FEATURE ARTICLES

THE ROLE OF EQUIPMENT IN MAINTENANCE OPERATIONS

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INTRODUCTION

Highway engineers are frequently asked why present-day highway builders cannot build roads to last as the Romans did. It is certainly true that some of the Roman roads have lasted very well. Sections of the Appian Way have been in use for more than 2,000 years, but examples of this sort are misleading because they are only remnants of a road system that once extended from Great Britain to Egypt and from the Straits of Gibraltar to India.

Roman maintenance engineers also had their troubles, and a reading of milestones along old roads indicates that Roman roads required frequent reconstruction. Even the Romans failed to develop road surfaces that did not require maintenance, and surface maintenance was a painstaking task for them. Replacement paving stones were apparently cut and shaped at a quarry, and the edges were marked with numerals and letters so that each stone could find its way correctly into the mosaic of the road (1). Lavish use of man-hours might be justified so long as conquests and Roman armies produced an almost unlimited supply of slaves, but similar labor supply pools are not available to state highway departments, whose operations must depend on mechanical horsepower to replace manpower in maintenance tasks.

The state of North Carolina has been a leader in this effort, as have others. Kansas, for example, started a total mechanization 5-year plan in 1964 and the State Maintenance Engineer reported at the 1969 Highway Research Board meeting that the plan had succeeded. He has not approved the purchase of any hand tools for more than two years. Patching has been all but eliminated by establishing a scheduled resurfacing program (12), and hydraulic tools—operating off a common truck hydraulic system that also operates salt spreaders and reversible snowplows—are replacing pavement breakers, drills, etc. (13).

A complete recital of the innovations made in Kansas is not required here. Suffice it to say that the Kansas research division has engaged in maintenance research and for a number of years the State Maintenance Engineer has made available lists of worthwhile projects to the division. Results from that continuing program are now showing up in the form of maintenance improvements. The following are some of the findings:

- The most economical maintenance truck is a medium-duty, 5-ton capacity truck operating 5 to 7 years with 140,000 miles.

*This paper was originally presented at the State Highway Conference, Raleigh, North Carolina, January 28, 1969. The opinions and conclusions expressed in this paper are those of the author and not those of the Highway Research Board.

- Truck bodies last up to 25,000 miles longer if washing facilities are available in maintenance garages.
- Almost all towed equipment has been replaced with self-propelled units because pull-type equipment is involved in more than 50 percent of accidents.
- Use of automatic transmissions plus other charges permitted operation under snow conditions with one less man per truck. The operator also required less training.

The California Division of Highways has an active equipment research and design section as an integral part of its equipment division. One of the results of its efforts is shown in Figure 1. The small asphalt heater is used for patching. Note the portable sign standards and the cab-controlled electrically operated warning sign, which may be changed as necessary to reflect varying work tasks.

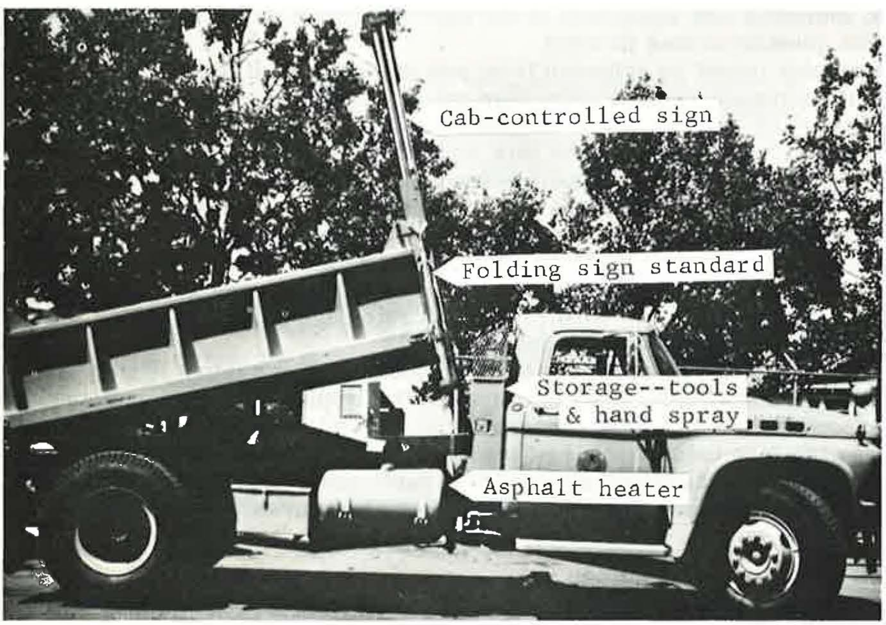

Figure 1. The four c.y. dump truck developed by the California Division of Highways.

A continuing effort, such as the Kansas and California programs, requires that certain questions be continuously posed about every operation. The larger the operation, the greater the value to be derived from a questioning attitude.

FACTORS AFFECTING EQUIPMENT SELECTION

The wise investment of $30 million, the 1966 value of North Carolina's equipment fleet, is a heavy responsibility requiring that equipment be chosen wisely and assigned intelligently to the tasks that must be accomplished.

Let me focus attention on certain basic principles of equipment selection and assignment by asking some questions.

First and foremost, test the need. Is the task, the function, necessary? Can you get along without it? Could it be combined with something else? Would your time be more profitably spent studying a different aspect of the problem? Is the task proportionately large enough to justify considering it at all?

If the operation or task is in fact essential, a value analysis is needed. How can you perform the task for less?

Analyze existing records. What is the size of the task? How much work has been done in past similar study periods and what is the amount of work to be accomplished this year, next year, five years from now? Is the amount of work to be done over the period enough to justify purchase of equipment or should the work be let to a contractor or be done less efficiently with presently available methods and equipment?

How will the equipment be employed? Does addition of equipment necessitate a change in your organization? Is there a need to go from patrol-size crews to larger crews? To specialized crews? How much work can a crew accomplish in terms of cubic yards of mat to be placed, acres of grass to be mowed, miles to cover by truck? How much investment can you justify per man employed?

If your records provide this kind of information, and if your analysis of the records indicates that equipment is the logical alternative for you to employ, additional questions come to mind.

Can greater output be achieved from new equipment? If so, how much output? Will equipment replace more than one piece of similar equipment? Should the equipment be multi-purpose or specialized? Are repair costs of present equipment too high? If so, is the new equipment designed to reduce repair costs? Do you have enough support personnel—mechanics, shop space—to properly maintain the equipment you add to the fleet? How soon will the equipment pay for itself in terms of additional output? Will the new equipment enable the Department to render improved service to the motoring public?

After the equipment has been acquired, record-keeping should be continued. What are the repair costs? What production rates are being attained? Is the production in agreement with predictions?

Doubtless it would be possible to extend such questions into a lengthy list. Instead, I will adapt these ideas to examples that apply to common maintenance tasks—specifically mowing, pavement striping, winter snow and ice control measures, surface treatments, test equipment, and litter removal. Hopefully, this will encourage the study of every task performed, to look for better ways of doing work and to question long-established procedures.

MOWING

First and foremost, I suggested that the need be tested. Is the task necessary? Can the size of the task be reduced? Right-of-way mowing is an area that lends itself very well to reduction of workload by reducing the amount of work that must be done—simply discontinue mowing some sections of right-of-way. This can be done by studying the roadsides to determine which portions can be left unmowed and permitted to grow back into natural condition. It is not difficult to then set mowing limits for the mower operators' guidance.

The current AASHO "Guide for Roadside Mowing" (3) suggests that the height of vegetation be maintained somewhere between a 3 inch minimum and an 8 to 12 inch maximum for a minimum distance of 15 to 20 feet from the pavement edge; it does not require that backslopes be mowed. Many state highway departments have adopted these standards with substantial dollar savings. North Dakota saved $150,000 last year by adopting these standards.

But even these standards may be too restrictive. As part of a research project the Ohio Department of Highways maintained a 12-mile section of highways with a minimum mowing height of 10 inches—this included median and shoulders (4). There were no complaints from the motorist; apparently at 70 mph the driver was unaware of grass height so long as it was not ragged with weeds and was of uniform height. The process not only resulted in a reduction in mowing costs but the researchers found that the section survived the summer better with a greener appearance and a faster recovery in the fall than those sections kept at a 4- to 6-inch height. It was further suggested that slopes 2 to 1 or steeper not be mowed, nor should areas beyond the ditch abutting woods or uncultivated areas, and volunteer woody growth should be encouraged.

Other investigators have also shown the adverse effects of untimely instances of slope erosion caused by dislodgment of sod under the wheels of mowers negotiating steep backslopes. Holly Mitchell (6) has stated that the spread of desirable grasses had been slowed in some areas because maintenance forces mowed the right-of-way just before the grasses went to seed.

The State of Missouri also adopted new requirements last year to reduce its annual bill of $3 million for mowing and to reduce a manpower requirement exceeding 1130 men (7). The new policy was described by Leland D. Fletcher, Maintenance and Traffic Engineer:

> All sight distance areas, such as inside of curves in the vicinity of approaches, and around signs, will be mowed as often as necessary to maintain good visibility for safety. Abrupt changes in widths will be avoided by contour mowing at transition points
>
> What should result is mowing which will heighten the beauty of the right-of-ways by blending them in more naturally with surrounding areas.
>
> The Department's new look mowing also calls for other changes. These include limits on mowing of steep slopes, more intensive mowing in urban and developed areas, and procedures for mowing after the growing season.
>
> The mowing operations will be coordinated with an effective herbicide and fertilizing program. The use of herbicides and fertilizer will help reduce the mowing required to keep vegetation to a desirable height, eliminate objectionable growth and improve the quality of desirable grasses.

Francis Staib some years ago became concerned about the cost of mowing the Ohio Turnpike's right-of-way. As a result of a careful analysis he established a new policy (8). All medians were to be kept in a lawnlike condition; inside loops of interchanges—locations were motorists would be looking toward the right-of-way as they made turns—were to be kept carefully mowed; shoulders were to be mowed; and areas adjacent to carefully maintained private property were to be kept mowed. After establishing these areas, Staib set general mowing limits that eliminated in large part the rest of the mowing. He coupled this change with a spraying program to eliminate weeds and other growth that would give a straggly appearance to the right-of-way. This very substantial reduction in mowing acreage was accomplished without a single motorist's comment. Apparently no one was concerned enough to complain.

The point to all this is, of course, to illustrate the substantial savings possible by simply asking the question: Is the task necessary? If the task can be discontinued, it would be pointless to develop greater efficiency in performing it.

Assuming that all possible savings have been made by eliminating mowing areas, the next step is to establish more efficient methods of mowing. This involves equipment selection, matching the equipment with the job site, and planning the work for maximum efficiency.

Mowing along guardrail is one area that has required high expenditures of hand labor in the past. Beasley (9) reported that guardrail maintenance might require 8 man-hours per mile. The Iowa Maintenance Study (10) reported that hand mowing was a relatively inefficient operation. There was a substantial amount of time spent in travel (over 20 percent). The men were actually cutting weeds or grass only 36 percent of net available working time (NAWT) spent on this operation and it took 257 minutes NAWT to cut 100 square yards of grass and weeds. Two- or three-man crews were normally used for hand mowing.

There are at least three options open for reducing costs. One is to let the weeds grow up past the guardrail—someone should test to see how many complaints would be generated by doing so. Personally, I have checked this at times by asking non-professionals in the car with me what they thought of a section of guardrail (after we had driven past the section) and I was surprised to find how few people notice such things. Most maintenance engineers tend to notice unsightly guardrail areas, of course, but I suspect that the traveling public tends to be more interested in pavement smoothness than the scrubby appearance of guardrail.

The second option is to use herbicides or paved sections under the guardrail—and many departments are making effective use of chemicals and paving for this purpose.

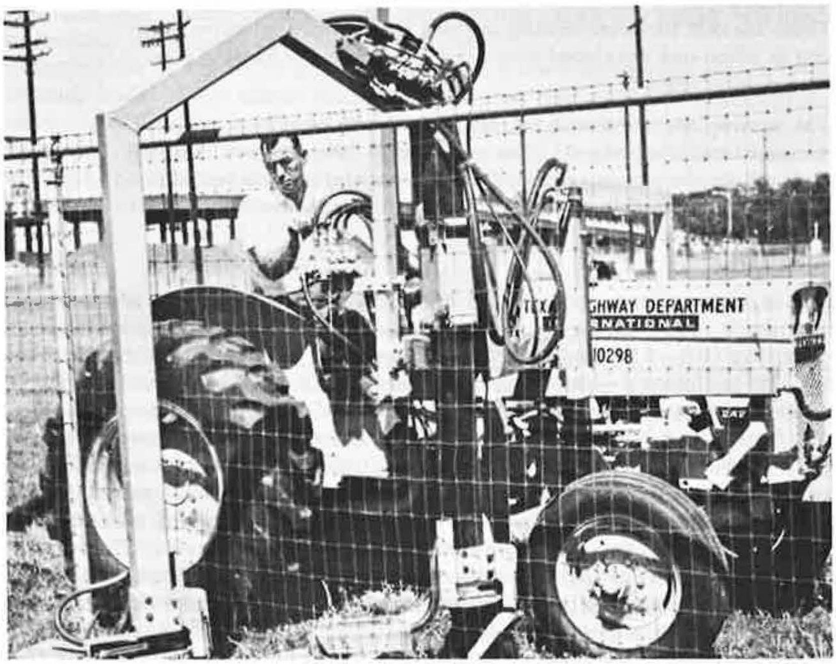

Figure 2. The new "Rail Bird" mower designed for guardrail mowing. (Photo courtesy of TEXAS HIGHWAYS.)

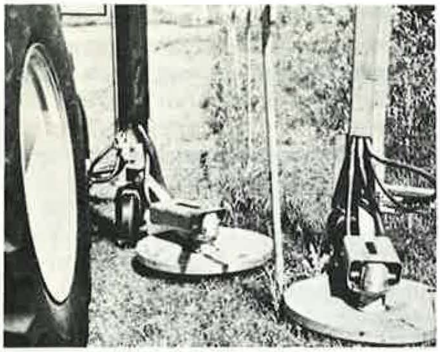

Figure 3. Close-up of the "Rail Bird's" cutting head. (Photo courtesy of TEXAS HIGHWAYS.)

The third option is the use of equipment. A new mower, known as the Rail Bird, is designed for guardrail mowing (Figures 2 and 3). It reportedly (11) can cut around fence posts, guardrail posts, mailbox posts, and any other kind of post; it can cut grass on both sides of a 6-foot chain link fence at once; it can cut under fences, and it can cut around bridge abutments. The mower has two 21-inch cutting heads like those on sickle mowers. Four blades are spaced 90 degrees apart on the rotor and the guard cover comes within ½ inch of the ends of the blades, allowing cutting to within ½ inch of obstacles. Hydraulic pressure keeps the heads cutting in an overlapping pattern so that there is at least a 30-inch swath. When the heads meet an object, they move out and around it because of the pressure. Manpower savings are apparent.

ROADSIDE MOWING

Despite the high unit cost of guardrail mowing and other hand-type mowing operations, the bulk of the mowing dollar is spent on large-area mowing, and the greatest potential for savings comes from studies of that operation. All of us are aware of the high productivity rate of mowers, particularly models that cut very wide swaths, but everyone is not equally aware of production studies showing that production rate per mower is substantially reduced if two or more mowers are employed together as a team. At first thought this may seem strange, but it may be more easily understood if one stops to consider the natural impulse of humans to help one another and to socialize together—whether it is to change blades, clean a jammed mower, or to take a coffee break. Furthermore, when an operator works alone he sets his own pace, but team efforts are limited to the production rate of the slowest operator.

Time studies have shown (14) that mower production rates are affected by the amount of downtime, the type of terrain, distance of travel to the job site, etc. To be specific without going into details, a tractor with sickle bar mower working alone may average something like 7.3 acres per standard working day, but three tractors working together would average only 5.2 acres per day per tractor.

Large units, such as tractors with 15-foot rotary mowers, should be used only on types of terrain where their inherent high capacity can be utilized. Although an average production rate of 18 acres per hour per tractor is to be expected, the average production drops to as little as 11 acres per hour per tractor when three tractors are employed as a team. Under difficult conditions, production rates may drop as low as 8 acres per day per tractor (3 tractors) or under favorable conditions may reach nearly three times that figure or 23 acres per day (1 tractor working by itself).

Futuristic concepts are embodied in at least three current areas of study. The national trend across the country is toward contour mowing or, in other words, the elimination of the past practice of mowing rights-of-way from fence line to fence line. This will tend to confine mowing to the area between the ditch lines—an area to which it is comparatively easy to gain access. This in turn will make feasible the use of highly maneuverable truck-mounted mowers. Developments in this field are already under way—truck-mounted mowers are currently under test on the New Jersey Turnpike, and I think there will be a great deal more development in this area from the equipment manufacturers, particularly as maintenance people make known their need for maintenance equipment that can operate at high speeds in the traffic stream—say 45 to 50 mph—so that maintenance equipment does not block highway traffic flow.

Figure 4. This is a pilot model of a mower that can be remotely-controlled by either radio or guide cable. It is being developed at the University of Illinois. (Photo courtesy of University of Illinois.)

Going one step further, there is work under way at the University of Illinois on radio-controlled mowers. Figure 4 shows the small pilot model tested. The Triumph Machinery Company has developed and is testing a much bigger model, similar in concept. Developments in radio-controlled equipment lead one to speculate on the possibility that in the distant future it will be possible for an operator in an air-conditioned pickup truck to operate two, three, or more units at one time.

Finally, there is the ultimate—a helicopter spreading chemicals along the right-of-way. Maybe a future equipment operator will need prior qualification as a helicopter pilot, and right-of-way mowing will be accomplished by dispensing growth-inhibiting chemicals from the air.

Mowing has been discussed here at some length because mowing costs loom large in some states' budgets, representing a sizable equipment investment and a sizable percentage of maintenance expenditures.

PAVEMENT STRIPING

Consider, now, pavement striping as an illustration of an area where study time can most profitably be spent in an area other than equipment improvements.

Equipment development in the field of striping is a striking success story illustrating a reduction in manpower requirements through the use of more efficient equipment. The striping unit illustrated in Figure 5 was used in Texas

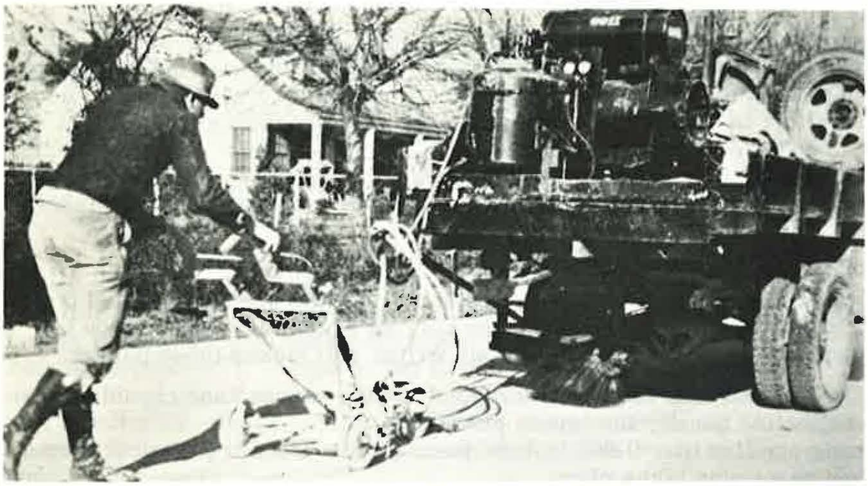

Figure 5. This was a striping unit used in Texas about 1939. The machine required the operator to follow on foot. (Photo courtesy of TEXAS HIGHWAYS.)

shortly before World War II. At that time it was actually necessary for a man to follow a striping unit down the road on foot. In those days material costs represented only a small percentage of the pavement striping cost. We have now reduced labor time to something like two hours per mile of strip and materials costs now represent the major component of striping costs. Equipment and labor costs now represent only 10 percent to 25 percent of the striping costs in a well-conducted striping operation (15). Materials, i.e., the paint and beads, represent 75 percent to 90 percent of the cost.* It seems apparent that there is a greater potential for cost reduction in materials than in labor and equipment.

Certain practices are so well established that the effort to change them is not justified. At least one study indicated that a center stripe narrower than 4 inches could be used without any noticeable effect on the separation of traffic, but the 4 inch width is so widely accepted that the potential materials cost savings are not large enough to justify an attempt to change the standard.

It may be that some sections of highway are striped too often or, conversely, that restriping is not done often enough to meet visibility standards. One highway department's maintenance levels book states: "Painted or plastic stripes and pavement markings shall be renewed when they have lost approximately 50 percent of their visibility as compared to their maximum effectiveness."

An interesting research project could be developed to evaluate the adequacy of paint striping programs in a state, and from that a striping program that reflected true needs could be developed.

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*An analysis reported in New York State Department of Transportation Research Report 674 (March 1, 1969) indicates materials cost represents 54 percent of the cost of the striping in that state.

Continuing further with the thesis that reductions in striping costs can best be achieved by reducing materials costs before giving attention to further reductions in equipment and labor costs leads into the subject of raised reflective markers. These have proved themselves to be economical and effective. They are durable, provide far better visibility under rainy conditions, and effectively separate moving traffic streams.

Unfortunately, raised reflective markers are dislodged by carbon steel-tipped snowplow blades and, for that reason, the markers have not been acceptable for use in snow-belt states, but their advantages are so substantial as to justify an effort to develop plowing equipment and procedures that will not dislodge the markers. One potential approach is to use rubber snowplow blades that would flex as they passed over the markers. I believe a careful study of snow and ice control procedures would lead to a greater use of these blades.

REDUCE USE OF GLASS BEADS

Questions have been raised as to whether or not the use of premixed traffic beads is justified and whether or not the current gradation specification for glass beads is a good specification. One writer (17) makes these points:

- Only 30 percent of the beads (dropped in) are exposed and capable of retroreflecting the day the line is placed.
- Beads smaller than 0.008 inch in diameter are lost for practical purposes when restriping takes place.
- Premixing has the effect of placing a paint film over the surface of large beads that would otherwise be exposed.
- Large beads obscure small beads.
- For a given wet paint film thickness, there is only one size bead that will give optimum optical performance.
- Of the 30 percent of current specification beads that are round and are not submerged in a 0.015-inch paint film, only those with diameters of approximately 0.025 to 0.027 inch are performing at their maximum efficiency.

Other investigators have questioned these points, primarily on the basis of the author's interpretation of the optical characteristics of the beads. I have no desire to judge the merits of either side's arguments, but I think the critics may be missing a most important point: Does it make sense to develop an expensive marking material to last 18 months if repainting is accomplished at 12-month intervals, or is it sensible to use an "18-month" paint for operations over an entire state when only a few high-traffic areas show accelerated wear?

Findings from research conducted in Colorado (18) indicate that expenditure reductions can be made. Colorado researchers found that a bead of smaller size of more uniform gradation could be used at a reduced rate of application and show high reflectivity over a longer period than could the standard specification. Colorado places approximately 1.8 million pounds of glass reflective beads annually and saved $50,000 during the 1967-68 traffic striping season with the new specification.

I mention this area of savings in materials cost to point out that analyses of equipment operations should be concerned with more than just reducing labor requirements by mechanizing. In some instances greater savings can come from a careful study of the materials used in a maintenance operation than by increasing labor or equipment productivity.

Two recent developments in paint striping equipment, interestingly enough, combine new materials with new equipment. The Maintenance Division of the Florida State Roads Commission modified a crosswalk striping machine for testing fast-drying pavement marking materials. Their objective was to eliminate the need for traffic cones, follow-up trucks, and supporting personnel required to protect traffic stripes. Experiments were successful and Florida can now place traffic stripes that do not require any protection against tracking. And the striping machine operates at the same over-the-road speed as conventional machines.

Another experimental striping unit places a small quantity of epoxy on the pavement and then drops ¼ inch reflecting beads into the epoxy to produce a traffic marker. The advantage of the machine is that it mechanizes button placement yet performs in a manner similar to conventional paint machines. Although experimental problems are occurring, a number of sections placed with this machine in Texas have performed very well for over a year. I expect that this machine and its successors will mechanize the placement of raised reflective buttons.

SNOW AND ICE CONTROL

After proposing consideration of a snow removal system comprising the timely use of salt and rubber snowplow blades to prevent dislodgment of raised reflective buttons, it seems fitting to discuss snow removal equipment. The selection and use of snow removal equipment is based on a number of preliminary decisions—usually made informally and unconsciously. I suggest that these decisions are made without adequate advance study and that more thought should be given to them.

The types of decisions being made in this fashion are referred to in a determination of the number of snow-plowing vehicles required by Port Hope District patrols as part of a study made by Roy Jorgensen in his Maintenance Management Study of the Ontario Department of Highways (19):

- How many miles of road are to be plowed?
- What is the average plow speed of truck plows?
- What rate of snowfall, in inches per hour, may be expected?
- What is the maximum depth of snow in inches permitted to accumulate on the road?
- How many plows will be broken down and not available at different times during the storm?

All of this information is required before the number of snowplows can be determined from the formula:

$$\text{number of snowplows per patrol} = \frac{\left(\text{single lane patrol miles}\right)}{\left(\text{plowing speed (mph)}\right)} \; \frac{\left(\text{snowfall rate at selected percent storms serviced (inches/hour)}\right)}{\left(\text{maximum allowable accumulation (inches)}\right)}$$

Without going into the details, and considering only those four variables, an analysis showed that 54 snowplows would be required for a Port Hope patrol if the supervisor decided to remove snow before it accumulates to more than ¼ inch in depth in 100 percent of the snow storms. Only one snowplow will be required if the supervisor is willing to permit 1 inch of snow depth in 50 percent of the storms.

A 28-foot folding wing snowplow was recently evaluated in a test program. I suspect most engineers would assume that the plow would move a lot more snow in a straight-line plowing operation than conventional plows even though they might question maneuverability, etc. Interestingly enough, test findings revealed an average production rate of 1726 tons of snow per hour. Tests of conventional plows showed production rates averaging 2099 tons per hour for similar snow depths. The conventional plows operated at more than 27 mph, the larger plow operated at only 13 mph.

Although the large plow probably would perform better in front of a more powerful truck, the findings point up the importance of a testing program. Appearances can be deceptive.

The most efficient means of snow removal is the displacement snowplow, even though it does not provide the bare pavement now demanded by the traveling public. Manufacturers have tried to respond to the demand for bare pavements and some ingenious devices have been tried. For example, jet deicers have been tried. Unfortunately, these machines have not been practical, reaching snow removal production rates of only 400 tons or so per hour despite ear-splitting noise, pavement damage, and high fuel consumption rates.

Snow removal equipment manufacturers just do not have sufficient developmental funds available to them to refine ideas of this type into workable solutions, and public agencies have not seen fit to encourage snow removal equipment improvements by funding research projects. Apparently bare pavements can be economically obtained only by chemical applications, and the use of chemicals brings related troubles.

Bare pavement is not provided without cost—costs such as concrete deterioration, auto body corrosion, pavement dowel bar corrosion, vegetation kill and, last but not least, the direct cost for chemical purchase. These costs cannot be eliminated, but they can be minimized.

An early step in application of salt for snow and ice control is the determination and accurate application of the correct amount of salt. A paper on that subject alone could be written but instead I will confine my remarks here to only one equipment aspect of chemical spreading—the inaccuracies in spreaders themselves. There is little value in establishing a policy stating the rate of chemical to be applied if the equipment provided cannot meet requirements. The first step in a chemical program is to set application rates and train equipment operators, but a problem in the past has been the inability of a spreader to maintain a constant spread rate.

Figure 6. Wyoming's snow removal efforts in 1929 were conducted the hard way. This photo was taken on 14 Mile Hill, north of Rock Springs. (Photo courtesy of Wyoming Highway Department.)

Tests of spreaders have shown gross variations—variations of 100 percent from one spreader to another. These variations are compounded by variations in truck road speeds because many chemical spreaders are set to operate at a certain speed and the assumption is made that truck speed remains constant. Truck speeds vary—they slow up on upgrades and speed up on downgrades. To overcome this weakness one manufacturer (20) has developed an electronic control device that maintains a constant spread rate at selected vehicle speeds within the control range of a particular conveyor belt and feed-gate setting. These controls can maintain correct chemical application rates, and their widespread use might save hundreds of thousands of dollars across the United States. In some areas, however, chemicals may not be used in sufficient tonnages to justify this refinement.

I often say that our snow removal techniques are hopelessly outdated—that we use methods and equipment essentially unchanged in more than 30 years—but I may be inaccurate. For example, Figure 6 shows the hand snow removal techniques used in Wyoming in 1929 as published in an annual maintenance report of the Wyoming Highway Department.

SURFACE MAINTENANCE

Another major area of maintenance concern is related to surface maintenance. It is not known what proportion of every State's maintenance budget is expended on surface maintenance, but in Wyoming a third of available maintenance funds are expended directly on surface maintenance. I hope to spur you to question your own operations by pointing out some interesting findings from studies in various states.

For example, have you ever asked yourself just why you place a sand seal on an existing deteriorated surface? Highway engineers in a northern state said one of the reasons was to seal cracks, but a controlled experiment designed to check results indicated that the surface cracks have returned in less than a year. For your own information you might want to set up some observations next summer on seal coat projects and see whether or not the cracks reappear.

Other similar findings have come to light. The important point is that you should ask yourself why certain things are done and then satisfy your own curiosity by inserting test sections here and there in your work programs. Long-accepted practices may not be correct.

Many miles of seal coats are applied every year but the trend is away from the old sand seals or chip seal coats in favor of thin asphaltic concrete overlays. Tests started in Nebraska in 1960 showed that a $\frac{3}{4}$-inch thick overlay performed better than ten different cutback asphalts with gravel, sand-gravel, and other cover courses.

Thin overlays are popular with the public and show good performance, but they are not always effectively used. For example, many highway condition rating methods and excellent test devices are available to aid the engineer in determining the best overlay thickness to use. Unfortunately, only three or four states make routine use of these techniques. As a result, thousands of miles of overlays are being placed without proper evaluation of the existing highway. At times this may result in an over-design and in other instances under-design occurs.

TEST EQUIPMENT

This leads to my plea that maintenance engineers make use of a different type of equipment for their operations. Specifically, greater improvements might result from use by maintenance engineers of Dynaflect trailers to determine overlay thicknesses, reflectometers for determining condition of signs, skid trailers to determine pavement surface conditions, and other types of test equipment than a similar investment in six or seven dump trucks or a couple of motor graders. Few maintenance engineers are aware that this equipment is available, and even fewer engineers have given thought to applying test equipment as a routine procedure.

Test equipment such as the Minnesota Roadmeter, the Dynaflect, and the BPR roughometer provide a means for predicitng future pavement needs as well as providing a yardstick for comparing conditions across section lines. From these predictions a preventive maintenance program can be developed that properly reflects budget considerations, management decisions, and a fair apportionment of maintenance funds to the operation divisions.

HIGHWAY LITTER

A more down-to-earth problem, and in some ways one of the most exasperating problems with which maintenance people must contend, is highway litter. An opinion survey was made to determine why people litter, and the survey showed that the public has a very low opinion of "litterbugs," equating them with pigs; yet the survey also found that almost every person surveyed had "littered" in the recent past. Increased traffic, wide rights-of-way and throw-away containers contribute to the problem.

Shelby (23) reported that litter pickup costs in Texas increased from $1 million in 1961 to about $1.5 to $2 million in 1967. Average cost for hand litter pickup on two-lane highways was reported to be $15.37 per mile. But he

Figure 7. The use of a litter-gathering machine, such as this one, can often be used to reduce the cost of litter removal. (Photo courtesy of TEXAS HIGHWAYS.)

also reported that at least some of the litter could be gathered by machines of the type shown in Figure 7 and that the average cost then decreased to $11.60 per acre.

Use of such machines involves some rethinking. For one thing, it is not economical to "sweep" an entire right-of-way; instead the operator follows a course that traverses the most unsightly areas. Also, the machine will not gather flat papers or litter from depressions. A management decision to mechanize the litter-gathering operation carries with it the implication that maintenance employees will be satisfied with a cleanup that is less perfect than a hand operation, and it requires special efforts to correct and level eroded areas and ditches so that the machines can operate. Furthermore, road designers should consider the limitations of litter machines when they are designing new highways.

Despite these restraints, there seems to be a place for litter machines in maintenance operations.

SUMMARY

To summarize, I have attempted to encourage you to question every maintenance operation you perform by showing that some concepts accepted as facts may not be supported by actual studies.

Total mechanization of maintenance is not just a dream—it can be achieved. Studies have shown that substantial savings in maintenance expenditures have been achieved by reducing the acreage mowed and by better management of mower fleets. Striping costs can be reduced. Raised pavement markers and rubber snowplow blades should be considered.

A great deal of work remains to be done in programming snow and ice control work operations and planning for winter maintenance. Maintenance engineers have been very slow in developing and using test equipment, and they may need to rethink their approach to the litter-gathering operation if successful litter removal machines are to be developed.

Research is not just something carried on by "mad scientists" in secret hideaways. Each of you can contribute to the storehouse of knowledge by studying your work and continuously seeking and reporting improvements.

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