INTRODUCTION

On April 7 Garrett County, Maryland, maintenance employees went on strike. Today, more than seven months later they are still on strike. No maintenance work has been done in seven months, motor grader tires are flat, trees are growing into road shoulders and potholes have grown to gigantic proportions. County roads scarred by winter snows and fall rains are crumbling, yet the public continues to go about its business in a near normal fashion.

Recently the Comptroller General of the United States recommended to Congress that the Secretary of Transportation should require the Federal Highway Administration to establish maintenance standards that define a State maintenance responsibility and take positive action to improve the pavement rating system (1).

A forecast of maintenance budget level requirements in Ohio illustrates the effect of varying levels, maintenance levels, and quality standards on the projected budget during the period ending 1980-81. Tallamy estimates that Ohio should spend $63 million to provide a minimal level of maintenance in 1970, but $81 million could be spent to provide a maximum desirable level(2).

These examples share a common element, all are concerned with maintenance quality standards. What do we mean by the term maintenance quality standard? Why do we need a quality standard? Where can we make use of standards? How can we obtain unbiased measurements of maintenance quality? Or simply, how well should the existing highway be maintained?

Business can use profitability as a measure of the success of its activities, but a highway department cannot measure success in terms of a balance sheet. It needs a yardstick that does for it what profitability does for business.

California defines maintenance quality standards thusly (3):

"Quality standards or levels of maintenance define the way a road and its appurtenances should look, serve and be preserved as a result of the maintenance effort."

Quality standards are needed and should be used to assess the physical integrity of the highway facility, the safety afforded to the user, riding comfort and visual appeal. Properly used they give an unbiased method for evaluating maintenance procedures and practices, promote a uniformly high level of maintenance and insure responsiveness to differing needs for different road classes. They foster improvements in the quality and applicability of personnel, equipment, materials and methods used in maintenance programs. They can offer justification for prorating funds to sub-units on the basis of demonstrated need and can be used as a public relations tool justifying requests for additional maintenance funds (4).

Unfortunately, standards are not universally used in maintenance operations. It would seem self-evident that the quality of maintenance service rendered on high traffic volume urban highways should be of a higher order than on low volume rural roads, yet 60 percent of the state highway departments do not officially distinguish between the classes of highways in their maintenance procedures, 66 percent do not set standards for physical maintenance on traffic volumes and 52 percent do not set different levels of service criteria (5).

One of the main problems faced by maintenance personnel in carrying out their operations is not how or with what, but when; too soon wastes scarce dollars and too late invites disaster. A lack of understanding of basic principles can lead to degrading rather than improving the facility. The judgment of individuals, however experienced, has been shown to be subject to wide variation and standards vary widely from area to area.

COSTS ATTRIBUTABLE TO DEFICIENT MAINTENANCE

Dr. Istvan Kazary showed, Fig. 1, that truck speed was affected by pavement roughness (6). Slower speeds caused by road roughness increase transportation costs. There are other costs as well. The presence of maintenance crews on the road can restrict traffic and increase motorists costs.

"On some roads the cost of traffic delays can exceed the total cost of all the maintenance operations on the carriageways." (7)

Good lighting may reduce night time accidents, but resurfacing to correct a slippery pavement condition can result in an increased number of night time accidents (8). Lighting is designed to produce a certain level of illumination at the road surface and decreases due to failure to keep lamps clean, can be expected to result in additional night time accidents. Figure 2 illustrates the effect of cleaning on efficiency. It shows efficiency curves for a street lighting system (a) ideally clean, (b) uncleaned, and (c) indicates the difference in loss of light per year, 0.4 percent of the design lumens over 4,000 hours (9).
Fig. 1. Relation between the average track surface unevenness and the average speed of the vehicle

Fig. 2. Effect of cleaning on installation efficiency (street lighting system)

Cobbe and Ridley found (Table 1.) that standards of maintenance of traffic signals is far from ideal as illustrated by the number of inspections and faults reported by Scotland Yard (10).

Similar studies in the United States may or may not show comparable results, the data is cited to point out that maintenance vigilance is required if our highway systems are to operate at maximum efficiency.

The problem of slippery pavements has received a great deal of attention and research findings now provide guidance to the maintenance engineer, but the work should be based on cost-benefit considerations. One can very well question the need for resurfacing pavement surfaces on the single criterion of skid number. A Road Research Laboratory report states this clearly (11).

"Logically the decision on the standards of skidding resistance should be made on a cost-benefit basis; instead of basing the standards on a chosen level of "skidding rate," i.e. accidents, a balance should be made between the cost of accidents involving skidding and the cost of maintaining the road surface at the corresponding level of skidding resistance. This balance should be struck separately for different types of roads."

QUALITY STANDARDS IN USE

Let's consider some maintenance quality standards which are currently in use. Several State highway departments have assembled quality standards in book form such
### Table 1. Number of Inspections and Faults Reported by Scotland Yard in the Metropolitan Police District

<table>
<thead>
<tr>
<th>Year</th>
<th>Number of Inspections Made</th>
<th>Number of Faults Reported</th>
</tr>
</thead>
<tbody>
<tr>
<td>1962</td>
<td>4889</td>
<td>1505</td>
</tr>
<tr>
<td>1963</td>
<td>5214</td>
<td>1445</td>
</tr>
<tr>
<td>1964</td>
<td>4216</td>
<td>1333</td>
</tr>
<tr>
<td>1965</td>
<td>4086</td>
<td>1255</td>
</tr>
<tr>
<td>1966</td>
<td>4703</td>
<td>1037</td>
</tr>
<tr>
<td>1967</td>
<td>4197</td>
<td>1676</td>
</tr>
<tr>
<td>1968</td>
<td>4533</td>
<td>2013</td>
</tr>
</tbody>
</table>

#### Fault Incidence

<table>
<thead>
<tr>
<th>Fault</th>
<th>Incidence</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum green time longer than setting (average 8.6 seconds too long)</td>
<td>On 11.4% of signal controllers</td>
</tr>
<tr>
<td>Maximum green time shorter than setting (average 8.4 seconds too short)</td>
<td>14.3% of signal controllers</td>
</tr>
<tr>
<td>Permanent demand on one phase</td>
<td>10% of signal controllers</td>
</tr>
<tr>
<td>Difference between setting of inter-green period and observed duration (average 2.6 seconds too long)</td>
<td>5.7% of signal controllers</td>
</tr>
<tr>
<td>Detectors malfunctioning</td>
<td>20% of signal controllers</td>
</tr>
</tbody>
</table>


We can compare standards for similar work items from these references. First, snow removal. Lady suggests that Urban Roads in Great Britain of first priority should be salted within one hour of warning or snowfall (12). California requires that snow should be removed from State highways as it falls . . . chemicals should be spread on the pavement at the beginning of a snowstorm. Washington's quality standard states, in part, "Priority-one class highways require that a continuous effort be made with sufficient equipment and personnel to prevent an excessive accumulation . . . snow plowing should have begun after an accumulation of 1/2 inch to 1 inch and before the snow becomes packed."

An FAA report states " . . . we will use a commonly accepted criterion, namely that runway clearance should take place when the accumulation reaches 1-1/2 inches of snow (13)."

The latter report also suggests that the effectiveness of a snow removal operation be defined by the time period during which traffic is interfered with when a clearance operation takes place. Miller and Ross used a similar criterion (14). They used the term "Storm impact period" as a measure of quality of ice and snow removal and defined it as the length of time that a road was not in a normal condition.

Storm impact periods could be shortened considerably by using currently available ice detection systems. A system of buried detectors coupled with a central computer facility have made it feasible to predict, with high accuracy at 5:00 p.m., that ice will form on pavement the following morning and with even more precision that ice would be forming within two hours (15). This system is expensive but reasonably accurate predictions are also available through the U. S. Weather Bureau and private forecasting services.

Accurate predictions make possible timely preventive treatments to prevent roadway icing. The public benefits from improved service and the maintenance organizations cost of deicing is considerably reduced.

Scotto demonstrated, in the Italian Alps, that preventive treatments of liquid calcium chloride provided a better distribution of material, prevented scattering of the solid material by traffic and that a higher efficiency resulted. Experiments showed that preventive treatments performed are far more efficient than those carried out with solid deicing chemicals, even when the amount used
is lower (16). Maintenance units in Michigan and North Dakota have also experienced success with use of brines for deicing purposes.

Thus research has shown a way of defining maintenance quality, a means for timing application of deicing chemicals and a better way to use chemicals in a snow and ice control program.

Another area in which research has provided a substantial body of knowledge concerns driver comfort related to road roughness and measured by road roughness indicators.

Last year reporters for the Chicago Tribune used a Wisconsin Road Meter to evaluate riding conditions on thousands of miles of Illinois highways and reported their findings in a series of newspaper articles. A Wisconsin roadmeter measures road roughness by automatically recording movements of the recording vehicles rear axle on a counting device. The reporters used the following classification:

- **0 - 75** — smooth
- **75 - 125** — slight roughness
- **125 - 200** — rough
- **200 - 300** — jarring and decidedly uncomfortable
- **300 - 350** — steering affected
- **350 - 400** — dangerous
- **over 400** — indescribable

Use of a Roadmeter by reporters is unusual, but a number of State highway departments are using similar instruments for the purpose of evaluating and ranking State highway systems pavement condition. Utah reported on a system employing the roadmeter at the HRB summer meeting, and Washington, now using a subjective rating system, is considering use of a similar roadmeter to eliminate some of the bias in their system.

The Asphalt Institute recommends that measurements of roughness be made with the BPR roughometer and suggests that corrective measures are needed when a roughometer reading exceeds 150-175 inches per mile, corresponding roughly to a PSR rating of 2.0 to 2.5 (17).

These instruments can be manufactured inexpensively (Minnesota constructed ten at a cost of about $700 each) and can be useful adjuncts to maintenance program planning. Roy Jump, Idaho Department of Highways, used roughometer measurements and a terminal quality standard of 2.5 PSI in forecasting long-range needs for asphaltic concrete overlays on Idaho highways. His experience in Idaho leads him to believe that in order to sustain an asphaltic pavement above a 2.5 serviceability index in that State, seal coats must be placed at the 2nd, 10th, 20th, 25th, and 30th years after the initial construction, with overlays at the 18th and 32nd years.

Averages of this sort are useful devices for long range planning but are not desirable for programming and scheduling work on a short range basis. A maintenance planner needs to have quality standards which enable him to define objectively the point to which a surface has deteriorated through erosion, surface polishing, rutting, etc. It has been established that a past practice of leaving such determinations to individual judgment can be improved by use of objective studies.

The University of Minnesota has been developing criteria to determine the need for seal coating on bituminous surfaces and found that a sand seal was not suitable when used as a correction for a large number of transverse cracks, or longitudinal cracking, nor as a means for improvement for the abraded condition of such cracks, even though some engineers have placed sand seals to correct such conditions (18).

Rather specific criteria have been established for rutting in several States. This is important because it has been reported that a water film thickness of only 0.02 to 0.09 inch is necessary for hydroplaning to occur with smooth tread tires, while if a ribbed tread is used, a water film thickness of 0.2 to 0.3 inch is necessary (19).

Ponding of water on road surfaces should be prevented by eliminating rutting, or possibly by providing water escape channels by constructing a rough textured pavement surface.

It may be desirable to prevent water depths from exceeding 0.25 inch but this is a seemingly impossible standard for a highway organization to meet. On the other hand, failure to meet this requirement will result in wet weather accidents due to hydroplaning. An alternative, which at least one highway department is considering, is to ask the State legislature to set weather speed limits.

A number of organizations have set less stringent standards in an attempt to minimize accidents within practical limitations. The Road Research Laboratory (Great Britain) proposes 1/2 inch as a standard, Minnesota uses 1/2 inch and Washington specifies a 1/2 inch requirement for interstate highways and applies a 1 inch standard to low volume roadway surfaces (20).

Logically, decisions on these matters should be made on a cost-benefit basis. Resurfacing decisions should balance the costs of accidents or loss of service against the cost of maintaining the surface to a preset standard.

Researchers in West Virginia have approached the skidding problem from that point of view. Campbell and Titus concluded that the state of West Virginia can afford to spend up to $2000 annually for every accident eliminated (21). They are using cost-benefit analyses of high accident sites involving slippery pavements to develop a program of de-slicking projects.

Mowing is a maintenance work function to which quality standards can be applied with beneficial results. A mowing criterion based simply on length of grass is not realistic unless all grass grows at the same rate, seeds in the same fashion, and matures at the same time. Texas Highway Department engineers developed their "Mowing Standards" after careful study of plant requirements along Texas highways. They considered such varying demands as different standards for urban and rural roads, the possibility of fire along dry roadsides and the prevention of erosion (22). Mowing is not started in some areas until wild flowers have developed mature seeds.
The Standard recognizes that some grasses, such as Bermuda grass, spread from runners and can be cut quite short. On the other hand, Western Wheat grass spreads by increasing the size of the leaf area above ground and it is essential to maintain a higher minimum cutting height to encourage growth.

Centerline painting is another area that benefits from attention to quality standards. A continuing problem attendant to determining the life of a given marking material is deciding whether or not a given marking is still performing effectively.

"Normal life for a given marking material is difficult to establish because of a number of variable factors, . . . (including), . . . Different engineers' assessments of whether or not a given marking is still performing effectively." (23)

Standards differ; for example, the Road Research Laboratory suggests that road markings should be renewed when more than approximately 20 percent of their area becomes worn away or ineffective (20); the Massachusetts Department of Public Works, in their contract pavement markings program, requires the paint contractor to replace markings when they are equal to or less than photographic reference No. 4 as outlined in ASTM D-821, or reference No. 4 as outlined in ASTM D-913 over 25 percent or more of their width or length (24); New York used as a criterion the point at which a single observer determined that 50 percent wear of the stripe had occurred (25); and Kansas used both relative brightness and percent chipped as criteria (26).

Applying criteria can result in rather large expenditure reductions. Kansas was able to reduce material costs by $6.98 per mile of two lane Federal or State highway, without sacrificing quality, by reducing wet paint film thickness from 12 to 10 mils. Massachusetts guaranteed maintenance program for contract striping has induced paint manufacturers to begin to think about variations in materials supplied. Some suppliers theorize that economical procedures would employ expensive but durable materials on high wear sections, such as curves, and less durable and expensive materials on sections not subject to high wear rates, such as long tangents. A wide-spread changeover by highway departments in the way they measure performance and an encouragement of paint application by contract on end result specifications with maintenance guarantees might provide great impetus to reductions in the cost of our pavement striping programs.

It would be even better to use more appropriate criteria than brightness and wear. The ability to separate traffic would be a more appropriate criterion; although it would be difficult to develop and apply.

In the future as in the past, it is likely that maintenance decisions will be based on inspections. Nothing under study is likely to supplant on-site viewing of roads but subjective judgment is no longer the sole basis for decisions. Research has developed a number of devices to assist the engineer to perform inspections of consistent quality but instruments do not give opinions and cannot adjust to unprogrammed requirements. They can't rely on their experience and judgment to tell us what they found, but on the other hand, they can't give a bad opinion. They report back what they find in factual, objective terms and we make judgments.

**EVALUATION EQUIPMENT**

Bridge durability is of such wide-spread concern that it seems appropriate to start a description of survey equipment by referring to the corrosimeter developed in the course of a California Division of Highways study now being demonstrated on a national basis by the Federal Highway Administration. The meter is quite simple in operation. One lead is attached to the reinforcing steel and another lead to a copper plate on a moist sponge. The leads from these electrodes are attached through an ohmmeter thus providing measurements of the electrical resistance from the reinforcing steel through concrete, membrane or overlay. The meter indicates the presence of active corrosion and it may be possible to use the device to predict bridge deck distress. The threshold voltage could be used as a quality standard, the point at which corrective action should be initiated in planning for repair work and for programming repair funds.

Pavement roughness has received a great deal of attention. Many years ago the Pennsylvania Railroad measured track roughness indirectly by determination of water spillage from a graduated container mounted in a railway office car. Since that time both railroads and highway agencies have made great advancements.

State highway departments now have available sophisticated devices for measuring road roughness, some elaborate and expensive, others simple and inexpensive. Pavement strengths can be measured and slipperiness measurements can become routine. A few devices are:

- GM profilometer
- BPR roughometer
- PCA roadmeter
- Mays Roadmeter
- PSI O Meter
- California Deflectometer
- Dynaflect Trailer
- LaCroix Deflectograph
- MuMeter
- Skid trailers

Many of these devices are in use although maintenance organizations have only begun to apply such devices to their operations.

**THE FUTURE**

Sufficient money will not be available to maintenance organizations to perform maintenance of the quality desired. Priorities will need to be set on the basis of quality standards which can be met within the constraints imposed by budget limitations.

Maintenance of futuristic traffic control devices now being tested and installed will be expensive. Hardware for ramp metering, highway surveillance, computer controlled traffic systems, electronic route guidance systems, automatic signs, disabled vehicle detection systems and
pacing devices are being tested. Such systems can be complicated yet little evidence exists to indicate that main­tenance reliability is of prime concern to the researchers developing this hardware and I suspect that maintenance considerations are being neglected. Undoubtedly, inspection and maintenance will need to be of high order and this means dollars and employee training.

Hopefully the systems will also result in greater safety and fuller use of our highways with a payoff in terms of decreased auto insurance rates (or a slower rate of increase).

Other speakers have suggested that we can look forward to equipment which can monitor trouble spots, feed back information to a computer and automatically diagnose the trouble, estimate costs, schedule and program repair crews to the work site. Perhaps we can look forward to high speed communications to each individual maintenance worker and to strong and continuing programs to seek out, develop and apply new methods and to a viable and continuing equipment program.

CONCLUSION

Maintenance levels and quality standards should be set. Decisions involving expenditures of millions of dollars should not be completely dependent upon the vagaries of individual judgment. We have some understanding of the relationships that quality standards bear to costs. Quality standards exist, and tools for measuring standards in an unbiased manner are available.

Our job is to use the knowledge we have for the benefit of the public who uses and pays for our highway system. And for researchers studying traffic systems — remember two words — MAINTAINABILITY AND RELIABILITY.

REFERENCES


