Virginia Department of Transportation's Maintenance Quality Evaluation Program

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On the basis of initiatives to enhance productivity and effectiveness in highway operations, the Virginia Department of Transportation formally implemented a maintenance quality evaluation program on July 1, 1989. The objectives of the program are to monitor the overall quality of maintenance, point out areas of inconsistent performance, and provide a more formal process for ensuring that consistent levels of service are provided statewide. The program provides an evaluative assessment of Virginia's Interstate, primary, and secondary highway systems. It qualitatively assesses the level of maintenance for flexible and rigid pavements, stabilized roadways, roadway shoulders, drainage, traffic control and safety, roadside, and structures. Statistical techniques are used to ensure a random selection of inspection sites and a 95 percent degree of confidence that the results are representative of an entire roadway system. Virginia's quality evaluation program provides comprehensive and systematic reporting of actual maintenance conditions and compares them with approved maintenance levels of service. The program provides the "missing link" in the maintenance planning, budgeting, and evaluation processes.

Quality of work and reliability of data and information have become the hallmarks of a successful organization in recent years. Although the concept of quality assurance is not new to the corporate or governmental worlds, it is increasingly realized that quality is more than a general emphasis in the workplace. It is, in John Naisbitt's phrase, a megatrend—a new direction that transforms lives (*1*).

In a 1987 report to the governor and the General Assembly of Virginia, the Virginia Department of Transportation (VDOT) stated that "efficient, productive, and successful companies exhibit two essential characteristics: (1) they maintain close contact with their customers; and (2) they maintain an environment which promotes constant innovation" (*2*). VDOT's report indicated that the department would initiate a number of proactive measures to place it closer to its citizens and cited numerous innovative cost-saving plans, including the Maintenance Quality Evaluation (MQE) Program. This program was one of several that were developed to help VDOT meet its mission of providing safe, efficient, and effective ground transportation systems now and into the next century.

OBJECTIVES

The main objectives of Virginia's MQE Program are to

- Monitor the overall quality of highway maintenance,
- Point out areas of inconsistent performance, and
- Provide a more formal process for assuring that consistent levels of service are provided statewide.

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LITERATURE SEARCH

The MQE section was formed in the fall of 1987 and staffed in January 1988. A literature search of all the states, FHWA, and TRB was subsequently initiated to determine what analytical programs, processes, or procedures existed that assessed all types of maintenance levels of service. Of particular interest were evaluation programs that assessed major maintenance items, such as the eight for which desired maintenance quality levels were defined in a VDOT document (*3*). These elements included flexible and rigid pavements, stabilized roads, hard and nonhard surface shoulders, drainage, traffic control and safety, roadside, and structures.

It was also important that the MQE Program, when implemented, be able to assess the level of maintenance quality by highway system and to assess rural and urban areas collectively and independently.

The program selected would also provide a confidence level of 95 percent relative to the maintenance quality rating. Ideally, the mechanism utilized during field inspections to identify whether maintenance quality was acceptable would be a simple yes or no designation.

There were 33 responses to the 51 requests for information on formal MQE programs. Five states (California, Florida, Iowa, Mississippi, and Ohio) had formal programs. Four states (Alabama, Maryland, North Carolina, and Texas) had informal programs. Formal programs are defined as those that assess all of the major maintenance elements indicated above on a statewide level and include a systematic numerical rating system, usually on a computer data base.

The literature search also included more than three dozen sources, which were reviewed to determine current practices and methods. A copy of the bibliography is available from the authors.

PROGRAM DEVELOPMENT

Maintenance Characteristics

During initial program development, the eight major maintenance elements represented in the VDOT document (*3*) were divided into 45 subelements or characteristics. For example, traffic control and safety, a major element, was divided into seven maintenance characteristics: signs, pavement

markings, signals, luminaires, barriers, delineators, and object markers. The purpose was to allow the ability to determine the reasons for a specific element's quality rating. For example, if traffic control and safety had an unacceptable rating, a review of each of the characteristics composing the element would allow a determination as to which characteristics caused the unsatisfactory rating. This would allow a concentrated effort, if necessary, to improve the quality of maintenance provided within the major element.

Maintenance Condition Standards

Maintenance quality standards or conditions were also designed and developed. The purpose of the conditions was to identify, by maintenance characteristic and highway system, what represented an acceptable level of maintenance quality. In addition, the conditions were intended to be the primary determinant of the inspection team's evaluation of maintenance quality, not only for a specific sample site but also for the entire highway system rating. A summary listing of some of these condition standards for each of the major maintenance elements is given in Table 1.

Preliminary Mapping

During this phase, computer-generated sample sites were identified, highlighted, and routed on state and county maps as well as inventory mileage records. The process was normally completed in the office before the inspection crew left to evaluate the sites, which contributed to efficiency.

Sampling Technique

To ensure the feasibility and validity of the program, it was necessary to use a technique that would determine a representative sample of the total roadway population.

The MQE unit developed a technique that randomly sampled all types of roadway systems on a statewide basis. The unit used the same statistical application as did the Florida Department of Transportation (*4*), which was validated by Florida State University's Statistical Consulting Center, and a sample size formula (*5*) (see Figure 1) that was validated by Virginia Commonwealth University's Institute of Statistics. The sampling plan was reviewed by VDOT's Research Council located in Charlottesville. Under the program, each highway system would be evaluated separately. A pilot sample of 50 randomly selected sites on each highway system was chosen to determine a representative "failure rate." Failure rate was defined as the percentage of sites that did not meet the desired levels of service. The failure rate percentage is a constraint of the sample size formula (Figure 1). The failure rates identified through the pilot sample were 30 percent for the Interstate system and 23 and 25 percent, respectively, for the primary and secondary systems.

On completion of field inspections of the pilot samples, the MQE unit calculated the centerline mileage for each of VDOT's three highway systems. Because each sampled site was 0.1 mi long, the centerline mileage had to be multiplied by 10 to obtain the true size of the population. With these data, plus the desired confidence level of 95 percent and precision rate of 4 percent, the sample size for each highway system could be determined.

The sites to be evaluated were generated through a mainframe computer random-sampling process. Additional sites were normally requested as alternatives if the inspection team encountered maintenance or construction work in progress.

Field Inspections

Through an analysis of the methodologies employed by the field inspection teams of other states, as well as what would be required of Virginia's inspection process, it was determined that an inspection team should consist of two individuals. This size would contribute to objectivity during the comparison of actual with desired quality of maintenance at a given sample site and would enhance the overall safety and productivity of the crew. Safety of the inspection crew and the public was of the utmost importance at all times.

The field inspection was performed by walking along the inside and outside shoulders for the entire 0.1-mi sample site and assessing current maintenance conditions for all inventory items within VDOT's right-of-way. Appropriate measurements of standard criteria were made as well as recording a "yes" if the actual condition met the desired maintenance standard or "no" if it did not.

The ratings were recorded on a form that listed all eight maintenance elements and each of the 45 maintenance characteristics. Lap-top computers were also programmed with these data and used increasingly as the automated capabilities of the MQE Program were enhanced.

PROGRAM VALIDATION AND FIELD TASK FORCE

Validation of a program of this scope and magnitude is extremely important. It is also important that the program be accepted by those who will make strategic decisions from the resulting findings and recommendations and by the field managers whose maintenance effort will be judged relative to quality level. Therefore, a task force was formed consisting of six maintenance field managers with an average of 23 years of highway experience. They had experience at the district and residency office levels and represented five of VDOT's nine highway districts. It was believed that the field managers could provide the MQE unit with valuable insights as to what was normally considered an acceptable level of maintenance. In addition, the quality of the validation of the formula weights assigned to each maintenance element and characteristic would be enhanced.

Before visiting each of the 200 sample locations selected for the validation process, the task force reviewed the proposed MQE Program. This completed the program's development phase.

The task force members were asked to assign a weight from 1 to 100 to each maintenance element and from 1 to 10 to each maintenance characteristic. The scores were averaged to obtain the formula weights used in the calculation of an overall maintenance level-of-service score.

TABLE 1 VIRGINIA MQE PROGRAM QUALITY STANDARDS

ELEMENTS OF QUALITY STANDARDS FOR TRAVELED WAY, FLEXIBLE - CRACKING, RAVELING, RUTTING, SHOVING/PUSHING, BLEEDING/FLUSHING, RIDE QUALITY, POTHOLES, DISTRESS

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

CRACKING	95% of the Interstate, 90% of the Primary, and 85% of the Secondary urban and rural pavements are free of severe cracks (i.e., 1/4" or greater in width).
RUTTING	90% of the Interstate, 85% of the Primary, and 75% of the Secondary urban and rural systems are free of severe rutting (i.e., 3/4" or greater in depth).
POTHOLES	The Interstate system is free of potholes, the Primary system has less than three, and the Secondary system has less than five potholes 4 inches in width or greater; 100% of all highway systems are free of potholes that present a tire or safety hazard.

ELEMENTS OF QUALITY STANDARDS FOR TRAVELED WAY, RIGID - CRACKING, SPALLING, FAULTING, JOINT MATERIAL, RIDE QUALITY, POTHOLES

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

SPALLING	There are no occurrences of severe spalling (i.e., 3" in width or 2 feet in length) on the Interstate, no more than one occurrence on the Primary, and no more than two occurrences on the Secondary urban and rural systems.
FAULTING	100% of all Interstate, Primary, and Secondary urban and rural systems are free of severe faulting (i.e., 1/2" or greater in height) and severe longitudinal joint separation (greater than 1/2" in width).
JOINT MATERIAL	75% of required joint material is present and functioning as intended in each joint on all Interstate, Primary, and Secondary roadway systems.

ELEMENTS OF QUALITY STANDARDS FOR TRAVELED WAY, STABILIZED - DUST CONTROL, RUTTING, POTHOLES, CORRUGATIONS

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

DUST CONTROL	75% of all Primary and Secondary roads along residential and commercial sections with at least 10 ADT are free of dust clouds that partially obstruct visibility rising above the truck of the vehicle.
RUTTING	All Primary and Secondary roads are free of rutted areas that average 2 inches in depth over a 25 foot section and there are no occurrences that are 3 inches or greater in depth.
CORRUGATIONS	All Primary and Secondary roads are free of corrugations that average 1-1/2 inches in depth over a 25 foot section on the roadway surface area and that are greater than 3 inches in depth.

TABLE 1 (*continued on next page*)

ELEMENTS OF QUALITY STANDARDS FOR SHOULDERS, HARD-SURFACED - DRAINAGE, DISTORTION, JOINT SEPARATION, FAILURE

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

DRAINAGE	100% of the shoulder is free of any evidence of severe flooding, ponding, pumping, or erosion, and there are no occurrences of a level or greater slope for all highway systems.
DISTORTION	90% of the elevation between the traffic lane and shoulder does not exceed 1/2 inch on the Interstate system or 3/4 inch on the Primary or Secondary system.

ELEMENTS OF QUALITY STANDARDS FOR SHOULDERS, NON-HARDSURFACED - DRAINAGE, DISTORTION, RUTTING

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

DISTORTION	90% of the edge drop-off or build-up between the traffic lane and shoulder does not exceed 1-1/2 inches on the Interstate or Primary system, or 2-1/2 inches on the Secondary system.
RUTTING	90% of the shoulder on the Interstate system and 80% of the shoulder on the Primary and Secondary systems are free of occurrences of rutting 2 inches or greater in depth.

ELEMENTS OF QUALITY STANDARDS FOR DRAINAGE - DITCHES, CULVERTS, CATCH BASINS/DROP INLETS, CURBS AND GUTTERS

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

DITCHES	50% or more of roadside and outfall ditches are unobstructed by soil or impermeable material and functioning as intended, and 75% of all paved ditches are structurally functioning as intended on urban and rural roadways for the Interstate, Primary, and Secondary systems.
CULVERTS	50% or more of the culvert is unobstructed and functioning as intended on urban and rural roadways for the Interstate, Primary, and Secondary systems.

ELEMENTS OF QUALITY STANDARDS FOR TRAFFIC CONTROL AND SAFETY - SIGNS, PAVEMENT MARKINGS, SIGNALS, LUMINAIRES, BARRIERS, DELINEATORS, OBJECT MARKERS

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

SIGNS	90% of roadway signs are functioning as intended and are at least 7 feet in height on all Interstate, urban Primary, and urban Secondary systems, and 5 feet in height from the shoulder on the rural Primary and Secondary systems. Overhead signs should be mounted at a minimum height of 17 feet on structures and 19 feet on cantilevers or double poles from the highest point in the roadway.
PAVEMENT MARKINGS	100% of pavement markings are visible up to 120 feet and functioning as intended on all highway systems. 100% of all roads requiring centerlines and/or edgelines are marked accordingly. Special markings and 70% of raised/recessed pavement markers are functioning as intended.

TABLE 1 (*continued on next page*)

TABLE 1 (*continued*)

BARRIERS	95% of all wooden fences and 100% of sound/noise barriers are aligned properly and free of missing or broken sections; and 95% of all metal fences/cable guardrails are taut, properly secured to posts and free of protruding metal parts. 90% of each continuous guardrail section does not have missing rails or parts, dents, rust, or interruptions within a section, and is a minimum of 27 inches high.

ELEMENTS OF QUALITY STANDARDS FOR ROADSIDE - MOWING, LITTER & DEBRIS, TREE/BRUSH CONTROL, LANDSCAPING, SIDEWALKS

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

MOWING	95% of the vegetation on all areas has a (1) minimum height of 6 inches, (2) maximum height of 16 inches on Interstates, high type Primaries, et al., and (3) maximum height of 18 inches on low type Primaries and all type Secondaries. 95% of medians in excess of 50 feet and roadside areas are mowed to the ditch line in cuts and to top of slope in fills. If median is 50 feet in width or less, 95% of the entire median is mowed. For the first mowing after July 1 and the final mowing: 95% of the entire median is mowed and 95% of the roadside is mowed one swath beyond the ditch line and one swath down fill slopes. 100% of the mowing at intersections and curves is adequate to assure safe sight distance for traffic safety. 95% of the urban and rural highway systems are free of weeds in areas around sign posts, guardrail, head walls, and in paved ditches and paved shoulders.
TREE/BRUSH CONTROL	100% of all highway systems has no encroachment of tree limbs within a vertical clearance of 15 feet over the pavement. 100% of the right-of-way has no dead or live leaning trees that present a hazard to pedestrian or vehicular traffic. 100% of all tree and brush encroachment within the right-of-way is controlled at all bridges, curves, intersections and signs to provide adequate sight distance for traffic safety.

ELEMENTS OF QUALITY STANDARDS FOR STRUCTURES - DECK DISTRESS, EXPANSION JOINTS, PARAPETS, BEARING DEVICES

EXAMPLES OF CHARACTERISTICS MEETING THE DESIRED CONDITIONS:

DECK DISTRESS	90% of the deck surface is free of severe pavement failures and 75% of all scuppers are unobstructed and functioning as designed.
EXPANSION JOINTS	100% of all expansion joints are flush with the deck and 75% of the material in each joint is present and functioning as intended.
PARAPETS	100% of the parapets, railings and sidewalks are free of severe spalling, severe cracking, severe faulting, severe misalignment, missing bolts, blunt railing ends, potholes, and voids between the deck and the parapet.

NOTE: A complete listing of maintenance characteristics and associated quality standards is available by request.

SAMPLING FOR QUALITY

-CONCERNED WITH PROPORTIONS (RATIOS) THAT MEET DESIRED LEVELS-OF-SERVICE (LOS)

-RECOMMENDS FIRST PROPORTION BASED ON PILOT SAMPLE

-COMPARES ACTUAL MAINTENANCE CONDITIONS TO APPROVED STANDARDS

-REQUIRES A YES/NO DECISION

SAMPLE SIZE FORMULA:

$$n = \frac{Z^2 \times N \times p\,(1-p)}{(A^2 \times N) + (Z^2 \times p\,(1-p))}$$

n = SAMPLE SIZE

N = POPULATION SIZE (Centerline Mileage X No. of 0.1 mi. Sites/Mile)

p = EXPECTED PROPORTION THAT DOES NOT MEET DESIRED LOS

A = DESIRED PRECISION

Z = CONFIDENCE LEVEL COEFFICIENT (95% = 1.96; 90% = 1.64)

FOR EXAMPLE:

$$n = \frac{(1.96)^2 \times (1{,}027.71 \times 10) \times .30\,(1-.30)}{(.04^2 \times (1{,}027.71 \times 10)) + (1.96^2 \times .30\,(1-.30))} = 8291 \div 17.25 = 481$$

Therefore, a sample size of 481 would be needed for a 95% confidence level and a 4% precision rate to arrive at a statistical conclusion of centerline mileage on the Interstate System Statewide. As the population is stratified (e.g., by highway district), the sample size will increase. The sample size will also increase if "p" increases.

FIGURE 1 Virginia MQE Program sample size formula.

While on site, the field managers were asked to assess whether current roadway conditions were within the department's maintenance policies. "Yes" meant that the field conditions for each maintenance characteristic were within the policy; "no" meant that the characteristic was not within the policy. They were also asked to compare their professional evaluations with the written quality standards and make recommendations for adjustments as necessary. The "yes" or "no" answers were entered into a lap-top computer on site. The task force members were then asked to rate the sample section from 1 to 10, and their answers were compared with a weighted score derived from the lap-top computer's Lotus 1-2-3 programmed formula.

"What if" analyses were made using the lap-top computer to determine an overall numerical value for the site, which would show whether the roadway section was within maintenance policy. If the site was within policy, the task force members were asked to "fail" maintenance characteristics until the site was not within policy. The same "what if" analyses were made if the original weighted score showed that the site was not within policy; that is, the task force members were asked to "pass" some characteristics until the overall section was within policy. In this manner, overall statewide qualitative numerical level-of-service ratings were obtained. It was determined by the task force that the maintenance level of service should be 80 on the Interstate and primary systems and 75 on the secondary system.

PROGRAM IMPLEMENTATION

After an exhaustive program development and validation effort, VDOT's MQE Program was formally implemented on July 1, 1989. From the task force's validation effort, it was determined that only two of Virginia's three highway systems could be evaluated annually with existing staffing levels; however,

these systems would be rated twice each year to take into account seasonal influences on maintenance. For example, during fiscal year 1989–1990, the Interstate and primary systems were evaluated.

The Interstate system was rated in the summer and winter, whereas the primary system was rated in the fall and spring. During fiscal year 1990–1991, the Interstate system will be rated in the fall and spring, and the secondary system will be rated in the summer and winter.

This alternating process will continue each year. The evaluation ratings provided through these inspections will provide an accurate assessment of a highway system's overall quality of maintenance on a statewide basis. It is anticipated that increased staffing in the future will allow more specific evaluative assessments down to the individual highway district and residency level.

CONCLUSION

"Quality is measurable," according to Tom Peters, author of a best-selling management book, and "measurement is the heart of any improvement process," according to senior IBM quality manager Jim Harrington (*6*). Virginia's MQE Program will provide comprehensive and systematic reporting of actual maintenance conditions and a comparison of current conditions with approved maintenance levels of service.

It is also anticipated that Virginia's MQE Program will assist the planning process by creating a foundation for systematically determining maintenance resource needs. Analysis of the quantitative data provided by VDOT's maintenance management system and the qualitative data provided by the MQE Program should provide valuable insight into problems that cause inefficient use of personnel, equipment, and materials.

This information will be valuable to the central office and field planning processes by bringing the overall maintenance operation into clearer focus. It should also provide management with better control and accountability relative to maintenance program expenditures and accomplishments.

Although refinements may be necessary, the program in its present form can be an effective tool in management decision making by identifying maintenance needs and helping to standardize the maintenance levels of service throughout the state. VDOT is both excited and confident that the MQE Program will provide the "missing link" in effectively connecting the maintenance planning, budgeting, and evaluation processes.

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