE 6 June 2002 (Baseline) MRP Survey Results: Element and Overall Ratings

Element	MRP Zone 1		MRP Zone 2		MRP Zone 3		Network	
	Actual MRP Rating	MDX Required Rating	Actual MRP Rating	MDX Required Rating	Actual MRP Rating	MDX Required Rating	Actual MRP Rating	MDX Required Rating
Roadway	100.0	75.0	99.4	75.0	99.5	75.0	99.6	75.0
Roadside	89.3	75.0	92.3	75.0	92.3	75.0	91.6	75.0
Traffic	**67.6**	**75.0**	86.1	75.0	82.0	75.0	80.9	75.0
Drainage	97.1	75.0	94.9	75.0	88.5	75.0	93.9	75.0
Veg/Aesth	78.6	75.0	76.8	75.0	**69.9**	**75.0**	75.7	75.0
TOTAL	82.6	75.0	89.1	75.0	86.3	75.0	87.0	75.0

TABLE 7 October 2002 MRP Survey Results: Feature and Characteristic Ratings

Element Group	Feature/Characteristic	No. Sample Segments	Avg. 1-to-5 Rating	MDX Required Rating	Avg. MRP Rating	MDX Required MRP Rating
Roadway	Flexible Pothole	75	4.9	3.5	98.7	70.0
	Flexible Edge Raveling	0	—	3.5	—	70.0
	Flexible Shoving	75	5.0	3.5	100.0	70.0
	Flexible Depression/Bump	75	5.0	3.5	100.0	70.0
	Flexible Paved Shoulder/Turnout	75	5.0	3.5	100.0	70.0
	Rigid Pothole	2	4.5	3.5	90.0	70.0
	Rigid Depression/Bump	2	5.0	3.5	100.0	70.0
	Rigid Joints/Cracks	2	4.5	3.5	90.0	70.0
	Rigid Paved Shoulder/Turnout	2	5.0	3.5	100.0	70.0
Roadside	Unpaved Shoulder	51	4.6	3.5	92.2	70.0
	Front Slope	65	4.6	3.5	92.9	70.0
	Slope Pavement	2	5.0	3.5	100.0	70.0
	Sidewalk	4	5.0	3.5	100.0	70.0
	Fence	61	4.7	3.5	94.8	70.0
Traffic	Raised Pavement Markers	75	4.3	3.5	86.0	70.0
	Striping	75	4.2	3.5	84.8	70.0
	Pavement Symbols	38	3.8	3.5	75.3	70.0
	Guardrail	48	4.2	3.5	83.8	70.0
	Impact Attenuators	3	4.7	3.5	93.3	70.0
	Signs ≤ 30 ft^2	46	4.2	3.5	83.0	70.0
	Signs > 30 ft^2	37	4.5	3.5	90.3	70.0
	Object Markers & Delineators	60	3.5	3.5	70.0	70.0
	Lighting	74	4.8	3.5	95.4	70.0
Drainage	Side/Cross Drains	19	4.6	3.5	91.6	70.0
	Roadside/Median Ditches	61	4.9	3.5	98.0	70.0
	Outfall Ditches	0	—	3.5	—	70.0
	Inlets	61	4.5	3.5	90.8	70.0
	Misc. Drainage Structures	48	4.9	3.5	97.9	70.0
	Roadway Sweeping	74	4.6	3.5	91.9	70.0
Vegetation/ Aesthetics	Roadside Mowing	67	4.6	3.5	91.9	70.0
	Slope Mowing	26	4.8	3.5	95.4	70.0
	Landscaping	5	3.6	3.5	72.0	70.0
	Tree Trimming	75	4.4	3.5	87.5	70.0
	Curb/Sidewalk Edge	20	4.3	3.5	85.5	70.0
	Litter Removal	75	3.5	3.5	70.7	70.0
	Turf Condition	73	4.3	3.5	86.6	70.0

TABLE 8 October 2002 MRP Survey Results: Element and Overall Ratings

Element	MRP Zone 1		MRP Zone 2		MRP Zone 3		Network	
	Actual MRP Rating	MDX Required Rating	Actual MRP Rating	MDX Required Rating	Actual MRP Rating	MDX Required Rating	Actual MRP Rating	MDX Required Rating
Roadway	98.8	75.0	100.0	75.0	99.2	75.0	99.6	75.0
Roadside	93.0	75.0	92.6	75.0	94.7	75.0	93.2	75.0
Traffic	83.0	75.0	90.4	75.0	80.5	75.0	86.4	75.0
Drainage	93.2	75.0	95.2	75.0	91.7	75.0	93.9	75.0
Veg/Aesth	90.2	75.0	82.7	75.0	85.3	75.0	85.0	75.0
TOTAL	90.6	75.0	92.0	75.0	89.1	75.0	91.0	75.0

The primary disadvantage of the expanded MRP is that it took time for field rating personnel to adjust from the pass–fail rating approach to the 1-to-5 scale approach. Once proficient in the 1-to-5 system, however, raters have experienced only slight increases in the time required to perform an MRP survey.

Based on the experiences to date, it is recommended that the 1-to-5 scale rating approach be considered seriously for use by state and local highway agencies in all highway maintenance work, regardless of whether the work is performed by agency or contract forces.

REFERENCES

1. Miami–Dade Expressway Authority. Highway map. 2002. www.mdx-way.com.
2. Zahn, D., S. Wu, and J. Stein. *Assessment and Improvement of the Maintenance Rating Program, Florida Department of Transportation*. Florida Department of Transportation, Tallahassee, Fla., 1996.
3. Roadway Maintenance Section of State Maintenance Office, Florida Department of Transportation. *Florida Department of Transportation Maintenance Rating Program Handbook: Data Collection for Maintenance Rating Program*. Florida Department of Transportation, Tallahassee, Fla., 2001.

PART 2

Customer Satisfaction

"So We're a 7.0, But What Does That Tell Me?"
Collecting and Analyzing Managerially Relevant Customer Data

MATTHEW DULL
University of Wisconsin, Madison

ALISON S. LEBWOHL
Wisconsin Department of Transportation

Despite heightened emphasis on customer input over the past decade, methods for gauging customer perceptions employed by state departments of transportation remain underdeveloped in comparison with market research techniques used across other sectors. Based on a review of current literature, practices across state departments of transportation, and our own experience assessing methods for collecting and analyzing customer data for the Bureau of Highway Operations (BHO) at Wisconsin Department of Transportation; we argue that many customer survey efforts fail to impact management simply because administrators are not sure specifically what—if anything—they can learn from customer data. While innovative methods offer substantial room for improved data quality, organizations must first carefully evaluate the cost and relative usefulness of data collection methods in light of the organization's priorities. This paper first describes our own review of customer data collection techniques identified as part of an effort to improve the value and relevance of customer data for BHO managers. Based on this experience, we then sketch a decision framework designed to guide the collection and analysis of useful information on customer priorities and attitudes. Finally we identify and briefly describe a series of implementation steps designed to track the customer data collection and analysis from mapping needs to communicating results. These are as follows: (1) develop a needs matrix; (2) map collection strategy; (3) collect data; (4) analyze data; (5) develop communications strategy; and (6) evaluate needs and review collection strategy.

Among the most prominent artifacts left by business-model public management reforms of the 1980s and 1990s, few are more pervasive than the effort to identify and measure customer satisfaction. The constituent-as-customer analogy, which seeks to improve agency responsiveness to citizens by adopting principles of customer service and customer-based quality, now seems a permanent feature in transportation agencies (*1*, *2*). During the 1990s, customer satisfaction surveys and other tools for gauging customer perceptions were among both the fastest growing and the most widely adopted state government reforms. By 1998, almost two-thirds of participating public officials reported that their state agencies had either partially or fully implemented systems for measuring customer satisfaction (*3*, *4*). Today, customer-driven management is supported by broad, sometimes ambitious efforts to measure the perceptions of constituents across the full range of department of transportation (DOT) functions.

REEVALUATING CUSTOMER DATA: WHAT ARE THEY TELLING US?

Two national initiatives during this period highlight efforts to standardize customer data collection and analysis across transportation agencies. First, *NCHRP Report 376*, published in

1995, reports on customer-based quality in several state DOTs. Focusing particularly on the use of focus groups for data collection, the report highlights uses of customer data, including: performance measurement, staff training, planning and budgeting, and public communications. Also in 1995, FHWA and the National Partnership for Highway Quality sponsored the first of two national telephone surveys of transportation customers designed to provide both model instruments for state DOTs and a standard on which benchmark satisfaction with highway operations and maintenance. Several states followed this lead, adopting the standardized instrument, including: Arizona, Florida, Illinois, Kansas, Kentucky, Maryland, Missouri, Virginia, and Washington (*5, 6*).

Our own organization, the Bureau of Highway Operations (BHO) within the Wisconsin Department of Transportation (WisDOT), adopted a survey instrument developed by the highway maintenance and operations division of the DOT in neighboring Minnesota. This approach both reduced development costs and offered opportunities for benchmarking against a comparable state DOT. We administered the random telephone survey three times: 1996, 1997, and 1999—each with between 800 and 900 responses. Among uses of the survey results, bureau administrators used a basic 2x2 matrix matching driver satisfaction with specific maintenance features (e.g. smoothness, plantings) against stated importance of these features to prioritize areas where services should be improved and to support budget allocations. The bureau also based one of its global performance measures on overall customer satisfaction ratings obtained through the survey.

In early 2002, as the bureau prepared to administer the survey for a third time, we began a review of the survey effort. Initially, our intention was simply to evaluate the usefulness of the current instrument for weighing the relative importance of specific features for overall satisfaction—an effort inspired by the development of a quality assurance program that relied in part on a weighted score of highway maintenance conditions across various features (such as stop signs, landscaping, hazardous debris). As we began to ask managers about their use of customer data, however, we were struck by how shallow the impact of the data has apparently been. The following list is a handful of prominent comments from highway operations and maintenance managers regarding the 1999 BHO Customer Survey:

- The current survey is too general, doesn't provide enough specific information;
- More useful information comes from the telephone calls I get—when I hear from individuals with specific concerns or complaints;
- When the results were reported, we looked at the data to see how we compared with other districts;
- How can we evaluate drivers' expectations about winter snow removal by simply describing conditions?
- Graphics and tables summarizing relevant data are particularly helpful—more of these;
- The results were not used; not widely distributed; and
- "So we're a 7.0, but what does that tell me?"

Feedback from staff members clearly indicated BHO could be doing a better job of collecting and analyzing customer data in a way that provides value to managers. We explored ways to make customer data more relevant and were further struck by a number of important weaknesses in the survey data undermining the validity of information we were collecting. Our

effort to identify an approach for gauging the relative importance of specific features on overall satisfaction illustrates our more general experience.

Listening to Customer Priorities: Gauging Importance Through Surveys

Like surveys in several other states we contacted, the BHO survey relies on direct 1-10 scale questions to gauge importance and quality of services across 16 service attributes. These questions are worded as follows:

> For each area I mention, I'd like you to tell me how important that issue is to you. To do this, we'll be using a scale from 1-10, where a score of "1" would mean that the issue is not at all important to you, a score of "10" would mean that the issue is extremely important to you, and a score of "5" would be of middle importance to you.

While this is a straightforward method of gauging respondents' priorities, reliance on directly stated importance is widely discredited among market researchers. As noted in the 2001 FHA report *Moving Ahead*,

> Customer satisfaction research in commercial markets has shown that relying on what people state is of greatest importance is not a reliable method of identifying true customer priorities as manifested by actual buying behavior (*6*).

Results from the 1999 BHO survey indicate that a substantial majority of respondents rated most attributes between 8 and 10. This provides little leverage for understanding the relative importance of the different attributes. More importantly, it is not at all clear what, if anything, responses to these questions can tell us. For example, Figure 1 illustrates the distribution for three "importance" questions.

Can we conclude from these results that clearing the highways of ice and snow is of greater importance to drivers than clearing the roads of other, potentially hazardous debris? Certainly, comparing responses to these two questions with responses to the third suggest that removing debris and snow from the roadway is more important to drivers than removing weeds from the roadside—but did we need a survey to tell us this? And, what does it mean that 12 percent of respondents stated that clearing weeds from roadsides is of no importance to them at all? Even if this information provides some value, one must wonder if it is worth the substantial cost associated with administering a randomized telephone survey.

The BHO survey does include an additional series of questions designed to elicit the relative importance of attributes, asking respondents to trade-off between different features. Respondents are asked to allocate $100 across service attributes. This provides some indication of the relative importance of different attributes not provided by direct rating of each item individually. However, at closer inspection these questions seem equally flawed. The vendor who conducted the 1999 survey for BHO states the following concern regarding this technique in their analysis of survey results:

> It is not clear whether respondents' allocations take into account any knowledge about the relative costs of these services, so it is possible that higher allocations in some cases may simply indicate that respondents the service costs more than others. For example,

more money may have been allocated to keeping pavements smooth than to eliminating weeds in part because customers believed keeping pavements smooth was a more expensive undertaking. (*7*)

Our review identified a number of alternative techniques for gauging the relative importance of services. As discussed in *NCHRP Report 376*, focus groups and other qualitative

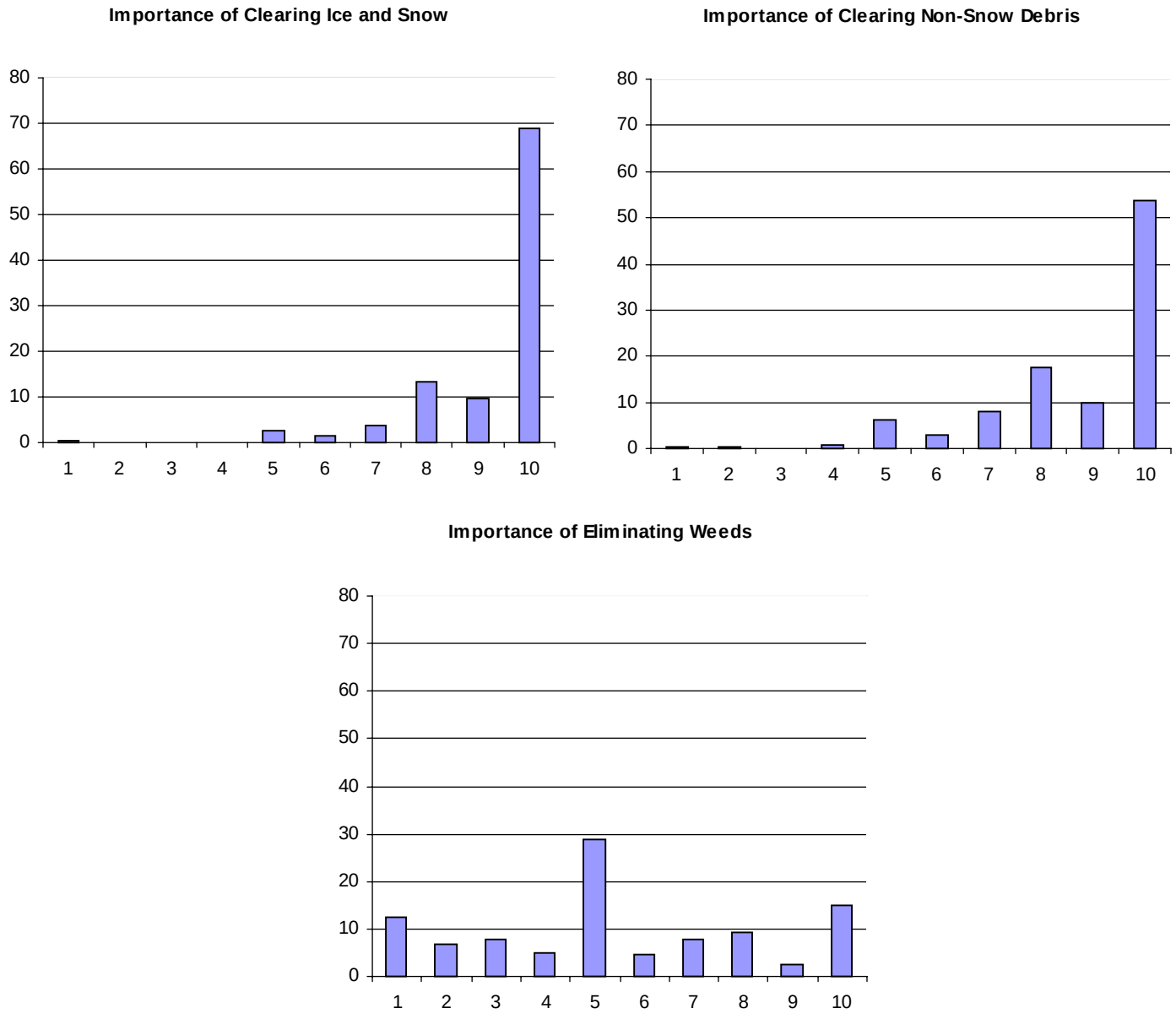


FIGURE 1 Distribution for three "Importance" questions.

methods are widely used and provide valuable information (*8*). Several sources emphasized the importance of conducting focus groups to make sure that the survey instrument ultimately employed is an accurate gauge of customer sentiments. It is important to note, however, that these approaches cannot guarantee an accurate representation of attitudes in the population as a whole, as they cannot provide statistically valid conclusions available through random sampling.

Our research also highlighted a number of quantitative analytical approaches, ranging in scope and resource intensity. Several quantitative techniques are available for deriving the importance of various attributes indirectly using data generated through a traditional survey design. These approaches have the advantage of being relatively inexpensive, as they require little in the way of development costs. One simple approach is correlation analysis, which derives the importance of different attributes using the correlation between the performance rating on an individual attribute and the customer's overall satisfaction. This correlation value is then charted against the individual attribute performance rating in a 4x4 matrix (*9*). In addition to being inexpensive, this approach generates results that are easily interpretable by managers unfamiliar with statistical analysis.

Correlation analysis is analytically similar to regression analysis, which also provides a relatively simple, inexpensive method for deriving the importance of various attributes on overall satisfaction after survey data have been collected. Here, satisfaction with relevant service attributes are regressed as explanatory variables using overall satisfaction as the dependent variable. However, one caution is in order: because of the restrictive assumptions of traditional linear regression, a similar model called ordered probit may be more appropriate in analyzing survey data, as is the case with the 1999 survey data (*10*, *11*).

To illustrate the usefulness of quantitative analysis, Table 1 highlights significant coefficients from ordered probit results for the 1999 BHO customer survey. A table identifying coefficient values is provided in Appendix A. Pluses indicate significant and positive variables, meaning the factor has a discernable positive impact on overall satisfaction. As labeled, the first column provides results for all respondents, column two only those who report that they drive more than fifty miles on an average day, and the remaining columns divide respondents by age and rural/urban driving. Across these models, the smoothness variable provides most of the explanatory leverage. Among those driving more than fifty miles per day smoothness is even more important, as are readable signs, striping, and availability of emergency information.

Dividing respondents by age and urban/rural drivers generates several interesting findings. In addition to the importance of smoothness, the overall satisfaction of respondents over 60 years old (21 percent of all respondents) is significantly influenced by open lanes/bridges. Counter intuitively, the higher they rate DOT's performance in the areas of snow removal and lighting, the *less* likely this population is to rate DOT's *overall* performance highly. Among urban drivers, standard maintenance statewide, weed control and highway lighting contribute to positive evaluation of overall performance, while these attributes do not register among rural drivers. Among rural drivers, shoulder condition, smoothness of ride, litter removal, and availability of emergency information all have significant and positive impacts on overall satisfaction.

Again, like correlation analysis, regression/probit results are relatively easy to interpret; however, several issues must be kept in mind when using both correlation and regression analysis. First, the size of the correlation or regression coefficient is partially dependent on the amount of variation in the explanatory variable. For example, results in Table 1 seem to indicate that satisfaction with the safety and cleanliness of rest areas has no impact on overall satisfaction.

Yet, this may simply be attributable to the fact that there is relatively little variation in responses to this question. Respondents were, in fact, generally satisfied—with 21 percent rating this variable a "10" and 59 percent rating this rest area maintenance an "8" or above. Therefore, results provided by regression analysis are more accurately interpreted as *opportunities* for a positive impact on overall satisfaction.

A second important concern that must be considered when analyzing survey data is the subjective nature of responses on which these data are based. As the results in Table 1 suggest, a variety of factors not related to objective highway conditions—including age, sex, and driving habits—have a clear and significant impact on driver perceptions. One of the additional questions included in the 1999 BHO survey provides still more intriguing (and worrisome) evidence of respondent subjectivity. The question attempts to gauge the respondent's general attitude toward state agencies using the following wording:

> How do you generally view state agencies like the Wisconsin Department of Transportation, the Department of Health and Human Services, the Department of Natural Resources, and so forth.

Again, respondents are asked to rate their satisfaction on a 1-10 scale. Consistently, when this variable is included in regression models such as those presented in Table 1, this variable is significant and positive. This result provides clear evidence that driver perceptions are in part determined by broader sentiments toward government that are entirely uncontrollable by the Department of Transportation.

TABLE 1 Factors Influencing Perceived DOT Performance: Significant Coefficients

	ALL	50+ miles per day	Over 60	Under 60	Urban driver	Rural Driver
Smoothness	+	+	+	+	+	+
Shoulders					–	+
Weeds					+	
Plants						
Litter		+				+
Lights					+	
Signs		+				
Guardrails						
Stripes		+				
Lighting		–	–		+	
Debris clearing						
Snow clearing			–			
Rest areas						
Open lanes/bridges			+			
Statewide standardization					+	
Emergency information		+				+

Detailed ordered probit results provided in Appendix A.

Comparing the State of the Practice: Innovations Beyond Transportation

Taking into account the various factors influencing subjective assessments of performance, tools developed in other fields to capture the relative importance of service attributes may deserve closer attention. One such approach, conjoint analysis (also referred to as stated preference analysis), has been the focus of more than two decades of market research scholarship and today is widely used in private sector product development. Conjoint surveys ask respondents to choose from combinations of product attributes—as if they were comparison-shopping. Results from a series of these choices are then used to derive relative utilities of various attributes based on statistical modeling. In other words, the results more accurately represent what a customer would choose, rather than what they say they would select. In addition, this technique more closely reflects a reality given constrained resources; trade-offs between various service attributes must be made (*12, 13, 14*).

Various improvements to the conjoint framework have been explored in recent years,. For example, adaptive conjoint was developed to simplify the trade-off process and minimize cognitive demands placed on respondents. This approach uses a computer application to customize survey questions based on the respondents' answers (*15*). There is a broad base of vendors with experience administering adaptive conjoint and other variations on the conjoint model and 1990 *NCHRP Report 329* cites the potential usefulness of conjoint in transportation research. This report looks primarily at its use in understanding modal trade-offs, however. As far as we are aware, this technique has not been used to gauge the importance of operations services (*16*). Applying this technique to operations may be complicated by two factors: 1) customers have no direct way to place a value (like a purchase price) on the various combinations of attributes; and 2) using this type of tool with more than 6-10 attributes can be complicated and tax the respondent's attention.

A second tool, contingent valuation, comes from cost-benefit analysis in economics and policy studies and has been widely applied to environmental planning and maintenance. Somewhat similar to conjoint, this approach gauges the overall "willingness-to-pay" for a given public service (say forest maintenance or wetlands protection). In the most common version, respondents are asked whether they would be willing to pay for a given set of conditions at a given price/tax (a value randomly drawn from a specified range). Individual responses are then aggregated across the population for an overall willingness-to-pay (*17, 18*).

Each of these approaches is analytically sophisticated and would represent a major advance in research on customer attitudes toward highway operations. However, as neither of these approaches is currently being applied to market research in highway operations, an individual state DOT seeking to use them may encounter significant costs. Developing these approaches may be time- and resource-intensive and, if not performed carefully, may carry the risk of generating information that is not terribly useful.

Our own effort suggests divisions of highway maintenance and operations are best served by returning to a more fundamental set of questions: Given the resources expended by state DOTs on customer data collection, are we generating and making use of meaningful information? Only when state DOTs begin to demand meaningful results from their customer survey efforts will they be prepared to take advantage of increasingly sophisticated tools developed in other fields of market research.

Listening but Not Hearing: Are Customer Surveys Props or Tools?

During the course of the effort described above, we contacted highway and maintenance divisions in approximately fifteen state DOT's, universities, and consulting firms to identify practices for maximizing the usefulness of customer data. While some respondents we spoke with reported exploring innovative approaches to customer data analysis and collection, we found that most reported a similar experience to our own. The adoption of randomized survey instruments has placed sophisticated tools in the hands of managers; however, the potential of these instruments appears to have rarely been realized.

In fact, this pattern of under-utilization characterizes not only customer data collection across state DOTs, but fits a more general pattern across organizations of all types. Collection of performance data often comes to serve a "ritual significance" focused on legitimizing rather than informing the organization's actions (*19*). In many cases, this may not be a conscious strategy. In fact, as the example above illustrates, the many technical barriers to reaching valid conclusions from survey data can easily frustrate managers. Faced with expectations from political and administrative overseers, the organization may be better off dedicating resources to a survey even if utility alone does not justify it.

The obstacles to effective use of customer data are more than simply technical. In some cases, the constituent-as-customer analogy itself obscures what DOTs can and should learn from the perceptions of its constituents. Services provided by state DOTs vary widely in their similarities to those provided by private businesses to their customers. Clearly, the concept of customer satisfaction offers greater traction for assessing services provided to individuals standing in line at the DMV than for "services" provided to an individual arrested by state patrol. In our own case, reviewing methods for evaluating driver perceptions of highway maintenance and operations, we grappled with important limitations in the customer analogy. Identifying what determines overall driver satisfaction with a non-rivalrous, non-excludable public good like the condition of a state highway poses significant challenges over and above those faced by businesses attempting to market products for private consumption. Divisions of highway maintenance and operations are in the awkward position of selling a product to customers who may never consider its cost or value—and, when asked, may lack the necessary information to articulate their true preferences.

Mapping the Utility of Customer Data

Despite these limitations, customer data can provide valuable information for administrators, planners, frontline managers, and political overseers seeking to improve organizational performance—even in areas where drivers lack sufficient information to articulate an immediate preference. Like any other outcomes data, customer data must be carefully evaluated for valid causal links. However, with a clear sense of its limitations, the data can be used to aid decision-making, or, accounting for the influence of other uncontrolled factors, provide important information about organizational performance.

One simple way of conceptualizing the potential uses of customer data is to map data needs along two dimensions. The first dimension varies according to two priorities: data may be used either retrospectively to measure performance or prospectively to help guide:

- Performance measurement—Managers and overseers seek objective data by which to evaluate the organization's performance over time and across functional or geographic areas; and
- Decision support—Managers seek information to help prioritize among demands for resources. This information takes two forms: first, managers seek general information regarding customer preferences. How do drivers prioritize among different factors? Which services do they value most? Second, managers seek customer input regarding specific decisions, projects, and circumstances.

The second dimension varies by the level of analysis. Information may be collected regarding the department as a whole or a specific unit or project. Figure 2 illustrates variations in data needs across these two dimensions.

A. What factors are most important to drivers?

Administrators, planners, and managers within the organization may seek information about the general preferences of drivers—an issue addressed in this paper's first section. Administrators and elected representatives may seek this information to support or defend budget allocations. Planners may seek this information in conducting long-term planning. Among the

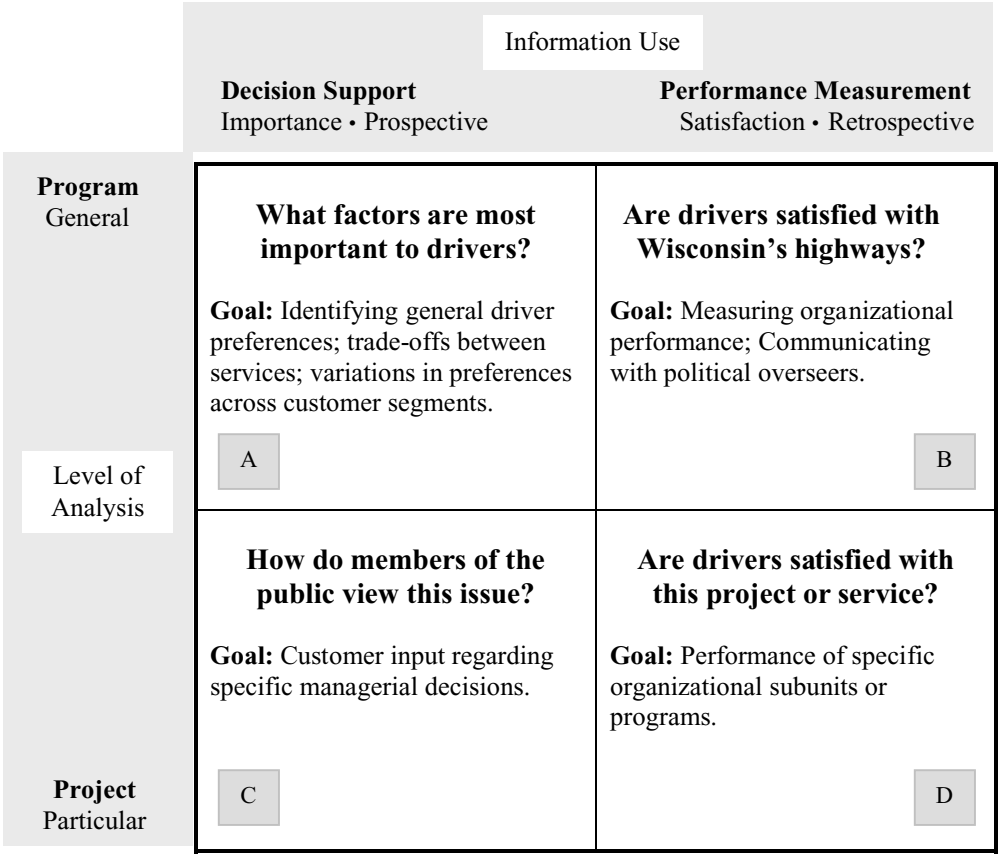


FIGURE 2 Mapping customer data types.

various tools that may be used to answer these questions are random surveys, focus groups, conjoint analysis, and regional and national studies of driver preferences.

B. Are drivers satisfied with Wisconsin's highways?

One of the most common uses of customer data is as a global measure of organizational performance. Elected officials, administrators, and others both within and outside the organization may seek this information to track changes in organizational performance over time. Among the tools available to respond to these needs are random surveys and regular processes for collecting customer comments and complaints.

C. How do members of the public view this issue?

Often, when transportation organizations prepare to make important decisions regarding budget allocations or initiation or termination of a specific service or product, policy makers and administrators seek information regarding customer attitudes toward this decision. This information both helps to ensure that the appropriate decision is made and helps administrators prepare for the likely public response. Tools that may help generate this information include: focus groups; non-random surveys; public forums; customer comments; and other sources of informal public feedback.

D. Are drivers satisfied with this project or service?

Performance information for specific operational units and services within the organization can help administrators, frontline and program managers identify both areas for improvement and successful practices that can be adopted more broadly within the organization. Among the tools that support these data needs are customer surveys, focus groups, and customer comments and complaints.

CUSTOMER DATA COLLECTION AND ANALYSIS: A ROADMAP

The conceptual framework identified above attempts to make sense of the types of customer data an organization may seek to use. It does not suggest the various specific factors determining the most appropriate data strategy for a given organization. What are the organization's needs and priorities? What are the barriers to data collection? What are the quality and cost of each data type? Answers to these questions are specific to the organization's priorities and environment—and, we believe, it is in asking and answering these core questions that customer data collection and analysis most often fails. Specifically, customer data collection efforts must avoid two frequent problems:

- First, the needs of internal staff may not be accurately gauged prior to data collection, resulting in survey efforts that provide little useful information to managers; and
- Second, relevant data, once collected, often are not communicated in a useful format.

This section sketches a roadmap for data collection designed to ensure that the above questions are explored in a way that improves the quality and relevance of customer data. We have organized this process into six steps illustrated in Figure 3.

Step 1: Develop a Needs Matrix

Customer data collection efforts typically bring together the needs of individuals responsible for diverse functions within the organization as well as those outside the organization concerned with its performance. (See Table 2.) The needs of each of these groups will differ. In addition, the cost of filling specific needs and the relative importance of specific needs will vary. As a result, customer data collection and analysis boils down to a series of strategic decisions,

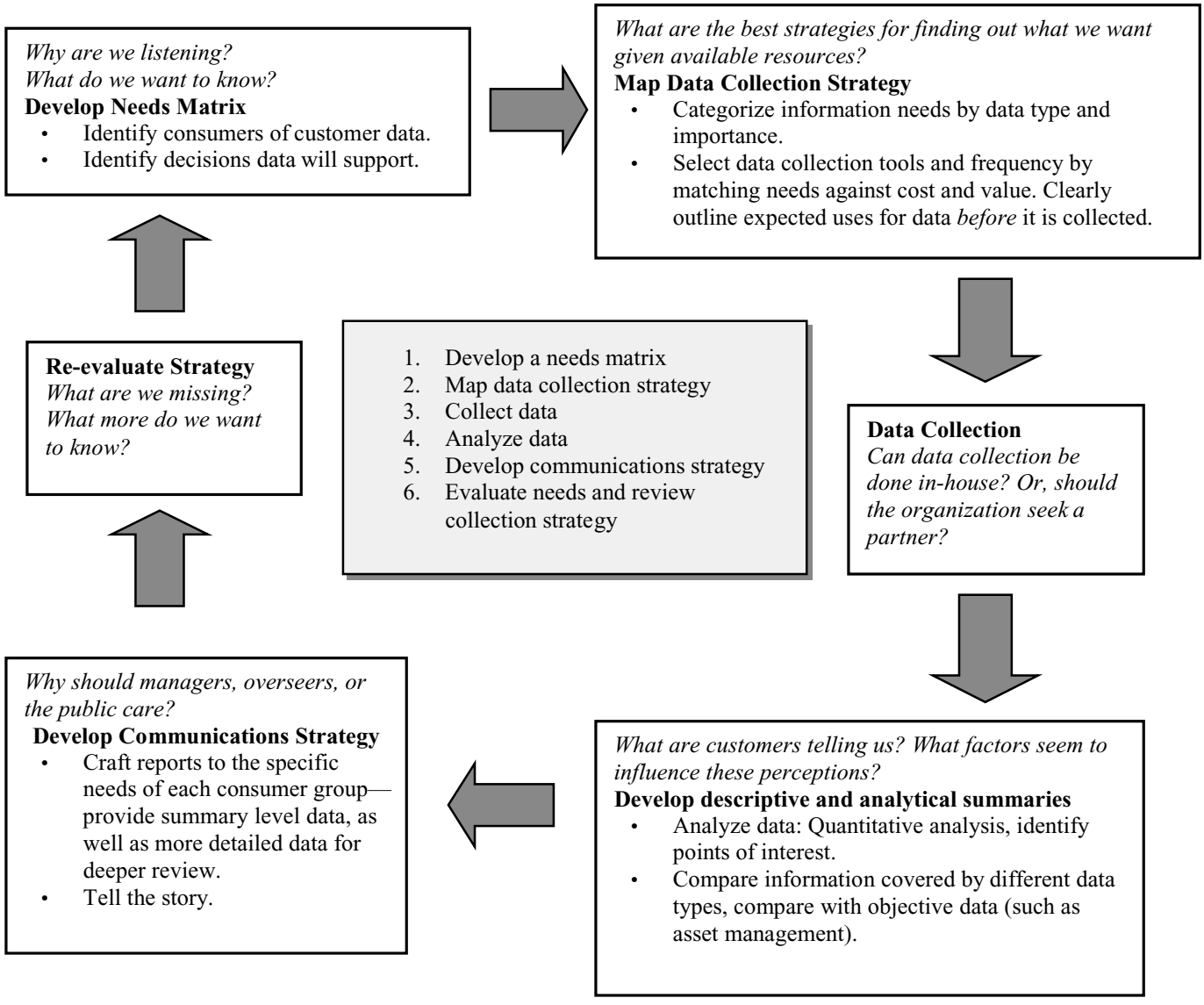


FIGURE 3 Customer data moving from needs to collection to analysis.

TABLE 2 Needs Matrix

	CONSUMERS OF DATA			
DATA NEEDS/ QUESTIONS	**Director, Operations**	**Manager, Winter Maintenance**	**District Operations Manager**	**Legislators**
Are drivers satisfied with the condition of our highways?	✓✓	✓	✓	✓✓
How will drivers react to new snow and ice removal standards?	✓	✓✓		
How is District 1 doing compared with other districts?	✓		✓	
How can we improve public perceptions over the long-term?	✓			✓
				✓ = data need
				✓✓ = strong data need

weighing the value of data types for each internal and external consumer against resource demands.

Step 2: Map Collection Strategy

Once the specific consumers of customer data and their specific data needs have been identified, overall data needs can be aggregated and weighted for importance and urgency. Aggregate data needs can then be matched with collection methods, taking into account overall resource constraints. Appendix B provides a rough sketch of the strengths of several prominent data collection tools. Table 3 provides an example of one method for matching needs to strategies.

Step 3: Collect Data

The central question that must be answered during the data collection phase is whether the organization has sufficient expertise and staff resources to administer the effort in-house. Organizations possessing the capability to administer a randomized telephone survey—requiring a computer assisted telephone interview system—are obviously the exception. However, many organizations employ staff trained and experienced in leading focus groups or conducting non-random in-person surveys.

In the case of our own organization, while WisDOT employs several staff members trained as focus group moderators, other demands on time of these individuals have forced us to look elsewhere. We are currently weighing two options: hiring a contractor, or–preferably–supporting the training of additional WisDOT staff in skills necessary to coordinate and moderate focus groups.

TABLE 3 Matching Needs to Strategies

	CONSUMERS				VALUE	DATA COLLECTION TOOLS		
DATA NEEDS/ QUESTIONS	**Director, Operations**	**Manager, Winter Maintenance**	**District Patrol Manager**	**Legislators**	**Do we need it?**	**Randomized Telephone Survey**	**Focus Groups**	**Customer Comments**
Performance measurement Program Level								
Are drivers satisfied with the condition of our highways?	✓✓	✓	✓	✓✓	✓✓✓	●	–	○
Performance measurement Unit/Project Level								
How is District 1 doing compared with other districts?	✓		✓✓		✓✓	–	○	◐
Decision Support Program Level								
How can we improve public perceptions over the long-term?	✓			✓	✓	○	◐	–
Decision Support Unit/Project Level								
How will drivers react to new snow and ice removal standards?	✓	✓✓			✓✓	–	●	○
					Price Tag:	**$$$**	**$$**	**$**

Step 4: Analyze Data

Data analysis anchors the larger process outlined through this paper. Many of the techniques we have explored—regression analysis, correlation analysis, conjoint analysis—are described in the paper's first section. As our own experience suggests, analysis plays the pivotal role in

generating and communicating meaningful information. Therefore, specific analytical approaches, as well as strategies and personnel for carrying out the analyses should be identified during the planning stage to avoid the 'data dump' that complete many survey efforts. Also, use the most simple and inexpensive approaches available for gathering valid information regarding each of the questions identified. The more easily understood a given approach is, the greater likelihood it will be understood and accepted by internal staff. While innovative analytical strategies may generate interesting results, if they are not understood they will be ignored.

Step 5: Develop Communications Strategy

The importance of effectively communicating survey results is frequently underestimated. Many of the customer survey reports we reviewed were dominated by large tables of frequency data with only minimal effort to synthesize and draw attention to interesting results. During our review of practices across states, we identified a handful of approaches that seemed to enhance the effectiveness with which survey results were communicated. First, in addition to providing descriptive summaries of survey results, attempt to articulate a 'big picture' summary of the findings. If, as was the case with our post-hoc analysis of the BHO's 1999 survey data, attitudes differ in important ways across customer segments—highlight these differences in the executive summary. Second, report only important data. The temptation to provide a full reporting of survey results is strong, but many unimportant results can be briefly summarized or placed in an appendix. Third, provide a clear, concise methodology, acknowledging important limitations in the data collection method in language that can be understood by managers not trained in survey design and analysis. Fourth, just as the planning effort will have identified the distinct needs of each type of customer data consumer, reports detailing results should be crafted to clearly fill those needs.

Step 6: Evaluate Needs and Review Collection Strategy

Finally, like the management strategies customer data are often collected to support, the most successful approaches to data collection and analysis are those that focus on continuous improvement. One potential barrier to improving instruments over time is the utility of developing a trend based on standard data collection methods over multiple iterations. Yet, while a data collection approach should not be lightly abandoned, improvement requires change. And, our review suggests that many data collection efforts will gain more through change than through continuing poorly conceived and underutilized customer survey initiatives.

ACKNOWLEDGMENTS

The authors would like to thank the support of the Midwest Regional University Transportation Center, Jason Bittner, John Nordbo, Richard Moss, and David Vieth.

REFERENCES

1. Osborne, D., and T. Gaebler. *Reinventing Government: How the Entrepreneurial Spirit Is Transforming the Public Sector*. Plume, New York, 1993.

2. DeLeon, L., and R. Denhardt. The Political Theory of Reinvention. *Public Administration Review,* Vol. 60, No. 2, 2000, pp. 89-97.
3. Brudney, J., and D. Wright, "Revisiting Administrative Reform in the American States: The Status of Reinventing Government During the 1990s," *Public Administration Review*, 62:3 (May/June 2002): 353-360.
4. Brudney, J., T. Hebert, and D. Wright. Reinventing Government in the American States: Measuring and Explaining Administrative Reform. *Public Administration Review*, Vol. 59, No. 1, 1999, pp. 19-30.
5. Poister, T., R. Harris, Jr., J. Robinson, Jr., and J. Reeder. Using Intensive Customer Feedback to Improve the Delivery of Highway Maintenance Programs in Pennsylvania. July 26, 2001.
6. Author Interviews, June-October, 2002.
7. *Wisconsin Department of Transportation, Bureau of Highway Operations, 1999 Highway Operations Customer Satisfaction Survey*. Wisconsin Survey Research Laboratory, Madison, Wis., January, 2000.
8. Stein-Hudson, K., R. Sloane, M. Jackson, and A. Bloch. *NCHRP Report 376*: *Customer-Based Quality in Transportation*. TRB, National Research Council, Washington, D.C:, 1995.
9. Arbor, Inc. 2001 County Maintenance Customer Satisfaction Survey: Exploratory Analyses. Report prepared for Pennsylvania Department of Transportation, Media, Pennsylvania, May 2001.
10. Long, R. *Regression Models for Categorical and Limited Dependent Variables*. Sage Publications, Thousand Oaks, 1997).
11. Miller, G., and M. Whicker, eds. *Handbook of Research Methods in Public Administration*. Marcel Dekker, Inc., New York, 1999.
12. IntelliQuest. "Conjoint Analysis: A Guide for Designing and Interpreting Conjoint Studies." *Marketing Research Technique Series*. American Marketing Association, Chicago, 1992. http://www.nri.co.jp/english/report/papers/2001/pdf/np200139.pdf.
13. Kowagoe, K., and N. Fukunaga. Identifying the Value of Public Services by the Contingent Valuation Method. *Nomura Research Institute Papers, No. 39*, Nomura Research, Ltd., Dec. 1, 2001.
14. Louviere, J., D. Hensher, and J. Swait. *Stated Choice Methods: Analysis and Application*. Cambridge University Press, New York, 2000.
15. Hunt, J., J. Abraham, and D. Patterson. Computer Generated Conjoint Analysis Surveys for Investigating Citizen Preferences. The University of Calgary, Calgary, Alberta, Canada. http://www.ucalgary.ca/~jabraham/Papers/corevalues/corevalues.pdf.
16. Jakabiak, S., R. Mudge, and R. Hurd. *NCHRP Report 329: Using Market Research to Improve Management of Transportation Systems*. TRB, National Research Council, Washington, D.C:, 1990.
17. Boardman, A., D. Greenberg, A. Vining, and D. Weimer, *Cost-Benefit Analysis: Concepts and Practice*, 2nd ed. Prentice Hall, Upper Saddle River, N.J., 2001.
18. Carson, R. Contingent Valuation: A User's Guide. *Environmental Science & Technology*, Vol. 34, No. 8, 2000, pp. 1413-1418.
19. Bennet, C., and H. Hill. Performance Management Systems: The Importance of Defining Their Purpose. Working paper, 2002.

APPENDIX A: MAXIMUM LIKELIHOOD RESULTS

This appendix provides basic details regarding the quantitative analysis included in this paper.

Dependent variable: Overall satisfaction with road maintenance (Q14)

Explanatory variables (satisfaction)

- Debris (not ice/snow) (Q15)
- Ice/snow (Q16)
- Similar statewide (Q17)
- Shoulders (Q18)
- Smooth surfaces (Q19)
- Open lanes/bridges (Q20)
- Weeds (Q21)
- Attractive plants (Q22)
- Litter (Q23)
- Lights/Signs (Q24)
- Readable signs (Q25)
- Guardrails (Q26)
- Visible stripes (Q27)
- Lighting (Q28)
- Rest areas (Q29)
- Emergency information (Q30)

Descriptive statistics for these variables are provided in Table 1 below.

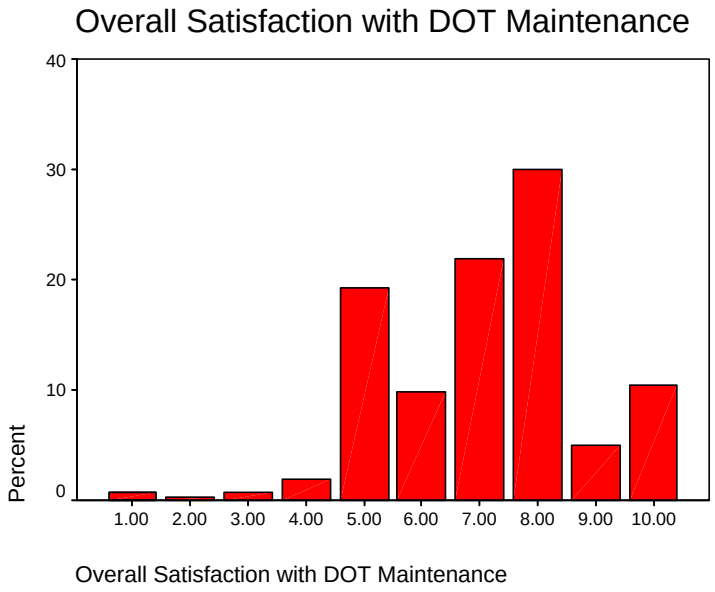
TABLE 1 Descriptive Statistics

	Median	**Mean**	**Standard deviation**	**Missing**	**Valid N**
Overall Satisfaction	7	7.09	1.71	4	814
Debris	8	7.33	2.02	11	807
Snow	8	7.62	1.92	9	809
Statewide stand.	7	7.06	1.97	51	767
Shoulders	8	7.29	1.83	19	799
Smooth	6	6.38	1.96	4	814
Open lanes/bridges	7.5	7.21	2.08	58	760
Weeds	7	6.79	2.13	30	788
Plants	7	6.80	2.11	27	791
Litter	7	6.72	2.17	8	810
Lights	9	8.33	1.66	4	814
Signs	8	8.22	1.67	5	813
Guardrails	8	8.28	1.68	31	787
Stripes	8	7.28	2.09	3	815
Lighting	8	8.08	1.80	27	791
Rest areas	8	7.63	1.97	51	767
Emergency info.	7	6.97	2.21	60	758
Miles per day	25	42.73	67.89	11	807
Year born	1954	1952.9	16.5	0	818
	Male	**Female**	**--**	**Missing**	**Valid N**
Gender	381	437	--	0	818
	Urban	**Rural**	**Equal**	**Missing**	**Valid N**
Urban/Rural driving	301	478	15	24	796

Ordered Probit: Recoding Overall Satisfaction

A second problem with using OLS regression in this case is illustrated in the chart below, which shows the frequency distribution (in percent) for the dependent variable. This highly skewed distribution is characteristic of the other 1-10 scale variables, with a small number of responses spread across values 1-4. As a result, these responses have disproportionate influence. In fact, the Cooks D values indicate at least one influential outlier in the sample, which may bias regression results.

More importantly, while a limited dependent variable will not linearly vary with the dependent variable as assumed in OLS regression, a dependent variable with 10 possible values typically generates similar results for both OLS and the more precise ordered probit model. However, the highly skewed distribution of the dependent variable suggests the assumption of a linear relationship is misleading.



To address this problem, I recoded the dependent variable into a four part ordinal variable as shown below in Table 2. Table 3 gives ordered probit estimates using the recoded dependent variable.

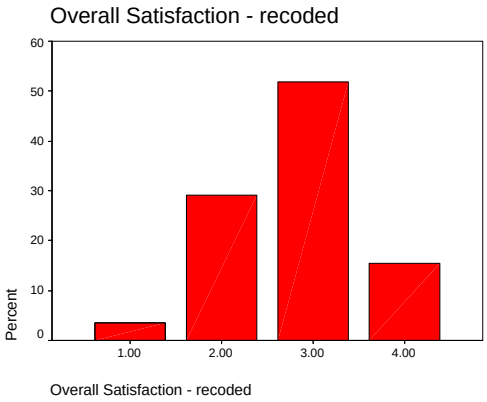


TABLE 2 Overall Satisfaction - Recoded

	Poor	Avg.	Well	Extremely well	Missing	Valid N
Previous value	1-4	5-6	7-8	9-10	--	--
New value	1	2	3	4	--	--
Frequency	29 3.5%	237 29%	422 51.6%	126 15.4%	4 0.5%	814 100%

TABLE 3 Perceived DOT Performance: Ordered Probit Estimates

	All Respondents	50+ miles per day	Over 60	Under 60	Urban driver	Rural Driver
Debris clearing	.044 (1.42)	-.046 (-0.62)	.059 (0.81)	.038 1.07	.052 (1.02)	.047 (1.17)
Snow clearing	.024 (0.78)	.063 (0.81)	**-.162*** **(-1.91)**	.056 (1.61)	-.024 (-0.45)	.046 (1.14)
Statewide standardization	.050 (1.51)	.022 (0.32)	.063 (0.67)	.047 (1.29)	**.180***** **3.10**	-.058 (-1.31)
Shoulders	.053 (1.45)	.016 (0.18)	.101 (1.15)	.048 (1.15)	**-.109*** **(-1.82)**	**.172***** **(3.41)**
Smoothness	**.285***** **(8.67)**	**.431***** **(4.95)**	**.267**** **(2.84)**	**.302***** **(8.19)**	**.229*** (4.62)**	**.392***** **(8.22)**
Open lanes/bridges	.022 (0.77)	-.039 (-0.55)	**.138*** **(1.79)**	-.002 (-0.07)	.010 (0.21)	.039 (0.96)
Weeds	.014 (0.42)	-.080 (-0.89)	.126 (1.52)	-.0003 (-0.01)	**.093*** **(1.74)**	-.032 (-0.71)
Plants	.017 (0.50)	.085 (0.94)	-.058 (-0.63)	.031 (0.84)	.025 (0.47)	-.012 (-0.27)
Litter	.033 (1.14)	**.131*** **(1.90)**	-.027 (-0.34)	.039 (1.23)	-.011 (-0.23)	**.068***** **(1.77)**
Lights	-.007 (-0.17)	-.153 (-1.55)	.146 (1.23)	-.036 (-0.79)	**.132**** **(1.97)**	-.089 (-1.56)
Signs	.021 (0.53)	**.208**** **(2.02)**	-.156 (-1.43)	.053 (1.18)	-.033 (-0.54)	.076 (1.31)
Guardrails	.053 (1.36)	.048 (0.44)	.093 (0.89)	.059 (1.36)	.065 (1.07)	.024 (0.43)
Stripes	-.022 (-0.74)	**.145*** **(1.83)**	.103 (1.26)	-.045 (-1.34)	-.020 (-0.42)	-.048 (-1.14)
Lighting	.022 (0.60)	**-.202**** **(-2.20)**	**-.186*** **(-1.90)**	.056 (1.36)	**.102*** **(1.67)**	-.023 (-0.47)
Rest areas	.010 (0.35)	.055 (0.73)	.084 (0.92)	-.008 (-0.24)	.060 (1.47)	-.005 (-0.13)
Emergency information	.038 (1.34)	**.190**** **(2.53)**	.113 (1.54)	.039 (1.24)	-.013 (-0.28)	**.102***** **(2.60)**
Cut Points	1.877 3.951 5.983	2.780 5.154 7.658	1.871 4.112 6.261	1.979 4.072 6.142	2.505 4.760 6.952	1.856 4.042 6.133
LR Chi^2	336.15***	106.63***	68.90***	278.68***	150.57***	231.49***
Pseudo R^2	0.2439	0.3633	0.2646	0.2515	0.2651	0.2863
(N)	634	132	124	510	269	365

Positive values indicate that satisfaction with the specific attribute has a significant impact on overall satisfaction.
Dependent variable: Overall satisfaction with highway maintenance, recoded into 4 part ordinal variable
Coefficients based on ordered probit estimates; Z-scores reported in parentheses.
* significant at .10 level (two-tailed test), ** significant at .05, *** significant at .01 level.

Appendix B: Data Collection Techniques

Ratings Key: ● = Good ◐ = Fair ○ = Marginal – = No Contribution

RANDOMIZED SURVEY: CURRENT APPROACH FOR WISDOT BHO

The overall satisfaction score provides an adequate performance measure—similar to those used by other states. The data also provide basic decision-support. However, measures in difficult to observe areas may not be accurate. Also, the current sampling approach provides little project level information.

One closely related alternative: several states use survey instruments based on two recent national surveys conducted by FHWA. These are similar to the current BHO survey and offer a potential for benchmarking against other states.

Resource demands: Using the un-modified survey instrument or adopting the FHWA design would minimize development costs, but telephone survey administration costs are comparatively high.

Decision Support	Performance Measurement	
○	●	Program
–	◐	Project

COST: $$$

RANDOMIZED SURVEY: INCREASING SAMPLE SIZE

Increasing the sample size would allow performance measurement at the district or county level. It may also provide additional decision support by identifying important organizational weaknesses across these subunits.

Resource demands: Moving from the current standard of generalizing to the district level to generalizing at the county level would add significantly to the necessary sample size and could be cost prohibitive.

One less-costly method of boosting the overall N is to administer the survey via mail; however, this will result in a reduced response rate and may introduce bias.

Decision Support	Performance Measurement	
○	●	Program
–	◐	Project

COST: $$$–$$$$

RANDOMIZED SURVEY: IMPROVING THE INSTRUMENT

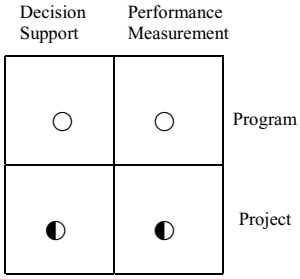
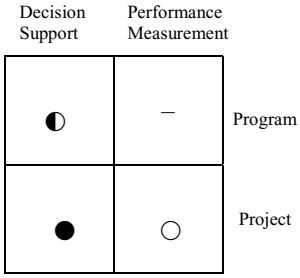
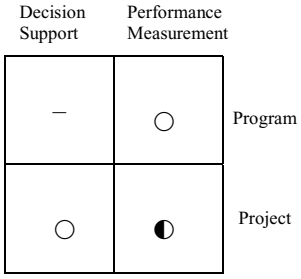
Additional investment in the current approach may improve planning support and performance measurement. Simple modifications, such as adjusting question scales from 10-point to 5-point to improve reliability (as detailed in June 2002 review), may be accomplished easily without the help of a vendor.

More ambitious improvements include redesign with the assistance of a vendor based on innovative survey techniques such as conjoint analysis. However, limitations inherent in the survey format, such as constraints in ability to provide additional background information or visual cues to inform responses, mean that improvements in the instrument to provide better decision support are limited.

Resource demands: Depending on the nature of modifications, the cost may vary from relatively low to high.

Decision Support	Performance Measurement	
◐	●	Program
–	–	Project

COST: $ – $$$$

NON-RANDOM SURVEY: CONVENIENCE SAMPLE	
Non-random sampling may help reduce survey costs and allow for targeting of specific populations. Options include: sampling frames based on lists from trucking associations, AAA, adjacent property owners, or questionnaires may be distributed at rest areas (focusing on specific highways) and public hearings. While data may provide a helpful indicator of attitudes among targeted populations, non-randomized sampling does not adequately support program-level performance measurement and should be used for decision-support only with caution. **Resource demands**: Depends on the nature of sampling technique—in general this approach will be substantially less expensive because it need not rely on administration of the survey by a CATI facility.	 **COST: $–$$**
FOCUS GROUP: QUALITATIVE ANALYSIS	
Focus groups offer two advantages: 1) They provide both more focused and more detailed data on issues of concern to managers—which may be particularly valuable in the areas of winter, vegetation and public information campaigns. 2) They provide for enhanced information on which respondents can base their opinions. For example, discussions with staff responsible for winter maintenance and vegetation and landscaping highlight the potential value of visual information in gauging driver preferences. The existing survey asks respondents to state what "percent bare" they feel the pavement should be during a storm and between storms. Given the potential for subjective interpretation of this question, it would be much more useful to gauge preferences based on visual cues. Among the disadvantages: The non-random nature of selection may bias the result of the analysis—focus groups cannot be generalized to the whole population. Also, qualitative data can provide *too much* information, making it difficult capture the most important research conclusions. **Resource demands:** Costs will be driven by the number of focus groups conducted, typically this will include 2-6 sessions per topic or customer segment.	 **COST: $$–$$$**
PROACTIVE FEEDBACK: COMMENTS, COMPLAINTS, PUBLIC FORUMS	
This is the most straightforward and easily gathered type of customer data. Customer complaints and feedback serve to highlight developing long-range problems or "squeaky wheels" that may generate additional scrutiny from the department's overseers. This information can be used to support decisions regarding specific projects or identify organizational weaknesses that require attention. While the data collected is not scientific, customer feedback can be compared over time to provide a rough trend in relative performance. Fewer complaints over time may be interpreted as an indication of improved performance. **Resource demands:** Minimal, additional resources may be invested in generating greater customer feedback and analyzing feedback that is gathered.	 **COST: $**

Customer and Market Focus Process

LAWRENCE J. BILOTTO
Pennsylvania Department of Transportation

"To develop a tool or systematic method for surveying, analyzing, prioritizing, implementing, and providing feedback on current and future customer needs." A District team was tasked with developing a system that captures the customer's thoughts and asks, "What can we do to improve our products and services to exceed or delight the customer?" The new Customer & Market Focus Process is broken down into three parts. The first is a Customer Service Index (CSI) that measures courtesy, responsiveness, effectiveness, knowledge, reliability, and helpfulness. The second portion is another CSI survey measuring the value of a specific product or service to our customers. Finally, the third is a measure of customer dissatisfaction (a ratio of complaints over compliments) for each of our products and services. This ratio is accomplished using an in-house developed MS Access database application. The Community Link System (CLS) was developed to aggregate all of our customer contacts (via mail, meeting, phone, email, etc.). The system is used to improve the District's processes associated with repetitive contacts asking for attention concerning one of our products or services. The database captures a variety of location data elements to help identify patterns. This provides an opportunity for repeat complaints to be analyzed to see if there is a process problem with either product or service delivery or the District not being proactive in eliminating the item before it becomes an issue. Finally, the CLS has an audit feature built in, which randomly samples 30% of the complaints received each quarter.

MISSION STATEMENT: *To develop a tool or systematic method for surveying, analyzing, prioritizing, implementing, and providing feedback on current and future customer needs.*

The mission statement is very much in line with the delivery of ever improving value to our organization's customers. A team was responsible for developing a process to determine what our customers want regarding our products and services. The team's solution was a three part system which asks the customers how we did professionally, the value of our products and services, and comparing the ratio of complaints to compliments.

THE CHANGING BUSINESS CULTURE

Tom Peters, a noted business author and quality expert, has been quoted as saying, "There are two reasons for being in business. The first reason is to satisfy the customer and the second reason is to stay in business to satisfy the customer!" We at Pennsylvania Department of Transportation (PENNDOT) District 9 value our customer's input and believe that customer complaints are opportunities that point out deficiencies in our products, delivery systems, or processes; this input is being used to improve those processes.

PENNDOT has for the last 20 years strived to improve productivity and increase customer satisfaction. After years of government waste and public mistrust the Department has systematically introduced productivity and customer focus ideas into the PENNDOT culture. This 20-year quality journey has not only benefited the Department but has more importantly provided the customer with better products and services.

The journey has been long and difficult at times while changing the old methods and adopting new ideas and processes. During the last several years, PENNDOT has been recognized in many areas as a leader and an innovator due to this culture change. As an example, the major products produced, such as smooth roads and winter services, has greatly improved as indicated by the public with steadily approving grades (see Figure 1). As we continue to improve, we have looked for processes and systems to help us take the Department to the next level.

Figure 1 shows District 9 improving from the first QUIK survey taken in 1997. The QUIK Customer Service survey is completed every other year and is used to gauge the progress of the 11 Engineering Districts in PENNDOT.

Currently, PENNDOT is using the Malcolm Baldrige Award (MBA) criteria to raise the level of productivity and service to our customers and partners. Even though a government organization is ineligible to receive the award, the criteria by which the award is measured is an excellent tool to gauge one's self against. The MBA criteria provides companies and organizations a tool to improve their processes and a way to ensure a steady positive growth in delivering their products and services.

THE TEAM

The age of brushing off customer complaints has taken a back seat to the current thinking of providing the customer with what they want to the best of an organization's ability or simply "to find the win-win solution." This is also in line with the thinking of the Baldrige criteria, which has a company continually asking what does the customer want and what does he think of the company's product or service.

With these two factors in mind, the PENNDOT Engineering District 9 Office formed a Customer Market Focus (CMF) Team in order to address these factors. The District Engineer

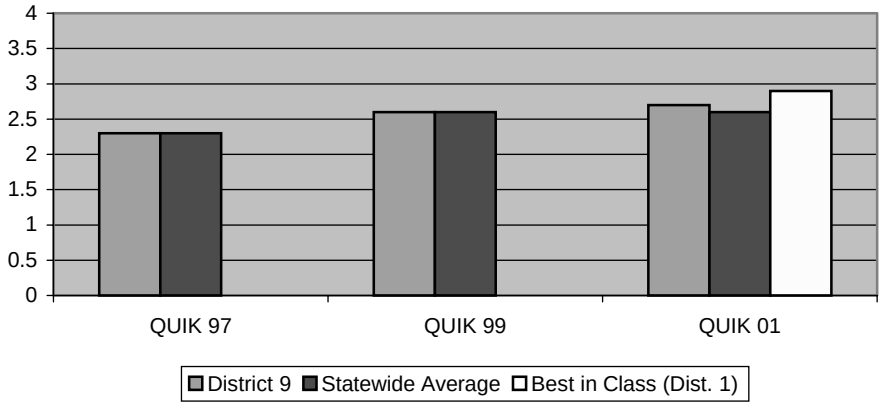


FIGURE 1 QUIK Customer Service Survey results for highway repair and maintenance.

(DE) was the leader of the team, which was comprised of staff personnel from various levels and included representatives from each of the four divisions (Design, Construction, Maintenance, and Administration). This group met regularly during a two year period to implement the suggestions of an organizational review team. The team had several objectives; to identify customer groups, to be proactive rather than reactive, to be customer focused, to map our key business processes, and to establish measures for those same key business processes.

Our key business processes for the District Office are safe smooth roads, project delivery, delineation/signage, winter services, and customer service. The team's role was to develop a process or method to support the key processes by identifying future customer needs. By benchmarking with several private organizations (Dana Corp., Crown American, and AT&T), the team realized the need to develop a systematic mechanism to not only capture the customer's thoughts but anticipate future requests. The team began to pull together a system that would not only track responses to customer requests, but would also allow the District to synthesize and breakdown the requests to the lowest possible denominator to allow for process revisions. Also, several customer surveys were developed to help identify opportunities for improvement in customer service. These actions follow the main objectives of the MBA Criteria for Category 3.

Using the benchmarking information and several creative ideas, the CMF Team developed a world class system that not only captures the customer's thoughts, but asks the question, "What can we do to improve our products and services to exceed or delight the customer?" This thinking was a significant part of the original motivation for the process improvement. The team had eventually developed a systematic three part process, known as the CMF Process, which included two Customer Service Indexes (CSI), or surveys, and the Community Link System (CLS) database.

CMF PROCESS

The team developed the new CMF Process with the intent of supporting and providing guidance for our products and services. Therefore, the system is a support system rather than a product or service. This then makes it difficult to provide direct business results. What the Customer & Market Focus Process does is identify those areas needing attention and possible re-engineering. Indirectly, this action is expected to result in higher customer satisfaction for our products and services.

The new process is geared around listening to the customer and then improving our effectiveness and capabilities. The system triggers process owners or units to look at those processes that keep reoccurring through complaints or those areas receiving low value scores to see what improvements can be made to a product or service. These work processes are looked at routinely by senior staff and monitored at the DE's Staff meeting. They look at the data received and select and implement new teams as necessary to adjust or re-engineer our key processes or a support process. This is done at a minimum each year during the annual update of our business plan. However, teams have been formed during the year as the need arises.

The personal learning of the process comes in to play not by the process developed, but by what happens as a result of the new CMF Process. As complaints come in and processes are receiving low scores, teams will be established to look at ways of making adjustments or improvements. These team efforts have improved the organization by improving our goods and services directly and indirectly. Directly, the teams have used comparative analysis or benchmarking to re-engineer a process. Indirectly, the individuals have taken the knowledge

gained in the team endeavors and used in their own areas or subsequent teams. It has also enabled poor to mediocre performers to develop their skills and become better employees. This personal learning has greatly improved the skill base in our organization, thus helping to develop future leaders of the organization.

The Mechanics

The new process is broken down into three distinct parts. The first two parts are CSI surveys which are done on an annual basis and asks how we are doing regarding being professional or how good is the value of our products and services. The third portion is a ratio of complaint to compliments for each of our products and services. This overall CMF score is done at every unit level based on their specific product and service.

The first survey is the external CSI survey that measures satisfaction in courtesy, responsiveness, effectiveness, knowledge, reliability, and helpfulness. This survey was developed by the team to be used by all units for their processes. The survey is to be used as a standard way to measure all units against each other and allow the office to provide a mechanism to ensure uniformity in delivering good customer service. The second portion is also a CSI survey except this time the survey is product or service specific. This survey asks questions regarding how we performed on a particular item or the value of the product or service.

These surveys are intended to determine if we are improving and, if not, where we can target for improvement. Since the CMF Process is relatively new, we have only gone through a few cycles and have not been able to determine direct impacts to products and services.

The CLS portion is a third of the three-part CMF system that looks at the district's customer service from different perspectives. Using the Complaint over Compliments or dissatisfaction over satisfaction ratio, the District uses this figure to determine its overall CSI score. Since the CLS captures all types of contacts from predominately complaints to compliments, with this information we can develop a ratio of complaints over compliments to monitor our success in making improvements to our processes, products, and services. This is developed using data directly from the CLS. The CLS will provide the ratio to help us understand if we are exceeding and delighting the customer's expectations. However, it will also provide a list of opportunities for product, process, or service improvements. These opportunities can then be looked at for reducing costs or time. This portion is also done annually to ensure that we are looking strategically in order to adapt and remain focused on the customer's ever changing needs.

Besides measuring our customer's satisfaction/dissatisfaction and how our customers value those products and services at the process level, we can also review the types of issues received to monitor if the issue is within our control. Since we are a government agency, we must abide by department policies and legislative rules. Therefore, if the complaints deal primarily with the later, the system can provide us with information to aid in suggesting appropriate changes to the Commonwealth's or Department's regulations. In addition, if there are no complaints about a specific process or product, we can assume our direct operations are providing the customer with the products and services they demand.

Once each of the three parts have been completed or data retrieved, then the scores are pulled together for each process / unit. The units are then combined and a division score is created. From there the four divisions are rolled together to produce a District score. The scores are viewed as a means of identifying who is providing the best customer service and who has an

opportunity to improve. Managers are able to quickly review their areas and spot which area or specific part of a process or unit needs attention and resources committed to improve.

The District has in the past selected the processes we believe impact the most important products and services that we provide. We have been successful in doing so, but we have not been 100% accurate. We are now using the CLS to help us identify a process, product, or service that consistently appears as a starting point for re-engineering and improvement. A work process specific team is then formed to analyze the issue and make recommendations for improvements.

CLS

Design

We segment our customers by the specific processes that produce the goods and services which they need. Our key customers are the transportation system users; contractors, consultants, public officials, material suppliers, and anyone using the transportation system for their individual needs. These segments have been identified through previous surveys and brainstorming sessions. However, we use the CLS to help narrow the focus based on their contact types.

The CLS was developed in house to address all of the Team's requirements in order to provide a world-class service to our customers by aggregating all of our customer contacts (via mail, meeting, phone, email, or etc.) and then using the system to generate the dissatisfaction ratio. Up to that point, there was no system such as a PC program, paper file, or other process that pulled together all contacts for easy retrieval and analysis. In addition, the system is used to point out those areas needing attention due to repetitive contacts asking for attention from one of our products or services.

The CLS is a Microsoft Access Database application. The menu driven system works very simply through data entry screens, user search tools, and predetermined reports. Our District Office is leading the way in usage since the system first became available in test mode in December 2000 and official use began January 1, 2001. The 6 counties that support the District Office were brought on line in January 2002, once they had been added to the Commonwealth's LAN network. The CLS is now accessible to all 900+ District employees who have access to a LAN connected PC. Since implementation, there have been over 1600 data entries.

The CLS was developed using a member of the initial team and power users of MS Access. The database has undergone several changes to continually improve upon delivery of the information. Overall, the basic information collected has not changed significantly; however, the manner in which it is displayed or delivered has been revised to make the system more "user friendly." The original group of 6 individuals developed the general layout of the CLS. One team member, plus another staff member, and a summer student actually produced the database system as it is used today. In addition, several users group meetings have been held to provide continuous user feedback for improvements such as ease of use for understanding of procedures.

During the development phase, the small work group worked closely with the original team to provide the look and features envisioned by the team. At various points, the screens and reports were shown to the team for their input and approval. As the database was assembled, other individuals who were most likely to use the system were asked for their input as to

functionality and ease of use. Changes were then made and improvements incorporated as suggestions were made.

How It Works

Besides using the system to capture customer complaints or compliments, it also captures meeting notices, general inquiries, or comments. These entries, which are delivered to us by various means (letter, email, site visit, legislator contact, and telephone calls), are logged in and an appropriate individual is designated to respond based on information gathered from the contact. The contact is also clarified so that any opportunity for improvement in the associated work process can be made. In addition, complaints are tracked from beginning to end to ensure prompt response is made. If necessary a follow-up contact is made to ensure that the complaint has been resolved to the best of the organization's ability and general satisfaction if not acceptance of the situation by the customer.

The use of pull down menus for many data items provides the user with quick and error-free data entry, along with providing a consistent data element for future retrieval efforts. This ensures that quality assurance reports run at a later date for auditing purposes or for process analysis are user friendly. The main data entry screen forms used each contains a sub form at the bottom. This sub form provides the user a quick history of previous contacts by an individual with the same last name. As the last name is entered, it will show all other contacts by date and provide a quick glance of the issue at that time. This provides an opportunity for the individual who will respond to the contact with background information as to whether or not this is a repeat contact or a customer with a history of complaints regarding other road and bridge conditions.

The database captures a variety of location data elements to help identify patterns in a county, along a particular State Route (SR), or even a segment of road to help with future programming of road improvement projects. Also, the database segregates the complaint type by organizational division, by unit or process, and finally by process owner. This provides an opportunity for repeat complaints to be analyzed to see if there is a process problem with either delivery or being non-proactive in eliminating the item before it becomes an issue. Finally, it indicates if a legislator is involved; this provides an indicator to the receiver as to the level of involvement and sensitivity of the contact. Figure 2 shows the fields in the database's Add/Edit Records Form.

Since the District and 6 county offices are all LAN connected, we can share this information electronically. With this capability and using MS Outlook, we have added a feature to our CLS to allow the data entry person to quickly email the contact and all pertinent information to the individual responsible for addressing the contact and copying all those who may have an interest in knowing or participating in the response. This now reduces the time lost through delivering the contact through our regular interoffice mail. This email feature enhances the ability by the District to respond to most contacts within the general 3-day time frame allowed by our office.

The application has numerous built-in check reports that can be viewed to see which contacts have been addressed and which still need to be followed up with a response. These reports are pulled regularly and addressed at the senior level staff meetings and at the DE's Administration meeting.

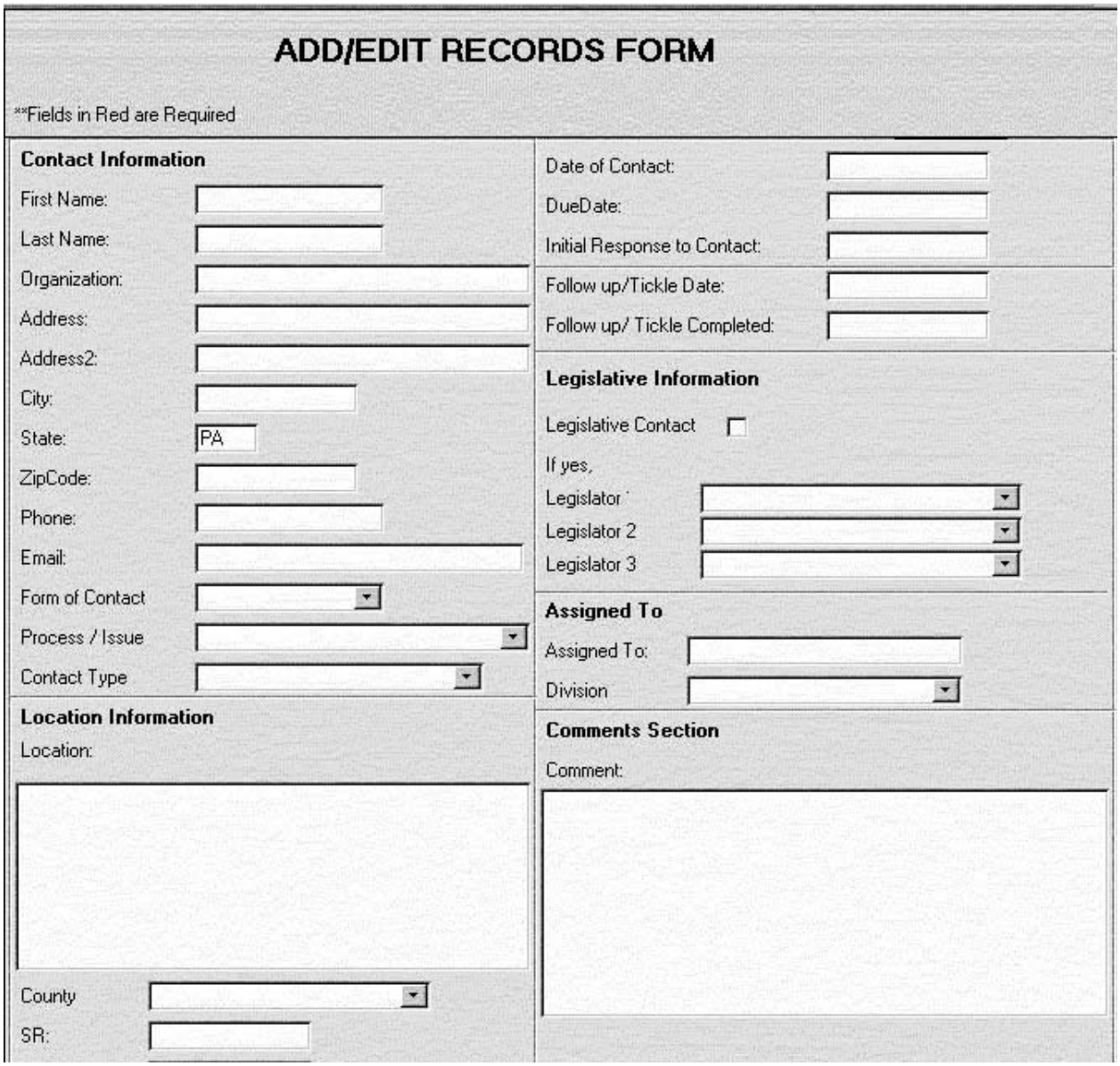


FIGURE 2 CLS Add/Edit Records screen.

Finally, the CLS has an audit feature built in, which randomly samples 30% of the complaints received each quarter. The system will select the individuals and generate a custom letter to be sent to those individuals asking how we responded to their complaint and how well we resolved or explained our position on the issue. The audit portion of the CLS system provides the District with information regarding our quick response to customer contacts and just how well we interacted with the individual or group. This information is gathered together and shared with senior management so that good customer service can be acknowledged or corrective action taken.

In Operation

In December 2000, the CLS was made available for BETA testing and refinement. The system was officially set in motion in January 2001 for the District Office only. The counties were latter added in January 2002 once the statewide LAN connections were in place at all 6 remote locations. As each group received access to the CLS, the development team provided just-in-time training to ensure user understanding and accurate data entry.

Since implementation, several CLS users group meetings have been held to provide the users with the latest system enhancements and to provide a forum to solicit for future enhancements and system understanding. Because of the difference in the nature of business between the District Office and the 6 County Offices, the system had to be adjusted to account for those differences in product and service terminology and processes.

The other side of implementation deals with using the data received. The District regularly looks for those sections of the organization that are not responding in a timely manner, which processes need re-engineering, and the areas providing good customer service. Routinely, the organization monitors response time in order to remain at the 3-day level for returning an initial response. This is a carry over from the previous smaller system, which only tracked arrival and closing of a letter contact.

PROCESS SHARING

As previously mentioned, the team had benchmarked with outside groups and has shared their results with those organizations helping us. It was necessary to work with top performing companies or previous MBA winners to ensure that the new process developed was a world class system. Our Center for Performance Excellence Bureau was used to help the team benchmark the new process. They have also been used to help share our results throughout the rest of our organization.

Because of the significance of the data storage and retrieval system, we have shared our CMF Process and CLS application with numerous state and federal highway organizations (for example, three other state DOTs, FHWA, and the AASHTO Standing Committee for Quality). Several of these asked for follow-up information and actual database copies in order to develop a custom application for themselves (5 District Offices & 3 Central Office Bureaus).

The system has now been mimicked in several PENNDOT Districts, with one District beginning the process of online data entry via the Internet for their employees. This action has lead to the formation of a statewide task force to oversee the complete access on the Internet by customers, partners, and employees in the near future. The goal now is to create a statewide system capable of statewide data sharing and web access to all.

RESULTS

To date, there have been no cost/time saving analysis done regarding the CLS; however, there is valuable knowledge gained by the feedback provided by the customers. Time and costs have been reduced for those processes selected thus far using data from the CMF process; but none have been directly associated with the CLS.

The CLS replaced a system that used to simply track correspondence that came into the office to be responded by a set due date. Before, the responding individual was lucky if they

knew of a previous or similar contact made regarding the customer or complaint. Now the system shows those contacts and allows the user to copy the text of a response letter and place it into the appropriate data field. This field is in a memo format and will allow for an endless input of data. This provides the user with the ability to maintain a diary of contacts if they so desire in order to record the history of any sensitive contact.

In addition, SR complaints are used to help identify roads needing resurfacing or repairs. This aids the County Managers when they are developing their annual spring and summer work. By pulling information per SR, we can provide a specific scope for the next scheduled improvement.

CONCLUSION

The organization can now be proactive by reviewing past contacts for patterns based on various criteria. Currently, the District uses 10 complaints for a particular process as a basis to start determining which process should be re-engineered next.

In effect, the District now has a virtual file cabinet the size of the Library of Congress held within the confines of a PC. The time and cost savings will be realized through the ability to research previous contacts within minutes of the letter arriving and the ability to store large amounts of data with relatively no cost for storage.

All senior management supports the system, and its use is discussed at their biweekly Administration Staff meetings. In addition, all personal are encouraged to keep a copy of a blank data entry form on their desks underneath their phone, so that new contacts can be captured immediately. If so inclined, the user can simply click on the icon on their Windows' Desktop and activate the system for immediate online data entry. Multiple-use access is available due to the LAN system, thus data entry can occur simultaneously from any District 9 or county PC.

ACKNOWLEDGMENT

The creation of the CLS database was made possible due to the CMF Team's creativity and motivation for improving customer service; and particularly to the vision of Karan A. Pasquariello. Therefore, I wish to express my appreciation for the opportunity to work with these fine employees on the development of that portion of the CMF System.

Management Decision Tools for Winter Operations

TERESA M. ADAMS
JUSTIN MALONEY
ALAN VONDEROHE
University of Wisconsin, Madison

TOM MARTINELLI
Wisconsin Department of Transportation

New winter maintenance vehicles are being equipped with differential global positioning system (DGPS) receivers and numerous sensors that collect environmental data (e.g., pavement and air temperature), equipment status (e.g., plow up/plow down), and material usage (e.g., salt spreading rate). These data are both telemetered to a dispatch center and recorded on magnetic media for later downloading. Data are transmitted and recorded as often as every two seconds. Data such as these, both in type and in quantity, have never before been available. With the availability of new data, agencies are exploring the possibilities for improving the performance of winter maintenance operations. Performance measures can be computed from data collected by DGPS receivers and sensors on winter maintenance vehicles using geographic information systems for spatial analysis. A performance measurement approach ensures that the applications of these data support the real needs of decision makers for evaluating and improving winter maintenance operations. The measures can be directly tied to the business processes and performance of operations. Performance measures and decision support chart representations of the performance measures were identified and refined through a series of meetings with transportation professionals from many levels including a workshop for winter operations engineers, county commissioners, patrol supervisors, program managers, and consultants. This paper presents performance measures for management of winter operations and a series of management decision tools that can be derived from the performance measures.

This paper presents results of a workshop to develop management decision tools for winter operations. The workshop was an activity of a research and development program, funded by the Wisconsin Department of Transportation (WisDOT), to evaluate and deploy advanced sensing, positioning, and data-collection technologies on-board winter maintenance vehicles. The data from the instrumented winter maintenance vehicles are processed off-line, in a geographic information systems (GIS) environment (named "Wiscplow") to produce calculated values for winter operations performance measures. The GIS application, currently under development, performs spatial analysis by relating the differential global positioning system (DGPS) coordinates of the vehicles to accurate spatial representations of roadway centerlines, demarcated by patrol sections containing measured routes and attributed by number of lane miles and roadway functional class. Performance measures are derived from the sensed data, temporal relationships among them, and computed traveled distances along the patrol sections.

The workshop was held in Wausau, Wisconsin in November 2002. It was the latest in a series of activities designed to identify, quantify, implement, and test a series of performance measures for winter operations and effective means (i.e., decision management tools) for representing the performance measures and their relationships. The workshop had sixteen attendees from Wisconsin counties, participating in the project, and from the private sector including county highway commissioners, patrol superintendents, shop supervisors, analysts, office managers, and consultants.

Workshop objectives were to 1) introduce participants to the Wiscplow (GIS) system, 2) provide participants with an opportunity to influence the functional capabilities of the GIS software, and 3) prepare participants for system deployment by providing details on necessary data and computing systems requirements. Workshop activities included 1) a demonstration of the Wiscplow software, 2) a presentation of to-date developed performance measures, 3) a table exercise on how performance measures could be used in the workplace, 4) a presentation on to-date developed decision management tools, 5) a table exercise on additional decision management tools, and 6) a presentation on system requirements.

PERFORMANCE MEASURES FOR WINTER OPERATIONS

A performance measure for winter operations is an indicator of how well the service, procedures, and guidelines meet and satisfy expectations. Performance measures were identified and refined through a series of meetings with winter operations engineers, county commissioners, patrol supervisors, program managers, and consultants. Consideration of the goals and objectives of winter operations led directly to identification of performance measures. The performance measures listed in Tables 1 to 3 satisfy the concerns of decision makers (*1,2,3*) by:

- Reflecting goals, regulations, or community vision;
- Indicating the outcomes from service availability and delivery;
- Reflecting local conditions and issues;
- Facilitating comparisons among alternative means of providing the service; and
- Representing a measurable, meaningful, and objective indicator as a basis for discussion and decision-making.

Many of the performance measures for winter operations can be computed from data collected by DGPS receivers and sensors on winter maintenance vehicles (*4*). The formulations for these performance measures are presented in a companion article presented at the 2003 meeting of the Transportation Research Board (*5*).

Table 1 lists the performance measures for statewide management of winter operations from the perspective of the central office and districts. These include monitoring labor costs, evaluating the effectiveness of different materials on corresponding pavement temperatures, and monitoring compliance of application rate guidelines by patrol section, and by operator. The measures include information provided on weekly storm reports submitted by the counties to the central office during the winter season from November 1 through April 30. A winter severity index is used to

normalize performance for comparison across multiple winter seasons and multiple storm events. Material usage, labor costs and overtime hours can be normalized by a storm severity index and compared across storms and patrol sections.

Table 2 lists the performance measures for budgeting and forecasting of equipment needs from the perspective of the machinery management committee made up of central office, district, and county members. This committee develops reimbursement policies and establishes reimbursement rates for winter maintenance equipment. The committee monitors the annual usage of the statewide equipment fleet and evaluates the relative durability and effectiveness of alternative equipment options.

Performance measures for managing winter operations from a county-level perspective are listed in Table 3. The measures address the needs of patrol superintendents and county highway commissioners in developing strategies to manage and enhance field operations including planning material, equipment, and labor needs prior to a storm and evaluating the use of resources after a storm. County-level managers are concerned with managing their inventories of sand, salt, and anti-icing liquids and complying with guidelines for LOS (level of service) and material application rates. Table 3 also includes measures for customer satisfaction, monitoring damage to state property, and uniformity at county borders; however, the data from instrumented winter maintenance vehicles cannot compute these measures.

Performance measures can provide useful information for guiding management decisions and desirable employee behavior if they are portrayed in a manner that facilitates their use (*6*). After reviewing the performance measures in Tables 1 to 3, county patrol superintendents were asked to comment on how they envision using the performance measures to save money, to improve level-of-service, to communicate with the public, and to communicate with the Wisconsin County Highway Association (WCHA) board and state legislature. The results of the ensuing discussion are summarized in the following paragraphs.

County patrol superintendents suggested the performance measures could be used to save money by eliminating waste and inefficiencies. Patrol superintendents said they could use the measures to better manage materials by avoiding over- and under-application according to air and pavement temperatures and by evaluating the effectiveness of different liquids for de-icing and anti-icing. The patrol superintendents said they could improve the efficiency of patrol sections by designating sections based on the location of fuel and materials supplies to minimize deadheading. The patrol superintendents said they could use the measures to better manage labor and equipment by comparing cost-per-lane-mile for alternative equipment configurations, and by comparing labor and equipment hours by patrol section.

County patrol superintendents suggested the performance measures could be used to improve service by identifying problem areas and areas that are over- or underserved, by distributing materials according to pavement temperatures, and by ensuring consistency of material spreading. The patrol superintendents said they could use the measures to predict the labor, material, and equipment needs for a storm based on analysis of past data and to analyze the effectiveness of night and overtime operations.

TABLE 1 Performance Measures for Statewide Management of Winter Operations

Goal	Objective	Performance Measure
Evaluate trends over multiple seasons	Calculate annual winter severity index	Winter severity index
Minimize environmental impacts	Monitor application guideline compliance by patrol section	Hourly average pavement temperature for each patrol section
		Hourly average application rate of salt (pounds/lane mile) for each patrol section
		Hourly average application rate of sand (pounds/lane mile) for each patrol section
		Hourly average application rate of prewetting liquid added to salt (gals/ton) for each patrol section
		Hourly average application rate of prewetting liquid added to sand (gals/ton) for each patrol section
		Hourly average application rate of anti-ice liquid (gals/lane mile) for each patrol section
	Monitor application guideline compliance by operator and event	Blasts for each operator and event
		Average application rate of salt (pounds/lane mile) for each operator and for each event
		Average application rate of sand (pounds/lane mile) for each operator and for each event
		Average application rate of prewetting liquid added to salt (gals/ton) for each operator and for each event
		Average application rate of prewetting liquid added to sand (gals/ton) for each operator and for each event
		Average application rate of anti-ice liquid (gals/lane mile) for each operator and for each event
Manage annual winter maintenance budget	Monitor material cost by event and patrol section	Tons of salt used for each event and patrol section
		Cubic yards of sand used for each event and patrol section
		Gallons of prewetting liquid used for each event and patrol section
		Gallons of anti-ice liquid used for each event and patrol section
		Storm severity index
	Monitor equipment cost by event and patrol section	Cost for all attachment units for each event and patrol section
		Storm severity index
	Monitor labor cost by event and patrol section	Overtime hours for each event and patrol section
		Labor cost for each event and patrol section (including overtime & clean-up)
		Storm severity index

TABLE 2 Performance Measures for Budgeting and Forecasting of Equipment Needs

Goal	Objective	Performance Measure
Post-season analysis to determine changes in attachment needs for next season	Assess operational use of attachment units	Total operating hours for each attachment unit (state roads only)
		Total operating hours for each attachment unit (state and local roads)
	Assess cost-effectiveness of attachment class	Average production rate (hours per treated lane mile) for each attachment unit and roadway class
	Establish cost reimbursement policy	Percentage of operating time for each attachment class

TABLE 3 Performance Measures for County-Level Management of Winter Operations

Goals	Objectives	Performance measures
County highway dept. tool for efficient winter maintenance operations	Optimize labor usage	Labor costs for each event and patrol section (includes overtime & clean-up)
		Percentage of labor cost for each event and patrol section attributed to clean-up for each storm
		Labor hours per lane mile for each patrol section and storm (includes clean-up)
		Percentage of labor hours attributed to clean-up for each event and patrol section
	Optimize equipment usage	Total operating distance (miles) for each attachment unit (state roads only)
		Total operating hours for each attachment unit (state roads only)
		Cost for all attachment units for each event
		Cost for each attachment unit for each event and patrol section
	Monitor material inventory use	Tons of salt used per patrol section
		Cubic yards of sand used per patrol section
		Gallons of liquid material used per patrol section
Good winter driving	Monitor compliance of LOS (level of service) policy	Cycle time for each patrol section and storm
	Minimize time to good winter driving	Clean-up duration factor
	Improve customer satisfaction	Number of customer complaints by highway
		Number of customer compliments by highway
		Customer satisfaction with snow/ice removal
		Uniformity at county lines
		Number of vehicle accidents on snowy and icy roads for each highway and storm
		Number of vehicle accidents involving snowplows for each highway and storm
Minimize environmental impacts	Application rate compliance	Blasts for each operator and event
		Average application rate of salt (pounds/lane mile) for each operator and for each event
		Average application rate of sand (pounds/lane mile) for each operator and for each event
		Average application rate of prewetting liquid added to salt (gals/ton) for each operator and for each event
		Average application rate of prewetting liquid added to sand (gals/ton) for each operator and for each event
		Average application rate of anti-ice liquid (gals/lane mile) for each operator and for each event
Minimize damage to highway facilities	Monitor amount of damage to state property	Number of vehicle accidents involving signs, guard rails, and bridges for each highway and storm
		Number of plow accidents involving signs, guard rails, and bridges for each highway and storm

County patrol superintendents could use the performance measures to communicate with the public about road conditions and service plans. The performance measures provide accurate and defensible service records for responding to complaints and for justifying time, material, and equipment costs to taxpayers.

County patrol superintendents could use the performance measures to communicate with the WCHA board and the state legislature. The performance measures could be used to provide objective data for assessing proposals to privatize the state's winter operations as compared relative to the current arrangement with the counties. Finally, the patrol superintendents suggested that the performance measures could be used to justify material usage, labor and equipment needs, county budgets for winter operations, and state funding levels.

COMPREHENSIVE LIST OF POTENTIAL MANAGEMENT DECISION CHARTS

Identifying, defining, and calculating performance measure is not enough. A crucial step in many decision-making processes, including the ones related to winter operations, is interpretation of relevant data. For numerical relationships, charts and other graphical representations are often easier to read and more effective than tables or lists (*2*). Identifying effective representation formats for the performance measures is not easy (*7*).

This section presents a set of decision charts for managing winter operations derived from two research activities. To identify and develop the charts, we started with the performance measures presented in Tables 1 to 3 and followed basic guidelines for decision tools (*2*). First, we developed chart representations for some of the performance measures through a series of meetings held between July 2001 and August 2002 with winter operations engineers and managers. Second, in the November 2002 workshop, county patrol superintendents identified additional chart representation of the performance measures. To illustrate our expectations and to motivate the discussion at the workshop, we presented the performance measurement charts that were developed by winter maintenance engineers and managers.

The following is a comprehensive list of the 22 decision charts that were identified through both research activities. Topic areas that relate to business functions and objectives group the charts.

Relationships Between Material Application Rates, Pavement Temperature, and Air Temperature

1. Hourly average salt application rate and pavement temperature over a 24-hour period;
2. Average salt application rate and pavement temperature for each 15-minute increment of a working day;
3. Comparison of average salt and sand/salt application rates for each 30-minute increments of a working day;
4. Comparison among storm events of average salt application rate and pavement temperature;

5. Hourly average asphalt and concrete pavement temperature and air temperature over a 24-h period; and
6. Comparison among patrol sections of average salt application rate, average sand application rate, and average pavement temperature for a storm event.

Cumulative Salt Usage

7. Cumulative salt usage throughout a winter season;
8. Seasonal winter severity index and salt usage; and
9. Total salt applied (tons) at each tenth mile point of a patrol section.

Application Rate Guideline Compliance

10. Prewet salt application rate guideline compliance for initial application; and
11. Prewet salt application rate guideline compliance for repeat application

Operational Use and Productivity

12. Comparison among front plow units of average production rate by high and low volume roads;
13. Weekly cumulative front plow operating hours and distance throughout a winter season;
14. Comparison among storm events of operating hours for front and wing plow, spreader, and underbody scraper relative to truck operating hours;
15. Comparison among front plow units of annual cumulative operating hours; and
16. Comparison among front plow units of weekly cumulative operating hours throughout a winter season.

Blade Life and Replacement Forecasting

17. Scatter plot of front plow blade life (miles) vs. average operating speed (mph);
18. Comparison of operating life among front plow blade units; and
19. Scatter plot of average downward pressure of underbody scraper (PSI) vs. blade operating life (hours).

Cost Accounting

20. Comparison among storm events of total storm cost for alternative overtime policies: shoulders cleared on overtime and shoulders cleared during normal hours;
21. Comparison among patrol sections of total cost with breakdown for labor, equipment, and materials; and
22. Comparison among storm events of total labor hours with breakdown for overtime and standard time.

EXAMPLES OF MANAGEMENT DECISION CHARTS

This section illustrates ten of the management decision charts. The charts are templates that can be used by decision makers to display performance measures in an easy to visualize manner. Many of these charts are illustrated using actual data derived from the instrumented winter maintenance vehicles in Columbia County, Wisconsin. Others charts are illustrated using hypothetical data. The charts present relationships between performance measures, information derived from the performance measures, or other information derived from the processed sensor readings.

Hourly Average Salt Application Rate and Pavement Temperature over 24-h Period

Figure 1 shows the average salt application rate and corresponding hourly average pavement temperature for a 24-h period of a winter storm event. The chart illustrates two performance measures from Table 1: hourly average pavement temperature and hourly average salt application rate using data from a single vehicle. The chart indicates the time periods when deicing activities occurred and how the pavement temperature changed during that time. Time periods with no curves indicate when no deicing activity occurred. These could be rest breaks, change of operator shifts, or when the vehicle reloaded materials.

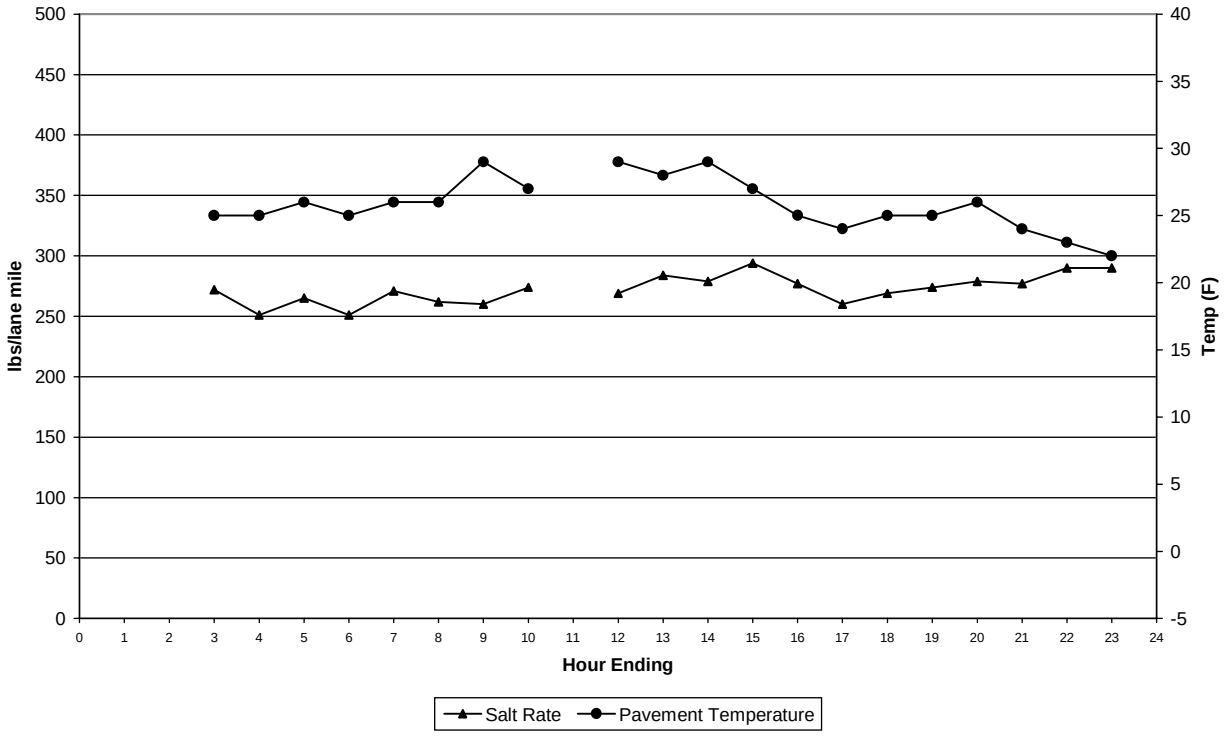


FIGURE 1 Hourly average salt application rate and pavement temperature over a 24-h period.

The chart is similar to a thermal map used to recommend anti-icing treatment (*8*). The chart provides a manager with a holistic view of how effectively material was used. The lower the pavement temperature, the more salt is needed to deice.

Comparison Among Patrol Sections of Average Salt Application Rate, Average Sand Application Rate, and Average Pavement Temperature for a Storm Event

Figure 2 compares the average material application rates and pavement temperatures across patrol sections during a single winter storm event. Data for this chart are derived from three performance measures in Table 1: hourly average pavement temperature, hourly average salt application rate, and hourly average sand application rate. The chart provides a high-level view of material usage and need trends across patrol sections.

Cumulative Salt Usage Throughout a Winter Season

Figure 3 plots cumulative inventory consumption for each patrol section over a winter season. The plot shows a weekly view corresponding to the annual winter season from the week ending November 1 through the week ending April 30. The chart can be used to compare material usage on individual patrol sections. Another purpose of this chart is for inventory management. Hence, the material units were converted from pounds-per-lane-mile to tons.

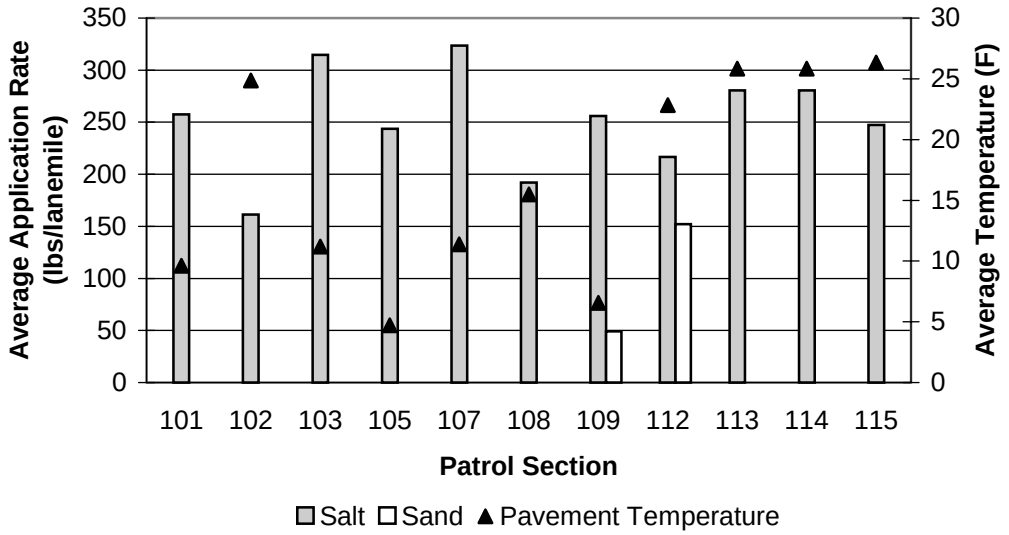


FIGURE 2 Comparison among patrol sections of average salt application rate, average sand application rate, and average pavement temperature for a storm event.

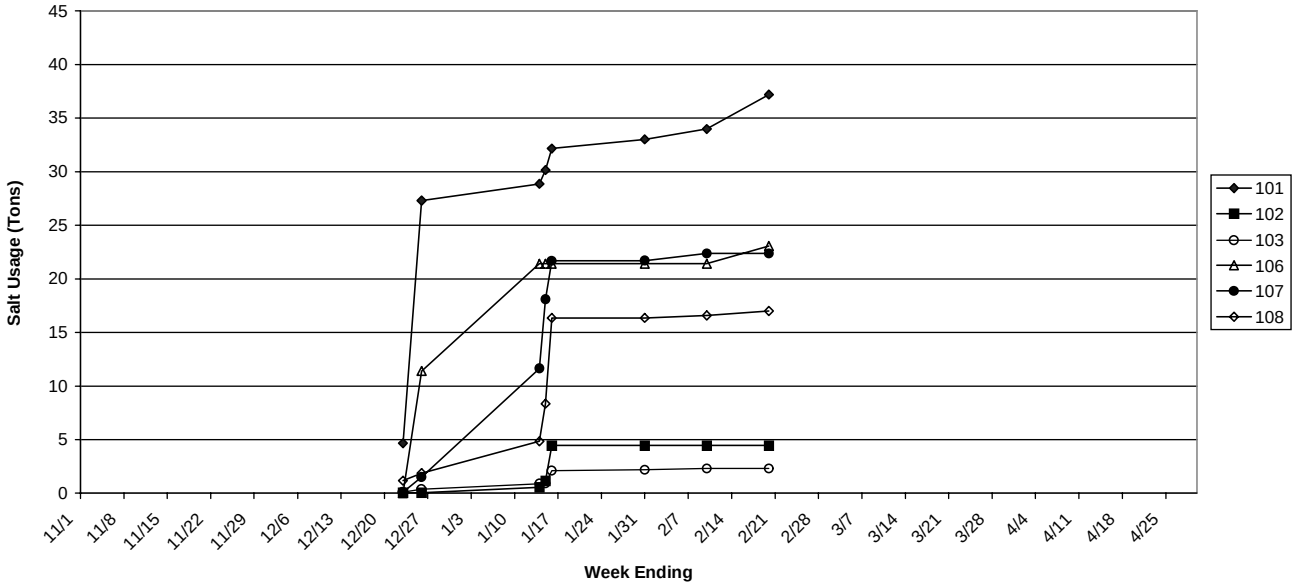


FIGURE 3 Cumulative salt usage throughout a winter season.

Data for this chart can be derived from performance measures for season-to-date cumulative material quantities (Table 3) or from material quantities for individual events (Table 1). Figure 3 shows an example of the latter; data points on each curve occur at the end of each event rather than at the end of each weekly reporting period. As shown, the winter season was unusually mild with only eight winter events.

Seasonal Winter Severity Index and Salt Usage

Figure 4 illustrates the relationship between annual salt usage and winter severity using two measures from Table 1: winter severity index and tons of salt used per event and patrol section. The higher the severity index, the greater the salt needs. Severity index is computed annually based upon number of events and incidences, duration of events, and amount of precipitation. The regional extent for this chart could be a single patrol section, a single county, a single district or statewide.

The chart can be used to monitor and predict annual salt usage and needs. Currently, the agency predicts salt needs based upon a five-year average of previous usage. This chart provides data for developing prediction models based on expected severity of the winter season.

Pre-Wetted Salt Application Guideline Compliance

Figure 5 provides for quick inspection of compliance with application rate guideline. The graph is compatible with the WisDOT guideline (*9*) for de-icing application rate for pre-wetted salt on two-lane roads (Table 4). WisDOT's guideline (Table 4) reflects best practices for maintaining roads during a winter storm (*10*). The recommended salt application rate is divided into two categories: initial rate and repeat rate.

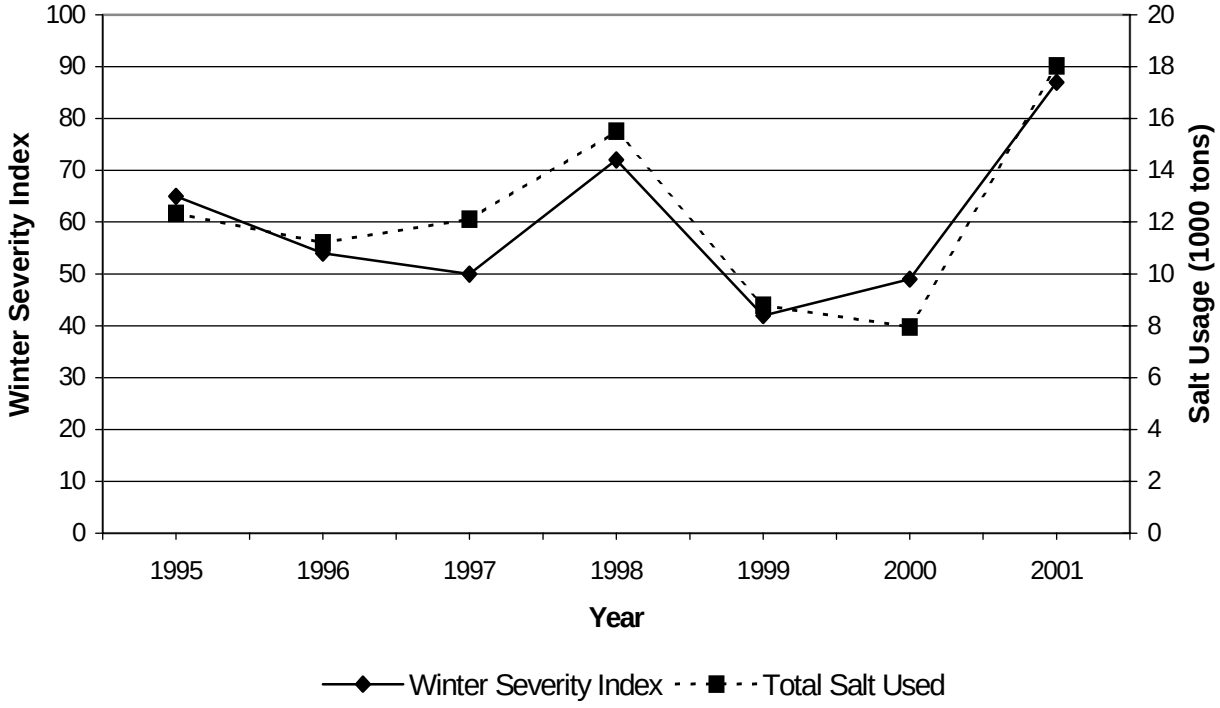


FIGURE 4 Seasonal winter severity index and salt usage.

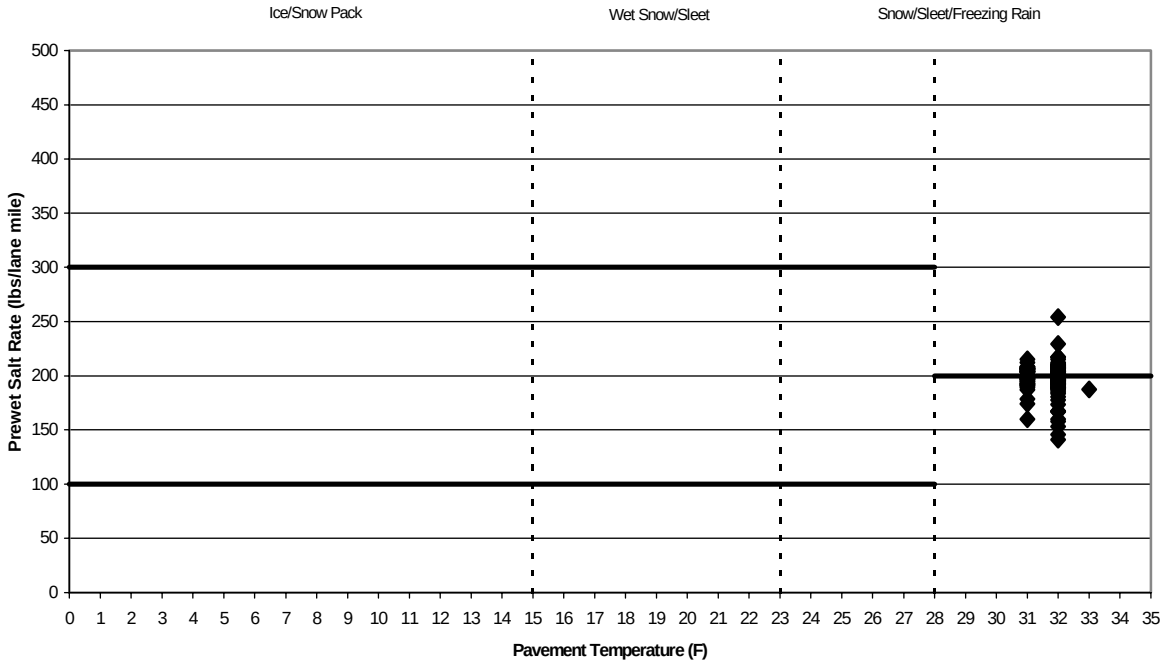


FIGURE 5 Prewet salt application rate guideline compliance for initial application.

TABLE 4 De-Icing Application Rates for Pre-Wet Salt (*9*)

WEATHER CONDITIONS		SALT APPLICATION RATE (pounds / lane mile of pavement)
PAVEMENT TEMPERATURE	PRECIPITATION	
28°F and above	snow	Initial at 200 of salt
	sleet/freezing rain	Repeat at 100-200 of salt
23-28°F	snow/sleet	Initial at 100-300 of salt Repeat at 100-200 of salt
	freezing rain	Initial at 100-300 of salt Repeat at 100-200 of salt
15-23°F	dry snow	Plow only
	wet snow/sleet	Initial at 100-300 of salt Repeat at 100-200 of salt
Below 15°F	dry snow	Plow only
	ice/snow pack	100-300 lbs salt, sand/salt mix, or salt mixed with dry calcium chloride

Figure 5 shows an example of the compliance chart for initial applications. A similar chart is possible for repeat applications. Data for the chart come from the processed sensor readings, not from the computed performance measures. The database contains sensor readings every two seconds for both pavement temperature and salt rate. For our purposes, the initial application comprises all application rate readings that were recorded before the vehicle completed one full application cycle. The cycle time is defined as the time duration required for the vehicle to traverse the full distance of the patrol section. All application rate readings occurring at times after the first full cycle are designated as repeat application rate readings.

By plotting field data, managers can evaluate compliance of their winter maintenance program. In Figure 5, the thick horizontal lines indicate the boundaries for application rates and the vertical dash lines indicate the boundaries for temperature ranges and precipitation types. Each data point plotted indicates a unique pair of application rate and pavement temperature readings. For compliance, the data points should fall within the bounded areas on the chart for the appropriate precipitation type.

Comparison Among Storm Events of Operating Hours for Front and Wing Plow, Spreader, and Underbody Scraper Relative to Truck Operating Hours

Figure 6 shows the operating hours for each equipment attachment relative to the number of hours the truck was used during each storm event. The chart uses the performance measure total operating hours for each attachment unit (Tables 2 and 3). For computational purposes, the truck is treated as an attachment unit.

The information in Figure 6 can be used to derive the average percentage of operating time for each attachment type, front plow, wing plow, spreader, and underbody scraper, which is useful for determining a composite cost reimbursement rate. When the composite rate is used, counties bill the state based upon the total time the truck is used rather than the time each attachment is used.

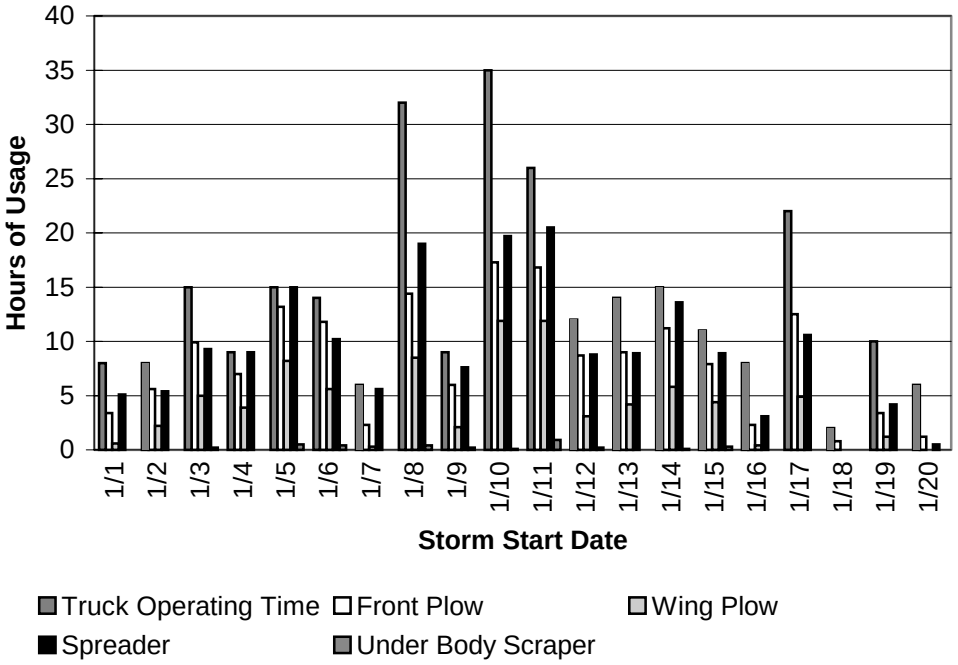


FIGURE 6 Comparison among storm events of operating hours for front and wing plow, spreader, and underbody scraper usage relative to truck operating hours.

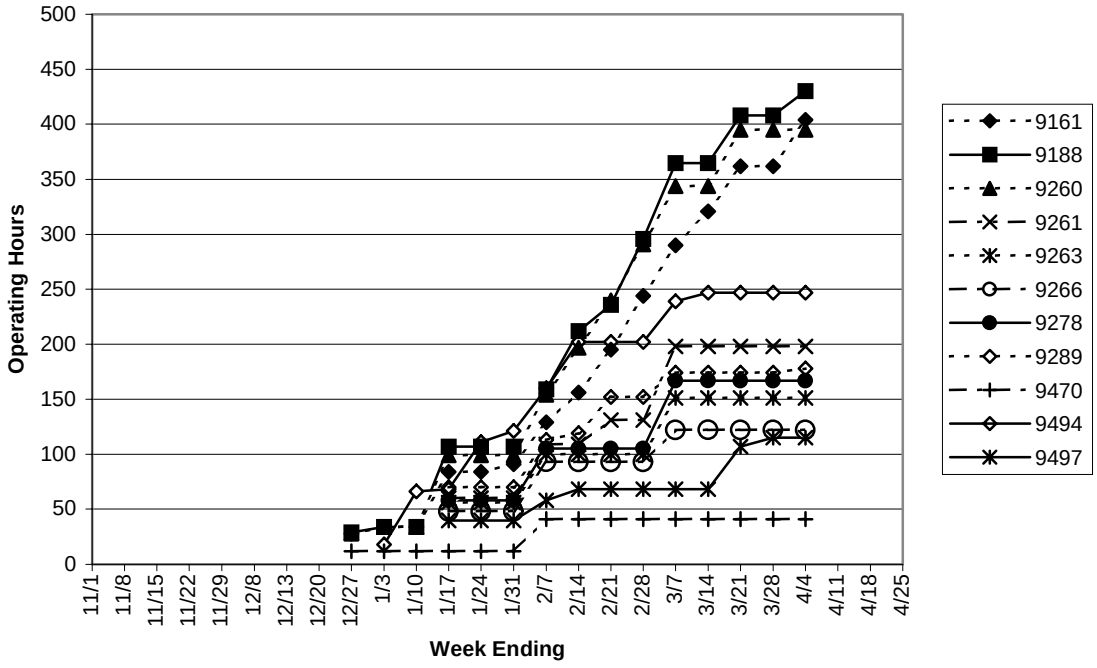


FIGURE 7 Weekly cumulative operating hours for operating units of an attachment class.

Comparison Among Front Plow Units of Weekly Cumulative Operating Hours Throughout a Winter Season

Figure 7 shows the cumulative operating hours for individual attachment unit for each week during a single season. Data for the chart were derived from the performance measure: total operating hours for each attachment unit (Tables 2 and 3). This information may be used for fleet management and replacement planning.

Comparison of Operating Life Among Front Plow Blade Units

Figure 8 compares the cumulative operating hours of individual front plow blades units. This chart provides information for managing blade replacement needs and eventually for comparing the service life of different brands of blades. Data for the chart come from the performance measure: total operating hours for each attachment unit (Tables 2 and 3).

Comparison Among Patrol Sections of Total Cost with Breakdown for Material, Equipment, and Labor Cost

Figure 9 compares total cost to maintain individual patrol sections over any period of time such as a single storm or an entire season. Total cost is broken down into labor, equipment, and material components so that the proportional cost of each can be compared among the different patrol sections. The chart uses six performance measures: cost for all attachment units for each patrol section (Table 1); tons of salt, cubic yards of sand, gallons of pre-wetting liquid, and gallons of anti-ice liquid used for each event and patrol section (Table 1), and labor costs for each event and patrol section (Tables 1 and 3).

Comparison Among Storm Events of Total Labor Hours with Breakdown for Overtime and Standard Time

Figure 10 compares total labor hours for each storm event for a single patrol section, a single county, a single district or statewide. The total hours are broken down into overtime and standard time hours so that managers can evaluate the effectiveness of different clean-up policies, e.g., only clean up on regular work hours or always clean up immediately after the storm regardless of regular hours or overtime. The chart uses two performance measures: overtime hours for each event and patrol section (Table 1) and percentage of labor hours attributed to clean up for each patrol section (Table 3).

DISCUSSION AND STATUS

The charts are derived from a database of performance measures calculated by spatial/temporal analysis in the Wiscplow GIS application. Many of the charts are temporally based (e.g., by storm event or cumulative to-date over a winter season). Some of the charts are spatially based (e.g., by patrol section). Since performance measures are being calculated in a GIS environment, it is a logical and straightforward step to develop

output decision management tools that are map-based. Furthermore, map-based representations of performance measures are required if the data are to be integrated in future applications with other geographically-referenced data such as crash locations or environmentally-sensitive areas.

One of the charts is very explicitly spatial in nature. The workshop participants suggested a chart illustrating total salt applied at each milepoint along a patrol section. Such a representation, in chart form, requires the interpreter to know the geographic locations of the milepoints. A better representation might be map-based, wherein the geographic locations are explicit. Such a map might show total salt in tons applied to each 1/10-mi segment of each patrol section. The time span for the map could be a single storm, season-to-date, or the entire season. The map could also include a theme showing average pavement temperature for the same duration of time. The map could be used for finding application "hot spots" and for monitoring operator compliance with material application rate guidelines.

Results of the workshop will be incorporated into a revised version of the Wiscplow GIS application. An intuitive interface is under development to allow users to select the desired performance measures and decision tools. Management decision charts are currently being developed with Microsoft Excel spreadsheets, derived from a computed database of performance measures. Future work will include seamless integration of the user interface, the GIS application, and the decision charts and, possibly, map outputs. It is expected that the application will be ready for deployment in participating county highway departments during the late spring or early summer of 2003.

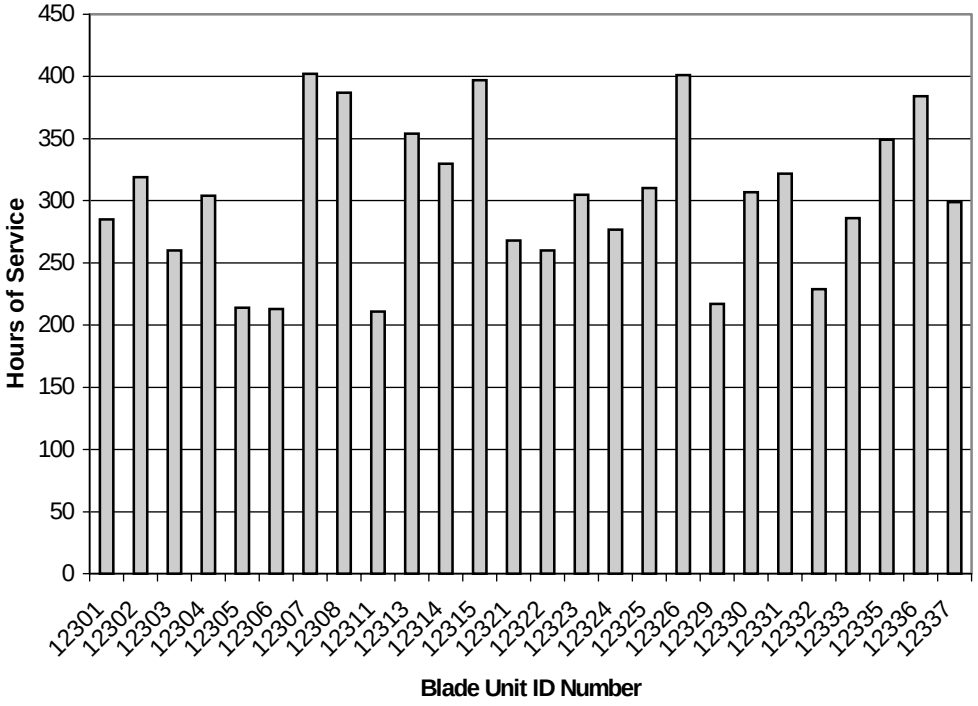


FIGURE 8 Comparison of operating life among front plow blade units.

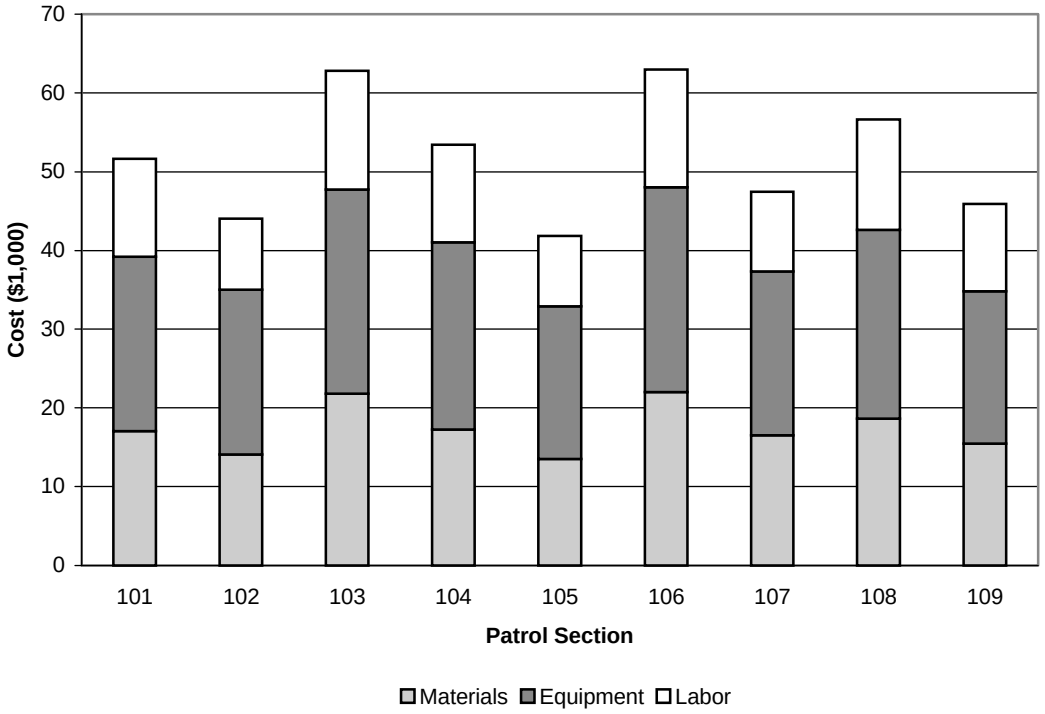


FIGURE 9 Comparison among patrol sections of total cost with breakdown for material, equipment, and labor cost.

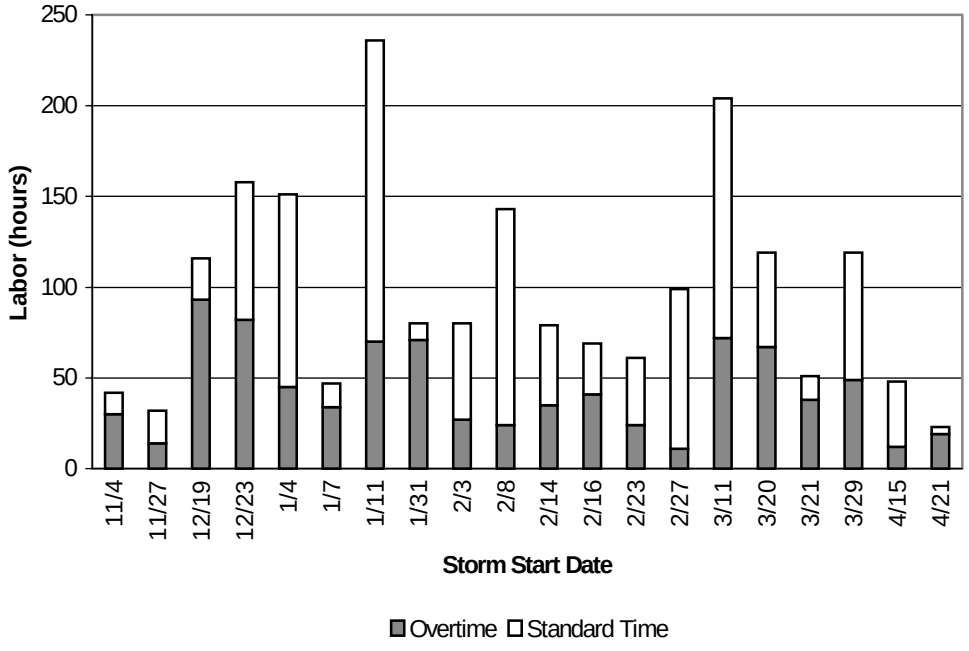


FIGURE 10 Comparison among storm events of total labor hours with breakdown for overtime and standard time.

ACKNOWLEDGMENTS

This work was partially funded by the Wisconsin Department of Transportation, Bureau of Highway Operations. The authors wish to acknowledge the following individuals for participating and contributing in identifying and developing performance measures and decision tools for winter maintenance: Sandra Perry and Jerry Pich, Barron County; T.O. Boge, Jim Cross, Kurt Dey, Shawn Gee, and Terry Kleifgen, Columbia County; Tom Martinelli, Doug Meek, Scott Schnack, and Mike Sproul, WisDOT; Gary Sipsma, Kenosha County; Francie Freeberg, Marion LeFleur, and Claude Wilcox, Florence County; Dale Peterson and Tom Wanserski, Portage County; Ron Lofken and Dave Lyga, Trempeleau County; and Jeff Coleman, ThomTech Design Inc.

REFERENCES

1. *Measuring and Improving Infrastructure Performance.* National Research Council, Washington, D.C., 1995.
2. Neely, A., H. Richards, J. Mills, K. Platts and M. Bourne. Designing Performance Measures: A Structured Approach. *International Journal of Operations & Production Management*, Vol. 17, No. 11, 1997, pp. 1131-1152.
3. *NCHRP Report 446: A Guidebook for Performance-Based Transportation Planning*. TRB, National Research Council, Washington, D.C., 2000.
4. *Operations Manual AMS 200 Data Console.* Raven Industries. January, 2001.
5. Adams, T. M., M. Danijarsa, T. Martinelli, G. Stanuch, and A.P. Vonderohe. Performance Measures for Winter Operations. Presented at Annual Meeting of the Transportation Research Board, Washington, D.C., 2003.
6. Tsang, A.H.C. Measuring Maintenance Performance: A Holistic Approach. *International Journal of Operations & Productions Management*, Vol. 19 No. 7, 1999, pp. 691-715.
7. Triantaphyllou, E., B. Kovalerchuk, L. Mann Jr., and G.M. Knapp. Determining the Most Important Criteria in Maintenance Decision Making. *Journal of Quality in Maintenance Engineering,* Vol. 3, No. 1, 1997, pp. 16-28.
8. McDonald, A. Defrosting America: Advance Technology for Anti-icing in the USA. *Traffic Technology International*, 2001.
9. *Winter Maintenance Manual Guideline 35.30 Application Rates – De-icing*. Wisconsin Department of Transportation. Bureau of Highway Operations. Effective Oct. 1, 2002.
10. Ketcham, S.A., L.D. Minsk, R.L. Blackbur, E.J. Fleege. *Manual of Practice for an Effective Anti-icing Program.* Federal Highway Administration, Hanover, New Hampshire. 1996.

PART 3

Equipment

Financial Aspects of Equipment Acquisition

ARLEN T. SWENSON
International Institute of Marketing Excellence

Selecting the appropriate financial acquisition method can have a dramatic impact on the effectiveness of equipment budgets, total costs of equipment purchases, and fleet upgrade factors. To assist professional fleet managers in making informed decisions, the Transportation Research Board Committee on Equipment Maintenance reviewed many of the popular financial acquisition methods available today for agencies to satisfy the level and duration of equipment needs for key maintenance operations. Before applying any financial acquisition method, it is important to identify the best or appropriate equipment to accomplish the work to be performed, the number of pieces of each required, and the requirement's duration. The results of this equipment need analysis will significantly influence the choice of the best financial acquisition methods for an agency. The financial choices reviewed include closed-end leases, open-end leases, municipal leases, residual value guarantees, short-term rentals, total cost bids, life-cycle cost analysis bid, skip payments, and a multitude of other combinations. All of these different choices and variables were grouped into one of the following categories of equipment acquisition methods: (1) rental; (2) lease; (3) cash purchase; (4) lease purchase; (5) cash purchase with trade or buyback guarantee; (6) any of the five above methods combined with all, some, or one of the following guaranteed costs for (a) repairs, parts, and labor; (b) manufacturer's recommended maintenance; and (c) replacement equipment. These financial choices can be confusing in the aggregate. However, the choices can be simplified by asking the basic question, "Do I want to only pay for the use of the equipment or do I want to pay to own and use the equipment?"

[TRB *Transportation Research Circular E-C047: Financial Aspects of Equipment Acquisition*, available on the Internet at http://www4.trb.org/trb/onlinepubs.nsf/web/circular, provides a discussion on each of the acquisition methods and examples looking at the relative, bottom-line costs for rental operating lease, lease purchase, cash purchase, and life-cycle bids. It should be noted that the best acquisition choices for a specific fleet and geographic location at any given time may vary from the examples shown in Circular E-C047; examples in the Circular are presented only for demonstration purposes.]

PART 4

Maintenance Management

Automated Work Management for State Highway Maintenance

STEVEN J. WILCOX
New York State Department of Transportation

Maintaining a 42,000 lane-mile highway system parsed by 9,000 bridges is not like maintaining a building, a physical plant, an institution, an equipment fleet, or a campus. The needs of the system are not completely plannable, cyclical, or systematizable. Maintenance management, however, is also not completely driven by emergent demands, random events, or failures in the infrastructure. And contrary to the beliefs of some, highway and bridge maintenance is manageable. It can even be managed with a certain degree of efficiency. The requirement that it be done efficiently is growing as available resources decrease. The Maintenance Program of the New York State Department of Transportation (NYSDOT), in partnership with Booz Allen Hamilton of McLean, Virginia, is currently designing a highway maintenance management system to replace the system that has been in place since the 1980s. The new system will take advantage of a system that Booz Allen Hamilton has evolved from initial implementations in Vermont and New Mexico, to a web-enabled version developed for the Georgia Department of Transportation (GDOT). This award winning system was designed for the specific needs of large-scale highway maintenance management. The approach in NYSDOT has been to customize the GDOT application for use in New York with one significant new development that is being referred to as a "work management" process. The NYSDOT system is being called MAMIS for Maintenance Asset Management Information System. The process is organized around the creation of a to-do list called "Needs," the assignment of selected work to either State Maintenance Forces or Contractors for completion, and the reporting of what was accomplished by location or asset. To many who read this, the process described above will be seen as nothing earth-shaking or new. What is new to us in the NYSDOT Maintenance Program is the structuring and automating of the process of managing day-to-day, cyclical, and seasonal work—and to associate that work with particular sections of highway, individual bridges, snow and ice beats, or other State assets. This provides a standardized structure for managing work across the State's Maintenance Program and will lay the foundation for both the management and analysis pieces of infrastructure asset management.

The Transportation Maintenance Division of the New York State Department of Transportation (NYSDOT) has been working with Booz Allen Hamilton of McLean, Virginia, to replace and enhance the Division's existing maintenance management system with a more modern system.

The Division's current system is called DAISY for Daily Accomplishment Information System and is built on what Governmental Accounting Standards Board terms the Service Efforts and Accomplishments approach. This output per unit input approach focuses on collecting data related to labor, material, and equipment utilization as work inputs and work accomplishment as output. The labor piece of the system is used to drive the payroll process through the electronic capture of time and attendance data. Some state's also attach an activity- or performance-based budgeting component to this process where funds are tied to proposed activity-based work accomplishment.

Traditional maintenance management systems—such as DAISY—are like accounting or reporting systems. They take a "rear-view mirror" approach to management. The systems can provide good after-the-fact source data for analysis, but they typically don't provide functionality for managing the deployment of work crews or targeting the needs of the transportation infrastructure in a proactive manner. If a function of management is to efficiently, effectively, and proactively organize work, these systems do not perform that function. The work management functionality that will be discussed in this paper is the attempt of the Maintenance Program of NYSDOT to provide logic and structure for seasonal, weekly, and daily management of maintenance work.

The system currently under design is called MAMIS for Maintenance Asset Management Information System. This system will replace and enhance the functionality currently in DAISY, capture all work performed by asset and location, place the new system in a modern web-enabled technical architecture, push the user community out to Maintenance Supervisors, and add a robust work management functionality. This final piece is the focus of this paper.

OPERATIONAL VERSUS ECONOMIC APPROACH TO INFRASTRUCTURE ASSET MANAGEMENT

The common conception of infrastructure asset management is a macroeconomic approach targeted at making best value investments from a "cost to society" perspective. Macroeconomic asset management is a promising and potentially useful tool for planners, budget analysts, and economists. Asset management from the "god-as-economist" perspective does not translate well into meaningful management tools in an operational setting.

The work management process looks at asset management from the perspective of providing the organization an automated, systematic and structured approach for managing the "needs" of the infrastructure. This approach includes: a process for assembling a database of all system needs from an array of sources, a process for sorting and prioritizing needs for action, a process for assigning work by way of work order or contract order, and finally a process for tabulating a history of completed work by asset type and location for evaluation and analysis.

This represents a grass-roots, bottom-up approach to asset management similar to a cost build-up approach used in an activity-based costing environment. More importantly, it is an approach to asset management that is much more meaningful to an operations manager or highway superintendent than the more common macroeconomic approach.

WORK MANAGEMENT PROCESS

The process of work management is presented in Figure 1. The core of the process is the structured management of infrastructure needs. Needs are at the core of what operations managers and highway superintendents work with every day. A needs database is essentially an ongoing to-do list of work that needs to be done on the infrastructure. It includes potholes that need patching, litter that needs removal, culverts that need cleaning, guide rail that needs straightening, bearings that need lubing, or rest areas that need cleaning. The rest of the process involves how needs are identified and entered into the system and how—once in the database—the work is assigned, completed, and reported.

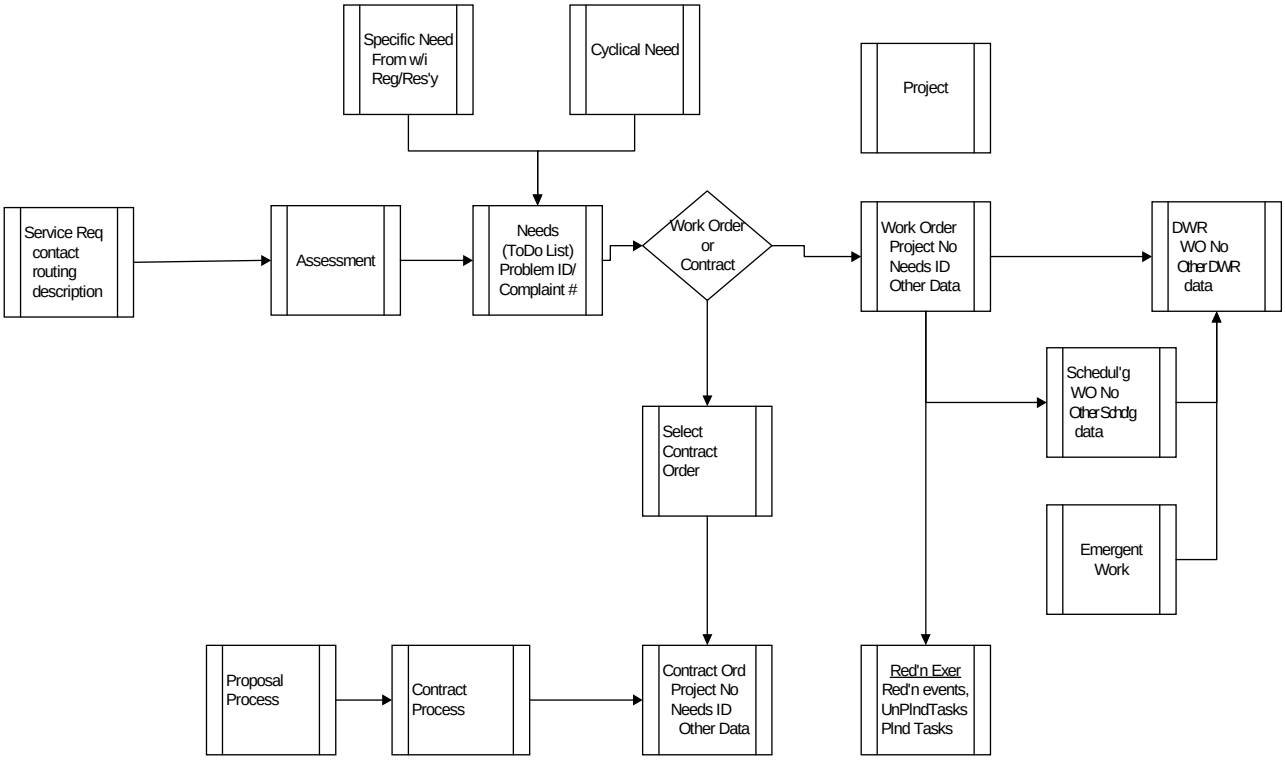


FIGURE 1 Work management process.

The needs database is populated from three sources: external sources through a service request process, internal sources such as routine patrols or condition assessments, and system-generated needs based on predetermined maintenance cycles. Service requests pass through an assessment process prior to being placed in the needs database to ensure that the requested work is needed and that the work is on the State system and under the jurisdiction of that particular maintenance organization.

Once a need has been selected to be addressed it is assigned to either a State maintenance crew via a work order or to a contractor via a contract order. Work can be bundled into projects which can include any mix of State Forces and contract work. In-house work can then be scheduled through a scheduling screen or simply performed, and then reported through a daily work report (DWR). Completed contract work is also recorded—so that a comprehensive history of all work managed through the Maintenance program is entered into the work history file. This will result in a work and cost history for all assets by location and asset identifier. The process also recognizes that a portion of maintenance work is emergent, or demand driven, and can be recorded as completed work without having to pass through the entire work management process. This results in a process that enables the manager to manage the needs of the infrastructure asset in a forward looking manner while also capturing a comprehensive asset work and cost history for retrospective analysis.

Feeding the System: Service Requests, Cyclical Needs, Seasonal Plans, and Patrols

There are four mechanisms for identifying infrastructure maintenance needs. These come from: requests for service from the public or others outside of the Maintenance organization, cyclical

needs that are automatically generated by the system, patrols and condition assessments by managers and supervisors, and seasonal plans.

Service requests are defined in MAMIS as coming from a source external to the Maintenance organization. These are entered into the system by office staff or a radio dispatcher who receives a phone call, letter or e-mail from a citizen, elected official, or some other non-Maintenance person. Figure 2 shows the Service Request Detail Screen.

Service requests are not entered directly into the needs file because they first require an assessment to determine whether the request is within the jurisdiction and capabilities of the organization. To do this, the initial request goes to the manager who then assigns the request to a supervisor for assessment. Once the assessment is completed the request is either saved as a need or another determination is made which will be included in the response to the requestor on the resolution of the request. The system will not allow the request to be closed until the user indicates that a response has been made to the requestor. An example of the assessment screen is shown in Figure 3.

A cyclical need is one that occurs at a regular interval such as bridge washing, bearing lubricating, joint sealing, or mowing. The screen in Figure 4 has been developed so that these needs can be identified automatically when their particular cycle comes due. For a particular task associated with an asset or beat the system will automatically generate a need based on the cycle frequency and last completion date.

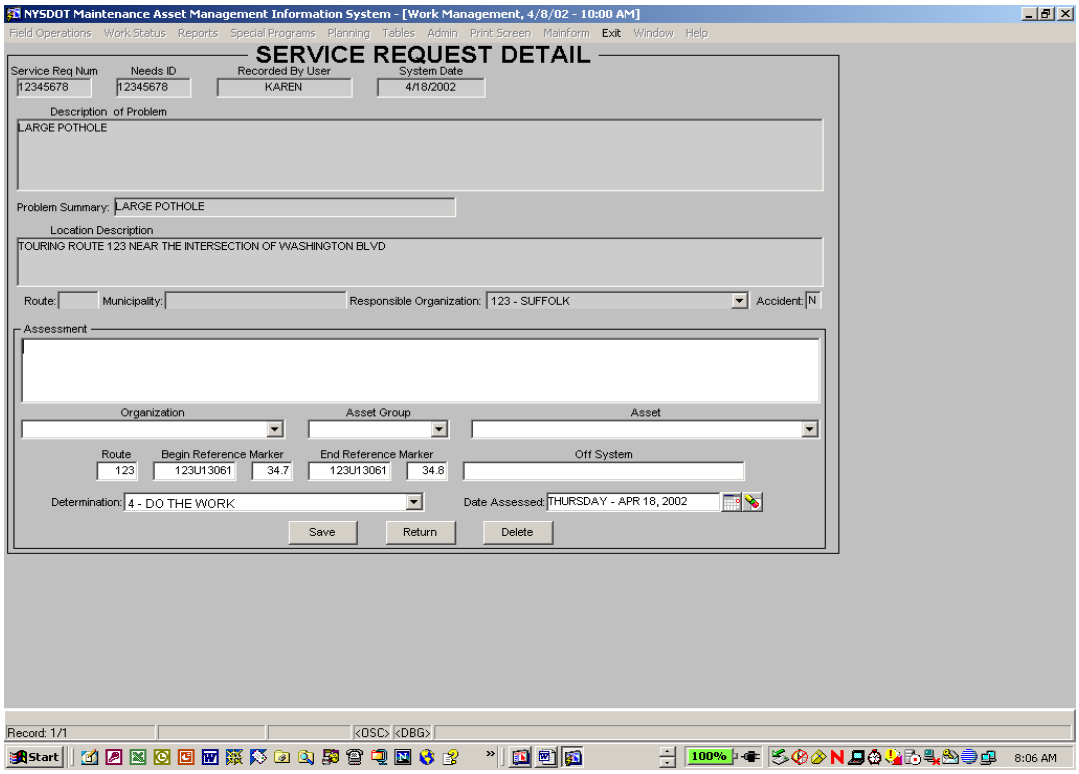


FIGURE 2 Service Request Detail screen.

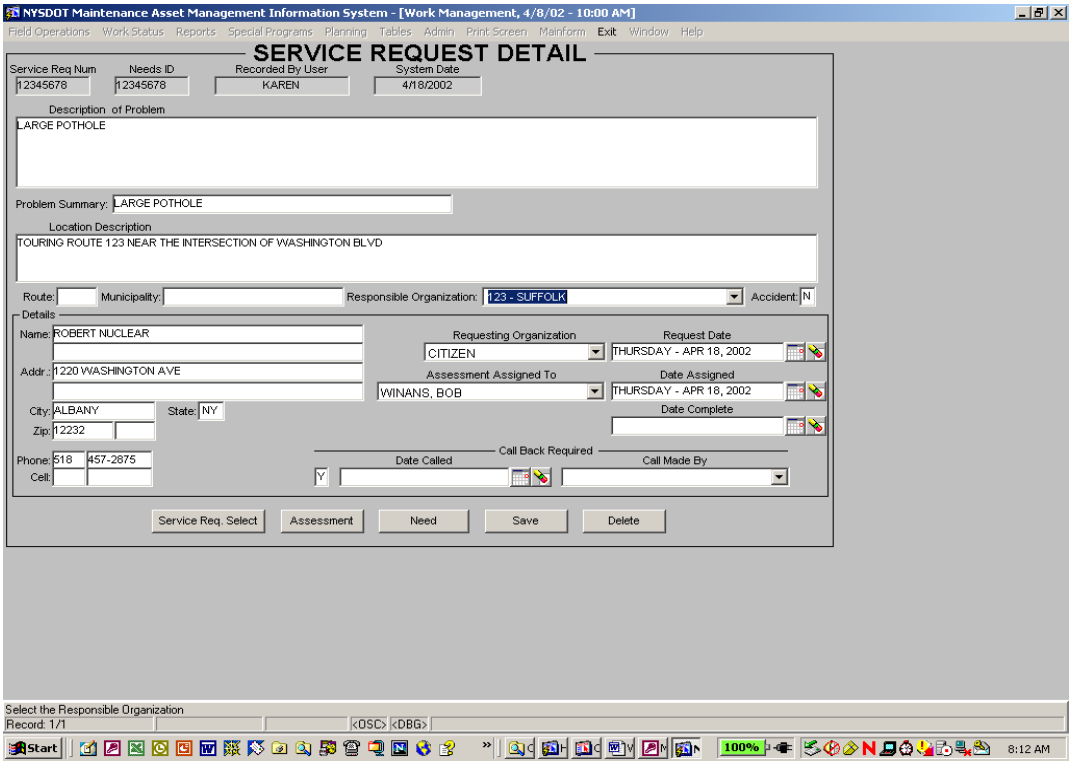


FIGURE 3 Assessment screen.

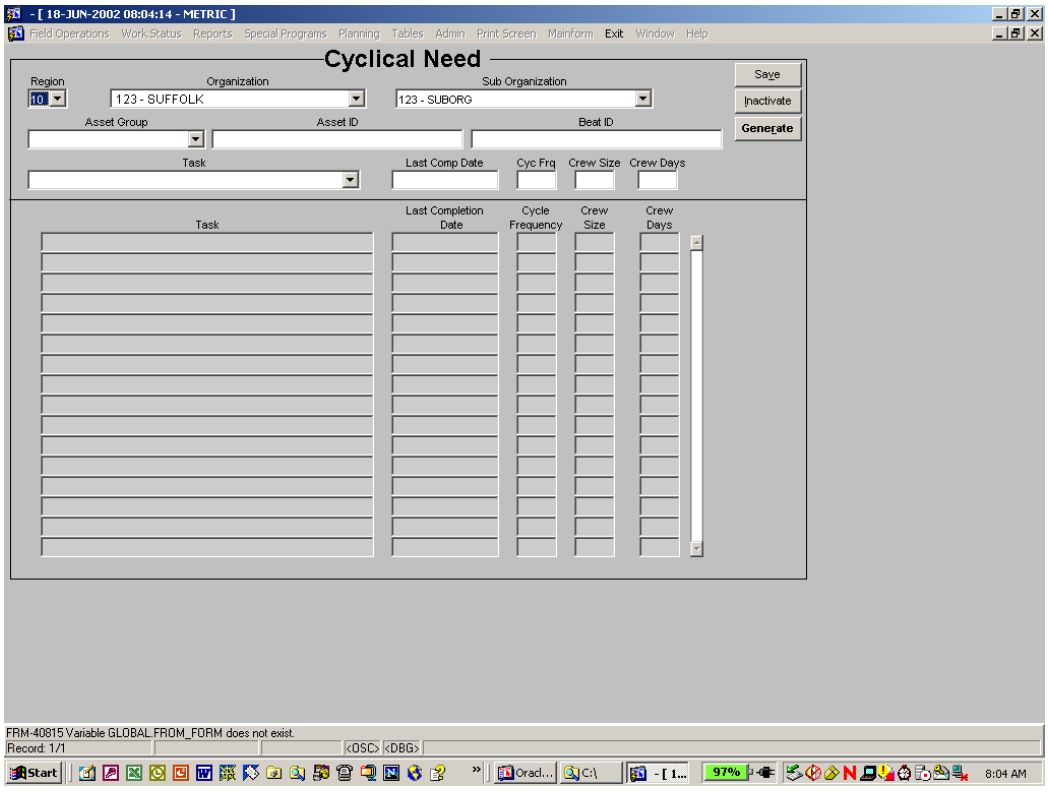


FIGURE 4 Cyclical Need screen.

A third way to enter needs is through an annual or seasonal planning process. In MAMIS this is referred to as the Summer Program/Reduction Exercise. The screen for this process is shown in Figure 5. This process provides a mechanism for a manager to total the resource hours available to the particular organization for the summer maintenance season and then reduce those hours by the hours devoted to administrative functions and leave to get to a plannable number of hours. Those plannable hours can then be used to identify work orders that will be committed to for the season and assigned.

Work that is identified through routine patrols or condition assessments can be entered directly into the needs file through the Needs Detail screen.

The Core: Identified Needs

Needs are entered into the system as a general description of work that should be addressed at some point. The Needs Detail prototype screen is shown in Figure 6.

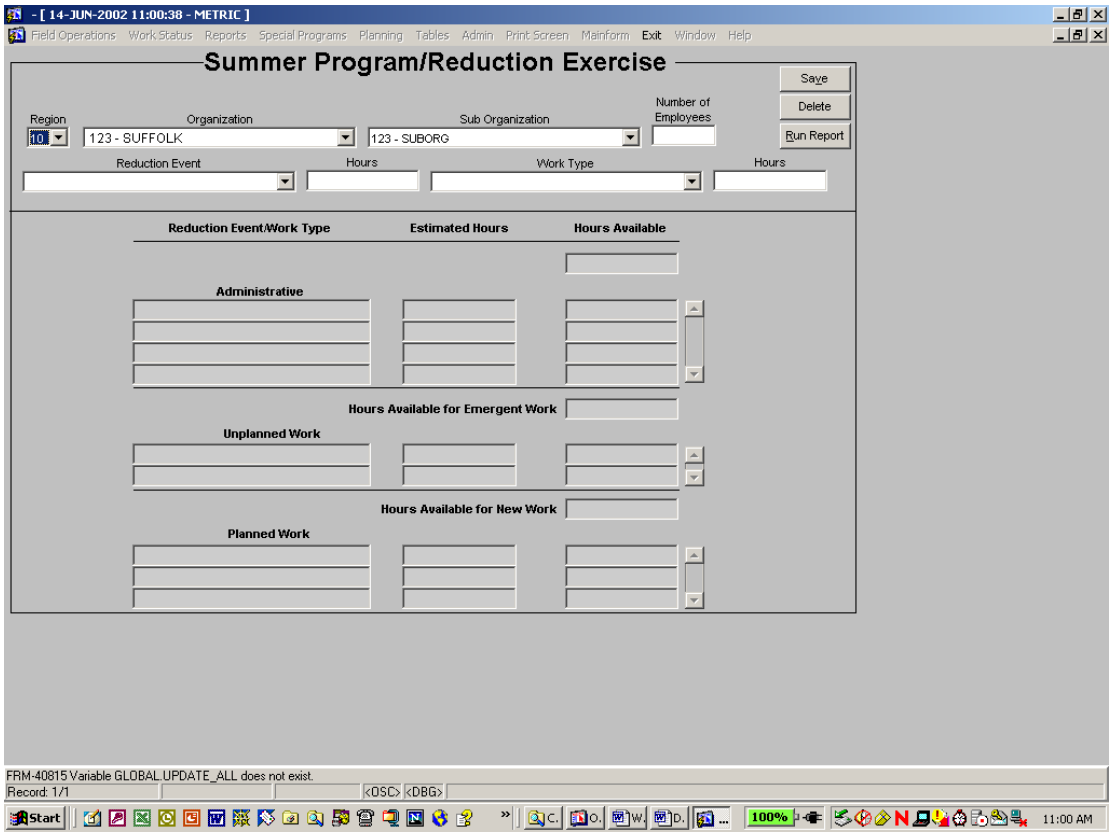


FIGURE 5 Seasonal Process Planning screen.

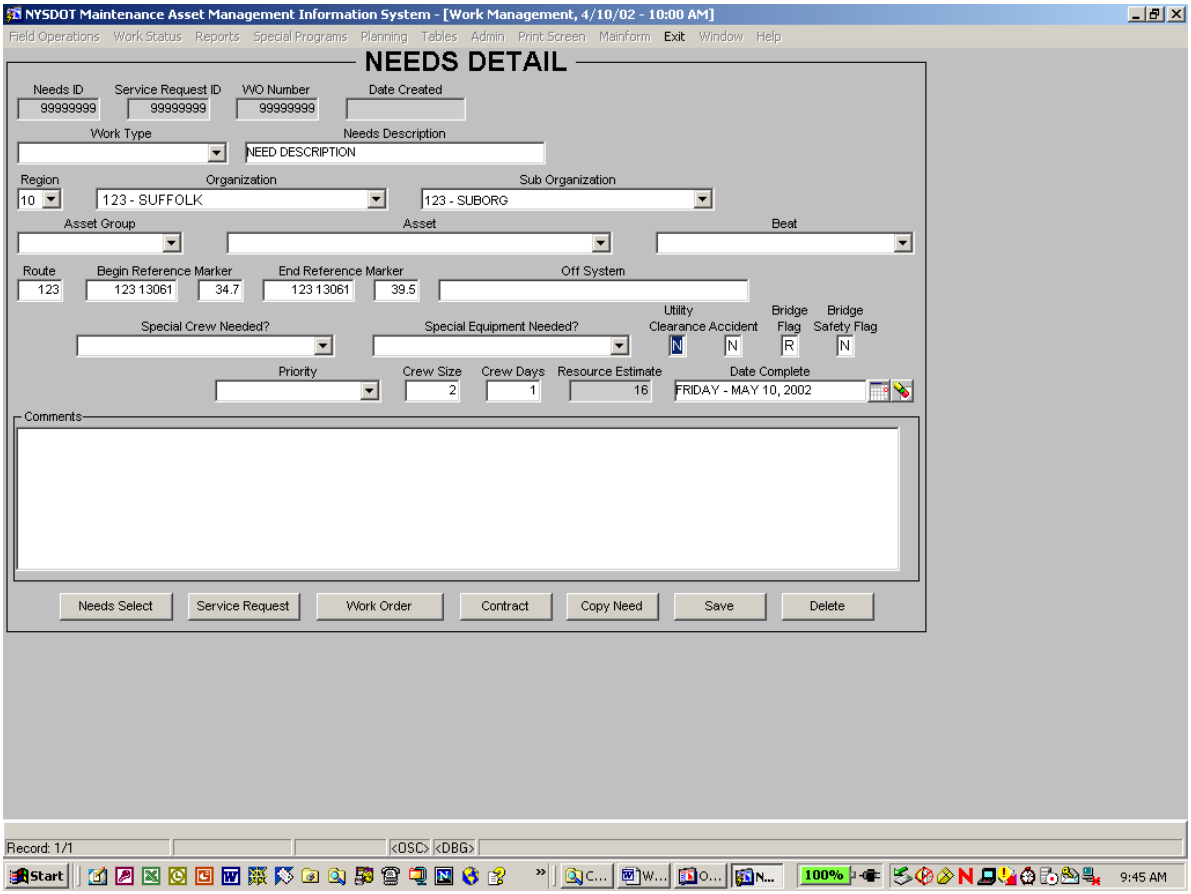


FIGURE 6 Needs Detail screen.

Needs are raw descriptions of work that is expected to be addressed with some information associated to identify the location of the problem (reference marker location, bridge identifier, culvert number), the type of asset (bridge, rest area, highway), the type of work (guide rail, drainage, vegetation, etc.), the need for a specialized work crew (tree crew, bridge crew, striping crew, etc), or specialized equipment (large gradall, sewer cleaner, etc.) that allows the manager or supervisor the ability to sort needs in a way that will facilitate the organization and assignment of work. Additional attribute information has also been identified to help with the organization and assignment of work such as: the status of underground utility clearances, priority of the need, accident identification for collection purposes, structural flags, and resource estimates.

A manager or supervisor can use this information in organizing the work of either in-house crews or contractors. For example, all work for a particular stretch of highway can be identified by clicking on a beginning and ending reference marker. This selection can be refined by identifying work of a particular type, such as sign, drainage, pavement, guide rail, or vegetation work. This can be further refined if a special crew or equipment is necessary.

Once needs are identified for assignment they can then be formally assigned and detailed through the use of work or contract orders.

Taking Action: Assigning Work Orders and Contract Orders

A work order is a mechanism for assigning work to an in-house crew or supervisor. A contract order serves the same function for a contractor. The contract order also serves to account for work done on the transportation infrastructure so that, when combined with state forces work that is recorded in a daily work report, a complete accounting of all work managed by the maintenance organization can be kept. This provides an asset manager a complete accounting of all maintenance work performed on a particular asset at a particular location by: cost, work type, task accomplishment, and resource utilization (labor, equipment, and material for in-house work and expenditure for contract work).

A work order or a contract order can be used to address one or more needs. A work order or contract order can be created directly from the need screen, or from the work or contract order screen. If the work or contract order is created from the need screen it carries that particular need—but only as need identifier and organization—since crew and task assignments do not occur until the work or contract order is created. As work is completed that resolves a need, the need can be closed out manually and removed from the needs database. When all the needs are completed the work or contract order is closed automatically. Work orders can be scheduled using a scheduling screen. Daily work reporting can associate the day's work with the work order so that work order costs and accomplishments can be tracked and analyzed.

Figure 7 is the Work Order Detail screen followed by three overlay screens.

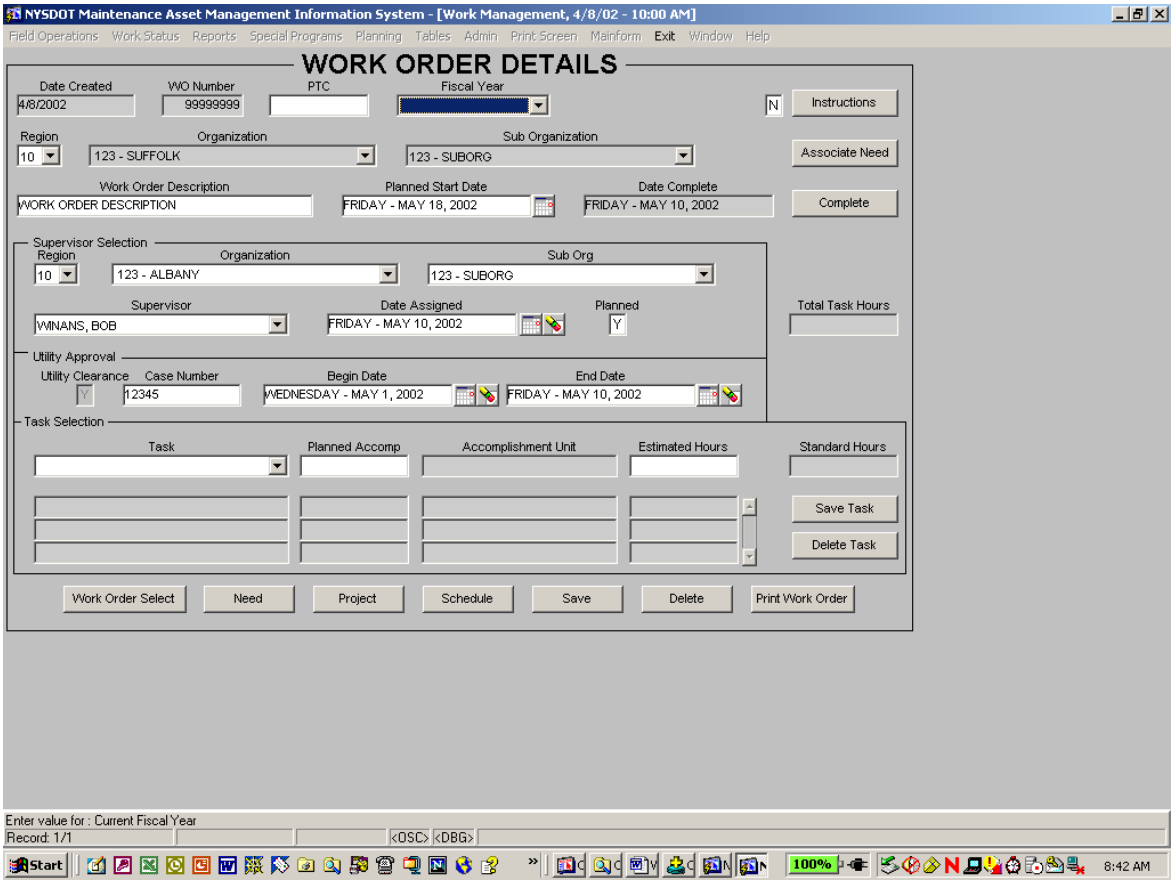


FIGURE 7 Work Order Detail screen.

A work order is assigned to a maintenance supervisor who may then assign the work to a crew. The above screen enables the supervisor to assign particular tasks, and to estimate the number of hours necessary to complete the work – based on historical productivity rates. A planned start date and actual completion date can be entered on this screen. The screen also provides a date range for utility clearances to ensure that the work is done during the time period which they are approved to work. By clicking on "Instructions," the supervisor can see if written instructions have been passed along with the assignment, or can provide instructions to the crew that is assigned the work. The instruction overlay screen is shown in Figure 8.

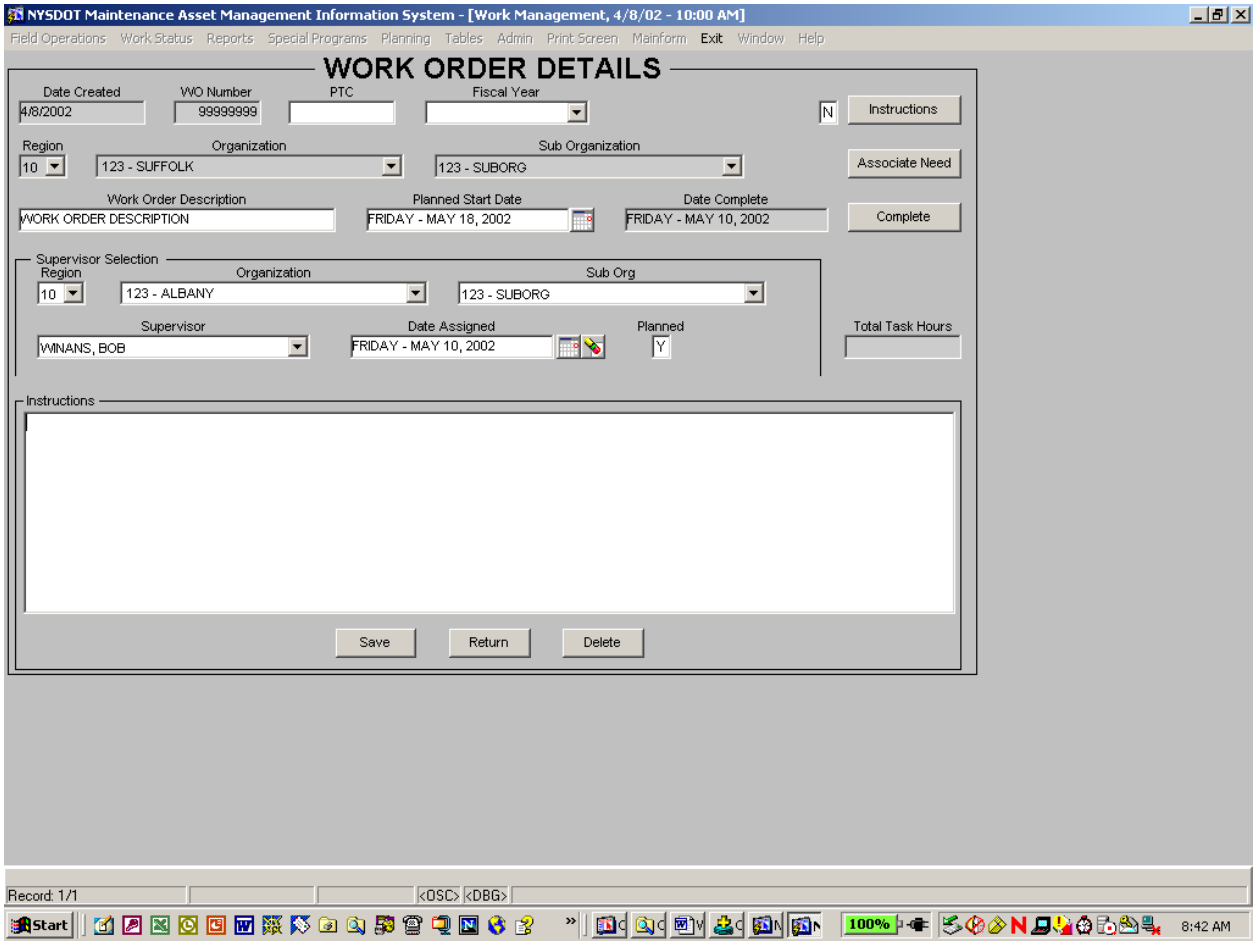


FIGURE 8 Instruction Overlay screen.

When work is assigned to a crew it may be advantageous to assign work that will resolve multiple needs. By using the filtering criteria on the screen shown in Figure 9, a supervisor can address multiple needs by consolidating the assignment by asset, location, special crew or equipment, or priority. So, for example, if a crew is going to work on particular bridge, all identified maintenance related needs can be displayed so that the supervisor can assign some, or all, of the work necessary to take care of those needs. This also enables a supervisor to display all work related to a specialty crew—like a tree crew—so that all needs that would be addressed by that particular crew can be identified.

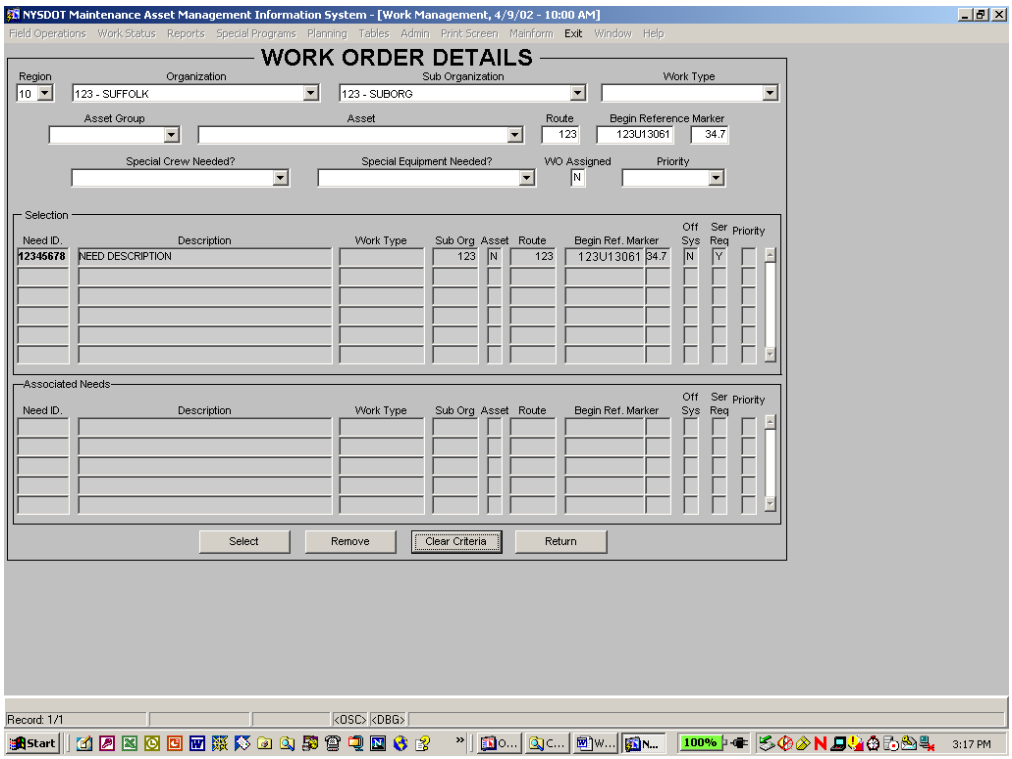


FIGURE 9 Work Order Detail screen with filtering criteria.

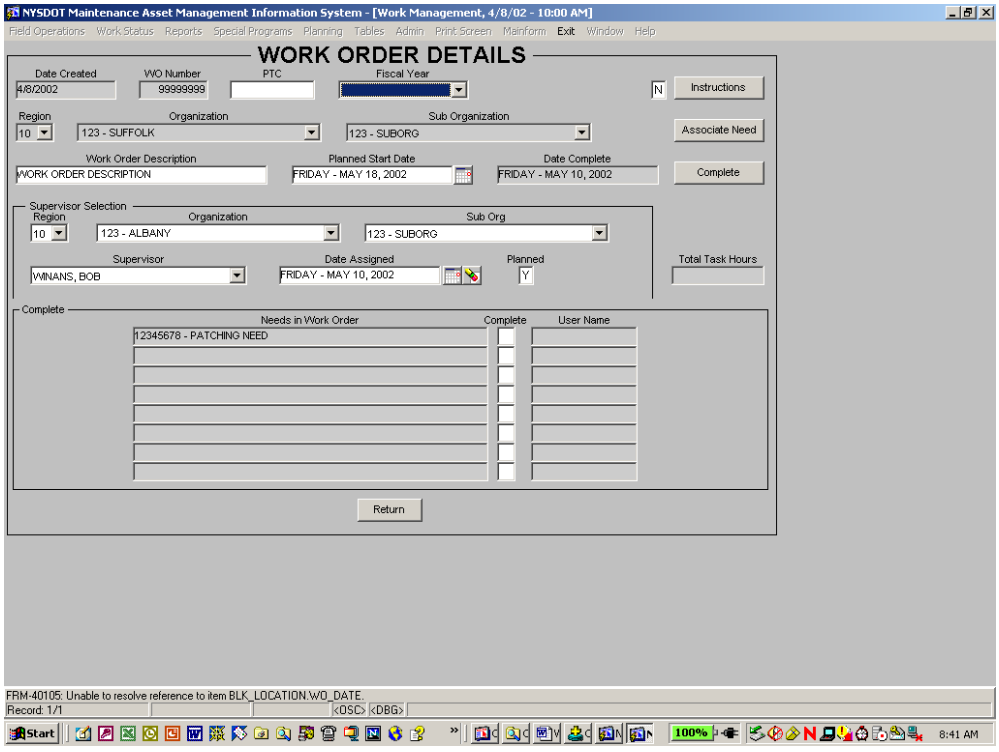


FIGURE 10 Associated needs in Work Order.

Needs can then be linked to the work order by clicking on the needs that the supervisor wants to associate with the work order. This is used to close the needs out when they are addressed so they can be removed from the needs database. The screen in Figure 10 shows the associated needs which can be closed by checking off the "complete" box for that need.

A parallel set of screen overlays exist for contract orders including: assignment, instructions, and needs association and close-out. The primary difference in the contract order screen is the tracking of total amount paid for work on a particular asset or highway location so that those costs can be added to develop total maintenance costs for both in-house and contract work. This will enable an asset manager to see a complete accounting of maintenance costs associated with a particular stretch of highway, a bridge, other asset, or beat.

Multiple combinations of work and contract orders can be associated to form projects which will be described in the following section.

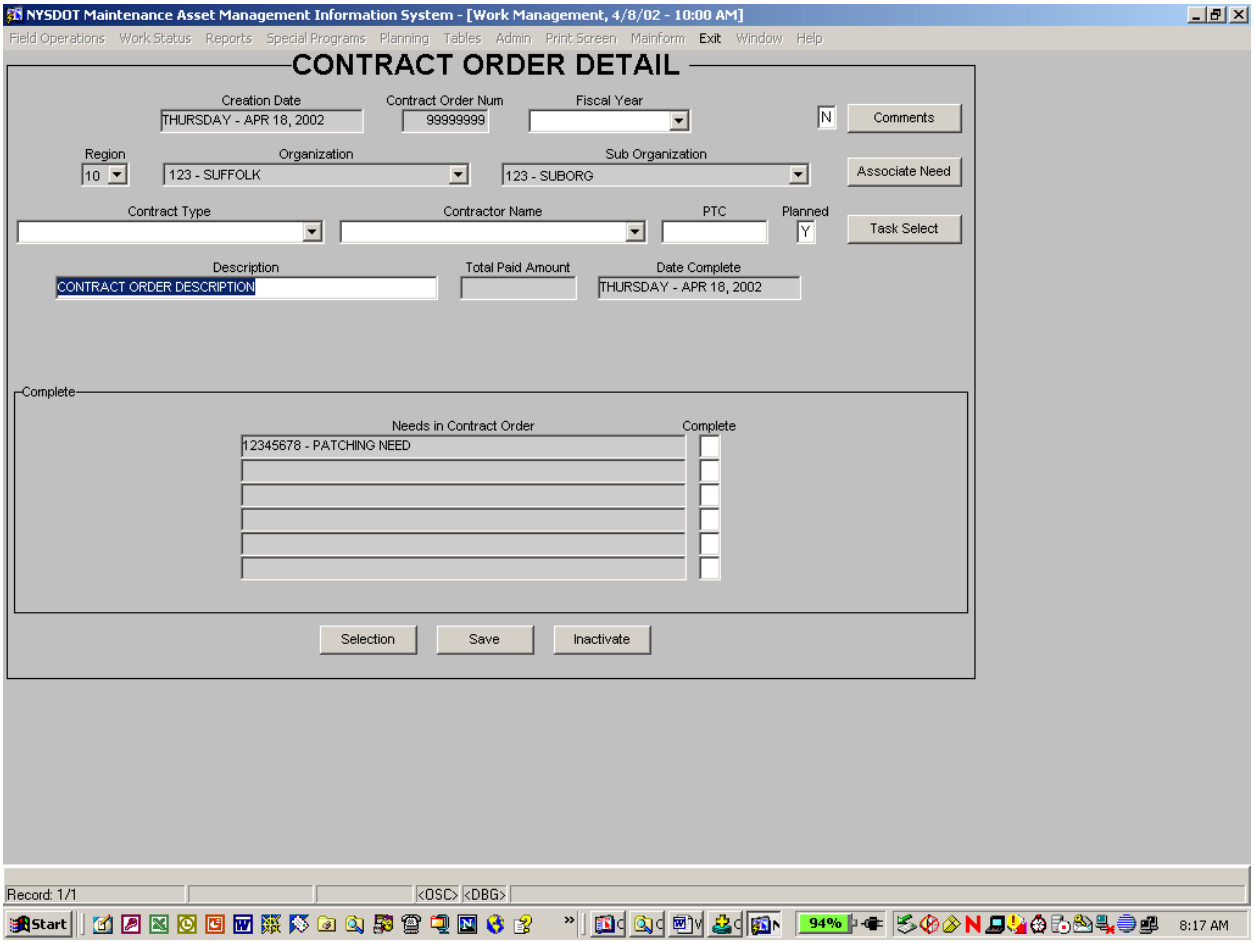


FIGURE 11 Contract Order screen.

Managing Projects, Special Events, and Emergencies

There is often a need or desire to account for work and costs associated with emergencies, special events, or projects that involve multiple organizations, different crews, or a mix of in-house and contractor resources. The following screens enable a manager or supervisor to

associate multiple work orders or contract orders with an emergency, special event or project. This will be used for federal disaster reimbursement through the inclusion of FEMA and FHWA reimbursement rate tables, the association of functional classification in the location reporting tables, and through the ability to—in most cases—report by county. For consistency, an emergency event can be set up centrally so that all maintenance organizations responding to the event can report their work against the one event. The main office will then be able to sort the FEMA from the FHWA reimbursable work using the county and functional classification attributes to the location reporting.

This will also be used to determine the full cost of paving projects. This is useful for bonding purposes. Projects—as essentially mechanisms for associating work orders, contract orders, and daily work reporting—are extremely flexible and simple mechanisms to organize crews and contractors proactively, and to provide full cost accounting for all work associated with that project or event.

The screen shown in Figure 12 is used to set up the project. It includes the organization, a description, a project identification number (PIN) if appropriate, an indicator of whether the project is bondable, a system generated project tracking code (PTC), indicators of whether any work or contractor orders have been associated with the project, and a field that can be used to further describe the project.

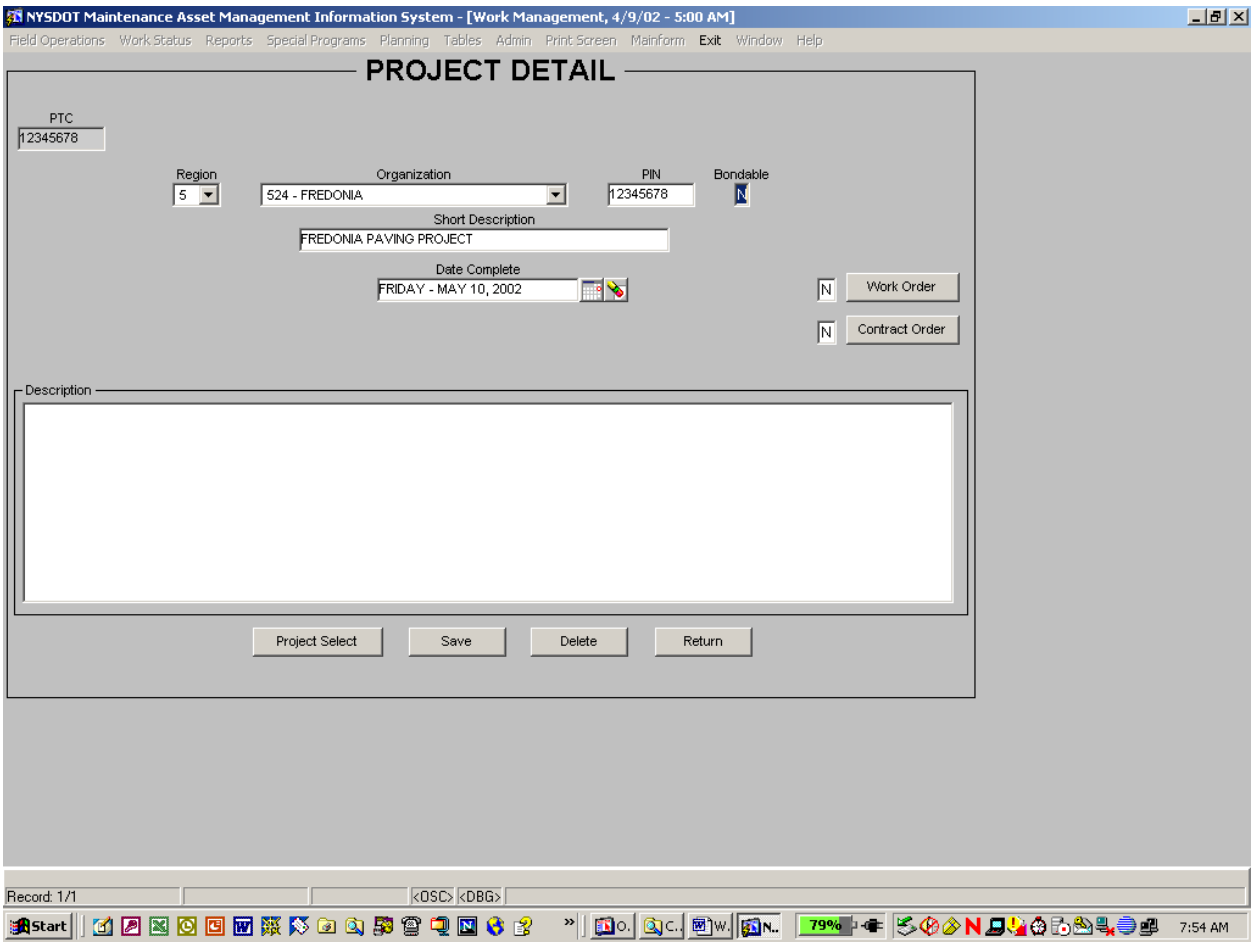


FIGURE 12 Project Detail screen.

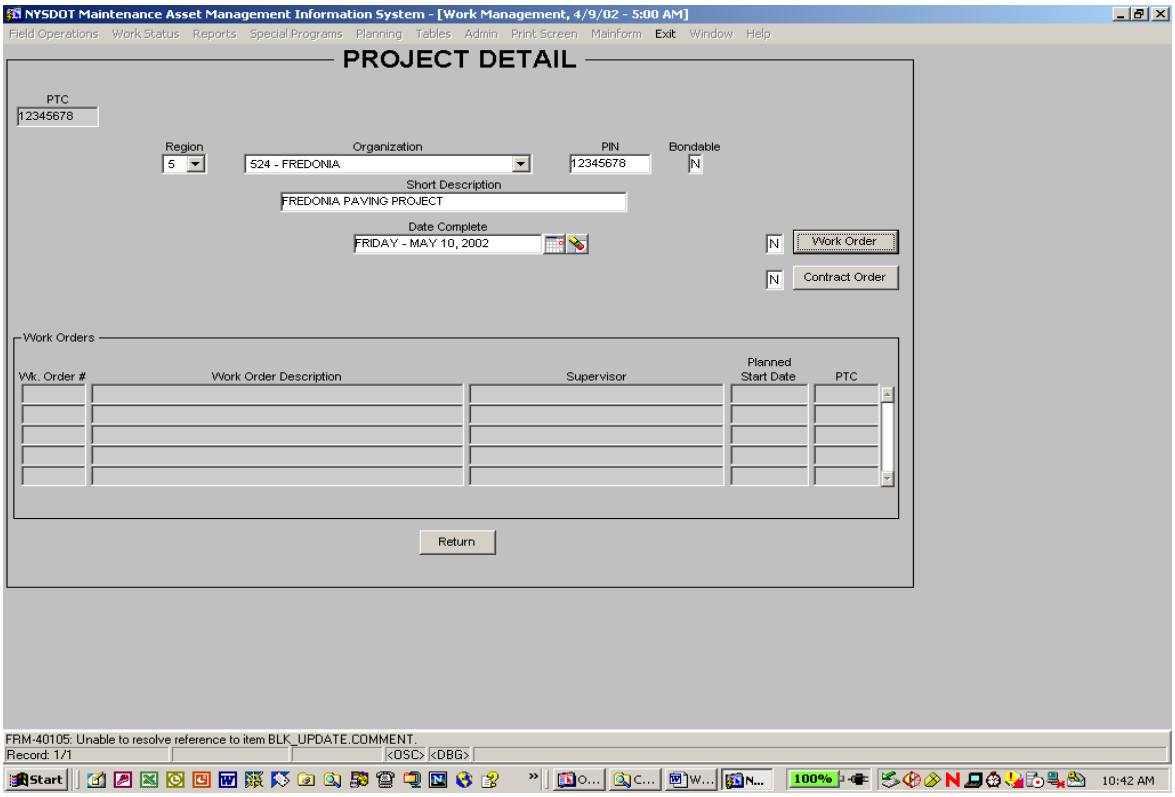


FIGURE 13 Project Detail screen with associated Work Order fields.

The screen shown in Figure 13 enables the user to associate work orders with a project. A similar screen has been developed to associate contract orders with a project that simply substitutes Contract Order for Work Order.

By having the ability to track work—from the simplest entry of an emergent need into a daily work report, to the organization of tasks by crew or contractor into work or contract orders, to the combination of work and contract orders into projects—an asset or operations manager will have considerable flexibility in organizing work and analyzing costs.

Asset- and Suborganization-Oriented Work History

It is important for a manager to understand which assets or locations are the most cost intensive. This can and should drive asset management decisions—at least from the operational perspective. While cost-to-society is an interesting and compelling concept for macroeconomic planning or analysis, a maintenance or operations manager needs to know where actual hard-dollar resources are being expended. By identifying stretches of highway or bridges which are consuming disproportionate amounts of the organization's maintenance budget, an asset or operations manager will be able to target high priority candidates for major rehabilitation, reconstruction or replacement. Similarly, by comparing performance across suborganizations, training, equipment, and other needs can be readily identified.

The screen in Figure 14 has been developed to provide the ability to look at the cost of all maintenance work performed by either in-house or contract forces. This can be done for any

date range where records are available, for any or all work types, for a group of assets or a particular one, or for an entire length of highway or a particular section. This can be run at the suborganizational, organizational, regional and even the statewide levels. It is also possible to limit the report to specific tasks so that costs can be produced related to individual tasks, like patching or culvert cleaning, or a group of tasks, like all pavement or bridge related tasks.

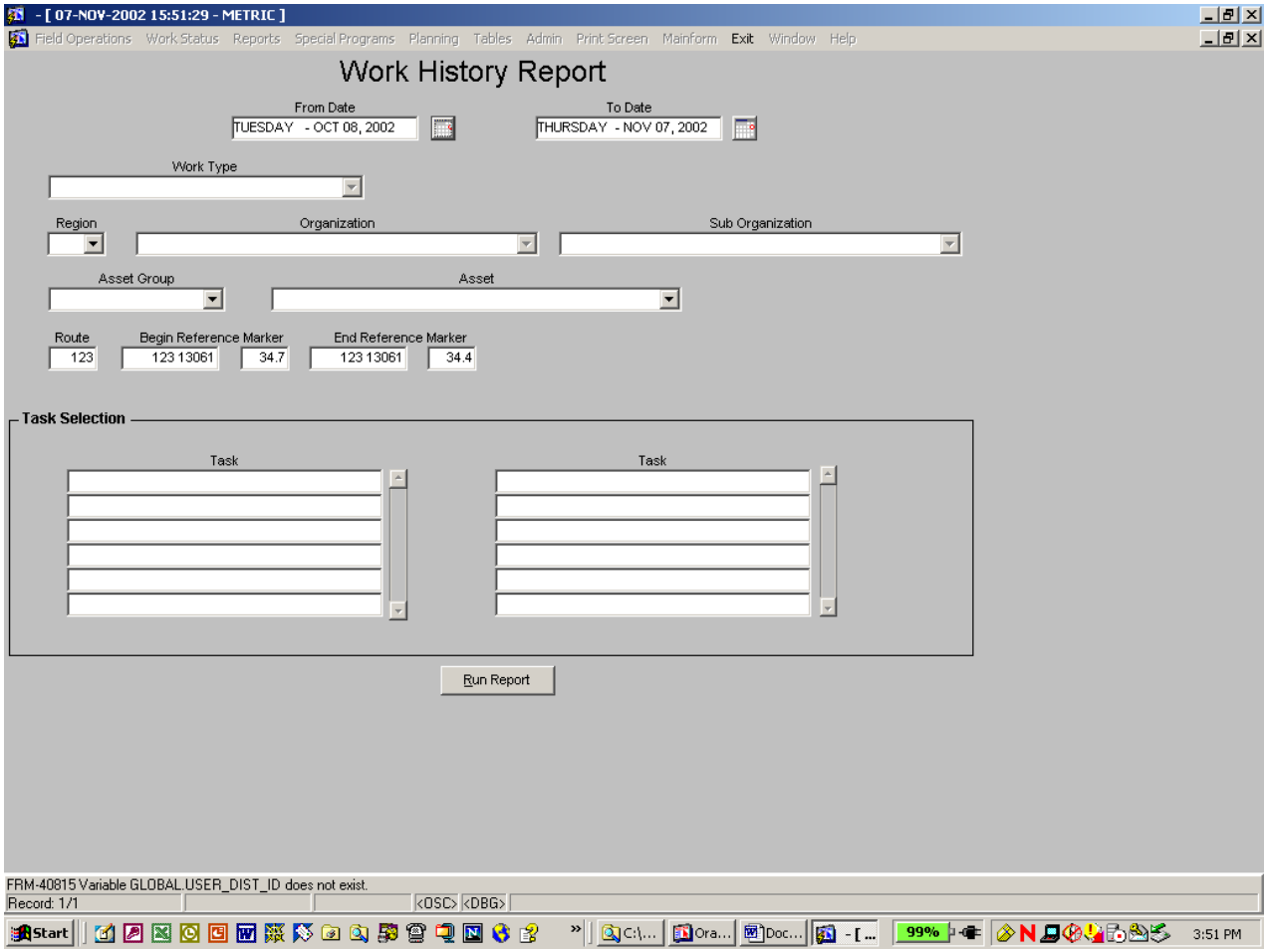


FIGURE 14 Work History screen.

POTENTIAL BUDGETING AND INVENTORY DEVELOPMENT IMPLICATIONS

There has been some discussion about the possibility of using needs as a budget driver. The idea is to shift funding to organizations with greater infrastructure needs with the overall goal of providing an asset infrastructure that is in as consistent a condition as possible. This would involve a needs-based budget where resources would be shifted from organizations with fewer needs to those with more. This would require a thorough identification of needs across the various assets maintained by the organization. There would be two principal checks to ensure that this process is not improperly manipulated involving performance measures and quality assurance condition assessments.

In a needs-based environment a manager would document all needs that come from an array of sources including patrols, condition assessments, cyclical needs, work plans, and service

requests. Organizations with greater needs would get additional resources shifted from organizations with fewer. As a check, a performance measure would be instituted that would look at the number of needs addressed as a percentage of total needs. There would also be an annual quality assurance condition assessment — which is currently done — to statistically assess conditions across organizations. Organizations given additional resources would be expected to address a higher percentage of documented needs, and to improve overall conditions.

This approach could also be beneficial in the overall departmental budgeting process. With some experience the Maintenance Program should be able to predict what percentage of the overall database of needs will be addressed at an existing funding level. If funding changes are anticipated the number of needs that will be able to be addressed could be predicted so the implications of the changes could be demonstrated.

Working on a needs basis is also more practical for an organization with limited resources than working from a full asset inventory and condition assessment. Full inventories with cyclical condition assessments are extremely labor intensive and provide questionable benefits relative to the overall investment. What the system will do is continuously identify assets, as their associated needs are identified, which can eventually be "grown" into inventories of these assets, rather than having to develop entire asset inventories from scratch.

TECHNICAL ENVIRONMENT

MAMIS is being developed using the Oracle 9i tool set in a web-enabled environment using Oracle Developer and Oracle Web Forms and is being deployed primarily over the Department's wide area network, though some smaller suborganizations will use a dial-up connection. The database is also Oracle. Interfaces with other Department systems will occur using "views" wherever possible, though some flat file transactions will occur. The system has also been designed to use the Department's official data sources. There has been significant effort placed into avoiding duplicating data that resides in other systems. The system is primarily table-driven and utilizes drop-down menus, lists of values, and so on to minimize key-stroking and errors. There are many edit functions to ensure the quality of the data. The daily work reporting and many of the work management functions will be performed by Maintenance Supervisors to improve data quality by way of source data entry, and to encourage the use of the robust functionality in the work management module and in other modules of MAMIS. The system is linked to the personnel and payroll processes that provides an important incentive for recording transactions daily.

SUMMARY

Maintenance management systems have traditionally provided a retrospective view of maintenance work. This approach has been useful for reporting and analyzing work accomplishment and resource utilization. It has not supported the management of the maintenance of the transportation infrastructure assets or the intelligent assignment of maintenance resources. Work management is an attempt to fill this practical need.

The work management approach systemizes and automates the collection of infrastructure asset needs from both internal and external sources, and provides mechanisms for organizing and assigning work to resolve these deficiencies. By associating location and asset

identifier information with work reporting, a comprehensive work and cost history is available to assist in asset management decision-making.

This is a non-traditional approach to infrastructure asset management that is focused on the asset management needs of a maintenance and operations manager. It is an approach aimed at utilizing the "assets" available to the manager — workers, equipment, materials, contractors — in a way that will help optimize those assets in maintaining the "transportation asset," which is the mission of any maintenance organization.

APPENDIX: WORK MANAGEMENT BUSINESS RULES

The following are the rules that govern the relationships between the various work management entities.

1. A Work Order or Contract Order must have one or more associated Needs.
2. Needs can have either one asset or one location reference. A beat can be an asset.
3. Needs have one and only one work type.
4. A need has zero or one Service Request.
5. The only attribute data carried from need to work order is Need ID and Organization, i.e., Region, Residency and Sub Organization.
6. Needs will be selected and "closed" manually (no automatic completion) from the DWR and the Work Order screen.
7. Needs can be completed directly on the Needs detail screen.
8. Needs can be disassociated from the Work Order on the Work Order screen, but not from any other screen.
9. A work order is completed automatically when all needs are completed.
10. Complaints and problems will require an assessment before they are classified as needs.
11. Each need will be associated with one and only one Work Order or Contract Order before work is assigned.
12. A need can result in either a Work Order or a Contract Order, but not both.
13. Projects will be represented by zero or more Work Orders and/or Contract Orders.
14. A work order will have zero or more Scheduling records.
15. A work order will have zero or more DWR records.
16. A work order or contract order may be related to one and only one Project.
17. Emergent work that results in a DWR, but does not have an associated Work Order, and does satisfy a need or a service request will require the associated need or service request to be closed manually.
18. Work Order numbers will be assigned by the system.
19. Contract Order numbers will be assigned by the system.
20. Need numbers will be assigned by the system.
21. Service Request numbers will be assigned by the system.
22. A Work Order or Contract Order can have zero or more Tasks.
23. A Contract Order Task can have zero or more Locations.
24. A Contract Order Location can be an Asset, a Beat, or a Location Reference.
25. A Contract Order must have one or more associated Needs.
26. A Contract Order cannot be completed until all Needs are completed.

27. A Contract Order will be automatically completed when all associated Needs are completed and Contract Paid Amount is entered.

28. An asset, a beat is an asset, can have zero or more cyclical need tasks.

29. An asset can have a cycle of 1 year or multiple years. For assets that have an occurrence of multiple times in one year, the cycle will be one. When this cycle is completed the user can copy this need to a new need. The only difference (data elements) will be the Need ID, the creation date and the Need Description (need description will be taken from the task description field similar to the initial creation of the cyclical needs).

30. Cyclical needs will be created from the Asset/Cycle table in an annual process. Cyclical needs will be created once and only once per annum.

31. Data added to the Need table for the cyclical need generation will include:
    - Region
    - Organization
    - Suborganization
    - Work Type (inferred from task)
    - Need description (use task description from table)
    - Crew Size
    - Crew Days

32. When a cyclical need is completed, the completion date on the Asset/Cycle table will be set to the same date as the need complete date.

33. If the need for the previous cycle for a specific asset and task has not been completed, a new need entry will not be generated.

34. The annual cyclical process will create a Need table entry for each asset that is scheduled for a cyclical need for the requested fiscal year. The needs must be associated to a new work order before work will begin.

35. A task can be related to one and only one work type.

36. The Reduction Exercise process will use four types of input:
    - Number of employees by Suborganization Unit
        - This data will be entered by the user.
        - The system will use this number to calculate total hours available.
    - Reduction Event
        - Event description will be obtained from a table.
        - Event description table will include an attribute to indicate whether the event will have a positive or negative impact on the balance, i.e., vacation hours will have a negative impact (reduce the balance), temporary employees (increase the balance).
        - Event hours will be entered by the user.
    - Unplanned Work
        - Unplanned work description will be obtained from the Work Type table.
        - Unplanned work hours will be entered by the user.
    - Planned Work
        - Planned work description will be obtained from the Work Type table.
        - Planned work hours will be obtained from the Work Order table.

ACKNOWLEDGMENTS

The development of the concept of work management within the context of a maintenance management system would not have been possible without the thoughtfulness, experience, and insight of Dave Bixby, who was instrumental in developing DAISY, has maintained that system for over 15 years, and has mentored me for the past ten.

Don Hoffeditz, Owen Murphy, and Rob Jackson of Booz Allen Hamilton have been essential in helping Dave and I flesh out these concepts. We owe them a great debt of gratitude for their professionalism, intellect, patience, and good sportsmanship.

Compass
Case Study of How Wisconsin Adapted NCHRP Report 422 to Work at Home

ALISON S. LEBWOHL
Wisconsin Department of Transportation

When the staff of the Wisconsin Department of Transportation (WisDOT) decided to create a highway maintenance quality assurance program based on NCHRP Report 422, they needed to implement the program in a way that would take into account the state's unique maintenance structure. In Wisconsin, maintenance delivery is contracted out to the state's 72 counties and is prioritized and coordinated by two WisDOT divisions. This structure made buy-in at all levels critical. To facilitate this, the program was piloted for six months, with key decisions about that pilot being made by teams of operations workers from all levels and regions. Other factors identified by the program's Advisory Team as critical to the pilot and the program's success included: a dedicated manager position; flexibility in decision-making; a compressed time frame; and extensive communication. Piloting a program this way also has its caveats and drawbacks, however, including a need to find a meaningful role for operations managers. This article will provide a more extensive exploration of some of those success factors and drawbacks. It will also look at some of the specific choices that Wisconsin made in developing its program.

At the time I am writing this, it is December 2002, and in a month Wisconsin's Compass program will issue the first statewide reports on maintenance conditions of shoulders, roadsides, drainage and selected traffic devices. Compass is the Wisconsin Department of Transportation (WisDOT) quality assurance and asset management program for highway operations. It is a year and a half since this program kicked off and it has the support of the Secretary's Office, its measures have been incorporated in organizational performance measures, and 75% percent of the front-line workers performing the field reviews report that the program has value for them outside of the data generated.

MAKING IT WORK FOR WISCONSIN

Compass

Compass is based on the maintenance quality assurance program laid out in NCHRP Report 422. It will provide a common understanding of what condition our state roads are in, what condition we would like them to be in, and what it would cost to get them there. Managers plan to use these reports, and other program tools, to support providing consistent service across geographic boundaries; demonstrating accountability to top decision-makers, including the legislature; and prioritizing needs and activities. In its asset management phase, this program will also help managers make trade-offs among different choices in light of future uncertainties, and demonstrate how decisions made in highway operations interact with those made elsewhere in the organization.

Collaborative Effort

Since Compass' inception, highway operations workers from across the state have made choices about the priorities, implementation, and future direction of the program. They have stood up and championed the program with their colleagues and peers. As program manager, my job is to coordinate their expertise, get them the resources they need, and make sure we are creating measures that make sense and that we can use. It is to make sure that we are creating a program that works for Wisconsin.

In Wisconsin, maintenance delivery is contracted out to the state's 72 counties and is directed and coordinated by two WisDOT divisions. This structure makes buy-in at all levels critical. To facilitate this, the program was piloted for six months, with key decisions about that pilot being made by teams of operations workers from all levels and regions. Other contributing factors to the pilot's success include: a dedicated manager position; flexibility in decision-making; a compressed time frame; and extensive communication.

Piloting a program this way has its caveats and drawbacks, however. It is critical that managers who are not part of the daily decision-making process are nonetheless brought along in the program's development. Fast implementation means that there is less time to understand the range of implications of decisions before they are made. Finally, early success carries its own risks, including that of raising un-meetable expectations.

In the spring of 2002, the Advisory Team that has shepherded this program from the beginning sat down to identify the factors that had been critical to the pilot and the program's success so far. Based on that and other conversations and observations, this is the story of the choices we have made and the lessons we have learned along the way.

CRITICAL SUCCESS FACTORS

Dedicating a Position

For a few years after managers decided they were interested in a maintenance quality assurance program, they tried to develop one by adding the task to their staff's existing responsibilities. Not surprisingly, however, those other responsibilities ended up taking precedence, and the quality assurance program's development was slow. Having someone dedicated to this full time allowed us to provide the necessary resources to gain effective participation from front-line folks and launch the program quickly, both of which proved critical to the pilot's success.

Some organizations have handled this challenge by hiring consultants. For us, however, there were several benefits of doing it internally, including heightened credibility for the program, improved relationships with field managers, and improved organizational knowledge in our central office. Instead, we used consultants to provide specific skills, including training design and data modeling. Other states have also used consultants to provide statistical support.

Assembling Teams of Champions from Across the State

Early on, Compass committed to a philosophy that the people who do the work know the work. This was going to be a program that was collaboratively created by the operations community for the good of Wisconsin's citizens; not a program created by a central authority to monitor field operations. Turning decisions over to teams of operations managers and workers from

throughout the organization and across the state provided the program with two critical things: broad expertise and perspective; and buy-in on the data and the program from the folks who make the daily choices about highway conditions. Moreover, at a time when budget constraints were putting stress on the relationship between the counties and WisDOT, this program helped to build and strengthen that relationship.

Choosing Team Members

The program has four teams: an Advisory Team, a Standards Team, a Training Team and a Ratings Team. With the exception of the Ratings Team – which includes the day-to-day managers of the state highways for each of Wisconsin's 72 counties – members are hand-selected. We look for members who meet the following criteria as a group and individually:

- Represent the diverse geography of the state: rural and urban, north and south.
- Represent the diverse organization and the different stakeholders in the program: central office, district and county folks; managers and front-line workers.
- Individuals are opinion-leaders; their peers respect them.
- They are willing to be champions, to speak up for the program.
- They believe that this program is a good idea, but they are willing to speak up to the team about individual decisions or strategies with which they disagree.

Managing Teams Effectively

It is important to us that our team members feel their experience with Compass is a valuable one. Feedback from them indicates that, by and large, it has been and continues to be. We check in with our teams fairly often, to hear what they feel is working or not working. WisDOT's Office of Organizational Development Services – which handles training, facilitation, process-improvement and team-building – has also been a great resource for effective team management. Based on those sources, here are some of the factors contributing to the success of our teams. While none of these is ground-breaking, I think they're important enough to mention.

- Asking for a limited time commitment, usually 6-12 months. When that time is up, we ask explicitly if people are willing to renew; we don't assume that they are.
- Providing clear expectations. Teams are given a charter at the outset, which details objectives and expectations of time, participation and support. For individual tasks, they are given a list of objectives and steps, if appropriate.
- Supplying necessary resources. These are, of course, task-dependent. Among other things, we ensure that teams have access to facilitators, expertise from other states or other areas of the organization, training, materials, and enough time and information to do what's being asked of them. We also help build the team by ensuring that team members receive face-time with each other, as well as recognition for their work.
- Giving teams only decisions we're willing to let them make. Of course, nothing is as discouraging than putting time, energy and thought into making a decision – and having it ignored.
- Making good use of everyone's time. We asked ourselves repeatedly if we could eliminate any pieces of the program because we wouldn't use them, or they duplicated other

efforts, or the costs outweighed the benefits. We didn't have regular team meetings, but only called members together when necessary. For each meeting, we had an agenda and supporting materials ready, and we were willing to use teleconferences when we were trading information, rather than making decisions.

Getting a Fast Start

We piloted the program in six months: this included assembling the teams, developing the standards, creating the supporting materials, training the teams, rating the segments, and issuing the reports. After that, we gathered feedback from the teams and other stakeholders, evaluated other options, and put together a recommendation to continue the program as a joint effort of our two divisions. The operations managers accepted our recommendation, and twelve months after the pilot began, we launched another cycle of road rating: developing improved materials, automating the segment selection and mapping, training new teams, and rating almost ten times as many segments. (See Table 1.)

The momentum this created was very powerful. Team members said repeatedly how much they felt they had accomplished in a short period of time, and how much they enjoyed being a part of *doing* something, rather than just talking about doing something. Some said that the speed of the program's launch helped minimize the resistance to change that faces any new program; because people didn't have too much time to anticipate the program, they also didn't have too much time to worry about it before they could see for themselves its costs and benefits. Finally, it encouraged us to leave decisions open until we had information gathered from actual experience.

Having Flexible Decision Making and Extensive Feedback

Decisions were made using what we called the "80% rule." This meant that if we were 80% sure that a decision was the right one, we would go ahead with it on a trial basis, and then review it at the end of that rating cycle, once we'd had a chance to gather feedback on how it was working. This worked for decisions of high-level strategy and on-the-ground choices. We used multiple feedback mechanisms – including anonymous questionnaires, open and guided discussions with groups – and emphasized at every opportunity our desire to hear from anyone with ideas, concerns or questions. This combination enabled us to make decisions relatively quickly, to take risks in our decision-making, and to revise our decisions to incorporate experience and feedback as we went.

TABLE 1 From Pilot to Statewide

	Pilot	**Statewide**
Year	2001	2002
Number of counties	8	72
Number of trainings	1	4
Number of raters	19	112
Number of segments	240	2325

For example, during the pilot, the Advisory Team needed to decide who would rate the roads. Although most other states had used a small group of raters out of their central office, we wanted to use a two-person team for each county: the county patrol superintendent and the district area assistant. Would they be willing to do this? we wondered. Because if they weren't, it would only make them resent the program. And, if they were willing to do it, would we be able to get them to make consistent enough measurements to make meaningful distinctions among regions?

At the end of the pilot, we brought the eight teams of patrol superintendents and area assistants together for a half-day debrief. We asked them, among other things, if they were the right people to be rating the roads, and they said yes. So we decided to continue using try this combination during our statewide rating. At the end of the 2002 rating, we gave an anonymous questionnaire to each member of the rating team. An impressive 83% said they wanted to be the ones to rate the roads.

We then performed a quality assurance check on two counties we believed were most likely to be rating consistently – ones that had been pilot counties and where the patrol superintendent served on the training team. The purpose of this was not to gauge how reliable the raters were in their first year, but how reliable we could expect them to be at their best. Those results will be ready in the next few weeks.

The results of the questionnaire and the quality assurance check will be given to the Advisory Team this spring as they make decisions about how to perform the next rating cycle.

Communicating Extensively

Communication has been a two-way effort and is often integrated with other pieces of the program, like training and process improvement. It includes the feedback mechanisms mentioned above that help us listen to our program's customers and team members. Regional trainings and district meetings offer opportunities to both provide information and open a dialogue about the program. Our website (see Figure 1) and program materials offer a range of information for different audiences: a quick overview of the program; a training schedule for the current year (with links to area hotels and the training sites); and Advisory Team meeting minutes.

This range of communication strategies helps keep stakeholders up-to-date on the program; reminds the operations community that their peers developed and oversee this program; ensures that the program fulfills its commitment to transparency; allows us to gather the information we need to improve the program and its processes; and demonstrates credibly that this program welcomes feedback.

Examples of specific communication efforts include:

- A simple brochure provided a general overview of the program, its teams and benefits.
- As program manager, I speak at the district operations meetings that happen in the fall and the spring. I provide a general update on the program, a specific update on what's happened or is coming up for them, and spend some time hearing back from them.
- I also provide general program updates at statewide conferences for district and county personnel.

- Informal communication at all of these events has been critical. It has built confidence in the program, strengthened relationships between me and the team members, and has often provided feedback that people didn't feel comfortable giving in a larger crowd.
- Compass Training – required for all members of the Ratings Teams – provides two days of hands-on information about the program and its standards.
- Videos about the program are targeted for different audiences. We have a general overview video for managers, a short introductory video for county patrol superintendents who want to talk to their workers about the program, and a longer video that's shown during training which stresses the critical role of the Ratings Team.
- A website available to all of WisDOT and the counties has general and specific program information. See Figure 1.
- Process measures that let us know how the program is doing (e.g., Were the standards clear and relevant? Were the roads rated by the deadline?) will be gathered and published with the reports on the data.

Reports on the data will be issued after each rating cycle and will include a summary of the program's efforts over the last year.

Demonstrating Strong Management Support

When I first started speaking about this program, some of the questions I heard most frequently were: *How long will this program be around? How do we know this isn't just another flavor of the week?* And when I asked people what they needed to see in order to be assured that this program wasn't going anywhere, they said, *I want to hear it from the director of highway operations.* Or: *I want to hear it from the DOT Secretary.*

FIGURE 1 Compass Website homepage.

When the program kicked off with a one-day event in the state's capitol, we had the DOT Secretary introduce the event. At major events, the director of highway operations introduced me and mentioned his strong support of the program. The video documenting the pilot and the ones used in training showed both men talking about their support for their program, and the benefits they believe it will offer. And while those questions haven't stopped, I certainly get them far less often.

OTHER LESSONS LEARNED

Manage Expectations

One of the dangers of early success is that expectations soar. At the end of the pilot, our Advisory Team looked around at the program and the organization and listed, among other things, what it believed to be the biggest threats to the program. Unmanageable expectations topped the list. They recommended drawing a clear line between what the program does and doesn't deliver; what it delivers now and in the future. This has helped.

Explore and Expand Your Options

There are a lot of different ways to rate the roads. Ratings can be organized by physical feature or by worker activity. The state can be divided by geography, by management unit, by road class, and by all of these things. We could gather data by listing actual observations (this segment has 3 deficient culverts) or by having thresholds (this segment fails on culverts). Wherever possible, we try to know what those options are, consider the implications of different choices, and where we weren't sure, to find options that don't close out the others.

For example, when deciding between recording actual data versus pass/fail data, we chose actual data because it was more flexible. We figured we could always go back and select a threshold later and recategorize the actual data to become pass/fail data. But once we had pass/fail data, there was no going back to actual.

We have also learned that it's helpful to have at least one person – perhaps more than one – in the room with expertise in statistics and in information technology when making decisions. Our Advisory Team made several choices that seemed relatively small, but that ended up having large implications for programming our database or for our ability to extract meaning from the data. Now our database programmer sits with the Advisory Team as an expert advisor during decision-making sessions. I have a background in statistics, and now pay closer attention to our decisions, try to have at least one other person there in the room who understands the statistical implications of decisions, and try to make time afterwards to review and revisit decisions so we understand their statistical impact.

Define a Role for Operations Managers

In many states, the decision-making body for a program like this is the team of operations managers who serve under the operations director. Because we chose to use the team structure discussed above, we needed to find ways to keep the two-division team of operations managers – central office and districts – engaged and supportive. Since our district offices report to a

different administrator than ours, it was especially critical that we get buy-in from district managers.

We had operations managers from both divisions help us select many of the pilot team members, and provided them with regular updates on the pilot. At the end of the pilot, all data was presented to district managers and they voted to recommend continuing with the program with the districts as full partners in the process. They then took that recommendation to their bosses, who accepted it.

Still, keeping this team fully engaged has been challenging. Since they are one of the primary customers of this program – and their workforce is one of the primary suppliers, we decided to have them be the decision-making body on the shape this program takes as it moves forward. The Advisory Team will put together a body of recommendations this spring for the next round of ratings, but the operations managers will make a decision to accept that recommendation or to revise it.

Know That Random Sampling Has Its Challenges

We use random sampling to select the 1/10-mi segments of highway that are rated for this program. Many teams were concerned that their segments of road were too good or too close to each other, or not representative of the full range of state highway conditions. Let us pick the segments, they said. Or: put every highway project in there once and draw from that.

Segments are selected to ensure that every 1/10-mi segment in the system has an equal chance of being chosen. This reflects drivers' experiences, since drivers experience the road in miles, not highway projects.

The observation that the roads are too good comes most likely from the fact that maintenance workers spend most of their time on the roads that need their help. Their impression of road conditions comes from the worst roads. If we let them pick the segments, that bias would be in there. We created a small exercise during training to illustrate how random sampling works. We talked about what they might see out there and why. Raters came back with the same concerns.

In fact, the condition of a 1/10-mi segment of road is not independent of the condition of the segment next to it. Chances are, if this section of road is pretty good, the next one will be as well. This is true for pavement, shoulders and striping; it is likely true for other aspects of maintenance and operations as well. And the segments need to be independent for the sampling protocol to work the way it's designed.

For next year, we're considering different ways of dividing up the road so segments are further apart, perhaps dividing the road up into 10-mi segments, choosing randomly among those segments, and then rating the 1/10 of a mile in the center of that segment. This would make the segments more likely to be independent – and would make the rating process feel more intuitive to the raters.

THE CHOICES WE MADE

The discussion above is mostly about *how* we developed the program. So at the end of it all, *what* does the program itself look like? Here are the basics.

Teams

Advisory Team

This group of 15 makes strategic choices about the implementation of Compass. It meets two to four times a year and members are expected to bring expertise and judgment to the table and to provide public support for the program, but not to effect implementation. About 1/3 of members are from counties; 1/3 from districts; and 1/3 from central office. This team strengthens the credibility of the program, and provides a community of expertise for the program manager on a formal and informal basis.

Standards Teams

Every new element in the program (e.g, traffic, roadsides, winter operations) gets its own four- to eight-person standards team. This team selects the features that make up that element (e.g., regulatory and warning signs, centerline, beamguard) and sets standards and measures for those features (e.g., number of signs not functioning as intended; linear feet of centerline with more than 20% of paint worn or missing). Members are subject experts from the districts and counties, with a central-office facilitator who is responsible for ensuring that standards reflect current policy. Teams meet once to choose the features and set the standards; once to revise these based on feedback from the rating. For more complicated elements – those involving the adaptation of automated data or the creation of new kinds of operational measures – teams may meet more frequently and may include technical or IT experts. These teams lend expertise and credibility to the measures that are at the heart of this program.

Training Team

This six- to eight-person team conducts regional trainings for the Ratings Team to introduce the program and to train raters. It includes at least one member from each element being rated in the field, as well as the program manager. The trainings have been carefully designed and revised with feedback from the trainers and participants. Members receive two days of initial "train-the-trainer," and a training coach accompanies the team and provides general support and feedback on the road. They select their own slides for their element and commit to a fairly intensive training schedule over a compressed period of time. (Eight days, not including travel, in just over one month.) This team provides front-line credibility and support for the program, and has also proven to be a valuable resource on standards and strategy.

Ratings Teams

Each county has its own two-person Ratings Team consisting of the front-line managers for maintenance of state highways in that county: the country patrol superintendent and the district area assistant. Area Assistants may serve on several teams. These teams perform a field rating of the 30 to 40 segments within their county, based on the standards laid out in the training and documented in the rating manual they each receive. The field ratings, with travel to segments, take two to three days within a two-month window. Training takes two days the first year; one day per year for refresher training after that. Although rating reliability is lower with more teams,

we decided that having front-line workers rate the roads made sense for several reasons. It strengthened the key partnership on which we rely to care for our state highways. It ensured that most front-line workers were applying the same standards to the state highways. And, most importantly, front-line workers have the greatest opportunity to directly impact the condition of the state highways, so it's critical that they buy into the data that can help them do this; having them collect it is an effective way to help make this happen.

Measures

Our program currently has four elements: shoulders, roadside, drainage, and selected traffic devices. We are in the process of adding pavement and winter operations. Each of these elements is composed of a set of six to eight features. Each feature has a standard that is designed to reflect whether the feature is worn or damaged to a point where it would become part of maintenance's workload, and a measure that is designed to tell us how extensive the wear or damage is. (See Table 2.) As mentioned above, these features, standards, and measures are selected and revised by the Standards Team for that element.

Data Gathering

For these four elements, ratings are done in the field, from September 1 to October 31, and are recorded on paper and sent into the central office to be recorded in an Access database. Our sampling protocol allows us to gather feature information at the district and statewide level, and element information at the county, district and statewide level. For each feature we record actual data (25 linear feet of deficient curb and gutter) as opposed to binary data (pass/fail). Road classes are not differentiated.

Before the pilot, we had thought that we would be able to see the condition for every feature in every county. But not every feature (take, for example, culverts or crash cushions) appears on every segment, and statistics tell us that you need to see a feature at least 25 times to make any meaningful conclusions about it. Which means we need to look at some 240 segments to draw any meaningful conclusions at the feature level. Elements, on the other hand, are a composite of whatever features happen to appear on the segment, which means that every segment has four element scores.

The reports being issued this January will reflect data gathered once a year, in the field, in the fall, by two-person teams. In the future, however, reports will reflect data gathered myriad ways. The method and frequency of ratings will be determined by how important that element is to the system and our customers; how frequently it changes; who maintains it; and what other sources of information on that element already exist.

Training

Every district is responsible for ensuring that all its counties are rated, and training is mandatory for anyone performing those ratings. Since this was our first year rating the roads statewide, we offered four regional trainings of 2 days each. Training was a mix of classroom instruction and hands-on practice; it explained the program and its benefits and taught raters to recognize and document the conditions of the four elements. Next year, we will offer one 2-day training for anyone new to the program; and four regional 1-day refresher trainings for anyone who will be

rating the roads, but has already had the 2-day training. This is delivered by the Training Team. See Table 3 for the training curriculum.

TABLE 2 2002 Compass Measures

Shoulders	
Hazardous debris	Number of items large enough to cause a safety hazard.
Drop-off/ build-up	Linear feet with drop-off or build-up > 2 inches
Cross-slope	Linear feet of cross-slope >= 2x planned slope
Cracking	Linear feet of unsealed cracks >¼"
Potholes/ raveling	Total square feet of BOTH potholes and raveling > 1 sq ft by 1" deep
Erosion	Linear feet with rutting > 2 inches
Drainage	
Ditches	Linear feet of ditch with greater than minimal erosion of ditch line OR obstructions to flow of water requiring action
Culverts	Number of culverts that are > 25% obstructed OR < 80% structurally sound
Under-drains/ edge-drains	Number of drains with outlets, end walls or end protection closed or crushed OR water flow is obstructed
Flumes	Number not functioning as intended OR a hazard in the clear zone
Curb & gutter	Linear feet of curb and gutter with severe structural distress OR > 1 inch structural misalignment OR > 1 inch of debris build-up in the curb line
Storm sewer system	Number of inlets, catch basins, and outlet pipes with >50% capacity obstructed OR < 80% structurally sound OR > 1 inch vertical displacement OR not functioning as intended
Roadsides	
Litter	Number of pieces of litter and non-natural encroachments on shoulders and roadside visible at posted speed, but not causing a safety threat
Graffiti	Square feet of graffiti visible at posted speed
Mowing	Number of instances in which each roadside deviates from standard in terms of the height of the grass, the width of the mowing, and no-mow zones
Noxious weeds	Percent of roadside with visible clumps of leafy spurge, bindweed or Canada thistle
Woody vegetation	Number of instances in which a tree >4" in diameter is present in the clear zone OR trees and/or branches overhang the roadway or shoulder creating a clearance problem
Fences	Linear feet of right-of-way fence missing OR not functioning as intended
Landscaping	Value of 1 (dead/deteriorated and overrun with weeds) to 5 (healthy and well-tended, with no deterioration or weeds)
Barriers	Linear feet of noise barriers and retaining walls not functioning as intended
Traffic Control and Safety	
Centerline/ edgeline markings	Total % worn or missing
Special pavement markings	Number missing OR not functioning as intended
Raised pavement markers	Number missing OR not visible at posted speed OR damaged
Regulatory/ warning signs	Number missing OR not visible at posted speed OR damaged
Other signs	Number missing OR not visible at posted speed OR damaged
Delineators	Number missing OR not visible at posted speed OR damaged
Protective barriers	Linear feet of beam guard, concrete barrier walls, and cable guard not functioning as intended
Impact attenuators	Number of impact attenuator systems not functioning as intended

TABLE 3 Compass Training

Getting in the Driver's Seat: Day 1	
Getting in Gear	The training team sets up the day and provides an overview of the program and its development, including a video featuring top managers and participants' peers. Everyone in the room introduces him- or herself. The team solicits initial questions and concerns.
Choosing Your Destination	An interactive questionnaire provides basic information about the program and underscores the important role the ratings teams play in this program. A small group exercise helps raters understand what's in it for their county or district.
Unfolding Your Map	Features, standards and measures are introduced. Participants take turns reading aloud the measures from the Ratings Manual, as the group fills in an overhead showing these measures.
Reading the Legend	This is the heart of the training. Each trainer walks the Ratings Team through his element, feature by feature, using slides as illustrations, with the Ratings Sheet on an overhead. Participants read the definition and standards for each feature from the Rating Manual, rate the feature shown in the slide, and see that rating recorded on the overhead.
Packing Up	The program manager provides a brief explanation of how the raw data will be rolled up and reported out. In small groups, participants work on a case study, asking how they would have used this program to address the budget crisis caused by a severe winter.
Getting in the Driver's Seat: Day 2	
Checking Your Mirrors	The training team again sets up the day. They ask some quick questions of the entire room to refresh everyone's memory, and then the small groups report out on their case study results.
Hoping for a Smooth Ride	The groups get practice rating two of the four elements. Trainers divide into two groups, as do raters; each group rates one site and then switches. The groups debrief the segment on site, so they can look directly at the features they're discussing.
Enjoying a Nice Drive	After lunch, the groups go out and rate two more segments, looking at all four elements.
Hitting the Road	We talk about what happens next: when segment rating sheets will arrive, how to find the segments, what to bring, and when to return the completed sheets. All this information is also available in their Rating Manuals. All trainers come up to answer any final questions.

NOTE: This curriculum was developed by a training consultant, in close collaboration with the Compass trainers. It is a mix of exercises and field work, with very little lecturing, and draws heavily on the principles of adult learning.

Reporting

By the time this paper is published, it will be summer of 2003. We will have analyzed our first data set, published our first statewide reports, and gathered feedback on what was and wasn't useful and what people would like to see in the future. Here, however, is what I know now.

Rolling It Up

In order to get from the raw data to measures we can use for decision-making, the Standards Team mapped different feature condition levels to different scores from 0-100. So, for example, a district with 10% of its culverts deficient would receive a 75. One with 15% deficient would receive a 50. Feature scores are calculated across a county or district, and reflect the maintenance condition of that feature, regardless of how frequently it appears on the highway system. So to understand how *common* a problem is reflected in a low feature score, you would need to combine that score with inventory information.

In order to go from features to element scores, the Standards Teams weighted each feature within an element. The element grade from A-F is calculated on a segment-by-segment basis, based only on those features that actually appear on the segment. Because of this, features that appear more frequently will weigh more heavily in the final element grade; and thus element grades are more reflective of the driver's point of view than are feature grades.

Analyzing and Reporting

Once the data is entered, we will generate some sample reports to take to the Advisory Team. The content and design will be based on the feedback we got from last year's pilot reports, reports from other states, suggestions made by a statistics consulting class at the UW-Madison, and the principles of effective information design laid out in Edward Tufte's three books on that subject. We will likely start by comparing average condition levels across districts, and differences in variability across counties and districts.

The Advisory Team will then help us figure out what questions they'd like to ask and what reports – of those given and those they can design – best help them ask those. We will use that information to generate our final reports for this round of ratings, and will gather feedback to help us better design our reports in the future.

Next Steps

After we receive feedback on the reports, the Advisory Team will sit down to evaluate this round of ratings, as well as possible additions or changes to the program, and will assemble a list of recommendations for the next year to be presented to the Operations Managers. The team will evaluate the success of the field ratings in their current form, with the assistance of a set of process measures (See Table 4.) and will choose whether our next steps include expanding the list of elements or adding additional tools to the program. To help them in their evaluation – and their communication to the ops managers – they created a decision matrix that helps them explain both their criteria for program choices, and the ways in which different options meet those criteria. Table 5 illustrates this matrix, which also provides a powerful tool for envisioning a completed program, and for noting the achievement of milestones. Once the operations managers have either approved or revised that set of recommendations, we will begin implementing another 12-month round of ratings and program evaluation and revision.

TABLE 4 Process Measures and Indicators for Compass 2002

Goal	Indicator/Measure
Time and costs are appropriate over time.	Total time spent
	Total dollars spent
We are measuring the outcome of our efforts.	% of operations budget measured by Compass.
	Number of elements being measured.
	Number of features being measured.
Standards reflect the way we maintain the roads.	% of raters agreeing with this statement.
Standards are clear.	Was there a significant difference between field raters and QA team?
	# of feature standards rated "clear" by over x% of raters
Assess training effort.	# of counties trained
	# of raters trained
All raters are being trained.	% of raters who are qualified.
Training time and costs are appropriate over time.	Total hours in training
	Total non-salary cost of training
Raters felt prepared when they completed training.	% of raters responding "yes"
Raters felt prepared when they rated.	% of raters responding "yes"
Maps and rating sheets were issued in a timely fashion.	% of trainings at which maps & segments were ready
Segments could be found.	% of segments tossed because they could not be found.
	Sample % of segments accurately located.
Raters were provided with enough segments.	% of counties not rating enough segments because of running out of "spare" segments.
Assess rating effort.	# of segments rated
	Average time per segment
	Total time spent on rating activities (rating, prep and travel)
All counties were rated in the same time frame.	% of counties with ratings completed and postmarked by 10/31
All counties were rated by qualified raters.	% of segments rated by at least two qualified raters, with at least one rater from WisDOT
Raters were rating the same thing the same way (inter-rater reliability).	Was there a significant difference in ratings between field raters and QA team?
We can use this data to make meaningful distinctions.	Width of confidence interval for features and elements
	# of features for which we have information at the county level for >x counties
Reports are useful for decision making.	% of managers responding "yes"
Reports are clear.	% of managers responding "yes"
Reporting is timely.	# of weeks between October 31 and reports being mailed
The program is institutionalized.	Is Compass in the maintenance manual? Yes/no
	Does Compass have cost codes? Yes/no

TABLE 5 Draft Decision Matrix

	Additional elements							**Program Products**			**Reporting**					**Integration & Deployment**					
	Winter	Pavement	Bridges	Traffic	Rest areas	Electrical	Emergency response	Priorities	Alternatives	Targets	Validate measures	Customized measures	Canned reports	Targeted reports	Customizable reports	Integrate with [Model A]	Integrate with [Model B]	Take to legislature	Take to media & public	Use for decision-making	Use for budgeting
Dealbreaker (Yes/Somewhat/No)																					
Our domain (Y/S/N)																					
Importance of asset (Hi/Med/Lo)																					
• % of ops budget																					
• Critical to public, legislature or safety																					
Importance of tool/info (H/M/L)																					
• Help us with key decisions or tasks																					
• Critical to public, legislature or safety																					
• Other tool available																					
Prerequisite resources (H/M/L)																					
Resources (H/M/L)																					
Probability of success (H/M/L)																					
Builds support (H/M/L)																					

NOTE: As of this writing, this document is still being revised.

Development of an Integrated Highway Maintenance Management System
The Maryland Experience

MANOJ K. JHA
Morgan State University

LEONARD SCHULTZ
Maryland State Highway Administration

Due to the increasing highway traffic over the last two decades the highway maintenance procedure has become increasingly complex. This complexity is attributed to the collection and analyses requirements of the maintenance data as well as the overlapping needs for data analyses by various offices within a highway agency. The highway maintenance data needs to be accurately collected and efficiently entered in a computerized database so that most accurate and meaningful inferences can be drawn regarding future maintenance activities and budget allocation. In addition, in order to avoid duplication of data collection and data entry into various databases such as the pavement, bridge, and financial management databases, development of an integrated system with easy uploading and downloading features is desirable. This paper describes the experience of the Maryland State Highway Administration in attempting to develop an Integrated Highway Maintenance Management System. The lessons learned may be of great benefit to other states.

Highway maintenance and management has become increasingly complex over the last two decades. With the increasing traffic on our highways, shrinking right-of-way for new highway development, increasing security concerns, and limited resources, highway maintenance has become more critical then ever. Highway statistics for the United States (*1*) show that about 26% of the highway expenditures in 1995 for all levels of governments went to maintenance and services. Novak et al. (*2*) found that the average maintenance cost for pavement in unacceptable condition for Michigan's freeways and other roads was $745/lane-km and $2,857/lane-km, respectively, based on 1989-90 data. An analysis of highway life cycle by Bentley (*3*) indicated that for a typical highway the time necessary for design/engineering, construction, and maintenance/operations is 4%, 6%, and 90%, respectively. The typical expenditures in these three categories are 8%, 37%, and 55%, respectively. This implies that maintenance and operations constitute a major portion of expenditure and highway life and ought to be given due consideration.

A recent survey done by the American Society of Civil Engineers (*4*) indicates that one third of the nation's roads are in poor or mediocre condition and 29% of the bridges are structurally deficient or functionally obsolete, costing American drivers an estimated $5.8 billion a year. This entails that new technologies and mathematical models for improved maintenance and operations must be explored.

A number of infrastructure maintenance management systems have been developed to predict maintenance costs, such as highway maintenance management systems (*5, 6*), bridge management systems (*5*), and pavement management systems (*7*). However, these systems do not look at maintenance planning, scheduling, and budget allocation in an integrated fashion.

In the early days the Maintenance Management System (MMS) at the Maryland State Highway Administration (SHA) relied on physical features along the roadway, correlated with maintenance activities, average daily traffic, annual quantity standards, and resource requirements, i.e., average labor, equipment, and materials in order to perform maintenance activities. The system would develop an annual work plan and produce a budget for each maintenance activity and maintenance office by Interstate, Primary, and Secondary systems. In addition, inputs into the system would result in performance and production measures to show work accomplished each fiscal year.

As the highway traffic increased over time so did the maintenance activities resulting in heavy interdependence of highway maintenance, pavement maintenance, bridge maintenance, and the financial management system, making the precise forecasting of maintenance budget, distinction of preventive and reactive maintenance activities, and accurate display of performance and production measures increasingly difficult. The requirement of a zero-based budgeting further added to the complexity.

The Maryland SHA has made several attempts to acquire a MMS since the early 1990s, most notably in the recent years to acquire an Integrated Highway Maintenance Management System (IHMMS). In this paper we discuss a planning study that was completed for acquiring that IHMMS. A comprehensive requirement analysis was performed by setting up a cross-functional team and thoroughly analyzing the system requirements. A survey to identify the type and sophistication of other states' MMSs was also conducted (see Appendix). Leading vendors capable of satisfying most of SHA's IHMMS requirements were invited to demonstrate their products. Each demonstration was rated against the criteria established by the cross-functional team. In the end an incremental benefit-cost analyses was performed to acquire the optimum product. The purpose of this paper is to share Maryland's experience in the IHMMS development. It is expected that the proposed approach for the design and development of the IHMMS for the SHA would be of great benefit to other highway agencies.

REQUIREMENT ANALYSIS

A requirement analysis was performed to understand the requirements of the IHMMS in relation to SHA's business process. For this purpose the following tasks were performed:

- Task I—Perform a "business process analysis" of highway maintenance processes and associated information requirements that includes operational needs and decision support functions for management;
- Task II—Conduct a "fit analysis" of the current computer-off-the-shelf (COTS) product being utilized by SHA for maintenance management relative to identified information requirements; and
- Task III—Perform a market survey/industry analysis to identify and analyze current product offerings in regard to SHA's maintenance information requirements.

Task I: Business Process Analysis

The objective of this task was to identify the core business processes associated with highway maintenance management, and to evaluate and validate the functional requirements necessary for

a computerized highway maintenance management system. The approach involved gathering the data, analyzing and evaluating the information, and presenting the findings.

A core cross-functional team was formed for the IHMMD development. Open forum meetings were conducted with the core team and the development team, during which attendees described their duties, current maintenance procedures, reporting requirements, and interface requirements of the IHMMS. These initial Joint Application Development (JAD) sessions helped understand how the different units within SHA functioned together to provide facilities maintenance. The meetings also provided a forum for SHA personnel to express their concerns with the current application and to note the functionality necessary for an automated solution.

TABLE 1 Validation of Consensus by JAD Sessions

General Functionality	Overall Consensus		Qualifying Comments from the Final JAD Sessions
	P	T	
REFERENCE SYSTEMS & GIS			
1. Linear Reference Systems	H	1	Prerequisite for location referencing
2. Coordinate Reference Systems	H	1	Prerequisite for location referencing
3. Correlation of Linear and Coordinate Reference Systems	H	1-2	Prerequisite for location referencing
4. Highway Centerline	H	2	Prerequisite for location referencing
5. Geographic Information System	H	3	Prerequisite for location referencing
INVENTORY, CONDITION AND LEVELS-OF-SERVICE ASSESSMENT			
6. Condition/Levels-of-service Goals	H	2	Needed for budgeting and work planning
7. Inspection Module	H	2	Not addressed in JAD sessions
8. Feature Inventory	H	1	Needed for budgeting and work planning
9. Inventory to Activity Conversion	H/M	1	Needed for budgeting
10. Condition and Deterioration Rates	M	2	Desired budgeting process includes ability to forecast
11. Levels-of-service (Random sample)	M	2	Needed as input to budgeting
WORK PLANNING, BUDGETING, AND DISTRIBUTION OF FUNDS			
12. Quantity Standards	H	1-2	Needed as input to budgeting
13. Service Level Adjustment	H/M	2-3	Part of budgeting and work planning
14. Work Planning and Balancing	H	2	Desired business process
15. Basic Budgeting and Needs Assessment	H	1-2	Desired business process
16. Managing for Results	H	2	Implied as part of the overall business process
17. Relationship to Capital Program	H/M	1-3	Needed for budgeting
18. Levels-of-service (Choices and costs)	H	2-3	Needed for budgeting
19. Advanced Budgeting and Needs Assessment (Optimal Resource Allocation)	H/M	3	A desired business process
20. Benefit Cost Analysis	M	3	Desired for budgeting (i.e., optimization) and project level analysis
21. Distribution of Funds	H	1-2	Desired business process
22. Risk Management	M	3	Part of a number of desired processes

NOTE: P = priority (H = high; M = medium; L = Low; N = not needed) **T** = timing of need (1 = within 1 year; 2 = within 2 years; 3 = within 3 years; 5 = within 5 years; N = not needed within 5 years)

TABLE 1 *(continued)* **Validation of Consensus by JAD Sessions**

General Functionality	Overall Consensus		Qualifying Comments from the Final JAD Sessions
CONTRACTING OUT			
23. Contracting Comparisons	H/M	3	Desired business process
SCHEDULING AND DAILY WORK ASSIGNMENT			
24. Periodic Maintenance	H	1-2	Needed for scheduling
25. Preventive Maintenance	H	1	Needed for scheduling
26. Corrective Maintenance	H	1	Needed for scheduling
27. Advanced Preventive and Corrective Maintenance	H	3	Addressed in desired budgeting and scheduling
28. Project Management	H	1-2	"Bottom up" approach needed along with "Top down" approach
29. Customer Request Module	H	1-2	Scheduling needs to address customer requests
30. Work Order System	H	1	Sometimes desired for scheduling
31. Scheduling and Daily Assignment	H	3	Desired business process
32. Resource Needs and Availability	H	1	Scheduling and daily assignment needs to address
33. Daily Assignment	H	1-2	Desired business process
34. Optimal routing	M/L	3-4	Not addressed in JAD session
FIELD AND OFFICE DAILY WORK REPORTING			
35. Daily Work Reporting	H	1	Desired business process
36. Electronic Field Data Collection	H	2	Remote data entry identified as a need
37. Office data entry as back-up to field data entry	H	1	Necessary
38. Other remote access for daily work reporting	H	3	Web access not addressed directly; only indirectly as remote access
QUALITY ASSURANCE/QUALITY CONTROL			
39. Error checking	H	1	Needed for daily work reporting
40. Other QA/QC	H	2-3	Needed in various ways
COSTS AND EXPENDITURES			
41. Indirect Costs (Activity Based Costing)	H	1	Needed for budgeting and cost and expenditure tracking
42. Unit and Daily Costs	H	1-2	Needed for budgeting and cost and expenditure tracking
43. Repair Cost Recovery	H	1	Not addressed in JAD sessions
44. Tracking of Money Spent	H	1	Desired business process
REPORTS			
45. Variances and Incomplete Work	H	1	Needed
46. Status, Details, and Summaries	H	1	Needed
47. Regular, Tailored & Ad Hoc Reports	H	1	Needed
48. History	H	2	Needed
49. Winter Storm Reports	H	1-2	Needed
50. Presentations	M	3	Needed
ENVIRONMENT AND OCCUPATIONAL HEALTH			
51. Environmental and Occupational Health and Safety Compliance	H/M	3	Desired business process

NOTE: P = priority (H = high; M = medium; L = Low; N = not needed) **T** = timing of need (1 = within 1 year; 2 = within 2 years; 3 = within 3 years; 5 = within 5 years; N = not needed within 5 years)

TABLE 1 *(continued)* **Validation of Consensus by JAD Sessions**

General Functionality	Overall Consensus		Qualifying Comments from the Final JAD Sessions
BENCHMARKING AND BEST PRACTICES			
52. Performance Measurement and Productivity	H	1-2	Reflected in various business processes
53. Best Practices and Benchmarking	H/M	2-3	Desired business process
DOCUMENT MANAGEMENT			
54. Document and Site Map Retrieval	M	2	Needed
DATA INTERCHANGE, SHARING, AND INTERFACES			
55. Data Interchange	H	1	Needed
56. Data Sharing	H	1	Needed
57. Data Repository	H	1	Needed
58. Security	H	1	Needed
59. Pavement Management System Interface	H	2	Needed -- bi-directional; history from PMS to MMS; MMS adds history to PMS
60. Bridge Management System Interface	H	2	Needed -- bi-directional
61. Equipment Management System Interface	H	1	Needed -- bi-directional
62. Materials Management System Interface	H	1	Needed -- bi-directional
63. Financial Management System Interface	H	1	Needed -- bi-directional
64. Payroll System Interface	H	1	Needed -- bi-directional
65. Master File, HPMS and GIS Interface	H	1	Needed -- one-way from HPMS/Master to MMS
66. Accident Record System Interface	H	2	Needed -- one way from MARS to MMS
67. Historic Traffic Information	H	2	Needed -- one way from Traffic records to MMS
REAL TIME OPERATIONS			
68. Real Time Traffic and Storm Information	H	2	Needed -- one way from sensors to shops
69. Automated Vehicle Location	M	3	Not addressed in JAD session
OTHER MANAGEMENT SYSTEMS			
70. Traffic Device Management System	H	2	Desired functionality
71. ITS Maintenance Management	H	2	Desired functionality
72. Landscaping Management System	H	1-2	Desired functionality
73. Facilities Management	H	2-3	Desired functionality
COMPUTER BASED TRAINING			
74. Computer Based Training	H/M	1-3	Not addressed in JAD session

NOTE: P = priority (H = high; M = medium; L = Low; N = not needed) **T** = timing of need (1 = within 1 year; 2 = within 2 years; 3 = within 3 years; 5 = within 5 years; N = not needed within 5 years)

Following these initial JAD sessions, a series of interviews with individual SHA personnel were conducted to understand further the core business processes and specific functional requirements of a computerized highway maintenance management system. A questionnaire was developed that summarized the general and advanced functional requirements for an IHMMS system. Each participant was requested to rate the priority and timing of need for each type of general functionality according to the following:

- Priority (H = high; M = medium; L = low; N = not needed), and

- Timing of need (1 = within 1 year; 2 = within 2 years; 3 = within 3 years; 5 = within 5 years; N = not needed within 5 years).

The requirements analysis task concluded with a series of JAD sessions that resulted in a consensus on the functional needs (Table 1) of an integrated highway maintenance management system and a series of additional interviews that provided further detail on the business processes associated with specialized operations such as landscaping and electronic equipment maintenance. After determining clear and concise ways to present the wealth of data that was accumulated, the information was ordered, prioritized, and organized in preparation for subsequent analyses and evaluations associated with the next tasks.

Task II: Fit Analysis

The purpose of this task was to determine whether the current highway maintenance system fully and effectively supported SHA's highway maintenance related business process and end user needs. For this purpose the following categories were identified:

- Required, desired, and "nice to have" attributes (relative to existing and anticipated needs) of a future maintenance management system;
- Critical success factors;
- Strengths of the current COTS product;
- Weaknesses and deficiencies of the current COTS product; and
- Impact of identified deficiencies in the existing system.

Task III: Market Survey/Industry Analysis

In this task, a survey was conducted to identify existing custom systems in use at other state and local agencies and analyze how they mapped to SHA's requirements. The basic approach was to:

- Identify a set of requirements to be satisfied by the application;
- Develop a weighted assessment methodology;
- Identify candidate applications;
- Obtain detailed information on the capabilities of each application; and
- Compile a short list of finalists.

Work/Process Flow Review and Analysis of Existing Business Processes

The existing core business processes of SHA were analyzed by focusing on the following three perspectives:

1. High level views of the overall highway maintenance management process—The high-level view presents a simple overview composed of the following six basic business processes (Figure 1):
   - Collecting and updating feature inventory and condition data;
   - Budgeting, distribution of funds, and work planning;
   - Scheduling and assigning daily work;

- Responding in real time to incidents, storms, and emergencies;
- Reporting work completed and resources used; and
- Monitoring and measuring performance and funds spent.

2. Existing core business processes—The following existing core business processes were reviewed and analyzed:
   - Identify inventory, condition, and level-of-service (LOS) data;
   - Prepare budget, distribute funds, and develop work plan;
   - Schedule and assign daily work (including determination of resource availability);
   - Complete daily work report;
   - Transfer data and upload to related systems; and
   - Track costs and expenditures.
3. Selected maintenance operations—The following selected maintenance operations were reviewed and analyzed:
   - Sign maintenance;
   - Landscape operations;
   - Maintenance of electronic equipment other than traffic signals;
   - Traffic signal maintenance;
   - Bridge maintenance; and
   - Office of Maintenance (OOM) contract maintenance.

Detailed Analysis of Existing Core Business Processes

Identify Inventory, Condition, and LOS

The objective of this business process was to identify and assemble feature inventory, condition and LOS data for potential use in maintenance budgeting and annual, seasonal, or other periodic work planning. SHA had a variety of inventory and condition data pertinent to maintenance features, pavements, and bridges. It was determined that inventory data for maintenance features other than pavement and bridges is only 50 to 60 percent complete and accurate. The traffic signal inventory was complete and accurate, and a detailed inventory was being developed for electronic devices such as cameras and variable message signs. Bridge inventory data was of high quality. There was a complete interstate sign inventory as well as a historical markers inventory. A statewide sign inventory did not exist, although some districts or areas had their local sign inventories. An inventory of landscape features and plantings did not exist. The Office of Materials and Technology (OMT) maintained a construction history database for a long time, and was an excellent source of pavement feature information. Highway Performance Management System (HPMS) covered 100 percent of the state and federal aid highway system and contained much useful information regarding roadway characteristics, such as number of lanes, pavement type, and presence of shoulders. The OMT collected and stored condition, distress, and other data for pavement management. Each signal must be inspected every year, but there are no condition ratings for signals. Various *ad hoc* inspections occurred in different parts of the state during the year, usually in response to internal and external questions. For example, a District Engineer may request a round of night-time inspections to determine the reflectivity of pavement markers within the District. The Office of Maintenance (OOM) also conducted a Maintenance Quality Peer Review Process. This procedure was adopted from

Florida Department of Transportation, and involved assessing the level of service for different maintenance features and services for a random sample of roadway sections.

In summary, the integrity and quality of inventory, condition, and LOS data is uneven. This has a significant impact on the business process for identifying and assembling inventory, condition, and LOS that can be used for planning and budgeting. Because much of the inventory data is incomplete or unreliable, its use for budgeting is questionable, although there is often no alternative to using existing data. Further, where adequate or excellent condition data is available, it is not used as input to the planning and budgeting process.

Figure 2 shows the current business process for the identification and assembly of feature inventory, condition, and LOS data for potential use in the budgeting process. The steps shown in the business process are as follows:

1. OOM assesses whether it has a certain type of roadway feature inventory data;
2. If yes, OOM assesses whether the feature inventory data is adequately complete and accurate enough;
3. If yes, OOM may use the feature inventory data for planning and budgeting;
4. If OOM does not have the feature inventory data or if OOM has the data but it is not sufficiently complete and accurate, other organizational units assess whether they have the particular type of feature inventory data;
5. If other organizational units do not have the type of feature inventory data, then the feature inventory data is not used for planning and budgeting;
6. If other organizational units have the feature inventory data, then they assess if it is complete and accurate enough;
7. If yes, the other organizational units may use the feature inventory data as input into their planning and budgeting activities and/or send the data to OOM for its potential use in planning and budgeting. Otherwise the feature inventory is not used for planning and budgeting;
8. If OOM has the inventory data or receives it from other organizational units, then OOM assesses whether there is corresponding condition/LOS data;
9. If yes, OOM assesses whether the condition/LOS data is complete and accurate enough;

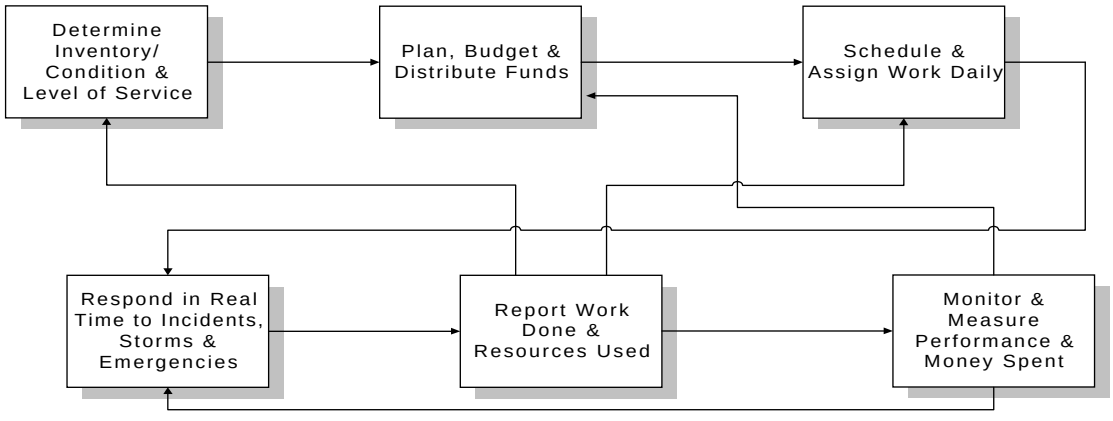


FIGURE 1 High-level process.

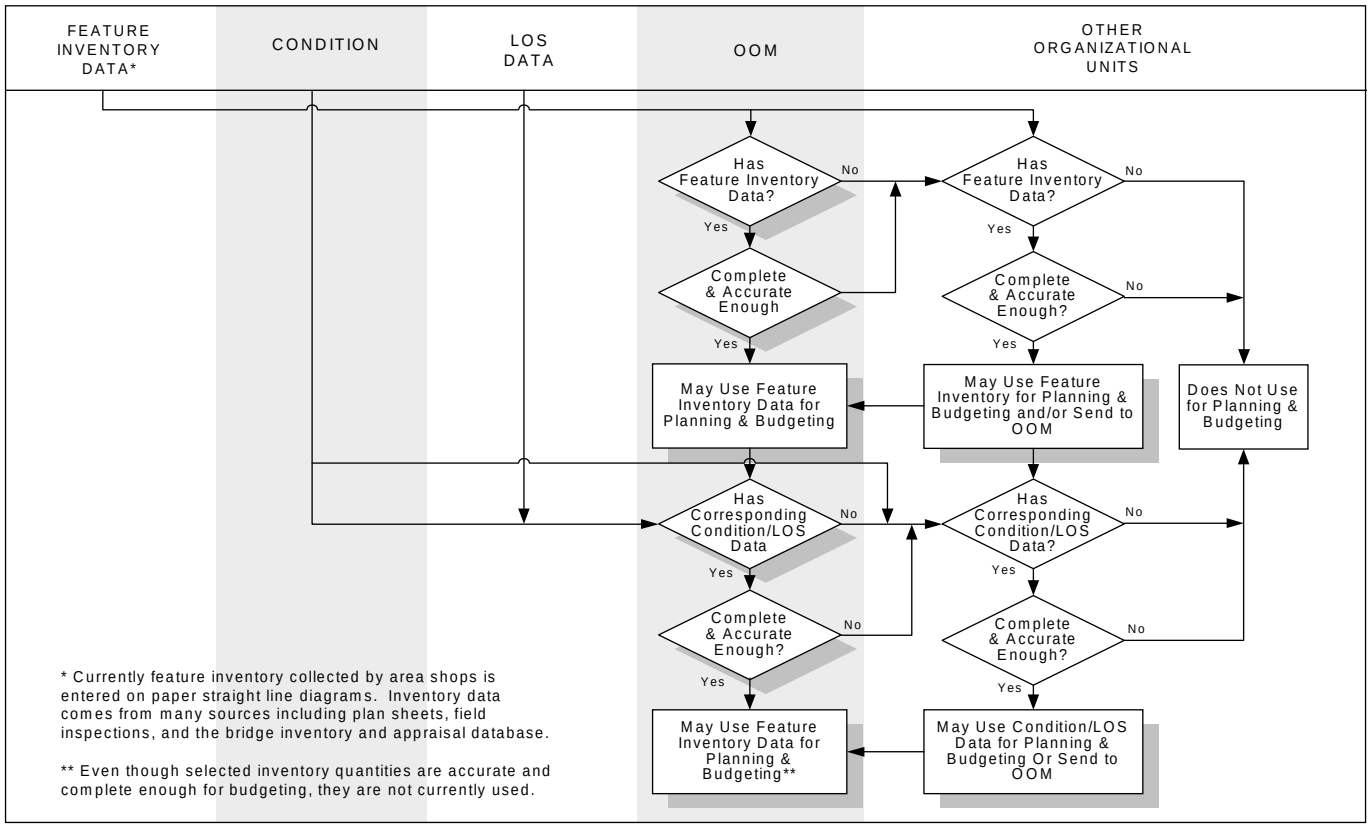


FIGURE 2 Inventory, condition, and level-of-service flow chart.

10. If yes, OOM may use the corresponding condition/LOS data for planning and budgeting;

11. If OOM does not have the corresponding condition data or if OOM has the condition/LOS data but it is not complete and accurate enough, other organizational units assess whether they have the corresponding condition/LOS data;

12. If yes, then other organizational units assess whether the condition/LOS data is complete and accurate enough;

13. If yes, the other organizational units may use the condition/LOS data as input into their own planning and budgeting activities and/or send the data to OOM for its potential use in planning and budgeting. Otherwise the condition/LOS data is not used for planning and budgeting.

Note that while certain types of information may be available, the approach the SHA takes for budgeting in a particular year or for a particular type of maintenance asset or service does not use inventory, condition, or LOS data.

A component of the core business process regarding identification and assembly of feature inventory, condition, and LOS data is an annual quality assessment process, known as the Maintenance Quality Peer Review Process. The objective of this process is to identify maintenance levels-of-service for a random sample of roadway sections in order to monitor over time the quality of highways affected by maintenance work and to generate information for potential use in resource allocation (i.e., budgeting). LOS is determined for different attributes

of a road section. These attributes pertain to specific roadway features such as signs, guardrail, pavement, shoulder, striping, and roadside vegetation.

Budgeting, Distribution of Funds, and Work Planning

The objective of this business process is the projection of future work needs and allocation of limited resources to various organizational units and maintenance activities. In the past, SHA used a traditional budgeting process based on performance standards, quantity standards, quality standards, and inventory quantities. SHA's former maintenance management system was capable of supporting the development of a budget recommendation and could be used to help make modifications if required, based upon executive and legislative input. When that system was operational, and after the budget was approved, the SHA developed an annual work plan for each activity based on quantity standards, quality standards (LOS), and inventory quantities. The annual work plan was converted to a monthly plan and the workload balanced over the year. Spending by expenditure objects—labor, equipment, and material—were derived from the overall budget and allocated to specific activities in accordance with the work plan. Team Activity Cards consistent with the annual work plan were distributed to areas and shops throughout the state as the basis for managing the year's work.

In practice, the maintenance budget has generally been based upon some percentage change in the maintenance budget from the previous budget period. Recently the SHA has explored a zero-based budgeting process that builds a budget from quantity standards, quality standards, and inventory quantities. SHA staff with responsibilities for different activities or programs have sought to gather this type of information relating to their areas of responsibility, although budgets may be based upon historical trends. Budget inputs are reviewed by higher level managers within the maintenance organization and then modified appropriately to develop an overall maintenance budget request.

Budgeting Process

The objective of the budgeting process is the development of recommendations for the level of funding required for highway maintenance for approval by the legislature and governor. It has the following steps:

1. Department of Budget Management prepares instructions;
2. Office of Finance/Secretary of the DOT forwards/adds instructions and enhancement requests;
3. The SHA Office of Finance and Program Management/Chief Engineer/Administrator forwards or adds instructions and enhancement requests;
4. OOM receives instructions;
5. OOM identifies line item dollars for previous fiscal year budget;
6. OOM prepares guidelines for budget preparation (e.g., percent change from previous year, zero-based budgeting);
    - When other organizational units besides OOM have responsibility for preparing initial budget request input, they receive and discuss budget preparation guidelines;

7. For maintenance activities where OOM has responsibility for preparing the initial budget request, OOM makes percent adjustment to previous year budget level or applies quantity standards, quality standards, and inventory quantities to determine budget level;
   - For maintenance activities where other organizational units have responsibility for preparing the initial budget, they make a percent adjustment to the previous year budget level or use quantity standards, quality standards, and inventory quantities to establish the recommended budget level;
8. OOM takes budget input from all sources and prepares the budget request by expenditure object;
9. SHA Finance and Program Office/Chief Engineer/Administrator approves and incorporates the maintenance budget request into SHA budget; otherwise OOM must revise the budget request and send it through the approval process again;
10. The Office of Finance and the Secretary of Department of Transportation approves and incorporates the maintenance budget request into the Maryland DOT budget; if the maintenance portion of the budget is not approved, OOM must revise the maintenance budget request and send it through the approval process again;
11. The Department of Budget Management approves the budget; if the maintenance portion of the budget is not approved, OOM must revise the maintenance budget request and send it through the approval process again;
12. The Governor's Office approves the budget; if the maintenance portion of the budget is not approved, OOM must revise the maintenance budget request and send it through the approval process again;
13. The Legislature enacts budget legislation; if the maintenance portion of the budget is not acceptable to the legislature, OOM must revise the maintenance budget request and send it through the approval process again;
14. The Governor's Office determines whether it desires amendments including those the OOM identifies;
15. OOM provides changes to the maintenance budget if the Governor Office staff desires amendments;
16. The Legislature either enacts or does not enact legislation to approve the budget amendments; and
17. The Governor signs the enacted budget legislation or amended budget legislation.

Work Planning

The objective of work planning is to convert a portion of the budget allocation into a work plan broken down by activity, identify workload imbalances and problems, and revise the work plan as required. The process applies to both annual and seasonal work loads. The steps are as follows:

1. OOM converts its own part of the budget to work plan by objectives;
   - Office of Traffic and Safety (OOTS), Office of Bridge Development (OBD), Office of Materials and Technology (OMT), Office of Environmental Design (OED), and the Statewide Operations Center (SOC) convert their allocations to work plans by objectives;

- Districts, areas, and shops convert their allocations to work plans by objectives and then by activities;

2. OOM identifies workload imbalances and problems;
   - OOTS, OBD, OMT, OED, and SOC identify workload imbalances and problems;
   - Districts, areas and shops identify workload imbalances and problems;
3. The Statewide Maintenance Quality Council works out problems monthly, taking into account expenditure tracking information from finance, OOM, OOTS, OBD, OMT, OED, SOC, Districts, areas, and shops;
4. OOM facilitates adjustments and provides support to the Statewide Maintenance Quality Council (Step 3);
   - OOM revises work plan as required;
   - OOTS, OBD, OMT, OED, SOC revises work plan as required;
   - Districts, areas, and shops revise work plan as required;
5. OOM tracks expenditures;
   - OOTS, OBD, OMT, OED, and SOC track expenditures; and
   - Districts, areas, shops track expenditures.

Scheduling, Resource Availability and Acquisition, and Daily Assignment

The objective of this business process is short-term work planning in order to identify the activities that will be performed, the location of the work, traffic control needs, and the resources required, as well as to assemble the necessary equipment, materials, and tools in a timely fashion.

A small percentage of maintenance supervisors schedule activities two weeks in advance. Most managers find it difficult to schedule work far in advance because of the need to respond to changes that arise daily. In most shops a significant portion of the scheduled work is deferred when resources are re-directed to respond to needs with higher priorities. The need to respond to emergency and customer service requests frequently determines upcoming work, and the various shops and operations have developed manual procedures to log customer service requests, and to schedule them for immediate attention.

The older maintenance management system accommodated a bi-weekly scheduling process. The Team Leader Handbook also includes a template for a bi-weekly schedule, for optional use by maintenance supervisors. The steps of the existing bi-weekly scheduling process are as follows:

1. Resident Maintenance Engineer (RME), Assistant Resident Maintenance Engineer (ARME), Highway Tech Manager (HTM), or Team Leader (TL) fills out a bi-weekly schedule if it is considered useful;
2. Customers may make requests;
3. If there is a customer request, a secretary fills out a customer request form;
   - The secretary logs the request;
   - The RME, ARME, HTM, or TL investigates the customer request;
   - The RME, ARME, HTM, or TL determines if the work is SHA's and the unit's responsibility;
   - If no, then the RME, ARME, HTM, or TL replies to the customer or redirects the customer to a different office;

- If the work applies to a different area, the District office receives a copy of customer request;
- District office responds to the customer request;

4. If there are no customer requests, or if there is a customer request and the work is SHA's and the unit's responsibility, the RME, ARME, HTM, or TL reviews/revises the work schedule;
5. The RME, ARME, HTM, or TL determines equipment needs;
6. If equipment is available, then the business process continues as shown in Figure 2; otherwise the ARME, RME, HTM, TL, or Shop Chief assesses if another piece of equipment will suffice; if yes, then the business process continues;
7. If the equipment is not available, the ARME, RME, HTM, TL, or shop chief assesses if the piece of equipment can be borrowed from another shop; if yes, then ARME, RME, HTM, TL, or shop chief gets the piece of equipment from another shop and the business process continues; and
8. If the equipment cannot be borrowed, the ARME, RME, HTM, TL, or shop chief assesses whether the piece of equipment can be rented from a local vendor; if yes ARME, RME, HTM, TL or shop chief will rent the equipment with a credit card purchase, and the business process continues; if the equipment cannot be rented from a local vendor, the RME, ARME, HTM, or TL reviews/revises the work schedule and the business process returns to Step 5 and continues there.

Complete Daily Work Report

The steps of this process are as follows:

1. Team sets up work zone traffic control;
2. Team begins work;
3. Team completes work;
4. Was work zone traffic control used? If yes, Team removes work zone traffic control; otherwise the team returns to shop;
5. Facilities maintenance technician returns tools and cleans up equipment;
6. Facilities maintenance technician turns in odometer readings and additional information to TL;
7. TL completes Team Activity Card;
8. RME, ARME, or HTM reviews Team Activity Card;
9. If Team Activity Card is not correct, HTM, ARME, or HTM returns Team Activity Card to TL with an explanation of errors; TL corrects/completes the Team Activity Card and Steps 8 through 9 are repeated until the Team Activity Card is correct;
10. If Team Activity card is correct, the TL completes the Overhead Activity Card, which had previously been pre-filled by the secretary or TL; and
11. RME, ARME, or TL turns in all Team Activity Cards to office secretary.

Track Costs and Expenditures

Up-to-date information on costs and expenditures had been entered into ledgers by hand by the clerks in maintenance shops. Each shop maintained these ledgers because there is a significant

lag between incurring costs and performing maintenance activities and receipt of expenditure information from the computerized Financial Management Information System (FMIS). Subsequently a simple computer system was implemented mainly for cost and expenditure tracking. That computer system is no longer in use, partly because of lack of technical support. Today shops use another COTS system to keep track of expenditures, which has not worked well for this purpose; therefore, shops keep track of costs and expenditures on electronic spreadsheets, which they can use to compare with FMIS expenditure reports.

Task II: Fit Analysis

The purpose of this fit analysis was to evaluate whether the current COTS application had the desired general functionality identified in Task I, and if that application would be able to accommodate the general functional requirements of an IHMMS. A critical component of the overall analysis involves the validation of the selection of the current application as the appropriate COTS software, and the selection of any necessary COTS applications and customization to supplement the functionality provided by the current application. This evaluation is driven by both the immediate and long-term needs of SHA, and is intended to be flexible enough to accommodate new requirements as they were identified.

The main objective of this specific task was to determine which highway maintenance management functional requirements were not being met by the currently used application, and to identify any "gap" between what functionality and information the current application provided and what additional functionality and other capabilities were needed and/or desired.

Evaluation Methodology

The evaluation methodology involved using the results of the requirements analysis conducted during Task I, and applying the desired system requirements for an IHMMS as the basis for the evaluation. The core team looked into the desired functionality of the IHMMS and grouped them in two categories: *Basic* and *Advanced.* A Basic function was the one which ought to be in a Basic MMS whereas an Advanced function was interpreted as "desirable," which the SHA would like to have in an ultimate IHMMS.

The functional capabilities of the currently used COTS application were rated to satisfy each type of functionality listed in the Matrix according to the following scale:

1. Does not satisfy any of the functionality required;
2. Satisfies a small amount of the functionality required;
3. Partially satisfies the functionality required or could satisfy all or most of it if complemented with other third party products;
4. Satisfies most of the functionality required or could satisfy all of it if complemented with other third party products; and
5. Satisfies all the required functionality.

Table 2 shows the rating of the current COTS application.

Task III: Market Analysis

In this task a survey of maintenance management systems owned by State Departments of Transportation (DOTs) was conducted. The information obtained from the survey was analyzed against a market analysis to identify the top vendors who would possess most of the desired and advanced IHMMS functionalities listed in Table 2. Six such vendors (we will call them A-F) were identified. The vendors were asked to rate themselves against 78 categories (74 originally identified as shown in Table 1; additional 4 categories were added later).

TABLE 2 Rating and Weight of the Current COTS System

General Functionality	*Basic vs. Advanced*	Rating	Weight
Reference Systems & GIS			
1. Linear Reference Systems	*B*	3	H
2. Coordinate Reference Systems	*A*	2	H
3. Correlation of Linear and Coordinate Reference Systems	*A*	2	H
4. Highway Centerline	*B*	2	H
5. Geographic Information System	*A*	3	H
Inventory, Condition and Levels-Of-Service Assessment			
6. Condition/Levels-of-service Goals	*A*	3	H
7. Inspection Module	*A*	3	H
8. Feature Inventory	*A*	2	H
9. Inventory to Activity Conversion	*A*	2	H/M
10. Condition and Deterioration Rates	*A*	2	M
11. Levels-of-service (Random sample)	*A*	2	M
Work Planning, Budgeting, and Distribution Of Funds			
12. Quantity Standards	*B*	4	H
13. Service Level Adjustment	*A*	3	H/M
14. Work Planning and Balancing	*B*	3	H
15. Basic Budgeting and Needs Assessment	*B*	2	H
16. Managing for Results	*B*	5	H
17. Relationship to Capital Program	*A*	1	H
18. Levels-of-service (Choices and costs)	*A*	1	H
19. Advanced Budgeting and Needs Assessment (Optimal Resource Allocation)	*A*	1	H

NOTE: Weight: H = high; M = medium; L = low; N = not needed. Basic vs. advanced features: B = basic; A = advanced. Rating: 1 - Does not satisfy any of the functionality required; 2 - Satisfies a small amount of the functionality required; 3 - Partially satisfies the functionality required or could satisfy all or most of it if complemented with other third party products; 4 - Satisfies most of the functionality required or could satisfy all of it if complemented with other third party products; and 5 - Satisfies all the required functionality.

TABLE 2 *(continued)* **Rating and Weight of the Current COTS System**

General Functionality	*Basic vs. Advanced*	Rating	Weight
20. Benefit Cost Analysis	*A*	2	M
21. Distribution of Funds	*A*	2	H
22. Risk Management	*A*	1	M
Contracting Out			
23. Contracting Comparisons	*B*	3	H
Scheduling and Daily Work Assignment			
24. Periodic Maintenance	*B*	3	H
25. Preventive Maintenance	*B*	3	H
26. Corrective Maintenance	*B*	3	H
27. Advanced Preventive and Corrective Maintenance	*A*	2	H
28. Project Management	*B*	4	H
29. Customer Request Module	*B*	5	H
30. Work Order System	*B*	5	H
31. Scheduling and Daily Assignment	*B*	3/4	H
32. Resource Needs and Availability	*B*	3	H
33. Daily Assignment	*B*	3	H
34. Optimal routing	*A*	3	M
Field and Office Daily Work Reporting			
35. Daily Work Reporting	*B*	5	H
36. Electronic Field Data Collection	*A*	3	H
37. Office data entry as back-up until automated data entry is available	*B*	4/3	H
38. Web access for daily work reporting	*A*	1	M
Quality Assurance/Quality Control			
39. Error checking	*B*	4	H
40. Other QA/QC	*A*	3	H
Costs and Expenditures			
41. Indirect Costs (Activity Based Costing)	*A*	1	H
42. Unit and Daily Costs	*B*	3	H
43. Repair Cost Recovery	*B*	5	H
44. Tracking of Money Spent	*B*	4	H

NOTE: Weight: H = high; M = medium; L = low; N = not needed. Basic vs. advanced features: B = basic; A = advanced. Rating: 1 - Does not satisfy any of the functionality required; 2 - Satisfies a small amount of the functionality required; 3 - Partially satisfies the functionality required or could satisfy all or most of it if complemented with other third party products; 4 - Satisfies most of the functionality required or could satisfy all of it if complemented with other third party products; and 5 - Satisfies all the required functionality.

TABLE 2 *(continued)* **Rating and Weight of the Current COTS System**

General Functionality	*Basic vs. Advanced*	Rating	Weight
Reports			
45. Variances and Incomplete Work	*A*	4	H
46. Status, Details and Summaries	*B*	5	H
47. Regular, Tailored & Ad Hoc Reports	*B*	3	H
48. History	*B*	4	H
49. Winter Storm Reports	*A*	1-2	H
50. Presentations	*A*	4	M
Environment and Occupational Health			
51. Environmental and Occupational Health and Safety Compliance	*B*	2	H
Benchmarking and Best Practices			
52. Performance Measurement and Productivity	*B*	1-2	H
53. Best Practices and Benchmarking	*B*	2	H/M
Document Management			
54. Document and Site Map Retrieval	*A*	3	M
Data Interchange, Sharing and Interfaces			
55. Data Interchange	*A*	1	H
56. Data Sharing	*A*	1	H
57. Data Repository	*B*	4	H
58. Remote access to basic MMS functionality	*A*	2	H
59. Remote access to data	*A*	2	H/M
60. Web access to advanced MMS functionality and results from interfaced system	*A*	1	M
61. Security	*B*	4	H
62. Pavement Management System Interface	*A*	1	H
63. Bridge Management System Interface	*A*	1	H
64. Equipment Management System Interface	*B*	5	H
65. Materials Management System Interface	*B*	1	H

NOTE: Weight: H = high; M = medium; L = low; N = not needed. Basic vs. advanced features: B = basic; A = advanced. Rating: 1 - Does not satisfy any of the functionality required; 2 - Satisfies a small amount of the functionality required; 3 - Partially satisfies the functionality required or could satisfy all or most of it if complemented with other third party products; 4 - Satisfies most of the functionality required or could satisfy all of it if complemented with other third party products; and 5 - Satisfies all the required functionality.

TABLE 2 *(continued)* **Rating and Weight of the Current COTS System**

General Functionality	*Basic vs. Advanced*	Rating	Weight
66. Financial Management System Interface	*B*	2	H
67. Payroll System Interface	*B*	2	H
68. Master File, HPMS and GIS Interface	*A*	3	H
69. Accident Record System Interface	*A*	1	H
70. Construction Management System	*A*	1	H
71. Historic Traffic Information	*A*	1	H
Real Time Operations			
72. Real Time Traffic and Storm Information	*A*	1	H
73. Automated Vehicle Location	*A*	1	M
Other Management Systems			
74. Traffic Device Management System	*A*	1-2	H
75. ITS Maintenance Management	*A*	1-2	H
76. Landscaping Management System	*A*	1	H
77. Facilities Management	*A*	5	H
Computer Based Training			
78. Computer Based Training	*B*	1-2	H/M

NOTE: Weight: H = high; M = medium; L = low; N = not needed. Basic vs. advanced features: B = basic; A = advanced. Rating: 1 - Does not satisfy any of the functionality required; 2 - Satisfies a small amount of the functionality required; 3 - Partially satisfies the functionality required or could satisfy all or most of it if complemented with other third party products; 4 - Satisfies most of the functionality required or could satisfy all of it if complemented with other third party products; and 5 - Satisfies all the required functionality.

Maintenance Management Systems at State DOTs

A look at state DOTs around the country confirms that most agencies still use the older style maintenance management system. There are several that have been, or are currently being developed in-house, and a few of them are using Client-Server and/or COTS maintenance management systems. This is because the transition to a new generation of maintenance management systems is only just beginning. In a few cases, systems have been implemented that expand upon traditional maintenance management concepts, for example accounting for asset condition in the budgeting process (Georgia) or assessing Levels of Service being achieved (Florida).

Vendor Demonstrations

The six vendors were invited to demonstrate their product's capability against the 78 categories. A cross-functional team of SHA employees, including managers and grass-root level field workers, was developed to observe the vendor demonstration and rate the product's capability to

possess the 78 functional requirements. The rating scale was 1-5; 5 meaning the product fully supported the functionality. The demo ratings were averaged and compared against the self-ratings of the vendors. The demo and self ratings for all 78 categories for the vendors were added up and compared (Figure 3). The results showed that vendor C's and D's demo ratings fell below their self-ratings. The demo ratings of other vendors equaled or exceeded their self-ratings and Vendor F's demo rating far exceeded others.

Cost vs. Functional Capability

An estimate of implementation cost of the vendor products was obtained from the vendors and compared against their demo ratings. It was found that Vendor A had the highest demo-rating/cost ratio followed by Vendor F. The experience of the vendors with other State DOTs was also carefully considered in the rating and their reputation independently verified from the DOTs.

Conclusions and Future Work

Highway Maintenance has become increasingly complex over the years. This study presented the experience of Maryland SHA in designing and developing an IHMMS. A detailed requirement and product analyses were conducted. The results were very interesting and the analyses procedure could be of great benefit to other DOTs. While the requirements may slightly vary for other states they can be easily modified and used in the analysis presented here. Due to funding constraints the Maryland SHA has not been able to start the development of an

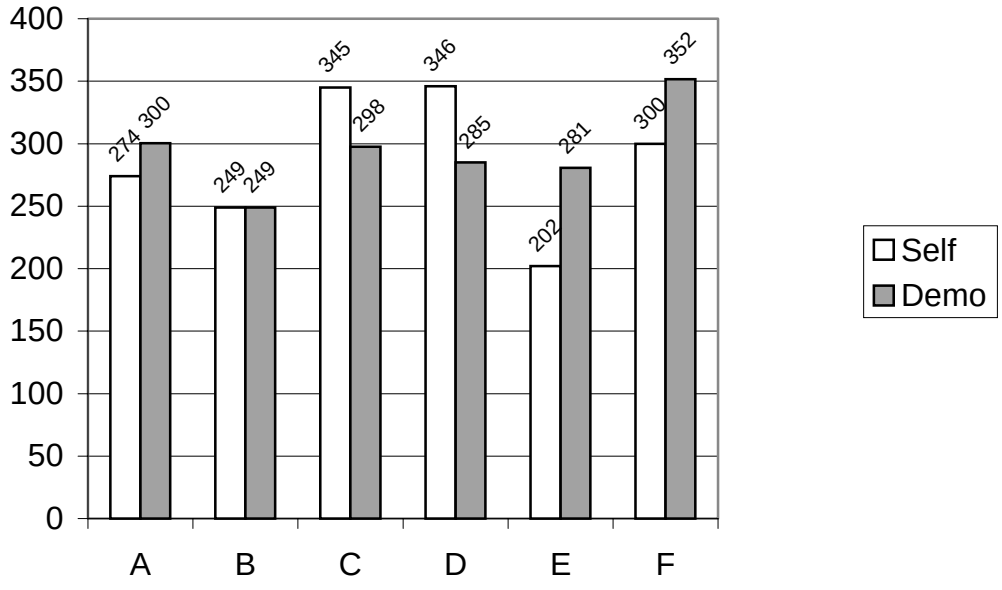


FIGURE 3 Demo vs. self ratings of the vendors.

IHMMS. However, in the interim, the current COTS software has been customized to some degree to collect and analyze feature inventory and other data that will allow limited functionality of the desired IHMMS. A research study with Morgan State University is underway to develop a mathematical model for asset depreciation that can be integrated to the IHMMS when funding becomes available for IHMMS development. A National Cooperative Highway Research Program problem statement has also been submitted for a related research problem, findings of which can be valuable inputs to the IHMMS development. Some state pool funds may be sought for the development of the IHMMS in future.

ACKNOWLEDGMENTS

The writers wish to thank SHA's Deputy Administrator, Doug Rose, Director of the Office of Maintenance, Russell Yurek, and the Chief of the Highway Maintenance Division, John Scally for their continued support for performing the requirement analysis to design and develop an integrated highway maintenance management system.

REFERENCES

1. Teets, M.K. *Highway Statistics 1996*. U. S. Department of Transportation, Federal Highway Administration, Office of Highway Information Management, 1997.
2. Novak, E.C. Jr., W.-H. Kuo and G. Y. Baladi. "Evaluation of Alternative Network Preservation Strategies," In *Transportation Research Record 1395*, TRB, National Research Council, Washington, D.C., 1993, pp. 88-98.
3. Bentley Systems, Inc. Architecture Automation Practices Survey. 1997 www.bentley.com. Accessed February 21, 2002.
4. ASCE. ASCE's 2001 Report Card for America's Infrastructure. *Civil Engineering,* Vol. 71, No. 4, 2000, p. 30.
5. *The Maintenance and Management of Roadways and Bridge.* AASHTO, Washington, D.C., 1999.
6. Markow, M.J., F.D. Harrison, P.D. Thompson, E.A. Harper, W.A. Hyman, R.M. Alfelor, W.G. Mortenson, and T.M. Alexander. *NCHRP Report 363: Role of Highway Maintenance in Integrated Management Systems*. TRB, National Research Council, Washington, D.C., 1994.
7. Irrgang, F.C., and T.H. Maze. Status of Pavement Management Systems and Data Analysis Models at State Highway Agencies. In *Transportation Research Record 1397,* TRB, Washington, D.C., 1993, pp.1-6.

APPENDIX

Survey of Current Maintenance Management Systems

Alabama	Basic system on a mainframe
Alaska	No maintenance management system (MMS) in use
Arizona	Basic system on a mainframe
Arkansas	Basic system on a mainframe
California	Advanced system
Colorado	Client-Server system
Connecticut	In-house client-server system
Delaware	Basic system on a mainframe
Florida	Mainframe with limited PC; a functional reporting system with excellent LOS metrics
Georgia	Advanced system
Idaho	In-house mainframe system
Illinois	10-year-old mainframe system
Indiana	Client-Server system
Iowa	No MMS in use
Kansas	In-house mainframe system, but does not use it for budgeting or scheduling
Kentucky	No MMS in use
Louisiana	Basic system on a mainframe
Maine	Advanced MMS
Maryland	PC-based intermediate level system
Massachusetts	In-house mainframe system
Michigan	No MMS in use
Minnesota	Client-Server based Basic system.
Mississippi	In-house client-server system
Missouri	No MMS in use
Montana	Oracle-based system
Nebraska	25-year-old mainframe system
Nevada	An in-house system currently being developed
New Hampshire	No MMS in use
New Jersey	No MMS in use
New York	Old PC-based system with plans to upgrade
New Mexico	Advanced MMS
North Carolina	No MMS in use; plans to acquire one
North Dakota	No MMS in use
Ohio	Old mainframe based system with plans to upgrade

Oklahoma	20-year-old mainframe system
Oregon	No MMS in use
Pennsylvania	No MMS in use
Rhode Island	No MMS in use
South Carolina	No MMS in use
South Dakota	Old style system on a mainframe
Texas	Old modified mainframe system
Utah	Old style system with plans to upgrade
Vermont	Advanced system
Virginia	No MMS in use; plans to acquire one
Washington	No MMS in use, but has a Maintenance Accountability Process system focused on LOS
West Virginia	Older mainframe system used to track work hours
Wisconsin	No MMS in use, but they have a pavement management system
Wyoming	Old style mainframe system

PART 5

Pavement

Developing an Asphalt Solvent Testing and Approval Program in North Carolina

A. BATTLE WHITLEY, IV
North Carolina Department of Transportation

One of the primary goals of the North Carolina Department of Transportation (NCDOT) is to protect the state's natural resources and promote environmental stewardship. As such, in 1991, NCDOT directed its field forces to use biodegradable asphalt solvents. Numerous companies have developed a variety of solvent products using citrus, pine, and/or soy extracts purported to remove asphalt from tools and equipment used in patching and paving operations. While products are marketed as environmentally friendly, safe, and effective, environmental or safety issues may still exist. Initially the Department's approval process consisted of a review of the product's Material Safety Data Sheet (MSDS) and field trials. The various formats used for MSDS, the allowable practice of listing ingredients as "proprietary" or "trade secret," and the subjective nature of the field trials made this approval process difficult to administer. Unfortunately, there is no standard test regimen that satisfies the safety and environmental concerns, as well as the efficacy claims made by vendors. Considering the potential safety and environmental impacts of purchasing, storing, and using such products, the NCDOT has developed a laboratory-testing program for asphalt solvent products. Implementing this testing program not only ensures that the Department is proactively addressing environmental and personal safety issues, it will also ensure that a cost-effective product is purchased. The development of such a program could potentially benefit other state and local highway agencies in a comparable manner.

Historically, diesel fuel has been the asphalt-cleaning agent of choice. Diesel fuel was considered very effective, inexpensive, and readily available. As society has become more environmentally conscious, it has become unacceptable to use diesel fuel as an asphalt cleaning solvent. The introduction of biodegradable solvent products made from citrus and pine terpenes in the 1980s provided a much-needed alternative to the use of diesel fuel for removing asphalt from tools and equipment. Given that a primary goal of the North Carolina Department of Transportation (NCDOT) is environmental stewardship, the Division of Highways made the use of biodegradable solvents in paving and patching operations mandatory in 1991 (*1*). Each year, NCDOT uses about 60,000 gallons (227,100 liters) of asphalt solvent per year to clean hand tools, asphalt distributors, paving machines, dump trucks, and other equipment.

Although only a few products of this type were available initially, it became necessary to develop a material specification for asphalt removers as more and more companies began providing biodegradable solvents. The original specification attempted to address environmental, safety, and performance concerns; however, there still was no definitive way to determine if a product actually met the requirements set forth in the specification. For several years, the only verification of a product's validity was a review of technical data provided by the vendor, and a field test of a product sample by maintenance personnel during routine patching operations. Over time, this simplistic method of approving solvents showed many problems ranging from Material Safety Data Sheet (MSDS) interpretation and reliability to questions of how well a product actually works. Given the overwhelming amount of product competition and

the budgetary constraints of government agencies, a comprehensive testing and evaluation procedure is needed to ensure that we are purchasing and using a safe, effective, cost-efficient product.

PROBLEMS

The NCDOT specification for asphalt solvents has four primary components: (1) the product shall be biodegradable; (2) the product shall not contain any chlorinated solvents, caustics, or acids; (3) it shall have a closed-cup flash point greater than 140° F (60° C); and (4) it shall have a solvent effect on asphalt. From the start, the approval process for a biodegradable solvent required the vendor to provide an MSDS to the NCDOT, State Road Maintenance Unit for review. Many times other marketing and/or technical data would accompany the MSDS. This information would be reviewed for compliance with the material specification, and, if acceptable, a sample of the product would be provided for a road crew to use and evaluate. If the crew used the product to successfully clean bituminous residue from tools and equipment, then the product was approved for use.

As with any material purchased and used in construction or maintenance activities, an approval process is necessary to screen out substandard products. Most vendors and companies are reliable and produce quality products, but it is the responsibility of agencies to evaluate a product before accepting it for use. For example, one product marketed to NCDOT as environmentally safe was found to contain a reportable toxic substance listed in the "Special Precautions" section of the MSDS. Approving this product based only on the marketing information could have created many future problems. Even though this approval process is logical and has worked to eliminate many undesirable materials, the process is subjective and has numerous weaknesses.

The primary weakness of this approval process lies in the review of the MSDS. Material Safety Data Sheets come in many formats and are prepared by the product manufacturer. It is a widely accepted and allowable practice to list a material's ingredients as "trade secret" or "proprietary," which makes it virtually impossible to determine from the MSDS if non-desirable constituents exist. In addition, there is no single required standard for determining and reporting the flash point of a material. This leads to inconsistencies when trying to evaluate and compare the flash points of products. In addition to the varying information and formats found in MSDS, the fact that the MSDS is prepared and maintained by the material producer/vendor provides the potential opportunity for misrepresentations, which could have serious consequences.

The weaknesses of the original approval process extend beyond the MSDS. The material specification for asphalt solvents states "final acceptance shall be performance based." The evaluation of performance was very rudimentary and had no established control for comparison. Product samples were given to a maintenance patch crew to use during routine pavement maintenance operations. While this gave the product a "real world" test, the evaluation was subjective and depended upon how the product was used and the experience of the personnel using it.

Main Issues

In addition to the problems encountered with the original approval process, the issues driving the requirements in the material specification are environmental, personal safety, and performance

considerations. Industry understands the significance of these issues, realizing that agencies are pushing for natural, biodegradable, safe products to use for removing asphalt residue. (*2*)

Environmental

Aggressive chlorinated solvents were used in the past by laboratory technicians at asphalt plants in the evaluation of pavement mixes. Regulations for the storage, use, and disposal of chemicals are stricter today due to society's better understanding of environmental impacts. Past use and disposal methods have led to the contamination of former asphalt plant sites, which are currently being cleaned and monitored at great expense to the Department. When cleaning tools and equipment during maintenance operations, small amounts of asphalt solvents will unavoidably be spilled on the ground. Understanding this situation led to the reduction and elimination of the use of diesel fuel and chlorinated solvents for this purpose. The development of solvents using citrus, pine, and/or soy extracts and by-products made it possible to substitute biodegradable materials for the chlorinated and petroleum solvents.

While the initial reaction is that these biodegradable solvents will not adversely impact the environment, this has proven to be an invalid assumption. The market competition has led manufacturers to create various formulations using a variety of additives to enhance or reduce certain properties of their solvent products. While the primary ingredient in many of these solvents is a biodegradable extract, in pure form these extracts may actually be classified as a hazardous material due to a low flash point characteristic. Therefore, other components must be added to increase the flash point to an acceptable level. By the same token, the biodegradable components have different solvent abilities. In an effort to get a product to dissolve asphalt faster or more completely manufacturers and vendors may add other chemicals to the formulation. It is these additives that cause concern and dictate the need for careful evaluation of these products. This concern was validated through initial screenings of a few "environmentally friendly" marketed products used by NCDOT. Some of these products were found to have traces of toluene, benzene, and trichloroethene, which is contrary to the specification requirement that the product shall not contain chlorinated solvents, caustics, or acids.

Personal Safety, Storage, and Handling

The primary personal safety issue with the use of these materials is flash point. The U.S. Department of Transportation (USDOT) Hazardous Materials regulations define flammable liquids as having a flash point of not more than 141º F (60.5º C) (*3*). Another closely related definition is found in the Environmental Protection Agency (EPA) Hazardous Waste regulations (*4*). These regulations define an ignitable liquid as having a flash point less than 140º F (60º C). Both sets of regulations require the flash point to be determined by a closed-cup ASTM Standard. Asphalt solvents are routinely used around hot equipment such as asphalt distributors, kettles, and various patching and paving machines. Using a flammable product in such situations should be avoided.

Another personal safety issue comes directly from how the product is used in daily operations. Patch crews use asphalt solvents daily under high exposure conditions. Splash, spray, and spill exposures are a daily occurrence and as such must be accounted for in defining the material criteria. Therefore, it is a requirement in the asphalt solvent specification that the product be non-toxic and the pH of the material be essentially neutral.

Not only is flash point a significant consideration in regard to personal safety, it also is an issue for storage, handling, and transporting. Safety requirements dictate that flammables must be stored in cabinets or separate buildings designated for such materials. Most maintenance yards do not have the flammable storage capacity or the capital funds to address the separate storage needs for the quantities they typically keep on hand. In addition to storage of the material, transporting flammables requires the vehicle and containers, in specific quantities, to display an appropriate hazardous materials placard. This would necessitate employees being well versed in the USDOT regulations governing the transport of these materials, as well as require them to have additional commercial drivers license endorsements, which would create the need for additional training and re-certification programs.

Performance

The performance of a product is a key consideration when it comes to acceptance by field personnel. If a product is environmentally benign, yet does not quickly and effectively remove asphalt residue, field personnel will be reluctant to use it. Also, the time it takes a solvent product to remove asphalt directly affects the time spent cleaning equipment, which can impact the productivity of the paving or patching crew.

Determining how cost-effective a product is also requires a measure of performance. When deciding between two or more products that are environmentally and operationally safe, and equally effective at removing asphalt, price becomes an important factor. In the situation where one solvent product may perform slightly better than another, is the difference in performance significant enough to justify the difference in purchase price? The only way to answer this question is to evaluate and compare the performance of each product.

DEVELOPING THE PROGRAM

After experiencing problems with the previous approval process, and considering the potential impacts of purchasing large quantities of materials that may not meet the specification criteria, the decision was made to create a reliable, definitive testing program. Based on the three primary issues of environmental compliance, safety, and performance, a battery of tests was selected which addresses each aspect. The approval process consists of the following three tests: (1) a flash point test, (2) an environmental screening, and (3) a test that evaluates the performance of the solvent.

Flash Point Test

Both the EPA and USDOT regulations establishing the definition of flammable liquids require the flash point to be determined by using a closed cup method. Determining the flash point according to these regulations will address several problems, and will be the first test administered. The method mentioned first in both codes is ASTM D-93 (Pensky-Martens Closed Cup). Since laboratories currently contracted with NCDOT for testing other materials perform the ASTM D-93 method, this method was chosen for the flash point evaluation. Initial screenings of solvent products already used in NCDOT found that many times laboratories will only run the flash point test once at 140° F (60° C) and report the flash point as greater than or less than this temperature. For the purposes of this program, especially since a determination is

to be made as to whether or not a product may be sold to and used by NCDOT, it is necessary for the laboratory to report an exact flash point by running the test at varying temperatures. An average of three flash point results will be the final result reported and used for passing or failing the product.

Environmental Screening

The EPA 8021 method was first selected for evaluating these environmentally friendly, biodegradable solvents. For the initial screenings, vendors were required to have their product tested by an independent, certified laboratory using the 8021 method. While some vendors had their products evaluated using the prescribed method, many of the products were also screened using EPA Method 8260B. Upon further consideration of this method, it was determined that the 8260B method was more comprehensive, and potentially a more appropriate test. Before making a final determination on this method, the North Carolina Department of Environment and Natural Resources (DENR) was consulted. According to DENR, EPA Method 8260B is frequently used to determine if it is necessary to clean up spills of unknown materials. It is also an appropriate method for detecting hazardous chlorinated solvents and other volatile organic compounds (VOCs) that may be present in the products being tested. Table 1 lists the compounds that can be detected using EPA Method 8260B. Given the potentially serious impacts of spilling any of these compounds, a product will not be approved if any quantity of the listed compounds is detected in the sample tested.

Performance Test

There is no accepted standard for evaluating the performance of an asphalt solvent. However, it is logically reasonable to consider applying asphalt emulsion to a metal object, applying the solvent, and measuring the amount of asphalt removed. In fact, one vendor proposed a similar method used in their operations to evaluate the performance of their formulations on a piece of aluminum foil and bitumen residue from pruning sealant. There was still the lack of a control for comparing the performance of the solvents. Since diesel fuel had been used for years to clean asphalt from tools and equipment, it was chosen as the control solvent. Knowing that it was crucial to develop a scientifically valid test, NCDOT partnered with North Carolina State University and Dr. Akhtarhusein Tayebali, PE to develop a simple, repeatable test for determining the efficacy of an asphalt solvent. The expectation in the beginning was that diesel fuel would perform better than its biodegradable counter parts at dissolving asphalt. In order to establish a minimum performance requirement, samples of all of the asphalt solvents used by NCDOT at the time were evaluated along with diesel fuel. Surprisingly, all but one of the asphalt solvent products performed as well as, or better than diesel fuel. Figure 1 illustrates that many of these solvent products perform significantly better than diesel fuel (*5*). Based on this finding, NCDOT decided that a solvent must perform as well as diesel fuel, or better, by removing at least 16% of the asphalt sample in this test method in order to be approved for use. The test procedure is simple and can be performed easily by any physical-testing laboratory. At North Carolina State University, Dr. Tayebali is pursuing the possibility of standardizing this test method.

TABLE 1 List of Substances Detected by EPA Method 8260B

Acetone
Acetonitrile
Acrolein (Propenal)
Acrylonitrile
Allyl alcohol
Allyl chloride
Benzene
Benzyl chloride
Bis(2-chloroethyl)sulfide
Bromoacetone
Bromochloromethane
Bromodichloromethane
4-Bromofluorobenzene (surr)
Bromoform
Bromomethane
n-Butanol
2-Butanone (MEK)
t-Butyl alcohol
Carbon disulfide
Carbon tetrachloride
Chloral hydrate
Chlorobenzene
Chlorobenzene-d (IS) 5
Chlorodibromomethane
Chloroethane
2-Chloroethanol
2-Chloroethyl vinyl ether
Chloroform
Chloromethane
Chloroprene
3-Chloropropionitrile
Crotonaldehyde
1,2-Dibromo-3-chloropropane
1,2-Dibromoethane
Dibromomethane
1,2-Dichlorobenzene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,4-Dichlorobenzene-d (IS) 4
cis-1,4-Dichloro-2-butene
trans-1,4-Dichloro-2-butene
Dichlorodifluoromethane
1,1-Dichloroethane
1,2-Dichloroethane
1,2-Dichloroethane-d (surr) 4
1,1-Dichloroethene
trans-1,2-Dichloroethene
1,2-Dichloropropane
1,3-Dichloro-2-propanol
cis-1,3-Dichloropropene
trans-1,3-Dichloropropene
1,2,3,4-Diepoxybutane
Diethyl ether
1,4-Difluorobenzene (IS)
1,4-Dioxane
Epichlorohydrin
Ethanol
Ethyl acetate
Ethylbenzene
Ethylene oxide
Ethyl methacrylate
Fluorobenzene (IS)
Hexachlorobutadiene
Hexachloroethane
2-Hexanone
2-Hydroxypropionitrile
Iodomethane
Isobutyl alcohol
Isopropylbenzene
Malononitrile
Methacrylonitrile
Methanol
Methylene chloride
Methyl methacrylate
4-Methyl-2-pentanone (MIBK)
Naphthalene
Nitrobenzene
2-Nitropropane
N-Nitroso-di-n-butylamine
Paraldehyde
Pentachloroethane
2-Pentanone
2-Picoline
1-Propanol
2-Propanol
Propargyl alcohol
$-Propiolactone
Propionitrile (ethyl cyanide)
n-Propylamine
Pyridine
Styrene
1,1,1,2-Tetrachloroethane
1,1,2,2-Tetrachloroethane
Tetrachloroethene
Toluene
Toluene-d (surr) 8
o-Toluidine
1,2,4-Trichlorobenzene
1,1,1-Trichloroethane
1,1,2-Trichloroethane
Trichloroethene
Trichlorofluoromethane
1,2,3-Trichloropropane
Vinyl acetate
Vinyl chloride
o-Xylene
m-Xylene
p-Xylene

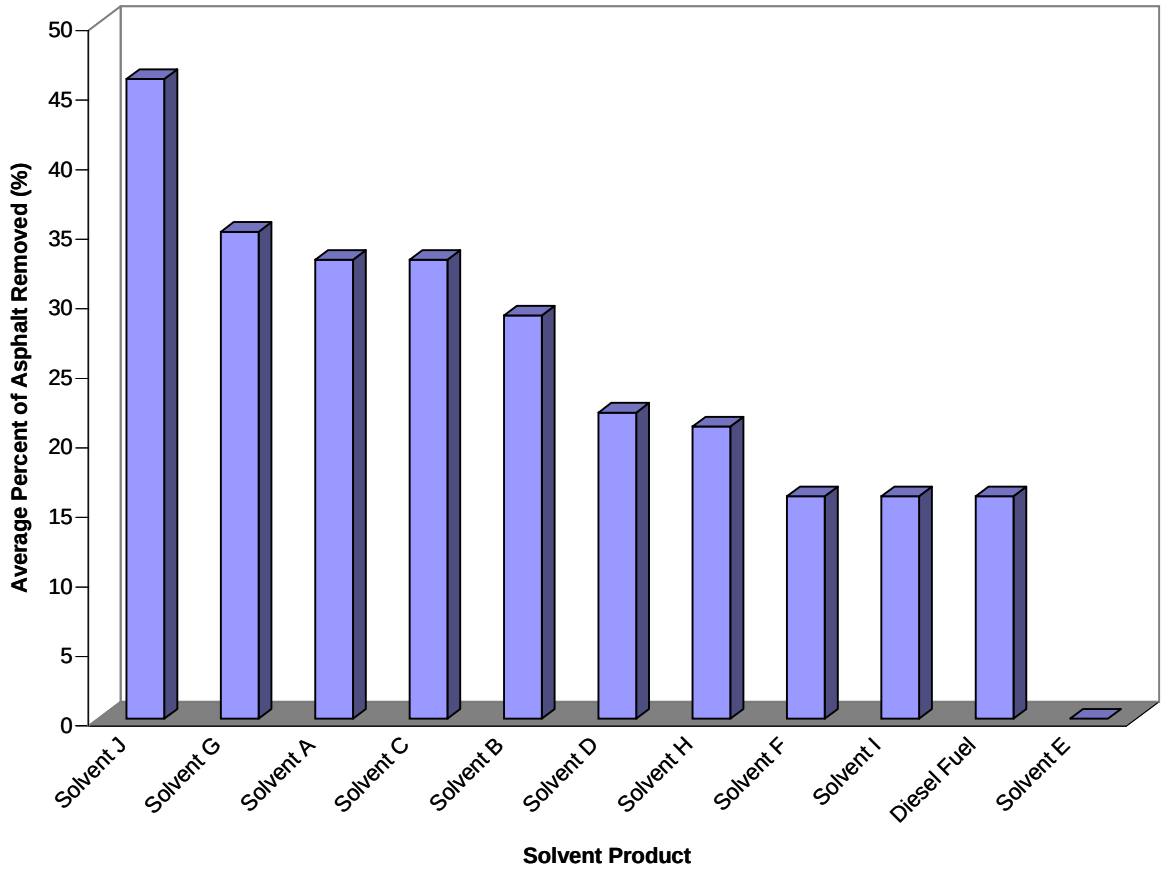


FIGURE 1 Average percentage of asphalt removed for the solvents tested.

Performance Test Procedure

The test procedure consists of applying 1.5 g of asphalt emulsion to a small aluminum dish and curing the asphalt sample at 140° F (60° C) for 24 hours. After the curing time, the dish is allowed to cool to room temperature and the weight of residual asphalt is determined. Next, 0.5g of the solvent being evaluated is applied using a dropper and allowed to work for 5 minutes. The dish is then allowed to drain upside down for 5 minutes and next rinsed thoroughly for 5 more minutes. Lastly, the dish and remaining asphalt residue is oven dried at 140° F (60° C) for 15 hours and the amount of asphalt removed is calculated.

ADMINISTERING THE PROGRAM

Now that a testing program has been defined, the approval of a solvent is handled through a multi-step process. First, any vendor seeking approval of their asphalt solvent product must submit a 2-liter (0.53-gallon) sample to the NCDOT Materials and Tests Unit (M&T). The chemical testing personnel at M&T will then split the sample and send half to a state certified laboratory for the ASTM D-93 flash point test, and the EPA Method 8260B screening. The same laboratory will test all product samples submitted for qualification. If the product passes the flash point and EPA tests, M&T will then administer the performance test using the remaining

portion of the sample. Products performing as well as, or better than, the diesel fuel control will be placed on a list of qualified asphalt solvent products. The approval process will only be performed once a year. If any additional vendors wish to have a product approved, the product would have to be submitted the next time that the approval process is opened. During the course of the year, NCDOT will randomly sample delivered asphalt solvent products and perform the flash point and EPA tests for quality assurance.

This testing and approval program has not been implemented at the time of the submission of this paper. January 2003 will be the first opportunity for vendors to submit samples for consideration, and it is expected that the resultant list of qualified products will be established by March 2003.

EXPECTED RESULTS

Given that there is a large amount of competition in this industry (*2*), it is expected that this program will increase operational efficiency by reducing the amount of time involved with the approval process. This will be done by eliminating the need to review technical information and marketing materials for products, and by limiting the time during which proposals will be allowed. Another expected benefit comes in the assurance that a safe, effective product will be purchased, without the current trial and error method many maintenance personnel now employ in deciding which product works best. Ultimately, if from this program there are sufficient qualified products available and a statewide contract for the purchase of a particular product can be established, then significant savings in the requisitioning and purchasing of asphalt solvents can be realized.

ACKNOWLEDGMENTS

The author acknowledges Akhtarhusein Tayebali, P.E. and his graduate assistants at North Carolina State University for their work developing the performance test; Chris Niver, LG, CHMM and John Kirby, CHMM of the NCDOT Roadside Environmental Unit for their efforts in reviewing environmental test methods and editorial contributions; Christopher Peoples, PE and Kelly Croft of the NCDOT Materials and Tests Unit for their willingness to participate in the program and technical assistance; Steve Varnedoe, PE, NCDOT State Maintenance and Equipment Engineer, Lacy Love, PE, NCDOT State Road Maintenance Engineer, and Jennifer Brandenburg, PE, NCDOT Maintenance Operations Engineer for their guidance and editorial contributions; and Emily McGraw of the NCDOT State Road Maintenance Unit for her formatting and editorial assistance.

REFERENCES

1. Strategic Plan for Transportation in the 21st Century. North Carolina Board of Transportation, 2001.
2. Release Agents Solve a Sticky Situation. *Asphalt Contractor*, April 2001, pp. 76-77.
3. U.S. Department of Transportation Hazardous Materials Regulations. 49 C.F.R., Part 173.120.
4. U.S. Environmental Protection Agency Regulations. 40 C.F.R., Part 261.21.

5. Tayebali, A., et al. *Final Report: Standard Test Method for Determining Effectiveness of Asphalt Removing Solvents*. North Carolina Department of Transportation Technical Assistance Program, No. TA-2003-02, North Carolina State University, Raleigh, August 23, 2002.

PART 6

Roadside and Environment

PENNDOT's Environmental Management Program

KENNETH THORNTON
GARY HOFFMAN
Pennsylvania Department of Transportation

DAVID SOLTIS
HENRY BALIKOV
JEFF SCHAEBERLE
TLI Systems, Inc.

Information is presented on some of Pennsylvania Department of Transportation's (PENNDOT) practices involving maintenance of transportation facilities in Environmental Maintenance Procedures and Practices. Particular attention is given to PENNDOT's practices in the following areas: (1) protecting the roadside environment, and (2) environmental management best practices for maintenance.

Over the last couple of years the Pennsylvania Department of Transportation (PENNDOT) has developed and implemented a strategic environmental management program (SEMP) for its maintenance unit and maintenance district activities in our Engineering Districts across the Commonwealth. These efforts are a fundamental component of an overall effort to implement an environmental management program for the entire Department. PENNDOT's SEMP, which is modeled on the ISO 14001 Standard for Environmental Management Systems, has thus far established ISO 14001-conforming environmental management procedures, processes, and tools that are used by managers and employees at all levels of the organization to practice environmental stewardship (i.e., *we* will protect and enhance the environment) in the following maintenance activities/operations:

- Roadside maintenance,
- Stockpile and garage operations, and
- Winter roads maintenance.

This paper and our presentation to conference attendees provides information on the decisions that led us to pursue SEMP and shares several of the procedures, practices, tools, and lessons learned that can be used by other transportation maintenance professionals in optimizing the level of environmental protection provided by and the efficient use of fiscal and personnel resources in their operations.

Throughout this paper we will also highlight key concepts and considerations that can help a transportation organization implement their own program of environmental management best practices. We will use the following symbol to highlight these keys.

BACKGROUND

PENNDOT's SEMP efforts began with two key commitments of State and Department senior executives. At the state level, Executive Order 1998-1, *The Governor's Green Government Council*, called on the agencies of the Commonwealth to incorporate:

> environmentally sustainable practices, including Strategic Environmental Management, into Commonwealth government's planning, operations, and policymaking and regulatory functions, and to strive for continuous improvement in environmental performance with the goal of zero emissions. Strategic Environmental Management includes and environmental management system with a strong pollution prevention and energy efficiency program, effective community involvement, measurable economic and environmental performance goals, environmental accounting, and life cycle analysis.

The commitment of PENNDOT senior management is shown in the Secretary of Transportation's response to the Executive Order as follows:

> One of the Department's Green Plan initiatives is to establish an environmental management system using the existing Department framework and the concept of the Department of Environmental Protection's Strategic Environmental Management (SEM). PENNDOT is the lead agency in SEM application. Once implemented, it is expected the environmental management system will yield quantifiable, positive environmental and economic impacts through a continual improvement process.

A Key: The Need for Management Commitment

The commitment of senior as well as middle management to any environmental management initiative, or for that matter any effort to change an organization, is the first key to success. This commitment helps in several ways, including:

- Demonstrates to all employees that the effort is important and requires the participation of all employees.
- Ensures that resources and direction will be provided on an ongoing basis to reach the objective.

A Key: Getting and Keeping Management Commitment

As with any activity that requires a commitment of resources and a commitment to change, the natural responses are "Why should I do this?" "What's in it for me?" and "How do we do this?" PENNDOT staff responsible for implementing SEMP recognized these questions early in the process. Following are several examples of actions that we have taken to obtain

management commitment. Please note, many of these actions also address the questions and concerns of employees throughout the organization.

- Involve a cross-section of the organization (by unit or department as well as by level) in planning and development. We involved various deputates and engineering districts in our committees.
- Select a program framework that adopts and is based upon accepted management best practices. We used the Plan – Do – Check – Act approach.
- Recognize that we will eventually address most if not all units/departments; however, select priorities to focus efforts. We chose MAINTENANCE.
- Select objectives, targets, and performance measures that are quantifiable and include a mix of objectives that can be fulfilled very quickly as well as in the longer term. For near-term objectives we are using measures that can show measurable progress quickly. Near-term successes build buy-in at all levels.
- Provide routine, periodic updates on progress and accomplishments.
- Incorporate environmental management into existing systems, procedures, practices, and tools instead of starting from scratch or making a stand-alone environmental management program.

BASIS FOR APPROACH

Framework

PENNDOT is using the ISO 14001 Standard for an environmental management system as the framework for our efforts to develop and implement SEMP throughout the Department. We have decided to use the ISO 14001 Standard for the following reasons (please consider our reasons for using the ISO 14001 Standard when selecting a model for your own program).

- The Standard promotes continual improvement.
- The Standard is based on the widely-demonstrated, commonly-accepted management principles of Plan – Do – Check – Act (Why reinvent the "wheel" if you can use existing tools?).
- The Standard incorporates global best-practices.
- The structure and criteria of the Standard promote adaptability and flexibility that accommodate:
  - Operations at a variety of facilities,
  - A wide variety of activities and services provided by an organization,
  - Activities performed by employees at various levels of the organization,
  - Activities with a wide range of experience, duties, education, and skills.

Please note, use of the ISO 14001 Standard as a model for an environmental management program does NOT commit an organization to obtaining ISO 14001 certification.

Figure 1 illustrates the fit between the ISO 14001 framework and the Plan – Do – Check – Act approach.

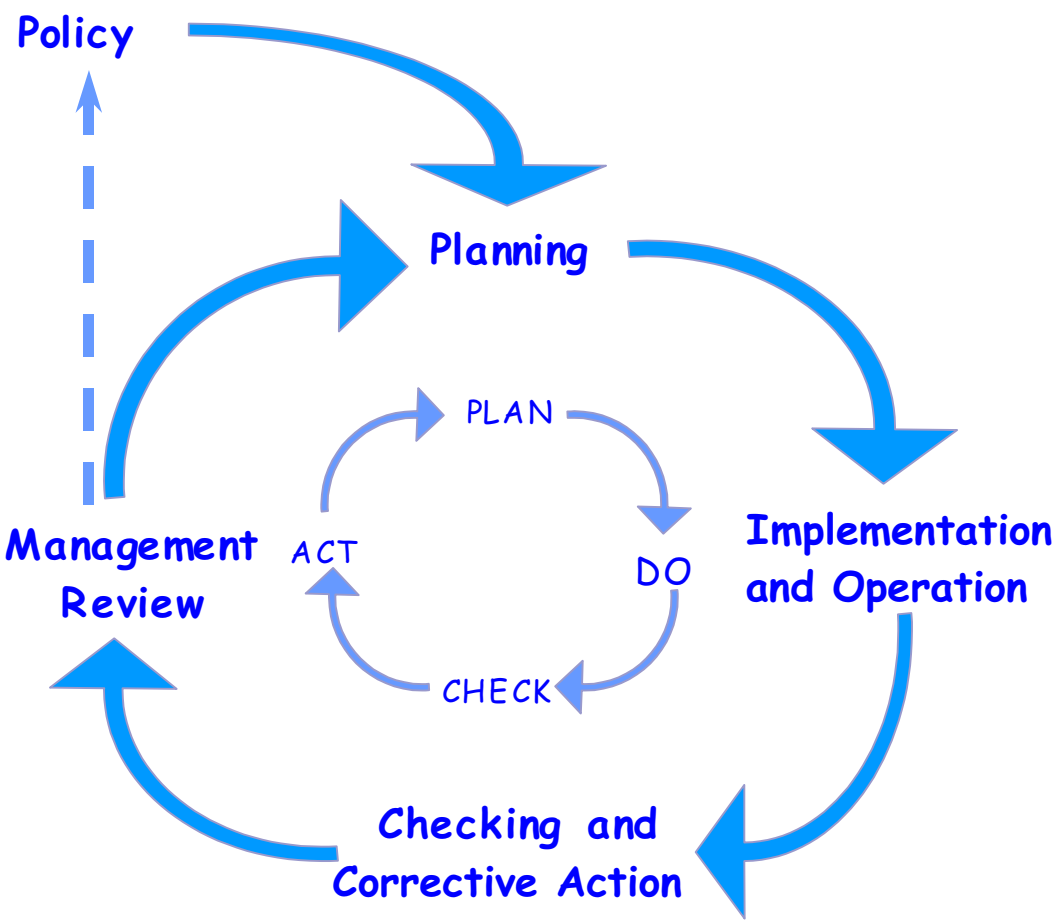


FIGURE 1 ISO 14001 standard and the Plan–Do–Check–Act approach.

Initial Focus

Our initial focus is on maintenance activities performed by the Engineering Districts. Maintenance was selected as the initial focus because:

- More than 75% of the PENNDOT workforce is involved in maintenance;
- Maintenance comprises the vast majority of PENNDOT's operating budget;
- Environmental protection in maintenance activities needed consistency in planning and performance; and,
- Environmental management successes could be readily achieved and integrated with regulatory streamlining and coordination initiatives being pursued by PENNDOT.

We started by identifying an engineering district that would volunteer to serve as a pilot. District 10 (encompassing approximately 500 maintenance employees working in Armstrong, Butler, Clarion, Indiana, and Jefferson counties in western Pennsylvania) offered to serve as the pilot.

We have worked with employee teams to develop processes, procedures, and tools that are readily understood by all employees, recognized by all employees as improving THEIR environment, and based on existing practices and instructions.

Within maintenance we are focusing on controlling:

- Erosion and sedimentation during roadway maintenance activities,
- Material usage when providing winter services, and
- Stockpile and garage facilities and operations.

We are now refining and adapting the procedures, processes, and tools developed in District 10 for use in Districts 4, 5, 11, and 12. Beginning this summer we will use the procedures, processes, and tools implemented in these Districts and in District 10 to implement maintenance unit SEMPs in the remaining 6 Districts.

Keys: Implementation and Buy-In at the Working Level

The commitment and interest of employees who do the day-to-day work of transportation maintenance are as important as management commitment to any environmental management initiative. We believe that a successful program is one that is OWNED by each affected employee and that is not dependent solely on management dictates to keep it alive. Following are some keys that we have used and found to ensure the ultimate success of our SEMP:

- Use employee teams to develop the procedures, processes, and tools;
- Provide initial and ongoing refresher training to all affected employees. It is more effective to provide a series of very brief training sessions than one or two lengthy programs;
- Keep the messages and instructions simple;
- Keep the messages frequent and "fresh;"
- Identify employee interests (e.g., fishing, hunting, agriculture, and family) and relate the environmental stewardship activities to these interests. We have found that a sound environmental LEGACY for family and neighbors is of significant interest to a wide segment of the workforce;
- Within existing constraints, involve union representatives in program development and implementation;
- Reinforce and provide the procedures and tools to plan for environmental protection – it shouldn't be an afterthought; and
- Be flexible – allow each unit to develop its own means to implement a procedure or process while maintaining focus on the overall objective.

ACCOMPLISHMENTS

Our SEMP efforts to date have provided several significant benefits. It should be noted that SEMP, as a program of continual improvement and a long-term commitment to environmental stewardship, will also provide future, ongoing benefits. The following are brief descriptions of some of our accomplishments and the benefits attained.

- We have obtained ISO 14001 certification of maintenance activities in Engineering District 10.
- A District 10 analysis of SEMP Erosion and Sedimentation (E&S) control procedures and practices shows training and planning provides an estimated 2 weeks of work crew and equipment productivity at no increase in cost (doing it right the first time instead of going back to correct problems). This translates to cost avoidance of $25,000/year for District labor and equipment.
- SEMP procedures and processes in Districts 10, 11, and 12 have been recognized by Pennsylvania Department of Environmental Protection (DEP) staff as best management practices that ease oversight, monitoring, and permitting needs.
- District 5's efforts for consistency and planning in habitat assessments have improved relationships with US Fish and Wildlife Services.
- SEMP practices provide a foundation for other quality improvement actions; this shows all employees that they play a vital role.
- Winter services – a ton of salt conserved equates to a ton of asphalt on the road. During the extreme conditions of the past winter operators and assistant managers confirmed that the materials usage control practices adopted by PENNDOT helped them to extend the life of their road salt inventory by as much as 3 weeks (based on their experience under similar conditions).
- An anecdote that demonstrates the true benefit of PENNDOT's SEMP success – During employee interviews for the ISO 14001 readiness audit in District 10, an operator commented on E&S procedures to the third party registrar: "I've worked here for more than 20 years. We never did this before but that doesn't mean we were right. This is what I want to do for my children and grandchildren."

PROCEDURES, PROCESSES, AND TOOLS

Following are sample SEMP procedures, processes, and tools that you may use to implement an environmental management program to optimize the consistency and effectiveness of environmental protection efforts while conducting transportation maintenance activities.

Activity Selection and Prioritization

Figure 2 illustrates the decision process that we used to focus our SEMP efforts on maintenance and on certain activities within maintenance.

Establishing Objectives and Targets

A first step in the implementation of an environmental management program is the setting of environmental performance objectives, measures, and targets. This information provides:

- A common set of goals,
- Measures that can be used to assess performance on an ongoing as well as annual basis, and

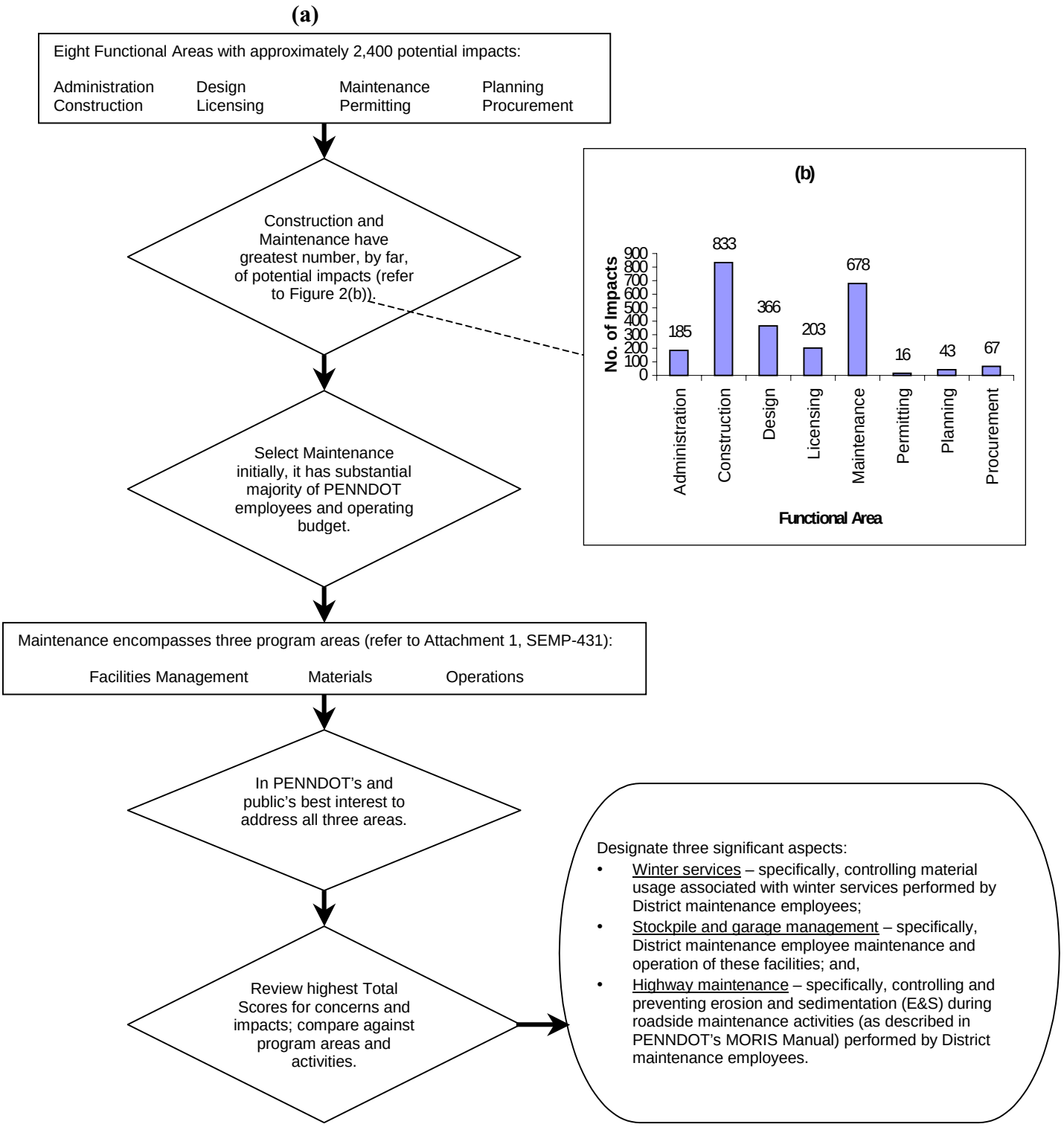


FIGURE 2 Activity selection and prioritization: (*a*) process map and (*b*) environmental impacts.

- Performance aims that are both challenging (move beyond the status quo) and achievable (aims that have little chance of attainment inhibit program interest and commitment).

In PENNDOT the planning for and implementation of SEMP and other programmatic activities begins with the annual Business Plan process. Table 1 presents examples of SEMP objectives, measures, and targets that are used by the Districts to plan their activities for a year and to communicate requirements to all managers.

Communications

The expected involvement of maintenance employees at all levels of the organization means that all reasonable efforts should be taken to communicate to employees the importance of, organizational commitment to, and their personal involvement in a program for environmental protection. SEMP implementation in each county began with and continues with communications that let all employees know what's happening. Figures 3, 4, and 5 provide examples of posters that we have used to communicate our SEMP commitments and involvement. Figure 5 is an example of a poster that was used following the release of the first two posters to keep the SEMP message "fresh."

Responsibility

To ensure environmental protection program success each employee must recognize that they have a role in environmental protection. This role can be communicated by and should be reinforced through informal means (such as posters and meetings). However, these methods should be accompanied by structured, formal methods that ensure that each employee is fully aware of their role in a program for environmental protection. Table 2 presents samples of SEMP responsibility statements that have been included in employee Job Descriptions.

Training

As the next step in the process of implementing an environmental management program each employee must be provided the training needed to fulfill their environmental protection responsibilities. Table 3 provides an excerpt of a matrix that highlights the SEMP training associated with each Working Title. This matrix is maintained in a SEMP Manual located at each office and stockpile; this Manual is available for review by all employees.

Training that simplifies complex environmental requirements helps affected employees easily understand and, in turn, fulfill their responsibilities. We have found that photographs and other illustrations that show the DOs and DON'Ts are useful tools. Figures 6 and 7 provide examples that we have used for stockpile training.

TABLE 1 SEMP Objectives, Measures, and Targets

Objective Code	Organization Objective	Owner/ Leader	Measure	Target 2003-2004	Target 2004-2005	Target 2005-2006	Target 2006-2007
Section 1. – Implement a Maintenance Unit SEMP in each District that addresses E&S control (for MORIS Manual activities, stockpile and garage management, and winter services.							
6-1A	Provide annual (i.e., full training program) E&S control training to employees involved in conducting MORIS Manual (Pub. 113) activities that may have an E&S impact.		% of involved employees trained (new and temporary employees must be included when calculating the % of employees receiving annual training).	25%	25%	25%	25%
6-1B	Provide E&S control refresher training (i.e., short program) to employees involved in conducting MORIS Manual (Pub. 113) activities that may have an E&S impact.		% of involved employees trained. (NOTE: this % does not include employees who receive annual/full program training.)	70%	70%	70%	70%
6-1C	Provide annual (i.e., full training program) Stockpile and Garage Management training to employees assigned to a stockpile or garage.		% of involved employees trained (new and temporary employees must be included when calculating the % of employees receiving annual training).	25%	25%	25%	25%
6-1E	Provide annual (i.e., full training program) Winter Services training (including the relevance of SEMP) to employees who may control the use and application of winter materials.		% of involved employees trained (new and temporary employees must be included when calculating the % of employees receiving annual training).	25%	25%	25%	25%
6-1F	Provide refresher training for Winter Services (including the relevance of SEMP) to employees who may control the use and application of winter materials.		% of involved employees trained. (NOTE: this % does not include employees who receive annual/full program training.)	70%	70%	70%	70%
6-1G	Implement District Maintenance Unit SEMP procedures, processes, and tools for E&S control to minimize or prevent the number of incidents of erosion or sediment release. At a minimum these SEMP E&S control procedures and processes include: reviewing maintenance Annual Work Plan (AWP) with conservation district manager and use of the bi-weekly planning process by all foremen to identify E&S control measures and resource needs.		Number of E&S control-related NOVs or other formal notifications from regulatory personnel (e.g., DEP or Conservation District) that are NOT followed up by corrective actions and evaluations to identify actions that could prevent the incident from occurring again.	0	0	0	0

What does SEMP have to do with me?

We will manage our environmental responsibilities.

What	How	Who
Winter Services	Control Material Application	You
Stockpile/Garage Management	Good Housekeeping and Operations (runoff control, PPC, salt under cover, etc.)	You
Erosion and Sedimentation Control	Minimize/Eliminate Runoff	You

FIGURE 3 SEMP communications: initial information.

What do our program and ISO 14001 require of me?

Ask yourself:

- How does my job affect the environment?
- How do I minimize or eliminate runoff and pollution?
- How do I stay in compliance with laws and District commitments to Sound Environmental Practices?
- How do I help with continual improvement?

FIGURE 4 SEMP communications: initial information.

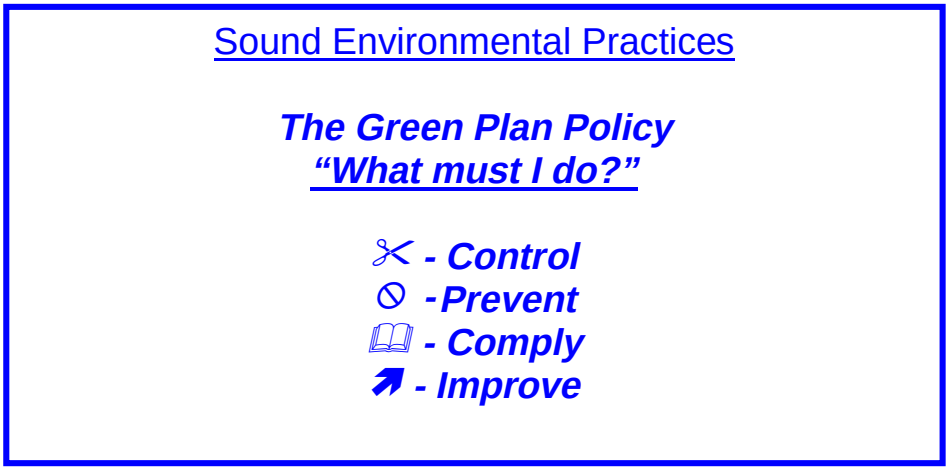


FIGURE 5 SEMP communications: refresher information.

Planning for Environmental Protection

Planning that incorporates the identification and fulfillment of environmental requirements is key to environmentally responsible job completion. Figure 8 presents an excerpt of a process map used for roadway maintenance. Please note, the sequence of steps includes coordination with regulatory agencies.

As another planning tool, we have developed simple checklists that provide simple, easy-to-use references to instructions and procedures presented in Manuals that are hundreds of pages long. Table 4 presents excerpts of an E&S requirements checklist for roadside maintenance activities.

Checking on Performance

Periodic assessment of conformance with the environmental protection goals and requirements adopted by and imposed upon an organization help to ensure continued compliance and environmental management program conformance by all involved managers and employees. To these ends an organization needs to provide independent (i.e., performed by individuals who are not employees of the unit assessed) as well as self-assessments. Self-assessments offer several advantages including:

- Can be performed more frequently;
- Findings can be quickly addressed;
- The individuals performing the assessments have the opportunity to learn more about environmental protection requirements and commitments; and
- By learning more about requirements and commitments individuals in an organization can adopt practices that ensure day-to-day conformance and compliance in their activities and at their facilities.

Figure 9 provides an example of a SEMP self-assessment. This checklist is completed by foremen at each stockpile four times a year.

TABLE 2 SEMP Responsibility Statements

Working Title	Responsibility Statement (refer to Section 6. of the Job Description)
District Engineer	Directs activities to fulfill the maintenance environmental requirements described or referenced in the District's Strategic Environmental Management Program (SEMP) *Manual for Sound Environmental Practices*. This direction of activities includes efforts to ensure that, within the fiscal constraints imposed through the Department's budgetary processes, resources are made available to fulfill the District's SEMP commitments and objectives. As a member of the District's Strategic Management Committee (SMC) performs the activities to fulfill the requirements identified for members of the SMC in the District's *SEMP Development and Implementation Manual*. Directs activities to fulfill the District's SEMP-related business plan objectives. Attends environmental training identified for this Working Title and for members of the SMC in the District's *SEMP Manual for Sound Environmental Practices*.
ADE Maintenance	Plans, organizes, and directs activities to fulfill the maintenance environmental requirements described in the Maintenance, MORIS, and Bridge Maintenance Manuals, and identified for this Working Title in the District's SEMP *Manual for Sound Environmental Practices*. This planning, organization, and direction of activities includes efforts to ensure that, within the fiscal constraints imposed through the Department's budgetary processes, resources are made available to fulfill the District's SEMP commitments and objectives. As a member of the District's SMC performs the activities to fulfill the requirements identified for members of the SMC in the District's *SEMP Development and Implementation Manual*. Also fulfills the environmental management requirements designated for this title in environmental training programs. Implements the SEMP-related maintenance unit business plan objectives designated for this title. Supports the efforts of other managers and employees to implement the SEMP-related maintenance unit business plan objectives. Attends environmental training identified for this Working Title and for members of the SMC in the District's *SEMP Manual for Sound Environmental Practices*.
County Maintenance Manager	Manages, plans, and organizes county roads maintenance activities to fulfill the environmental management requirements identified in the Maintenance, MORIS, and Bridge Maintenance Manuals and designated for this title in the District's SEMP *Manual for Sound Environmental Practices*. This management, planning, and organization of activities includes efforts to ensure that, within the fiscal constraints imposed through the Department's budgetary processes, resources are made available to fulfill the District's SEMP commitments and objectives. Receives new information for or revisions to the District's *SEMP Manual for Sound Environmental Practices* from the District SEMP Process Owner, incorporates this information in each county and stockpile copy of the District's *SEMP Manual for Sound Environmental Practices*, and implements the new or revised SEMP procedures, processes, or tools. Also fulfills the environmental management requirements designated for this title in environmental training programs. Implements the SEMP-related maintenance unit business plan objectives designated for this title. Supports the efforts of other managers and employees to implement the SEMP-related maintenance unit business plan objectives. Attends environmental training designated for this title in the District's *SEMP Manual for Sound Environmental Practices*.
Transportation Equipment Operator B	Implements the environmental protection requirements of maintenance work activities performed by the employee. Also fulfills the environmental management requirements designated for this title in environmental training programs. Recognizing that everyone is involved in the District's and County's actions to demonstrate sound environmental practices, each employee fulfills the maintenance unit business plan objectives related to the SEMP. Also, supports the efforts of other employees to meet these objectives. Attends environmental training designated for this position in the District's *SEMP Manual for Sound Environmental Practices*.
Transportation Equipment Operator A	
Temporary Equipment Operator A	
Highway Maintenance Worker	
Highway Sign Worker	
Carpenter	
Mason	

TABLE 3 SEMP Training Matrix

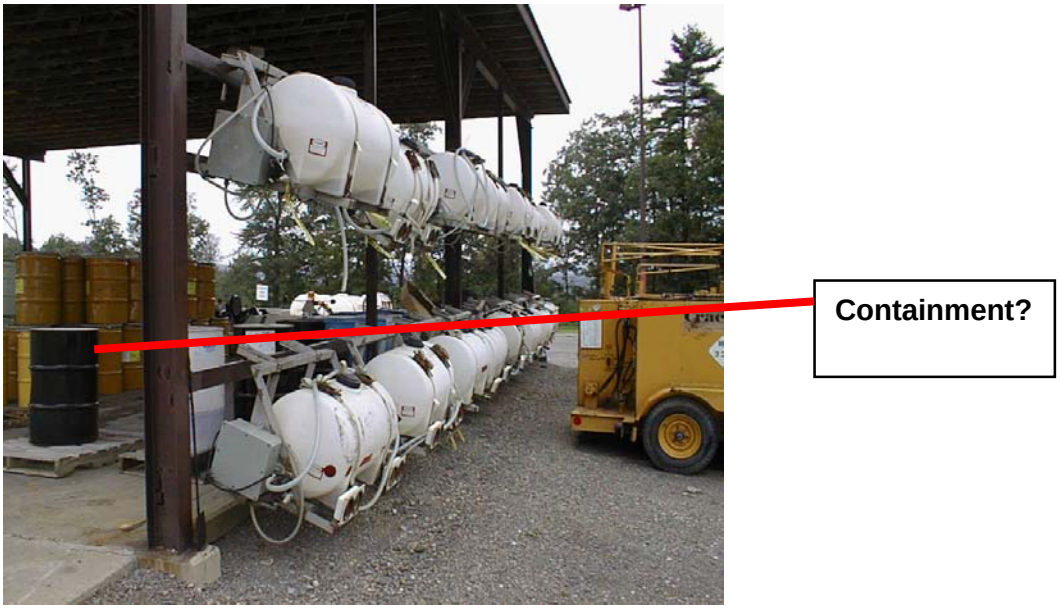
	Working Title	Training Programs									
		Environmental Awareness	Stockpile/Facilities Academy	Stockpile/Facilities Refresher	E&S Control	E&S Control Refresher	Winter Services	Spring Maintenance Meeting	Fall Maintenance Meeting	New Employee Orientation Prog.	First Responder/Incident Response
County Maintenance Unit	County Maintenance Manager	x	x	x	x	x	x	x	x	x	x
	Assistant Maintenance Manager	x	x	x	x	x	x	x	x	x	x
	Highway Foreman I, II, and III	x	x	x	x	x	x	x	x	x	x
	Transportation Equipment Operator B	x	x	x	x	x	x	x	x	x	x
	Transportation Equipment Operator A	x	x	x	x	x	x	x	x	x	x
	Temporary Equipment Operator A	x	x	x	x	x	x	x	x	x	x
	Highway Maintenance Worker	x	x	x	x	x		x	x	x	x
	Highway Sign Worker	x	x	x	x	x		x	x	x	x
	Carpenter	x	x	x	x	x		x	x	x	x
	Mason	x	x	x	x	x		x	x	x	x
	County Equipment Manager	x	x	x	x	x	x	x	x	x	x
	Mechanic Supervisor	x	x	x	x	x		x	x	x	x
	Automotive Mechanic	x	x	x	x	x		x	x	x	x
	Equipment Body Repairer Painter	x	x	x	x	x		x	x	x	x
	Maintenance Repairman	x	x	x	x	x		x	x	x	x
	Tradesman Helper	x	x	x	x	x		x	x	x	x
	Semi-skilled Laborer	x	x	x	x	x		x	x	x	x
	Welder	x	x	x	x	x		x	x	x	x
	Diesel Mechanic	x	x	x	x	x		x	x	x	x
	Custodian	x	x	x	x	x		x	x	x	x
	County Roadway Programs Coordinator	x	x	x	x	x	x	x	x	x	x
	Chief Clerk	x						x	x	x	
	Roadway Programs Technician (RPT)	x						x	x	x	
	Radio Operator	x							x	x	
	Stock Clerk	x						x	x	x	
	Accounting Assistant	x								x	
	Purchasing Agent	x						x	x	x	
	Clerical Staff	x								x	

(a)

(b)

FIGURE 6 Housekeeping: drum stacking—(*a*) improper signing (oil and paint in same containment); (*b*) proper stacking and segregation of materials.

(a)



(b)

FIGURE 7 Housekeeping: material storage—(*a*) poor containment/protection of materials and equipment; (*b*) good protection of equipment and materials.

Involved:
County Maintenance Manager (CMM)
Assistant County Maint. Manager (ACMM)
Roadway Program Coordinators (RPCs)
Foremen (FM)
District Environmental Unit (ENV)
Crew
SEMP Process Owner (SPO)
County Conservation District (CCD)
Fish & Boat Commission (FBC)

WHAT?	*WHEN?*	*WHO?*			
		Responsible	**Approves**	**Supports**	**Informed**
Develop Annual Work Plan (AWP) for each County.	December – January	RPC	CMM	ACMM **FM** **Crew**	SPO
Review AWP; identify E&S control requirements.	December – January	ACMM RPC ENV	CMM ENV	CCD	SPO
Develop Period Plan (PP); identify potential E&S control and permitting requirements.	January – March	ACMM RPC ENV	CMM ENV	**FM** **Crew** CCD	SPO
Contact CCD manager to inform him/her of planned activities.	February – March	CMM ACMM	CCD	RPC ENV	SPO

(Continued)

Legend: Responsible – performs the activity; Approves – signs off on the activity; Supports – provides input; Informed – notified after decisions are made

FIGURE 8 E&S control planning: process map.

TABLE 4 E&S Control Planning: Requirements Checklist

Activity	Description
711-7226-01	Paved shoulder base repair
711-7226-02	Shoulders,paved base/subbase rep.Heavy dut
711-7232-01	Shoulders, paved milling bit, surface mech
711-7311-01	Drainage inlet & endwall cleaning
711-7311-02	Drainage,clean inl & end,CLOGGED,manual & mech
711-7314-01	Drainage cleaning pipe & culverts mechanized
711-7321-01	Drainage,repair/replace inlets &endwalls,man.
711-7324-01	Drainage pipe replacement < 36", mech
711-7324-02	Drainage pipe replacement > 36" mech
711-7325-01	Repair/replacement of structure <8' length
711-7328-01	Drainage U-drain

Highlighted activities have E&S control requirements.

711-7215-01 711-7215-02

CONTOURS	Cut to original contour
CONTROLS	Straw bales, silt fence, or rock filters at point of discharge until disturbed area revegetated/stabilized
DISPOSAL	Do not dispose of excavated material in wetland or waterway
	Don't broadcast material onto slopes of ditches or channels Arrange for disposal beforehand – do not dispose in floodplain, wetland, or private property adjacent to wetlands so that material could be graded to wetland
DRAINAGE	Establish flow lines to drainage facilities
REMOVAL	Remove only debris or deposited material
STABILIZATION	Waste materials must be stabilized – rolling is acceptable
TEMPORARY MEASURES	Required if disturbed area is within 50 feet of stream

Please mark the appropriate boxes and make comments.

	Yes	No	N/A		Comments
1.	☐	☐	☐	Are all salt and premix materials stored under a permanently roofed building and stored on impermeable pad?	
2.	☐	☐	☐	Is the salt loaded properly at the front and sides of the storage structures?	
3.	☐	☐	☐	Is water directed away from the entrances to the salt storage buildings?	
4.	☐	☐	☐	Have all visible signs of salt trailing away from the storage area been cleaned up?	
5.	☐	☐	☐	Are all shingles in place on roofed structures?	
6.	☐	☐	☐	Are all buildings and structures completely intact and damage-free?	
7.	☐	☐	☐	Are all buildings completely free of pigeons and other animals?	
8.	☐	☐	☐	Are all lighting systems working properly?	
9.	☐	☐	☐	Are all lightning rods and electrical systems damage-free and working properly?	
10.	☐	☐	☐	Is there proper containment of aboveground storage tanks with the drain valve closed?	
11.	☐	☐	☐	Are all drums/containers properly labeled and stored?	
12.	☐	☐	☐	Are stored materials grouped together in separate areas with the proper signs posted?	
13.	☐	☐	☐	Are the truck heater outlets installed properly and operating?	
14.	☐	☐	☐	Do all buildings and structures have proper ID signs and presentable paint jobs?	
15.	☐	☐	☐	Are gutters and downspouts clear, free flowing, damage-free, and direct water away from the building?	
16.	☐	☐	☐	Are proper sanitary facilities provided?	
17.	☐	☐	☐	Is your site clean and litter free?	
18.	☐	☐	☐	Are all gates, locks, and fences completely intact?	
19.	☐	☐	☐	Is the PPC Plan on site and updated in the past year?	
20.	☐	☐	☐	Have the fire extinguishers been inspected, properly mounted, identified, charged, and accessible?	
21.	☐	☐	☐	Are all required signs properly posted?	
22.	☐	☐	☐	Is the Safety Station properly equipped?	
23.	☐	☐	☐	Have all necessary permits been updated and displayed?	
24.	☐	☐	☐	Are compressed gas cylinders stored properly, chained, and separated?	
25.	☐	☐	☐	Are all oil/water seperators properly maintained?	
26.	☐	☐	☐	Is there a storm water management system and is it operating properly?	
27.	☐	☐	☐	Is the landscaping properly maintained?	
28.	☐	☐	☐	Is the equipment wash facility operating properly?	
29.	☐	☐	☐	Are the exhaust systems operating properly?	
30.	☐	☐	☐	Has the Emergency Generator been tested in the last 7 days?	
31.	☐	☐	☐	Are confiscated/abandoned vehicles stored properly on site?	
32.	☐	☐	☐	Is winter material pile face tarped and secured?	

FIGURE 9 SEMP self-assessment: foreman's stockpile checklist.

PART 7

Snow and Ice

Guidelines for Snow and Ice Control
Materials and Methods

ROBERT R. BLACKBURN
Consultant

DUANE E. AMSLER
AFM Engineering Services

KARIN M. BAUER
Midwest Research Institute

Snow and ice control strategies and tactics that employ solid and liquid chemicals, abrasives, and mechanical methods—individually or in combination—have been used by many different highway agencies throughout the world. Research by the Strategic Highway Research Program, the Federal Highway Administration, the National Cooperative Highway Research Program (NCHRP), and other organizations in the United States and other countries has addressed many of the issues associated with snow and ice control treatments. However, widely accepted guidelines for selecting level of service driven roadway strategies and tactics for specific weather, site, and traffic conditions have not been developed. Without this information, the process of selecting treatment strategies and tactics that meet highway agencies level of service objectives is difficult. Five snow and ice control strategy and tactic combinations were tested and evaluated over several years with various ranges of weather, site, and traffic conditions found in North America as part of NCHRP Project 6-13. A pavement ice condition index was developed for determining the overall effectiveness of a given snow and ice control strategy and tactic combination as well as effectiveness of within-storm and end-of-storm winter maintenance operations. The field test results are being used to develop a set of guidelines for selecting roadway strategies and tactics for a range of winter maintenance operating conditions. The results will also used in developing snow and ice control material application rate guidelines. The results of this effort will be published by NCHRP in the near future.

Automated Gate Operational Test

FARIDEH AMIRI
Minnesota Department of Transportation

Due to frequent high wind, low temperature, and blizzards, the Minnesota Department of Transportation (Mn/DOT) has installed gates along I-90 and I-94 to guide traffic off the interstate and prohibit access during life threatening situations. Mn/DOT conducted a study that assessed the costs and benefits of gate operations. The study included potential reduction in delays and the number of accidents. A severe snowstorm that struck southwestern Minnesota in November 1998 provided a good case study to compare costs for clearing sections of highways with and without gates. Generally, it costs Mn/DOT 15% less to clear and reopen highways controlled by existing manual gates. An intelligent transportation systems (ITS) solution to reduce safety risks for law enforcement and snow maintenance teams is presently being tested by Mn/DOT. Mn/DOT, through a partnership with ThomTech Design team, developed a freeway management system at the I-90 and US 71 interchange at Jackson, Minnesota. Mn/DOT installed an automated system using ITS technologies. The system is being managed from Mn/DOT's Windom office. The pilot project started during the summer of 2001. The research report, work plan, hardware installation, software development, and acceptance test have been completed. The system is being tested by Mn/DOT District 7 Windom office. The I-90 gate operations involves the coordination of the following major subsystems: (1) the *Traffic Management Subsystem* consists of automated gate closure devices that are designed to operate in all climates and are FHWA approved for crash worthiness, safety, and operability. The existing gate arms are used with conjunction in an automatic electronic actuator to raise and lower the gates using a wireless signaling device; (2) the *Control and Monitoring Subsystem* is a website with a user name and a password that controls the gate operations. The web server is located at the intersection and designed to be controlled from the Mn/DOT District 7 Office in Windom, Minnesota; (3) the *Detection and Sensor Subsystem* provides a reliable means of visual, audio, and graphic interfaces to detect violations. It is also able to display, record, log, and playback the incidents; and (4) the *Communication Subsystem* is wireless communication with internet access and back up landline. Lessons learned from the I-90 gate operational test will be used as a management toolbox for future ITS initiatives that will allow Mn/DOT to better manage the roadway facilities.

The Minnesota Department of Transportation (Mn/DOT) and partners looked into new and innovative methods for controlling traffic through the use of gates. It is the goal of this project to test different technologies, communications, and public/private operational and maintenance partnering scenarios to develop the optimal freeway management system for I-90 at interchange of I-90 and US 71 just north of Jackson, Minnesota.

Utilizing gates to direct traffic off Interstates and prohibit access during unsafe driving conditions such as severe snowstorms is a relatively new technique for closing roadways to travel in Minnesota. As the use of gates has spread in Minnesota, Mn/DOT studied and documented its experience with the gates and now enhancing gate operations through the utilization of an Intelligent Transportation System (ITS) (*1*).

The test location is I-90 and US 71 interchange at Jackson, Minnesota. The system is

managed from Mn/DOT's Windom office. The project has been started since summer of 2001 and the final report is available at www.dot.state.mn.us/guidesatr/projects/gateproj.html.

BACKGROUND

Experience Before Gates

Prior to using gates, Mn/DOT's Districts 4, 6, and 7 used available resources to close Interstates and highways during unsafe driving conditions. These techniques were as follows:

- Barricades along with sandbags were the most common type of closure and were placed at entrance ramps by three person crews. Barricades were difficult to keep in place. They were often blown away during strong winds and caused injuries. Often the first step to close the Interstate was to make up sandbags;
- Cones were also used on the mainline and entrance ramps, and cones as well as barricades generally did not stay in place. Motorists could go around both barricades and cones; and
- Piling snow and using State Patrol personnel and vehicles.

Case Study with the Manual Gates

A severe snowstorm struck southern Minnesota in November 1998. I-90 was closed while Highway 75 remained opened. Mn/DOT crews were out cleaning both roadways. Reports from this storm indicated that Highway 75 experienced greater snow compaction because it was open to travelers. One other statistic from this storm was that I-90 bare pavement (95% clear) recovered four hours before Highway 75. As a result, using gates to close the first 130 miles of I-90 from South Dakota to Blue Earth was a potential saving of $4 per lane mile (*1*).

Operational Test with the ITS Approaches

System and Subsystems

The I-90 gate operations solution comprises four subsystems. Figure 1 provides a block diagram illustration of the four subsystems and their components.

Traffic Management Subsystem The traffic management subsystem consists of automatic gate closure devices that are designed to operate in all climes, are remotely controlled, and provide advanced warning to the motorist. In addition, each device needs to be FHWA-approved for crash worthiness, safety, and operability.

Another key area of design is the advanced warning signs and means to maintain traffic safety in the wake of environmental, weather, terrorist, and hazardous waste incidents. The mainline signs are located 1000 feet from exit entrances. Two signs are installed on both sides of the mainline. One sign is on the grass median and the other one is located at the side shoulder. The entrance ramp advanced warning signs are located on the right hand side of both east and west on ramps.

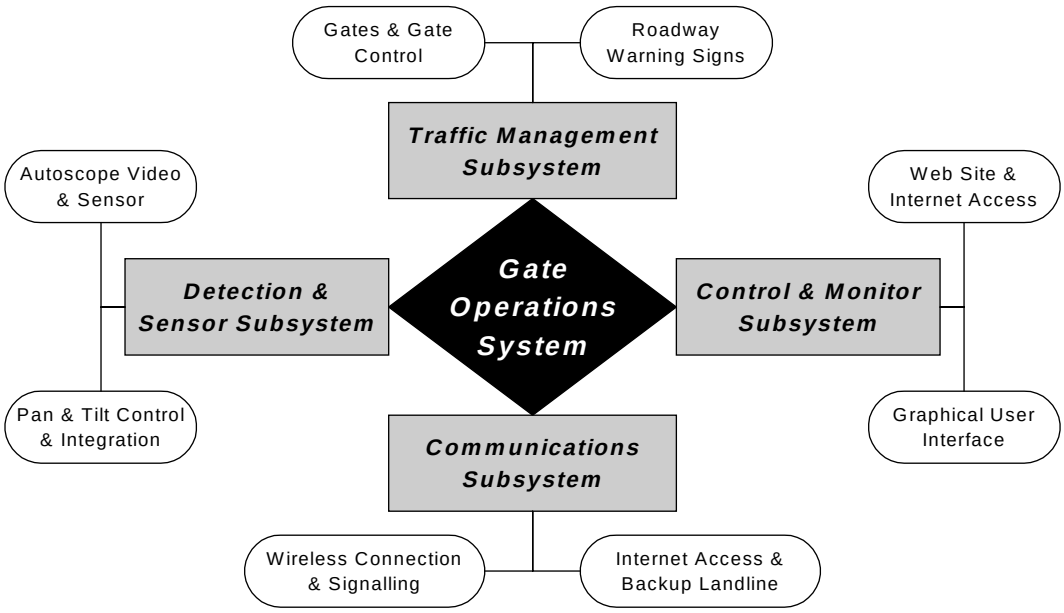


FIGURE 1 I-90 gate operations subsystems block diagram.

The I-90 gate project selected to use the existing gate arm mechanism and automate the gate raise and lower operation using an electric linear actuator. An appropriate steel frame was designed and implemented to attach the actuator to the gate. Figure 2 illustrates the completed installation for the gate.

Communications Subsystem The gate operations system is designed to be installed at existing intersections without extensive cable trenching and landline connectivity. Thus, maximum use of wireless communications is employed. Each of the frequency bands have been chosen to ensure adequate bandwidth, throughput, and range is employed to meet the various communications requirements. Other communications subsystem mediums were considered, specifically fiber-optic and microware.

Control and Monitor Subsystem A website with controlled access is used to control and monitor the gate operations system, which resides on the web server at each intersection or group of intersections. Access to the website is controlled by a user name and password. Once the system operator has successfully entered the website, they will have access to control and monitor gates and signs, data collection, access, video, violations, playback, and reports. See Figure 3.

The control and monitor subsystem consists of two ways to control the gate closure system. The first way is by manual control and is used if the intersection loses electrical power. The gate is returned to operation via the hand-cranked wench by disconnecting the electrical actuator, hooking up the winch cable and winding the gate down or up as needed. The automatic method is to use the website control provided by the web server at the Jackson Truck Station.

FIGURE 2 Automated gate lowered.

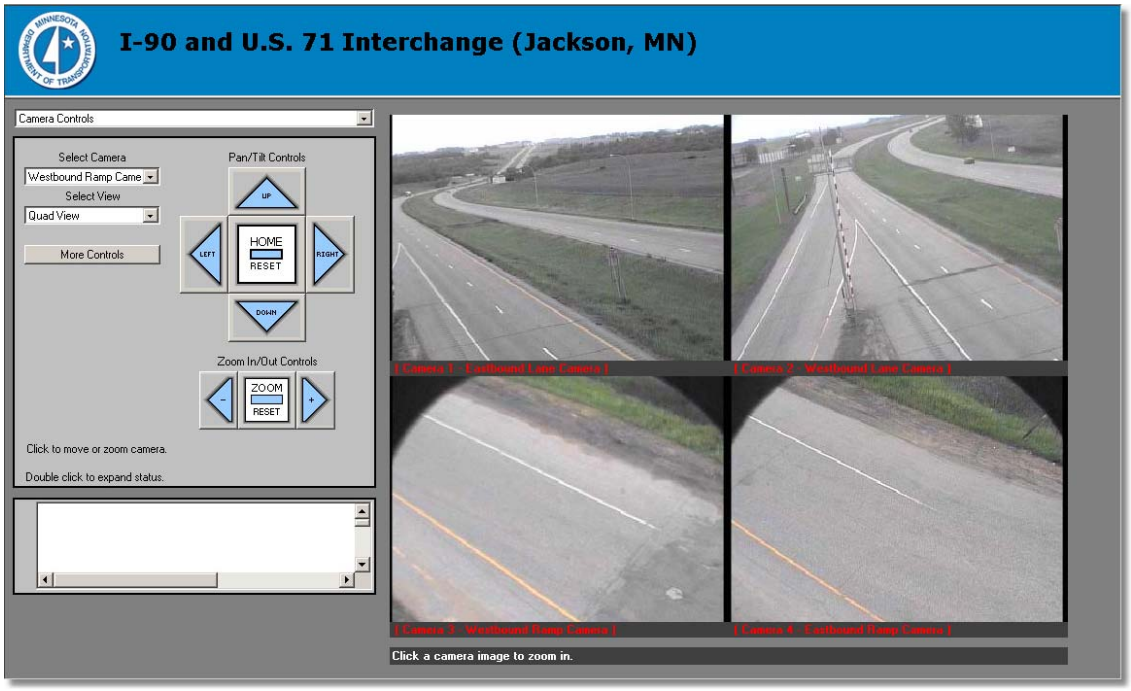


FIGURE 3 Screen display for website control.

An additional method of control is the emergency vehicle override. This method allows the gate to be raised if the emergency vehicle receiver "hears" the emergency traffic override signal. The lowered gate is raised until the receiver senses an absence of the emergency signal.

The project team considered several methods of controlling the gates if electrical power was lost. The method selected for the follow-on intersections is to purchase the hand wheel option on the actuator that allows for manual operation.

Detection and Sensor Subsystem The purpose of the detection and sensor subsystem is to provide reliable means of visual, audio, and graphic interface to detect violations of the traffic management system, record, log, and playback these incidents. The autoscope was used to provide the video and detection portion of this project. Two of the autoscopes were configured with pan/tilt platforms and were stationed on the mainline gates. Figure 4 provides a photograph of the autoscope, pan–tilt platform, and broadband radio mounted at the top of a nearby luminaire at the intersection of I-90 & US 71 in Jackson, Minnesota.

FIGURE 4 Autoscope, pan–tilt platform, and broadband radio installed on light pole at the I-90 and US 71 intersection in Jackson, Minnesota.

FINDINGS

The system has proven the concept of remotely closing the gates using real-time video, system security, and wireless communications. It is anticipated that this will improve safety of Mn/DOT personnel and significantly reduce the time to gain control of the interstate traffic when necessary. The system employs an open architecture philosophy and uses existing FHWA approved gate arms and communications protocols. The data is stored in common text files for use by other Mn/DOT software applications. Mn/DOT operated the system during the winter of 2002-2003.

The final report is available at: www.dot.state.mn.us/guidestar/projects/gatesproj.html.

REFERENCES

1. BRW. Documentation and Assessment of Mn/DOT Gate Operations. Prepared for Minnesota DOT Office of Advanced Transportation Systems. October 1999. http://www.dot.state.mn.us/guidestar/pdf/gatereport.pdf.

PART 8

Workforce Development

Training
The Key to Technology Implementation

LELAND D. SMITHSON
American Association of State Highway and Transportation Officials

During the past decade, research has made great strides in providing new materials, methods and equipment for improving maintenance of transportation facilities. Topping the list of accomplishments is the way governmental agencies are approaching snow and ice control operations. The 1988 to 1993 Strategic Highway Research Program (SHRP) began the process with nearly 20 million dollars being spent in a maintenance operations research program. The International Technology Scanning Tour program followed in 1994 with a winter maintenance operations scan of Japan, Germany, and Austria, followed by a 1998 scan of Switzerland, France, Norway, and Sweden; finally, the latest winter operations and ITS applications scan in 2002 revisited Japan.

This tremendous influx of new research knowledge and technological advances brings a societal obligation for government to increase the efficiency and effectiveness of private and public winter maintenance of transportation facilities. Environment Canada's recent declaration that chloride based chemicals should now be considered CEPA Toxic adds to this sense of urgency for the snow and ice community to focus on the proper handling, storage, and application of commonly used anti-icing and de-icing chemicals.

Training for supervisors and field operators in understanding the new processes and equipment used in these proactive snow and ice control techniques has been slow in developing. Lack of effective and scientifically based training has hampered progress in the implementation of anti-icing (AI) and road weather information system (RWIS) technologies from the SHRP and International Scanning Tours.

AASHTO, recognizing these educational needs, established a pooled fund study to provide the necessary financial support to develop a national computer-based, AI/RWIS training program for state and local governments. Nearly all of the snow-belt states and the American Public Works Association (APWA) and the National Association of County Engineers (NACE) contributed to this pooled fund.

The computer-based training (CBT) program developed to meet this need is fundamentally a menu-driven, hyperlinked, interactive, content manager. The user, once logged in, can work through this stand alone training from beginning to end, like a book, returning to the menu at intervals, as desired, to select another path. The content is photographs, illustrations, text, video, charts, animation, interaction, narration, and other means of communication. There are opportunities at various points to access the progress the user is making educationally, including quizzes, scenario-based problem cases, and exercises. The training can be individually administered or used in a group setting and can be the foundation for a certification program.

PROJECT DEVELOPMENT

The need for the development of an interactive computer-based, stand-alone, training program was identified during the AASHTO/Federal Highway Administration SHRP Implementation Program by the Lead States Team for the implementation of advanced AI and proactive snow and ice control technology. When the sun set on the Lead States program, the responsibilities for developing and implementing the computer-based training program was handed off to the AASHTO Snow and Ice Cooperative Program (SICOP). The Aurora Consortium, an RWIS research consortium, had training as one of its top program priorities. The Aurora Consortium and SICOP agreed to partner in the development of a national AI/RWIS training program with Aurora taking the lead in developing the scope of work and obtaining a contractor to build the computer-based training program. SICOP agreed to raise the necessary funding and coordinate the project.

A request was made to all state Departments of Transportation (DOT), APWA and NACE to make nominations for a team of experts in anti-icing and snow and ice control operations and instructors familiar with teaching maintenance field personnel. A Technical Working Group (TWG) was organized from those nominations to develop the content of the training program and guide the contractor in building the training program.

The contract for the project was signed in March 2001. By September 2001, 800 pages of storyboards had been drafted for TWG review. By spring 2002, the contractor had draft copies of the first lessons on CD-ROM ready for TWG review. The state DOTs received CD-ROMs of the first three lessons in September 2002 and were asked to make recommendations for customizations to tailor the training to their individual state needs.

COURSE CONTENT

The course consists of seven lessons containing a total of 38 units. The content outline is listed below:

Lesson I: Introduction to Anti-icing and Winter Maintenance
- Unit 1: The New World of Anti-icing
- Unit 2: Benefits of Anti-icing
- Unit 3: Anti-icing in a Nutshell
- Unit 4: Units of Measure

Lesson II: Winter Road Maintenance Management
- Unit 1: Components of a Successful Anti-icing Program
- Unit 2: Preparing for the Winter Season
- Unit 3: Level of Service
- Unit 4: Data Collection and Record-keeping
- Unit 5: Anti-icing Communications and Legal Matters

Lesson III: Winter Roadway Hazards and Principles of Overcoming Them
- Unit 1: Water and its Winter States
- Unit 2: Road Surface Heat
- Unit 3: Condensation and Dew Point Temperatures

Unit 4: Pavement Temperature—It's the Key!
Unit 5: Snow, Ice, and the Roadway
Unit 6: Snow/Ice Bonds and Freezing-Point Depressants
Unit 7: Dilution of Solution
Unit 8: Chemical Concentrations and Application Rates
Unit 9: Friction

Lesson IV: Weather Basics
Unit 1: Weather and Winter Road Maintenance
Unit 2: Air, Atmosphere, Heat, and Humidity
Unit 3: Weather Systems
Unit 4: Regional Weather Influences
Unit 5: Precipitation Hazards
Unit 6: Non-Precipitation Hazards

Lesson V: Weather and Roadway Monitoring for Anti-icing Decisions
Unit 1: Radar
Unit 2: Weather Observation and Data Gathering
Unit 3: An Introduction to Road Weather Information Systems
Unit 4: The Importance of VAMS
Unit 5: Eight Critical Questions
Unit 6: Combining Anti-icing and the Traditional Approach

Lesson VI: Computer Access to Road Weather Information
Unit 1: An Introduction to the RWIS Screens
Unit 2: Navigating Through the System
Unit 3: Other Online Resources

Lesson VII: Anti-icing Practice in Winter Maintenance Operations
Unit 1: Preparing for the Season
Unit 2: Equipment Types, Preparation, and Maintenance
Unit 3: Material Preparation and Storage
Unit 4: Chemical Application Rates
Unit 5: End-of-Season Tasks

COURSE DOCUMENTATION

- *AI/RWIS CBT Setup Guide* is a manual describing how to set up the CBT on your PC. The guide is written for the information technology staff.
- *AI/RWIS CBT User Guide* is the primary reference manual for the CBT. This manual is meant for the CBT users. The User Guide explains in detail how to use the software and provides a detailed description of each of the CBT's features and functions.
- *Training Manager Guide* is a guide for training managers. It details the Training Manager Tool.
- *Course Editor Guide* details the use of the Course Editor Tool. The Course Editor is designed for training managers.

• *Implementation Guide* is written particularly for training managers. It explains how to roll out the CBT and how to best monitor student performance both with the CBT and on the job.

USING THE CBT

The CBT structure and flow diagram is shown in Figure 1.

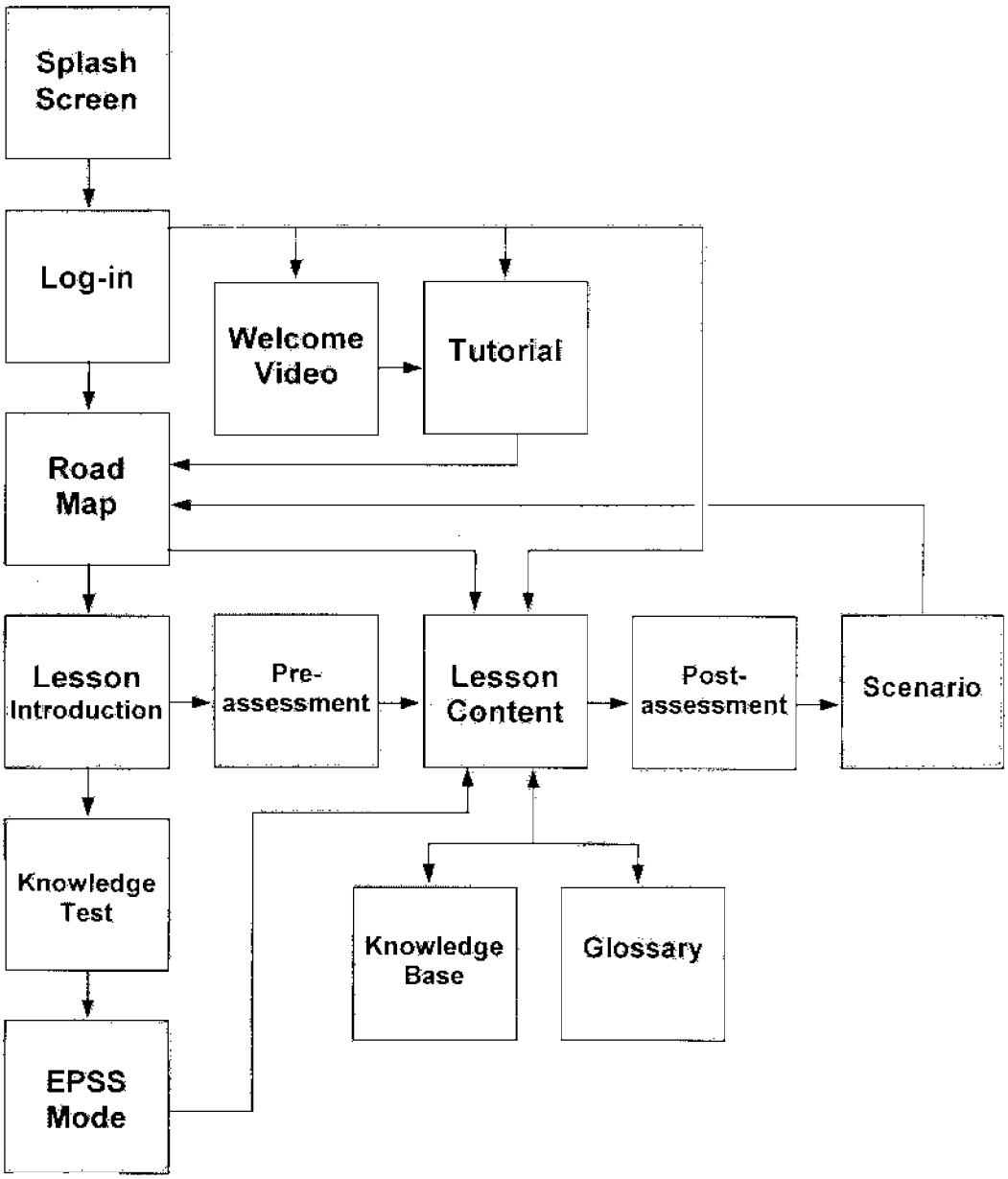


FIGURE 1 CBT flow chart.

- Splash screen appears each time the CBT is launched. It is a composite of small images reflecting training program content. As the images appear, music plays in the background. The splash screen requires about 15 seconds to build. If the student desires to bypass this screen, pressing the space bar or enter key will advance to the log-in screen.
- Log-in screen must be completed each time so student progress can be recorded. Log-in requires first name, last name, password, and job title. Thereafter the Microsoft® Agent "Jake," an online assistant, will address the student by their first name. Jake is an animated conversational personality that walks the student through the tutorial (discussed below) and provides assistance when the student needs help. In addition to the role of a guide, Jake will appear on occasion to drive home a point or sometimes just to entertain.
- Welcome video will present a brief video introduction to the course. The welcome video will play the first time the student uses the CBT.
- Tutorial will familiarize the student to the features and functions of the CBT. The full tutorial requires 31 minutes. The student can go through the entire tutorial or select tutorial topics. When the student logs back into the program for a subsequent session, they can revisit the entire tutorial, select topics or skip the entire tutorial.
- Road Map appears once the student exits the tutorial. The Road Map illustrates the student's progress and directs them to units within each lesson. Each road sign on the screen represents a lesson in the course. Lessons must be completed in order. Completed lesson signs will be checked off as soon as the student works through all of the lesson content and earns a passing score on the Post-assessment quiz and scenario.
- Lesson Introduction—each lesson begins with a video introduction to the content in that lesson. The main topics discussed in the forthcoming lesson are displayed on the screen as a real-person host mentions them.
- Pre-assessment quiz is administered after the Lesson Introduction. The purpose of the Pre-assessment is to evaluate what the student knows before going through the lesson so it can be compared to what they know after going through the lesson. The quiz contains questions in a variety of common formats (multiple-choice, true/false, and fill-in-the-blank). On the last question of the Pre-assessment a "Check My Score" button will appear. Clicking on that button will display a score panel with student results.
- Lesson Content in each lesson is organized into units. Each unit is broken down into screens. Lessons contain anywhere from three to nine units. Each unit has as few as five, or up to 40 to 50, screens. The lesson content is presented using multimedia elements, including:
  - Text,
  - Bullets (key points),
  - Photographs,
  - Illustrations,
  - Charts, graphs, or tables,
  - Screen element highlighting,
  - Narration,
  - Animation,
  - Digital video,
  - Sound effects,
  - Mouse and/or keyboard-controlled interactive exercises and simulations,
  - Review questions, and

- Interactive exercises will "engage" the student and topic being discussed. Review questions will be presented about every 5 to 10 screens. These are designed to check the student's understanding of the topic being discussed on the past few screens. Review questions are presented in a variety of formats, such as multiple choice, fill-in-the-blank, true/false, or drag-and-drop. Feedback will be provided so the student can see how they did and, if they missed a question, what the correct answer is.

• Knowledge Base is a warehouse of information related to AI/RWIS. The student should think of it as an online encyclopedia. Material in the Knowledge Base is arranged by tab groups discussion topics by subject or area or in an alphabetical index. In addition to text, Knowledge Base discussions may include photographs, diagrams, tables, web site links, digital videos, etc. Some discussions include links to other discussions. These are identified as blue underline text. The student can click on these "hot terms" to jump to those discussions in the Knowledge Base.

• Glossary contains a list of AI/RWIS terms and their definitions.

• Post-assessment quiz serves to evaluate what the student knows after going through the lesson. On the last question of the Post-assessment a "Check My Score" button will appear. Clicking that button will bring results of the Post-assessment quiz and Pre-assessment scores so the student can compare what they now know after going through the lesson compared with what they knew beforehand.

• Scenario—while the Post-assessment quiz evaluated the student's knowledge of AI/RWIS facts, the scenario evaluates their understanding of the lesson content by asking them to put the knowledge they have gained into practice. It is well known that working with theories is one thing; working within the constraints of the real world can be quite different. The scenario room gives the student hands-on practice in a simulated winter maintenance facility so that they can develop and refine their winter maintenance decision-making skills. The scenario room is set up to look like a field maintenance garage office. It provides the student with the tools most maintenance facilities have in some form or other to learn of an impending winter weather event. They should be able to research the particular nature of the event and make operational decisions based on that research. Everything the student does in the Scenario Room is tracked and evaluated. The student is encouraged to strive to use all of the pertinent tools available, yet not to waste time clicking on objects that will not aid for the particular event. Detailed feedback will be provided once the student has made an operational decision. If the student does not pick the optimal solution to the problem, they will learn what the optimal solution is. The results of their decision will be compared with the results of the optimal solution. This way the student will learn the consequences of making a less-than-optimal operational decision. The feedback will also list each step taken, the order they took each step, and the time needed to complete the step. There are two scenario modes: Practice and Evaluation. Practice mode lets the student work through the scenario without being graded. A student can take up to three practice scenarios before tackling the Evaluation, or graded scenario.

• EPSS Mode—The AI/RWIS CBT continues to be a valuable tool even after the student completes the course. When the student finishes the CBT, a new feature is activated. This feature is known as the Electronic Performance Support System (EPSS) or EPSS Mode. The student can now access this feature through the Road Map icon on the Road Map screen. The EPSS Mode screen is divided into two main panels. The panel on the left includes a scrolling alphabetical list of discussion topics in the CBT. The student locates the topic they wish to review, highlights the topic by clicking on it, and then clicks on the "Go to Selected

Topic" button to jump to the first screen of that discussion. Above the alphabetical list of topics there is a Search field. Rather than scroll through the extensive list, the student can type the first few characters of the topic of interest and the list will automatically scroll to the first topic matching the characters the student typed in. On the right hand side of the screen, topics are organized into a content tree. If the student needs help, click the Help button. Jake will appear and provide the assistance needed.

END PRODUCT

Two versions of the CBT program, one generic and the other customized, will be completed and in use by the time this paper is presented. APWA and NACE selected the generic version while nearly all the states desired the customized version specifically tailored to the methods and chemicals used in their snow and ice control operations.

Feedback from the State DOT maintenance personnel and trainers who are preparing their customization needs indicates that the product exceeded their expectations. The CBT was easily installed on their computers and will fit well into their training program. The CBT will work well in either the group or individual training mode.

A metric version of the CBT is being prepared for use in the Canadian Provinces.

Simulator-Based Equipment Operator Training

JAMES M. EDSON
California Department of Transportation

The Caltrans Maintenance Equipment Training Simulator (CMETS) was developed in an effort to reduce vehicle accidents, extend equipment life, and enhance the overall safety of field maintenance employees. The eight full-mission simulators are housed in a 48-foot semi-trailer that travels throughout the state providing training. The primary target audience consists of new-hires with little truck driving experience, although experience has shown that employees from all skill levels can be challenged in the simulator. CMETS can simulate almost any engine and transmission combination found in our fleet, with truck types including 5- and 10-yd dump trucks, and tractor-trailer combinations. The driving world consists of a 50-mi^2 area with over 100 miles of roads. Road types include city streets, freeways, secondary roads, dirt and gravel roads, as well as snow-covered roads. Instructor controlled inputs include volume and behavior of autonomous traffic, day or night, clear or fog, wind gust, ice patches, and specific autonomous vehicle behavior. Simulated failures to own equipment include tire blowout, loss of oil or air pressure, and overheating. Driving parameters that are measured and recorded for each student include number of gear shifts, number of gear grinds, number of transmission failures, speed control, following too close, brake temperature, riding the clutch, turns or lane changes without signaling, collisions, and others. CMETS is fully self-contained, and includes an onboard 50 kW generator. Setup and breakdown time at any maintenance station is less than 15 min. Two instructors conduct the 1-h class, followed by a 3-h driving session.

As early as mid-1994, discussions were held at the California Department of Transportation's (Caltrans) Maintenance Equipment Training Academy (META) concerning the feasibility of using simulator technology to train the Department's equipment operators. These early discussions did not produce any recognizable movement towards achieving this goal. The Superintendent of META was handed the project in mid-1997, as a "spare time" effort.

Caltrans currently employs over 2,500 personnel in the classifications of Caltrans Equipment Operator I and Caltrans Equipment Operator II, and over 1,000 as Highway and Landscape Maintenance Workers. In addition, there are another 3,000 field maintenance employees in various classifications that regularly drive fleet equipment. As with any work force that size, there are good operators, and not-so-good operators. After passing the written and performance test for their classification, they are ranked and placed on an eligibility list. After being hired, they are trained and qualified on the individual pieces of equipment by personnel certified by META. They are also required to attend a mandated two-week training session at the META facility in Sacramento. Here, during the first week, they learn the basics of pre-operation inspection, lubricants, coolants, brakes, and other classroom topics related to the safe operation of equipment. The second week is spent in our training area. They learn to back a trailer, as well as the basics of loader operation and truck driving. One of the staples of our fleet is the 4-yd dump truck with an Eaton 5 and 2 transmission, and these are used exclusively at META for training. This is a very reliable transmission, but must be shifted precisely. Proper

shifting technique is essential, or damage to the transmission or rear end unit will occur. Over the years damage of this type has even occurred during the training process. One of the common mistakes made by a student is to force the transmission into reverse while moving forward. As can be imagined, something, and usually something expensive, has to give.

It was hoped that the use of simulation in the initial stages of training would reduce the frequency and severity of repairs attributed to poor shifting technique as well as operator induced repairs in general. An added enhancement would be a driving world that presented defensive driving challenges for increased driver safety.

SPECIFICATION

The approach to developing specifications for the simulator was rather simple, and non-technical. Of concern was the desired teaching objectives, the parameters to be measured, and the documentation of driver performance, not the technology used in achieving the simulation. Being unaware of the state of science in the field of vehicle simulation, a search for vendors was initiated. After developing a list of vendors, in January 1998, the Superintendent embarked on field visits to the companies having, or claiming to have, capabilities in vehicle simulation. Several had no product, but were engaged in research and development. These companies were eliminated from the competition. A Request for Proposal was then circulated to the remaining vendors.

Some of the parameters it was decided to try to quantify were: speed control, rpm control, gears grinds, shifting into reverse while moving forward, brake use and temperature, fatal and non-fatal collisions, lane change without signal, riding the clutch, following too close, and overall fuel economy. Simulated equipment problems would include loss of air pressure, loss of oil pressure, over heating, and front tire blowout.

The project vision was to incorporate a number of simulator stations in a mobile unit that would travel statewide, taking the training to the customer in the field. This further complicated the specifications, and challenged some of the remaining vendors. Detailed discussions were initiated with three final competitors, and the decision was made to award a contract to FAAC, Inc. of Ann Arbor, Michigan.

FAAC had been in business since 1962, primarily as a Department of Defense contractor designing and building weapons systems simulators. In 1989 they ventured into the commercial vehicle simulation market, and by 1998 had almost 100 single unit truck simulators in operation worldwide. They were the only competitor that could allow the Superintendent to drive their product in various configurations at multiple locations, allowing a complete evaluation of quality and capabilities.

ACQUISITION

The acquisition cost of approximately $1.4 was not within the Maintenance Program budget. Only about a fifth of that amount had been allocated for that fiscal year to fund this project. However, a commitment for $300,000 a year for the next five years was secured from the Maintenance Program Manager. Of course, the vendor was not interested in financing the project, so a loan was required. The California Department of General Services has an innovative program, GS $MART, that encourages a number of lenders to finance state, county, and municipal projects. The participating lenders have been qualified for doing business with the

State of California and the financing plans have been streamlined for easy reading and understanding. Maintenance Program had never used these services, but was able to borrow the $1.4 million from a company called Koch Financial, Wichita, Kansas, at a very favorable interest rate. The loan was structured with five annual payments of approximately $295,000 each, which just fit the promised allocation. The entire amount of the loan was funded into an interest bearing acquisition account from which initial and milestone payments were made to the vendor. The first payment was due to Koch Financial in November 1999. In May of that year, towards the end of our fiscal year, META was able to identify enough disencumbered funds within the Maintenance Program that the entire loan was paid off before the first payment was due. This saved about $180,000 in interest had the loan gone full term. Plus, the interest bearing acquisition account generated over $17,000 to the Department's favor during construction of the simulator, which was deducted from the demand statement at payoff.

ACCEPTANCE AND OPERATION

After numerous trips to Ann Arbor to test and validate what would become the Caltrans Maintenance Equipment Training Simulator (CMETS), the unit was delivered to California in June 1999. As it evolved, CMETS consisted of eight driving stations mounted in a 48-ft semi-trailer that travels throughout the state providing training (Figure 1). The primary target audience consists of new-hires with little or under-developed truck driving skill, although experience has shown that employees from all skill levels can be challenged in the simulator. CMETS can simulate almost any engine and transmission combination found in our fleet, with truck types including 5- and 10-yd dump trucks and tractor-trailer combinations.

The driving world consists of a fifty square mile area with over 100 miles of roads. Road types include city streets, freeways, secondary roads, dirt and gravel roads, as well as snow covered roads. Instructor controlled inputs include volume and behavior of autonomous traffic, day or night, clear or fog, wind gust, ice patches, and specific autonomous vehicle behavior. Autonomous vehicles (AVs) are those vehicles that react to student driver inputs. There are up to 40 AVs in any driving scenario. They generate, disappear, and regenerate in a mile circle around the driving truck. Traffic volume can be regulated from "none" to "heavy." Traffic behavior can be set from "well behaved" to "very aggressive." Instructors may cause AVs to cross over the centerline or stop abruptly for no apparent reason, testing the defensive driving skills of the student. Any four of the simulators can be network linked in the same driving world. This allows students to interact with each other, as well as react to the AVs. Initial CMETS training uses individual driving worlds, with each student in its own world.

Another notable capability of CMETS is the ability to store the last 30 seconds of driver performance on a continuous basis. This allows the instructor to stop action and replay the last 30 seconds leading up to an accident or incident, discuss the event with the student including possible tactics for avoidance, then go back 30 seconds again and let the student re-drive and continue, hopefully making adjustments to avoid the accident (Figure 2).

Driving parameters that are measured and recorded for each student include number of gear shifts, number of gear grinds, number of transmission failures, speed control, following too close, brake temperature, riding the clutch, turns or lane changes without signaling, collisions, and others. The record of completion for each student is downloaded and transferred electronically to the META training database. The employee master list is maintained within CMETS and is updated electronically.

FIGURE 1 CMETS ready for the road. Note the 50-kW generator mounted behind the truck cab.

FIGURE 2 Joe Santoro, CMETS Supervisor, driving, and Jan Bullinger, CMETS Superintendent, operating the replay–redrive keypad.

CMETS is fully self-contained, and includes an onboard 50-kW generator. Setup/breakdown time at any Maintenance Station is less than 15 minutes. Frequent breaks and cool ambient temperatures have allayed initial concerns over simulator sickness. The overall incidence rate of dizziness or nausea is about 5%, well below industry standards. We have found that a totally inexperienced driver can become familiar enough with driving a truck and shifting a manual transmission in one simulator session, that they can safely transition to training in a real truck.

TRAINING PLAN

CMETS entered operational service in September 1999. The training plan was developed for a target audience that was not familiar with simulation at all. The vast majority of our field employees fit into this target audience. The four-hour session is split into an hour of classroom training, followed by three hours of "stick time" in the simulator. The classroom training is PowerPoint based, and gives the student an idea of what to expect. Topics include truck cab layout, driving tips, shifting patterns and techniques, and description of the driving world. Once inside the truck cab simulator, the students are given a dry run of shifting patterns and techniques. Initially, they are started in a rest area on a freeway. During the first driving session, conditions are set to dry road, daytime, clear skies, and medium and well-behaved traffic. Each driving session is limited to about 30 minutes, and is followed by a critique period with the instructor. Summary score sheets are printed and discussed with each student. During the second session, drivers are started in town, simulating an urban driving environment. Most of them will find their way out of town, and experience driving on secondary roads, gravel roads, and even snow covered roads. During this session, the instructors will induce darkness and fog to further challenge the skill of the drivers. By the third session, each student is usually comfortable with the simulation and has adapted well to the driving tasks at hand. Instructor input during this session includes inducing erratic behavior among the AVs, and generally testing the defensive driving skills of the students. At the completion of the CMETS class, the driving summary is saved, and student participation recorded for later download to their individual training record.

Similar training plans have been developed for more advanced students and equipment types, including tractor-trailer combinations using 9 and 13 speed transmissions.

THE FUTURE

CMETS underwent a period of preventive maintenance and hardware and software upgrades in December 2002. Transition to new vehicle model software allowed new choices in vehicle types and performance for more realistic training. The addition of scripting tool software will allow CMETS to precisely script vehicle and pedestrian dynamics to enhance defensive driving scenarios. It may also allow for future development of in-house accident re-creation capability, something in which our Legal Division has expressed an interest. CMETS instructors have been certified by the Department of General Services and the American Automobile Association to provide defensive driver improvement training that complies with California government code and regulations. This allows the Division of Maintenance to comply with the recurring requirement for periodic Defensive Driver training as a side benefit to simulator-based operator training.

FINDINGS AND CONCLUSIONS

The effectiveness of CMETS has been difficult to quantify, but some general conclusions may be drawn. It has been well received in the field. Students quickly adapt to the simulator environment and receive the full advantage of pure training derived from actual driving experiences, with the advantage of real-time instruction, evaluation, and demonstrated improvement. Repeated sessions in the simulator show measurable improvement in driving and shifting skill and technique in the vast majority of cases.

During the period of July 1, 2001 to June 30, 2002, preventable accidents, other than backing, within the Division of Maintenance statewide decreased 5.94%. Of the 649 preventable accidents that occurred within the Division of Maintenance during this period, 206 were backing accidents. This represents an increase of backing accidents from the previous year of 22, and will be used as an indicator that simulator training should be expanded to include backing exercises in the basic curriculum. This can be easily accommodated as the driving world includes loading docks and other areas suitable for backing practice.

The Division of Equipment is currently unable to track and compare transmission repair costs to trucks that are a result of failures attributed to poor driving or shifting techniques. This would be interesting data, and will be pursued in the future as funding allows. Of note, since the inception of simulator training, no transmissions have been damaged during subsequent META training in Sacramento.

Also hard to measure are the close calls that could have been accidents had it not been for the defensive driver training received at CMETS. Operators will rarely report to their supervisor that they had a near miss or close call unless they were clearly not at fault. And if reported, there is no data gathering system in place to document this.

CMETS represented the apex of current technology when introduced in 1999. Its capabilities have continued to expand as technology and funding allowed, and it will be a valuable training aid well into the next decade. Results continue to be monitored, but the fact remains, even if only one major accident has been avoided, CMETS has paid for itself.

APPENDIX

Author Contacts

Teresa M. Adams
Professor
Department of Civil and Environmental Engineering
University of Wisconsin – Madison
1415 Engineering Hall
Madison, WI 53706
608-262-5318 or 608-266-1380
Fax: 608-266-5199
adams@engr.wisc.edu

Farideh Amiri
ITS Project Manager
Office of Traffic Engineering and
Intelligent Transportation Systems
Minnesota Department of Transportation
395 John Ireland Boulevard, MS 725
St. Paul, Minnesota 55155
651-296-8602
Fax: 651-215-0409
farideh.amiri@dot.state.mn.us

Duane E. Amsler, Sr.
AFM Engineering Services
80 Blessing Road
Slingerlands, NY 12159
518-489-6055
Fax: 518-453-6481
damsler3@nycap.rr.com

Henry Balikov
TechLaw, Inc.
14500 Avion Parkway
Chantilly, VA 20151-1101
703-818-1000
Fax: 703-818-8813
hbalikov@tlisystems.com

Karin M. Bauer
Principal Statistician
Midwest Research Institute
425 Volker Boulevard
Kansas City, MO 64110-2299
816-753-7600, Ext. 1468
Fax: 816-561-6557
kbauer@mriresearch.org

Curt A. Beckemeyer
Applied Research Associates, Inc.
ERES Consultants Division
505 West University Avenue
Champaign, IL 61820
217-356-4500
Fax: 217-356-3088
cbeckemeyer@ara.com

Lawrence J. Bilotto
Maintenance Programs Engineer
Pennsylvania Department of Transportation
PENNDOT District 9
1620 North Juniata Street
Hollidaysburg, PA 16648
814-696-7126
Fax: 814-696-7121
lbilotto@state.pa.us

Robert R. Blackburn
Consultant
16540 East El Lago Boulevard, Unit #9
Fountain Hills, AZ 85268
480-837-4445
Fax: 480-837-4445
rrblackburn@uswest.net

Robert Bourdon
VMS, Inc.
5171 Perignon Way
Coral Springs, FL 33067
954-227-1068
Fax: 954-755-2041
bbourdon@vmsom.com

Matthew Dull
Department of Political Science
University of Wisconsin, Madison
110 North Hall, 1050 Bascom Mall
Madison, WI 53706
608-251-6325
mdull@polisci.wisc.edu

James M. Edson
Chief, Maintenance Training Academies
California Department of Transportation
4338 Dudley Boulevard
McClellan, CA 95652
916-643-8802
Fax: 916-643-8875
Jim_Edson@dot.ca.gov

Gary Hoffman
Chief Highway Engineer
Pennsylvania Department of Transportation
400 North Street 7th Floor
Harrisburg, PA 17120
717-787-6898
Fax: 717-705-1560
gahoffman@state.pa.us

Manoj K. Jha
Assistant Professor
Department of Civil Engineering
Morgan State University
5200 Perring Parkway
Baltimore, MD 21251
443-885-1446
Fax: 443-885-8218
mkjha@eng.morgan.edu

Alison S. Lebwohl
Wisconsin Department of Transportation
4802 Sheboygan Avenue, Room 501
P.O. Box 7986
Madison, WI 53707-7986
608-266-8666
Fax: 608-267-7856
alison.lebwohl@dot.state.wi.us

Justin Maloney
Project Assistant
Department of Civil and Environmental Engineering
University of Wisconsin – Madison
1415 Engineering Hall
Madison, WI 53706
jmaloney@cae.wisc.edu

Tom Martinelli
Winter Operations Engineer
Wisconsin Department of Transportation
4802 Sheboygan Avenue, Room 501
P.O. Box 7986
Madison, WI 53707-7986
608-266-3745
Fax: 608-267-7856
thomas.martinelli@dot.state.wi.us

David Myzie
VMS, Inc.
245 East Drive, Suite 101
Melbourne, FL 32934
321-733-0052
Fax: 321-733-1269
dmyzie@vmsom.com

Jeff Schaeberle
TechLaw, Inc.
14500 Avion Parkway
Chantilly, VA 20151-1101
703-818-1000
Fax: 703-818-8813
jschaeberle@tlisystems.com

Leonard Schultz
Senior Transportation Engineer
Maryland State Highway Administration
Office of Maintenance
7491 Connelley Dr.
Hanover, MD 21076
410-582-5569
Fax: 410-582-9862
lschultz@sha.state.md.us

Kelly L. Smith
Applied Research Associates Inc.
ERES Consultants Division
505 West University Avenue
Champaign, IL 61820
217-356-4500
Fax: 217-356-3088
klsmith@ara.com

Leland D. Smithson
AASHTO SICOP Coordinator
Iowa Department of Transportation
Bureau of Research and Technology Transfer
800 Lincoln Way
Ames, Iowa 50010
515-239-1515
Fax: 515-293-1766
leland.smithson@dot.state.ia.us

David Soltis
TechLaw, Inc.
14500 Avion Parkway
Chantilly, VA 20151-1101
703-818-1000
Fax: 703-818-8813
dsoltis@techlawinc.com

Arlen T. Swenson
President
International Institute of Marketing Excellence
Mansion House #1212
300 North 4th Street
St. Louis, MO 63102
314-241-2157
Fax: 314-241-2157
Arlens96@aol.com

Kenneth Thornton
Chief Engineer's Office
Pennsylvania Department of Transportation
400 North Street
Harrisburg, PA 17120
717-783-3616
Fax 717-705-1560
kethornton@state.pa.us

Alan Vonderohe
Professor
Department of Civil and Environmental Engineering
University of Wisconsin – Madison
1415 Engineering Hall
Madison, WI 53706
608-262-9854
Fax: 608-266-5199
vonderoh@engr.wisc.edu

A. Battle Whitley, IV
North Carolina Department of Transportation
State Road Maintenance
1567 MSC
Raleigh, NC 27699-1567
919-733-3725
Fax: 919-733-1838
bwhitley@dot.state.nc.us

Steven J. Wilcox
Performance Management Program Engineer
Transportation Maintenance Division
New York State Department of Transportation
Albany, New York 12232-0337
518-457-6911
Fax: (518) 457-4203
swilcox@dot.state.ny.us

THE NATIONAL ACADEMIES

Advisers to the Nation on Science, Engineering, and Medicine

The **National Academy of Sciences** is a private, nonprofit, self-perpetuating society of distinguished scholars engaged in scientific and engineering research, dedicated to the furtherance of science and technology and to their use for the general welfare. On the authority of the charter granted to it by the Congress in 1863, the Academy has a mandate that requires it to advise the federal government on scientific and technical matters. Dr. Bruce M. Alberts is president of the National Academy of Sciences.

The **National Academy of Engineering** was established in 1964, under the charter of the National Academy of Sciences, as a parallel organization of outstanding engineers. It is autonomous in its administration and in the selection of its members, sharing with the National Academy of Sciences the responsibility for advising the federal government. The National Academy of Engineering also sponsors engineering programs aimed at meeting national needs, encourages education and research, and recognizes the superior achievements of engineers. Dr. William A. Wulf is president of the National Academy of Engineering.

The **Institute of Medicine** was established in 1970 by the National Academy of Sciences to secure the services of eminent members of appropriate professions in the examination of policy matters pertaining to the health of the public. The Institute acts under the responsibility given to the National Academy of Sciences by its congressional charter to be an adviser to the federal government and, on its own initiative, to identify issues of medical care, research, and education. Dr. Harvey V. Fineberg is president of the Institute of Medicine.

The **National Research Council** was organized by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and advising the federal government. Functioning in accordance with general policies determined by the Academy, the Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in providing services to the government, the public, and the scientific and engineering communities. The Council is administered jointly by both the Academies and the Institute of Medicine. Dr. Bruce M. Alberts and Dr. William A. Wulf are chair and vice chair, respectively, of the National Research Council.

The **Transportation Research Board** is a division of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's mission is to promote innovation and progress in transportation through research. In an objective and interdisciplinary setting, the Board facilitates the sharing of information on transportation practice and policy by researchers and practitioners; stimulates research and offers research management services that promote technical excellence; provides expert advice on transportation policy and programs; and disseminates research results broadly and encourages their implementation. The Board's varied activities annually engage more than 4,000 engineers, scientists, and other transportation researchers and practitioners from the public and private sectors and academia, all of whom contribute their expertise in the public interest. The program is supported by state transportation departments, federal agencies including the component administrations of the U.S. Department of Transportation, and other organizations and individuals interested in the development of transportation.
www.TRB.org

www.national-academies.org

TRANSPORTATION RESEARCH BOARD
500 Fifth Street, NW
Washington, DC 20001

ADDRESS SERVICE REQUESTED