NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE **52**

MANAGEMENT AND SELECTION SYSTEMS FOR HIGHWAY MAINTENANCE EQUIPMENT

RESEARCH SPONSORED BY THE AMERICAN ASSOCIATION OF STATE HIGHWAY AND TRANSPORTATION OFFICIALS IN COOPERATION WITH THE FEDERAL HIGHWAY ADMINISTRATION

AREAS OF INTEREST:
- GENERAL MAINTENANCE
- CONSTRUCTION AND MAINTENANCE EQUIPMENT

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. 1978

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

Systematic, well-designed research provides the most effective approach to the solution of many problems facing highway administrators and engineers. Often, highway problems are of local interest and can best be studied by highway departments individually or in cooperation with their state universities and others. However, the accelerating growth of highway transportation develops increasingly complex problems of wide interest to highway authorities. These problems are best studied through a coordinated program of cooperative research.

In recognition of these needs, the highway administrators of the American Association of State Highway and Transportation Officials initiated in 1962 an objective national highway research program employing modern scientific techniques. This program is supported on a continuing basis by funds from participating member states of the Association and it receives the full cooperation and support of the Federal Highway Administration, United States Department of Transportation.

The Transportation Research Board of the National Research Council was requested by the Association to administer the research program because of the Board's recognized objectivity and understanding of modern research practices. The Board is uniquely suited for this purpose as: it maintains an extensive committee structure from which authorities on any highway transportation subject may be drawn; it possesses avenues of communications and cooperation with federal, state, and local governmental agencies, universities, and industry; its relationship to its parent organization, the National Academy of Sciences, a private, nonprofit institution, is an insurance of objectivity; it maintains a full-time research correlation staff of specialists in highway transportation matters to bring the findings of research directly to those who are in a position to use them.

The program is developed on the basis of research needs identified by chief administrators of the highway and transportation departments and by committees of AASHTO. Each year, specific areas of research needs to be included in the program are proposed to the Academy and the Board by the American Association of State Highway and Transportation Officials. Research projects to fulfill these needs are defined by the Board, and qualified research agencies are selected from those that have submitted proposals. Administration and surveillance of research contracts are responsibilities of the Academy and its Transportation Research Board.

The needs for highway research are many, and the National Cooperative Highway Research Program can make significant contributions to the solution of highway transportation problems of mutual concern to many responsible groups. The program, however, is intended to complement rather than to substitute for or duplicate other highway research programs.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the National Academy of Sciences, or the program sponsors.

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PREFACE

There exists a vast storehouse of information relating to nearly every subject of concern to highway administrators and engineers. Much of it resulted from research and much from successful application of the engineering ideas of men faced with problems in their day-to-day work. Because there has been a lack of systematic means for bringing such useful information together and making it available to the entire highway fraternity, the American Association of State Highway and Transportation Officials has, through the mechanism of the National Cooperative Highway Research Program, authorized the Transportation Research Board to undertake a continuing project to search out and synthesize the useful knowledge from all possible sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series attempts to report on the various practices, making specific recommendations where appropriate but without the detailed directions usually found in handbooks or design manuals. Nonetheless, these documents can serve similar purposes, for each is a compendium of the best knowledge available on those measures found to be the most successful in resolving specific problems. The extent to which they are utilized in this fashion will quite logically be tempered by the breadth of the user's knowledge in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis will be of special interest and usefulness to maintenance engineers, highway administrators, and others seeking information on selection and use of highway maintenance equipment. Detailed information is presented on equipment management and how it relates to maintenance management needs.

Administrators, engineers, and researchers are faced continually with many highway problems on which much information already exists either in documented form or in terms of undocumented experience and practice. Unfortunately, this information often is fragmented, scattered, and unevaluated. As a consequence, full information on what has been learned about a problem frequently is not assembled in seeking a solution. Costly research findings may go unused, valuable experience may be overlooked, and due consideration may not be given to recommended practices for solving or alleviating the problem. In an effort to correct this situation, a continuing NCHRP project, carried out by the Transportation Research Board as the research agency, has the objective of synthesizing and reporting on common highway problems. Syntheses from this endeavor constitute an NCHRP report series that collects and assembles the various forms of information into single concise documents pertaining to specific highway problems or sets of closely related problems.

Equipment plays a primary role in highway maintenance work. Proper

selection and use of modern mechanical equipment can improve the quality of maintenance and increase the productivity. Some transportation agencies have developed maintenance and equipment management systems, but information on these systems has been fragmented and not widely publicized. This report of the Transportation Research Board reviews existing knowledge on equipment management and how it relates to maintenance management needs and identifies needed research in the equipment management area. Emphasis is placed on documentation of methods presently used for establishing equipment need; inventory of equipment; procurement, assignment, disposal, and replacement procedures; preventive maintenance and repair programs; shop staffing; parts inventory; management reports on use, performance, and costs.

To develop this synthesis in a comprehensive manner and to ensure inclusion of significant knowledge, the Board analyzed available information assembled from numerous sources, including a large number of state highway and transportation departments. A topic panel of experts in the subject area was established to guide the researchers in organizing and evaluating the collected data, and to review the final synthesis report.

This synthesis is an immediately useful document that records practices that were acceptable within the limitations of the knowledge available at the time of its preparation. As the processes of advancement continue, new knowledge can be expected to be added to that now at hand.

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ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Paul E. Irick, Assistant Director for Special Projects. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. The synthesis was edited by Judy Wall.

Special appreciation is expressed to Arthur I. Morris, Tilford Nemour Incorporated, who was responsible for collection of the data and preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Donald R. Anderson, Highway Maintenance and Operations Engineer, Washington Department of Transportation; James E. Bell, Equipment Engineer, Illinois Department of Transportation; Paul E. Cunningham, Chief, Maintenance Branch, Office of Highway Operations, Federal Highway Administration; Charles T. Edson, Assistant Chief Engineer, Construction and Maintenance, New Jersey Department of Transportation; and Samuel F. Lanford, District Engineer, Arizona Department of Transportation.

Adrian G. Clary, Engineer of Maintenance, Transportation Research Board, assisted the Special Projects staff and the Topic Panel.

Information on current practice was provided by all of the state highway and transportation agencies, the Department of Defense, the U.S. Postal Service, and many others. Their cooperation and assistance were most helpful.

MANAGEMENT AND SELECTION SYSTEMS FOR HIGHWAY MAINTENANCE EQUIPMENT

SUMMARY

Highway maintenance has undergone significant change in the past decade, yet its fundamental purpose has remained unchanged: to provide safe, convenient, and economical highway facilities for the public. Today the preservation of our vital highway network is a difficult challenge in the face of inflation, reduced revenues, and increasing regulation.

Equipment management and selection must be assessed in relation to the demands of this Maintenance Challenge in order to support the highway maintenance manager. Equipment programs, however, clearly are not serving this purpose. Often, neither objective evaluations of the potentials of alternative equipment types nor fleet optimization are done. Actual replacement of equipment lags; preventive maintenance and repair are not monitored; few states use revolving funds to facilitate equipment replacement; equipment costing is governed by cash-flow accounting rather than performance evaluation; and meaningful management information is lacking, while the real issues are clouded with voluminous amounts of invalid data.

The above tends to promote controversy among engineering, administrative, and fiscal disciplines and can lead to expensive, aging, overly large equipment fleets having an inappropriate mix of types, costly shop operations, and imbalanced staffing patterns. The resulting equipment impasse deprives the highway maintenance manager of critical support needed to surmount the Maintenance Challenge.

Selection of equipment can be either informal (casual exchange of information and experience) or formal (thorough analysis and documented cost/performance comparisons). Most evaluation is informal: only 2 states often use formal evaluation methods; 12 use formal evaluation sometimes; and 35 never do so. Reasons given for not using formal evaluations include lack of reliable cost/performance data, staff shortages, and lack of an acceptable evaluation formula.

Optimization of fleet size is a function that merits attention, although only 12 states establish equipment requirements in unit-days at the user level and only 16 develop their needs on a projected month-to-month basis. Moreover, only 19 include downtime in their projections. Rental of equipment, however, is widely practiced, especially for high-cost specialty equipment.

Preventive maintenance is done in most states; however, only 12 states use time standards. Similarly, repair shop workload is monitored in only a few states.

Thirty-eight states report that they have been prevented, to a significant degree, from replacing equipment on average in 6 of the last 10 years. An under-

lying cause is the inability to document objectively the impact of not replacing worn-out equipment. Methods used to arrive at replacement decisions include:

1. Establishing replacement criteria for each equipment type, the criteria then being applied regardless of equipment condition.
2. Using these criteria as guidelines but also considering equipment condition.
3. Reviewing cost and performance data using a formula to monitor each piece of equipment through its useful life.

Only the last method can be called objective.

During periods of fiscal restraint, equipment purchases tend to be deferred, often without provision for the increased maintenance, repairs, and downtime generated by such deferrals. A device for overcoming this problem is the revolving fund. Fourteen states have such funds for equipment purchase; however, only 10 of these are true revolving funds that do not require the approval of another agency before equipment in the fund can be replaced.

Three methods of staffing shops are used by the 12 states that have formulas for this purpose. The first method uses a fixed ratio of units per mechanic. The second method assigns a point value for each type of equipment and then divides the cumulative expression of workload by a point value equivalent to the capacity of one mechanic. The third method is similar to the second, but it uses standard man-hours instead of points for each type of equipment.

Equipment management information systems too frequently were found to be by-products of fiscal systems. Some of these systems include requirements, under the guise of established accounting principles, that can defeat the purpose of improving productivity. Thirty-three states feel that the data available from their systems are essentially accounting-oriented and can not be used to make meaningful operating decisions. Only four states attempt to govern their equipment programs by monitoring deviations from planned performance.

Some of the conclusions reached in this synthesis are:

- The highway maintenance manager needs improved application of equipment to enhance productivity and yield of the primary resource—manpower. However, current equipment management practices are not fitting to the task.
- When available equipment information inhibits meaningful decisions and maintenance forces are prevented from replacing equipment, it becomes evident that a fruitful accord among fiscal, engineering, and administrative disciplines does not exist. Such an accord is essential if inroads are to be made into the Maintenance Challenge.
- Timely and relevant information, properly presented, is the catalyst best suited to bridging the gulf that surrounds equipment programs. What is needed are succinct and meaningful impact statements that are capable of leading all disciplines, as well as top management, to a rapid consensus for effective policy, operating, and funding decisions.
- Top management action is needed to (a) form properly constituted equipment revolving funds that are capable of replenishing fleet capacity in an economical and timely manner and (b) provide support for implementation of equipment management systems that make greater use of available technology and have the clear purpose and capability of bringing the right information to the right people at the right time.

CHAPTER ONE

INTRODUCTION AND CONTEXT

INTRODUCTION

The scope statement for this synthesis identifies five significant sequences in the life cycle of equipment within state highway agencies: selection, use, preventive maintenance, repair, and replacement. The scope also identifies two primary resources used in completing that life cycle: manpower and parts inventory. And the scope identifies the management information system needed to articulate equipment program needs and to measure the effectiveness with which the sequences and resources just mentioned are applied to meet program goals.

A questionnaire was sent to all 50 states. Responses were received from all but Wisconsin, to which the questionnaire did not apply. Wisconsin's maintenance is performed under contract by its 72 counties, which also own and operate all equipment used for the purpose. Eight responses were received from the 10 provincial highway agencies in Canada, which also were invited to complete the questionnaire.

CONTEXT

The Maintenance Challenge

There is little doubt that many among the state highway maintenance community would gladly forego the uncertain flux and complexities of the late seventies in favor of a return to the relative normalcy of but a decade ago. Indeed, the latter too was a time that posed its own particular problems, but from today's vantage point, the lines that existed then seem more clearly drawn and stable. The fundamental purpose of maintenance, nonetheless, has remained unchanged: to preserve safe, convenient, and economical highway facilities for the public.

The public, however, does not lend itself to easy definition. In one sense it is a mixture of geographically dispersed communities, each of distinctive characteristic, that will perceive their needs within the framework of local priorities. At the same time, it can be said to be a mixture of active special interest groups, such as conservationists, industries, and tourists, that exert influence within broader regional, state, or even national perspectives that can conflict with local priorities.

Delivering timely and acceptable levels of transportation service to such a spectrum of demand, under circumstances that can become complicated with political bias, has been made all the more difficult by rampant inflation, reduced revenues, and a proliferation of state and federal regulation.

Ten years ago, highway maintenance as a function was beginning to win an overdue and long-sought recognition. It began preparing itself to manage resources more efficiently, the better to accept responsibility for the costly, unendowed, depleting asset it had inherited from an age that may too readily have assumed continuing abundance to be a birthright—an age that also laid foundations for many new initiatives in social consciousness, the bills for which are now mounting.

Together with those imposed by several unforeseeable international developments, these bills, either directly or indirectly, have come to exert inordinate pressure on available capacity to fund adequate preservation of the highway network. Furthermore, the demand for maintenance is increasing, inasmuch as the use of highways has become even more vital to the national economic well-being than was anticipated. As a potential source of ready solutions, the federal treasury too must be recognized as having its limits. It can not be expected to provide an unending stream of money as the sole alternative for alleviating pressure on state highway maintenance budgets.

Hard choices lie ahead, not the least of which will demand even more assertive efforts to improve maintenance productivity. A measure of the leadership and initiative needed in this area may be gained from an insight into only the past five years.

In terms of the classifications defined by the TRB Committee on Maintenance and Operations Personnel, the work force most directly associated with highway maintenance comprises laborers, skilled craftsmen, equipment operators, and sectionmen. From 1973 to 1977, the number of these personnel was reduced by 13 percent, from 97,000 to 84,000. Had this reduction not occurred, present state highway maintenance expenditures would have been greater by $112 million in current dollars of direct payroll alone, excluding the cost of fringe benefits (Fig. 1).

This reduction represents a sizeable achievement if the lesser work force produced the same level of output or the reduction was not made possible by contracting work out to the private sector. Impressive though this accomplishment may be, the fact remains that it was erased in the same short period by inflation equivalent to twice the amount of the gain. One step forward literally was accompanied by two backward.

Inflation is a factor that too easily is attributed to be the concern of someone else. It is in fact a reality that must be dealt with directly by each sector of the economy that it invades, and state maintenance programs enjoy no special exemption from this responsibility.

The maintenance community has done well over the past 15 years or so to arm itself with tools for upgrading the management process and thus is equipped for this challenge. Now, however, it clearly is called on to apply those tools even more extensively, notwithstanding the credit that is justly due it for accomplishments to date. Every potential for improving the productive yield of all maintenance resources needs to be exposed, pursued, and realized.

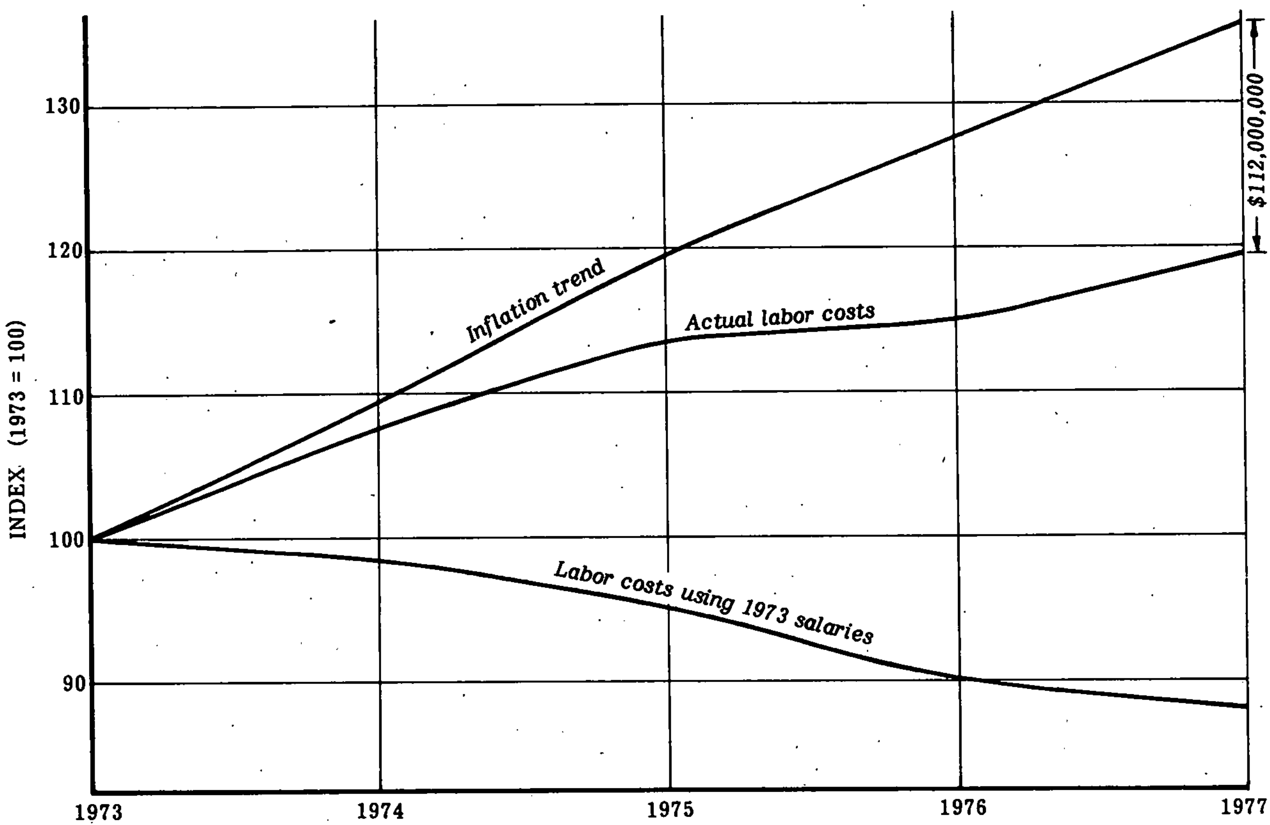


Figure 1. Direct labor cost trends for highway maintenance forces of all states. Although total direct labor costs increased between 1973 and 1977, the increase would have been $112 million more had there not been a reduction in personnel. The inflation trend depicts what total costs would have been if the number of employees had not been reduced. The actual labor cost line represents what has occurred. The lowest line shows what might have been had the actual decrease in employees occurred while labor costs stayed as they were in 1973. (Source: Transportation Research Circulars 133, 162, 174, 183, *and* 188.)

THE NEED OF SUPPORT

The brunt of the Maintenance Challenge ultimately falls on the individual highway maintenance manager, who must exploit every opportunity for achieving more with limited, if not dwindling, resources. Clearly, the dimensions of the challenge are such that the highway maintenance manager will need all the support that can be mustered.

In the absence of being made aware of the need to temper their impact within a broader context, the actions of people in any particular endeavor tends to reflect a momentum that leans in favor of the underlying disciplines of their trades or professions. This especially holds true of state highway agencies, wherein the dictates of design and construction occasionally have been known to saddle maintenance with impediments to its most effective execution. The underlying civil-engineering/service orientation of maintenance, in turn, is not always as mindful of its mechanical counterpart, and vice versa. And all three, to varying degrees, have been known to find discomfort with the assumed dictates of the fiscal discipline. The dimensions of the challenge now confronting the highway maintenance manager require that the disparities that can arise from interdisciplinary leaning be curbed or overcome wherever possible.

There is an evident need to expand the responsiveness capability of the highway maintenance manager and to take advantage of modern systems technology that shows promise of facilitating a more constructive interaction between this individual and the disciplines on which he or she depends. No one discipline should dominate another. Rather, all should be subordinate to their collective and overriding purpose of providing the public with safe, convenient, and economical highway facilities.

CHAPTER TWO

EQUIPMENT SELECTION AND MANAGEMENT PRACTICES

THE EQUIPMENT CHALLENGE

As would be expected, on a strictly technical plane there is every reason to believe that all states possess the requisite expertise for servicing highway maintenance needs related to specific mechanical problems on a day-to-day basis.

However, within the equally important broader context of serving the best advantage of the highway maintenance manager, this synthesis reveals that equipment programs on the whole are not being subjected to acceptable methods for managing such an important resource. This points less to any lack of managerial capacity than it does to an evolution of circumstance. With few notable exceptions, it could be said that management responsibility for equipment attaches to none in particular and to all in general.

The strongest control over equipment program operations in most states effectively rests in the hands of fiscal authorities. It is not to be inferred from this that fiscal authorities alone are responsible for the equipment impasse. There is indeed no evidence to justify a belief that they find any more comfort than do engineers in the vacuum that appears to enshroud most equipment programs. Rather, whenever the needs of a program are rendered incapable of meaningful articulation, that program inevitably stagnates and becomes inherited by fiscal authorities as a consequence of the default of all other disciplines related to it.

Fiscal authorities are obliged and accustomed to approve or decline submissions from program management. The economic circumstance of the day, which presents many difficult, competitive funding problems, leaves them with scant reason and less time to lead program management in how better to extract resources from them. On the other hand, by reason of its operations/technical background, the engineering discipline is not renowned in qualification to unravel the mystique of accounting principles with a view to recommending better ways of processing and presenting available data that would give their submissions a fighting chance of success. Their attempt to do so would attract as much derision as a mechanic would direct at a bookkeeper who presumes to tell the mechanic how to repair an engine.

The consequences, nonetheless, are unfortunate and costly, because they inhibit the flow of imaginative ideas and thereby hinder rather than aid the highway maintenance manager. The least influential voice in the arena, ironically, is that of the equipment manager. A significant shift on a national scale is needed to unseat this impasse in light of the contribution equipment can make toward meeting the Maintenance Challenge. It clearly represents the most promising of options available to the highway maintenance manager who is seeking improved productivity through more efficient use of the existing investment as well as alternative use of new types.

Furthermore, equipment is taking on a prominence in another, less desirable, sense that makes it deserving of more critical and meaningful evaluation than present methods permit. It already absorbs between 20 and 30 pecent of the highway maintenance dollar; and from 1973 to 1977, the same five-year period in which highway maintenance direct labor rates have increased by 35 percent, the cost of replacement equipment has risen by 100 to 150 percent. Thus, not only should its potential for improving the productivity of maintenance manpower be exploited more fully, but its own costs per unit of use need to be monitored closely.

In more specific terms, this synthesis shows that:

- Objective evaluation of potentials for enhancing highway maintenance productivity through the use of alternative equipment types is far from commonplace.
- Optimization of fleet size with a view to minimizing over-all equipment investment is not undertaken to any noticeable degree.
- Actual replacement of equipment extends significantly beyond the limits of criteria established for the purpose.
- Only three equipment revolving funds have been formed over the past 20 years among state highway agencies, and, of the limited number (14) presently existing, only 10 approach qualification as such in the strictest sense.
- Preventive maintenance and repair activity is, in large measure, not monitored.
- Voluminous amounts of data (restricted to expression by individual units of equipment) proliferate, but they serve little useful purpose, because they swamp the perception rather than raise the visibility of problems or potentials for improvement.
- The underlying thesis of most present equipment costing systems is outdated because it derives from traditional cash-flow accounting and cost liquidation rather than satisfying the requirements of performance evaluation.
- Management information that could serve as the keystone for overcoming all the previously mentioned items is barely in evidence.

The foregoing items can be expected to result in:

- Unnecessarily expensive, aging fleets that are too large and are comprised of an inappropriate mix of types performing at subpar rates of production in terms of use and availability.
- Costly shop operations with imbalanced staffing patterns, which are most likely confronted by erratic work flow and which together interact to yield less than acceptable productivity.

• Differences of opinion among engineering, administrative, and fiscal disciplines, tending to provoke counterproductive controversy, the most advanced state of which would be recognizable in stalemate and retreat from joining in the attack on important issues deserving of more constructive resolution.

These consequences coalesce into the worst of all worlds for the progressive highway maintenance manager. Far from providing this individual with much-needed support, any inclination toward such an equipment impasse can not help but discourage conscientious effort on the part of the highway maintenance manager. This individual effectively becomes deprived of the most promising of options with which to exert leverage on the much larger, more demanding task of surmounting the Maintenance Challenge.

SELECTION

Use of alternative equipment types sometimes shows promise for improving the productivity/cost-effectiveness of highway maintenance activities and methods. Evaluation of this potential can be either informal or formal. Informal evaluation entails an exchange of opinion among interested parties, based on their collective operating experience. Formal evaluation involves thorough analysis and documented cost/performance comparisons related to alternative maintenance methods employing different equipment types, capacities, or features.

It is acknowledged that a considerable amount of evaluation takes place on an informal basis within the framework previously described. It is also known that, over time, this approach has resulted in the adoption of several new and productive maintenance methods. It can also more readily lead to costly mistakes. Thus, it was surprising to find how infrequently states apply formal evaluation techniques in this important area that holds such promise for surmounting the Maintenance Challenge.

Two states and five of the eight responding Canadian provinces often use the formal approach. Twelve states seldom use the formal approach, and 35 states and two provinces never do (Fig. 2). Respondents who did not identify or illustrate any methods in which they had applied

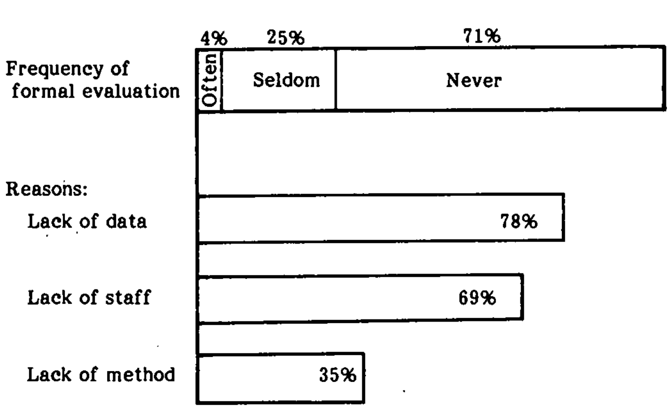


Figure 2. Formal evaluation in assessing alternative equipment types, including reasons for low incidence.

a formal approach are shown in Figure 2 as never doing so.

In advancing reasons for such a low incidence of formal evaluation, 38 states said that reliable cost/performance data invariably were not available for either existing or proposed maintenance methods, 34 attributed shortage of staff as another cause, and 17 declared that no acceptable evaluation formula was known to be available for the purpose.

A distinct possibility exists that the proponents of value-engineering/cost-effectiveness techniques, in seeking to gain a niche for themselves in the management hierarchy, inadvertently may have rendered the methodology to appear intimidating to those faced with manpower shortages. The process in fact constitutes no more than formalized common sense. With a view to furthering the application of value engineering, the Federal Highway Administration (FHWA) in 1976 developed a manual entitled "Value Engineering for Highways." FHWA also sponsored 10 studies in a series called "Value Engineering Analysis of Selected Maintenance Activities" to stimulate the use of more formal efforts in this area. The TRB-recommended National Highway Maintenance Research Program earlier had identified this area as the number one priority (under the title "Optimizing Expenditure of Maintenance Resources") from among its 28 research topics. Equipment modifications, in part, contributed to the exposure of extensive potential for improved productivity as a result of these studies. Similar potentials were revealed in another FHWA-sponsored project undertaken by North Carolina, the results of which are published in "Productivity Management for Maintenance."

Encouragement is to be drawn from the fact that, in addition to North Carolina, at least three other states (California, Florida, and New Jersey) are known to have staffed full-time organization cells devoted exclusively to productivity evaluation. The formation of such groups is highly desirable and certainly merited by the dimensions of the Maintenance Challenge. However, they do not of themselves, necessarily represent a condition precedent to the sound application of formal evaluation techniques as outlined in the FHWA value engineering manual. What is far more important than the ability to form such permanent productivity groups is that the methodology of formal evaluation be applied more extensively than it is. The effort can as well be undertaken by ad hoc teams recruited from among maintenance personnel. The contribution made by individual members of such teams, furthermore, need not severely hamper the performance of their normal duties.

Following is an extract from the final report submitted by one of the states that participated in the FHWA-sponsored "Value Engineering Analysis of Selected Maintenance Activities" program:

> It was interesting to note that the Value Engineering procedures very quickly pointed out areas of possible improvement. The strict adherence to the Value Engineering techniques did in most cases suggest areas for possible improvement that will result in cost reductions of 10% to 15% without degradation of the end product. Most of the recommendations made in this study will not require a large outlay of cash to get the program

underway. It will simply require a decision by management to carry through with the changes in our standard procedures and the development of some relatively simple equipment changes. Benefits from the implementation can be realized within the next year.

In a similar vein, the Environmental Protection Agency has published a booklet entitled "Decision-Makers Guide in Solid Waste Management." An extract from this publication is included as Appendix A to illustrate a simple method for making comparisons of cost-effectiveness among different types of equipment.

Twenty-eight states and seven provinces have undertaken major modification of equipment over the past five years, although only about half of each retain facilities and manpower to do so on a continuing basis. Six provinces say they cost-justify projects undertaken in this field in a formal manner beforehand, and only nine states say they follow such a practice.

Activity in the area of exchanging detailed equipment performance/cost data is not prominent in states or provinces. Twenty-seven states never engage in such exchange, and only two states and one province follow the practice on a regular basis.

In summary, FHWA has with foresight already provided a methodology for exploring how maintenance productivity can be upgraded. It has also seeded the application of that methodology in a number of states on several projects in which equipment alternatives contributed to the prospect of significant potential. It is to be hoped that this effort will attract the response it deserves in the form of more frequent and broader application of formal evaluation techniques by most states for the benefit of all.

USE

Minimizing the over-all equipment investment while still accommodating all approved user and shop requirements, or optimization of fleet size, is a function that merits conscientious application. This is even more relevant in an environment of rapidly rising equipment replacement costs.

Notwithstanding the great strides made in the adoption of highway maintenance management systems, a mere 12 states say they establish their equipment requirements in unit days at the user level, and all states say they do so in terms of units of equipment. Similarly, only 16 states develop patterns of need projected on a month-to-month basis through the year (Fig. 3), and 22 states restrict themselves to the level of need established by peak-demand months. Furthermore, only 19 states refine their demands for equipment capacity by specifically adding downtime to it.

The foregoing suggests that current methods for establishing fleet size are somewhat generous and undoubtedly result in investments greater than they should be. This opinion becomes entrenched with the revelation that 27 states determine equipment needs largely by round-table discussion with districts and that, further, once deployed or assigned, units in 96 percent of the states pretty much stay with a residency during the fiscal year.

In Canada, five provinces determine equipment demand in unit days, and six express it in units. Two of the latter

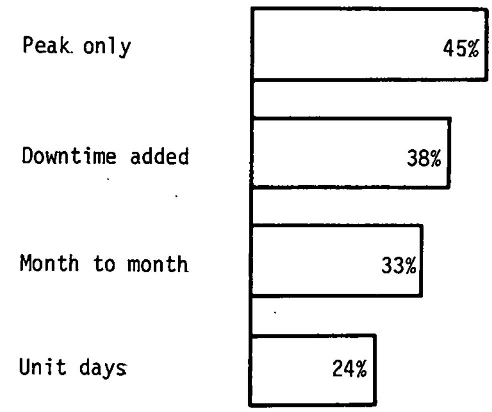


Figure 3. Techniques used in fleet size determination.

also confine their attention to the peak-demand month. Only one province, Quebec, projects its demand on a month-by-month basis through the fiscal year. As stated from Quebec, "Renting takes the work-load difference." Two provinces make specific provision for downtime in determining over-all fleet size. Six provinces report that equipment needs are largely established by round-table discussion with districts, and seven say that, once assigned, units pretty much stay with a residency during the fiscal year.

In identifying what happens to the capacity established in the manner discussed in the preceding paragraphs, two states do not record utilization at all; and, at the other extreme, only New York and Maryland maintain complete records of life-cycle time including seasonal/emergency time, idle time, and downtime in all its forms. Sixteen states track some but not all of these elements of unproductive time. All eight reporting Canadian provinces record utilization, only four maintain histories of seasonal/emergency time, and only five maintain histories of idle time. No province maintains complete records of downtime in all its forms.

In an area that must be conceded to be very difficult to control, 32 states report that their nonmetered utilization data are suspect or known to be poor.

Renting or hiring of equipment as an alternative to ownership appears to present a viable option to states and provinces. No state or province is prevented by regulation from doing so, although 7 states declare that their management is, on principle, opposed to the practice. It is likely that the "principle" in this instance is motivated more by a desire to enforce productive use of the existing equipment than from any disaffection with such an alternative method of providing needed capacity.

Forty-four states and all eight responding provinces hire specialty high-cost equipment, the normal need for which does not justify full-time ownership. A less prominent pattern emerges among states with regard to what may be termed regular equipment (e.g., trucks, loaders, graders, tractors, and mowers); 20 states indicate that they do not hire to meet seasonal workload peaks. A review of these responses, however, suggests either that the states in ques-

tion do not enjoy access to a pool of equipment that may be hired from the private sector or that their climates do not pose the problem of seasonal peaks to any marked degree. Only three states (New Hampshire, Pennsylvania, and Texas) and two provinces (Prince Edward Island and Quebec) report that they do hire some equipment full-time through the year.

PREVENTIVE MAINTENANCE

For purposes of enabling all respondents to move out from a common base of interpretation regarding preventive maintenance (P.M.), the questionnaire defined a formal P.M. program as being comprised of these five elements:

- *When* to administer P.M. (the intervals or frequencies at which it should be undertaken).
- *What* level of P.M. to apply at each frequency (normally referred to as first echelon, etc., or levels A, B, C, or D).
- *How* to administer P.M. (definitions of specific tasks to be performed within each level of P.M.).
- *How* long P.M. should take (time standards for each specific task).
- *Who* should perform P.M. (many permit equipment operators to perform P.M. A and reserve P.M. B, C, and D for mechanics).

Within the above framework, it is evident that all states but one attach importance to the role of preventive maintenance in their fleet operations. The one exception might be said to favor P.M., but not to the full extent defined in the type of formal, five-element program just outlined and favored by all others. Thirty-five states already have P.M. programs that may be said to include the elements of When, What, How, and Who (Fig. 4). However, the element of how long P.M. should take (time standards) is conspicuous by its absence from all but 12 of those state programs. An almost identical pattern emerges in Canada, with one notable exception. Three of the eight responding provinces, and with evident forethought, are not in favor of formal P.M. programs.

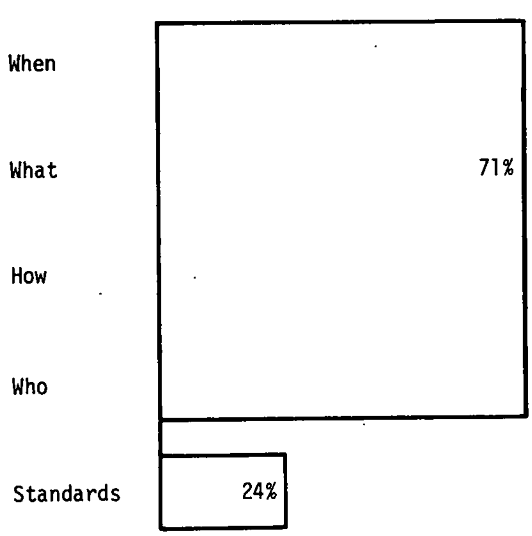


Figure 4. Preventive maintenance program elements applied to state highway maintenance fleets.

All but three states and two provinces acknowledge that P.M. can be overdone. In this regard it may be worthy to note a decided trend among large government fleets in the United States to draw back from previous levels of P.M. and veer in the direction of manufacturers' specifications for preventive maintenance. Only one study, sponsored by the Naval Facilities Engineering Command and dealing with the relative cost-effectiveness of four different approaches to P.M., could be identified. The study is entitled "Analysis of Preventive Maintenance Policies for Navy Transportation Equipment," and it compares (a) scheduled preventive maintenance service (as then practiced by the U.S. Navy on 50,000 nonordnance vehicles), (b) limited preventive maintenance service, (c) breakdown maintenance service (i.e., no P.M.), and (d) manufacturers' prescribed preventive maintenance.

The study concluded that the Navy should defer its own more extensive scheduled preventive maintenance policy in favor of manufacturers' prescribed preventive maintenance; this practice later was adopted. The potential savings related to this recommendation were forecast by the study to be $5.9 million per year.

In summary, there is evidence of a widespread acceptance of preventive maintenance among highway agencies from a technical point of view, but few have seen fit to retain an ability for monitoring the productivity of tradesmen engaged in performing it.

REPAIR

Small, outlying shops (two to four employees) usually can be justified only on the basis of a need for fast turnaround service aimed at maximizing equipment availability to user work crews. Because their capacity is limited in terms of space, facilities, spare parts, and manpower, such a service posture cannot be preserved unless care is exercised in governing the types of jobs such small shops undertake. Generally speaking, it can be shown that the longer the job, the more inefficient/uneconomic it becomes if performed in a small shop.

Under normal circumstances, therefore, small shops should restrict their attention to jobs of relatively short duration—the minor replacement/adjustment, service-type job. Other work in the equipment program's job mix should be contracted out to district, central, or even commercial shops, each of which would be able to justify its respective escalating level of investment in space, facilities, spare parts inventory, and manpower.

It follows that each type of repair job may be said to possess a distinct cost-effectiveness profile that, when related to the volume or the frequency of occurrence, has a direct bearing on whether the job should be undertaken at the residency, district, central, or commercial shop level.

New York is the only state known to have applied this thesis to the full. New Hampshire applies it to 80 percent of its workload. Maine has such a program under development. Five Canadian provinces report having such a policy

in place for most of their respective shop workloads. North Carolina uses it in somewhat abbreviated form by applying the rule of thumb that "if any job is estimated at an outlying shop to take longer than the travel time between it and its parent division shop, then the work is to be shipped in to the latter for repair." North Carolina applies this to all its workload.

Six provinces state that they make it a practice to go back and test the performance of specific equipment makes/types by comparing their actual repair experience with the expectation of engineered capacity originally provided for in drawing up specifications for procurement. Surprisingly, only seven states say they do so.

As is the case with preventive maintenance, very few states use time standards for repair work in their shops. Only eight states and three provinces do so.

It becomes evident that the flow of shop workload is not governed to any great extent and that scant capacity exists for allowing management insight into its productivity.

REPLACEMENT

In no single area is the consequence of the equipment impasse more damagingly evident than in the matter of replacement. This is amply illustrated by the fact that 38 states report that they have been prevented to a significant degree from replacing equipment on average in six of the last 10 years; and 5 provinces report the same difficulty for 7 of the last 10 years.

The reason given may be lack of funds, but the cause lies in a widespread inability to articulate, in an objective manner, the impact of the failure to replace equipment that has exhausted its useful economic life. A barrier that plagues most agencies in this regard is represented by the inadequate data presently produced by their equipment management systems (see the section entitled "Management Information Systems" later in this chapter).

Once an agency has been able to purify the data elements relevant to sound replacement decisions, the next requirement is a vehicle that will cause those data to interact and lead to sound replacements. After an acceptable replacement decision is arrived at, the final requirement is to ensure a funding capability sufficient to put that decision into effect. These matters are dealt with in the following two sections.

Vehicle

In order to establish what methods agencies use to arrive at their replacement decisions, the questionnaire defined three approaches, listed here with their appropriate responses:

TABLE 1

FACTORS USED IN REPLACEMENT FORMULAS

	Hawaii	Louisiana	New Jersey	New York	Ontario	Quebec	Saskatchewan
1. Operating Cost			X		X	X	
2. P.M. Inspection Cost					X	X	
3. Repair Parts & Labor:							
- Normal use	X	X	X	X	X	X	X
- Abnormal use			X			X	X
4. Labor Hours - Standard				X		X	
- Actual	X	X	X		X		X
5. Downtime	X	X	X	X	X	X	X
6. Disruption Cost		X				X	X
7. Depreciation		X	X	X	X	X	X
8. Interest		X			X	X	
9. Utilization	X	X	X	X	X	X	X
10. Projection of Future Repair trends	X	X	X	X	X	X	X
11. Inflation Factor:							
- Labor			X	X			
- Parts			X	X			
- Capital cost		X		X			

	States	Provinces
1. Occasional review of data (say, once every couple of years or more) to establish AGE and/or UTILIZATION milestones for a type of equipment (e.g., graders) that are then applied as replacement criteria for several years thereafter to all makes and model years of that particular type, REGARDLESS OF CONDITION	3	1
2. Same process as in (1) above, except that the criteria only serve as guidelines in relation to which some units may be held longer or sold/traded sooner, depending upon their particular CONDITION	42	4
3. Frequent review of cost and performance data, using a replacement FORMULA with which to monitor EACH individual unit throughout its useful life	4	3

It is evident that only the last of these three definitions, which is used by seven agencies, qualifies as an objective basis. The formulas used by these seven agencies share the common purpose of establishing a point in time at which a unit should be replaced. Their paths to this goal differ in some significant respects, as can be seen from Table 1, which identifies the agencies involved with the factors they take into account in their respective computations.

In its "Equipment Management Manual," the American Public Works Association includes a section entitled "Replacement Analysis," which might also be considered in comparison.

Although it is evident that objective methods for arriving at replacement decisions are not commonplace and that there are obvious differences of opinion, if not confusion, on what factors are relevant to the replacement equation, it is encouraging to note that 29 states and four provinces are active in developing bases for replacement more acceptable than those they presently employ.

Funding

The most valuable service that an equipment program can render in furthering highway maintenance productivity is to anticipate and be responsive to the needs of the highway maintenance manager. Any degradation in this respect translates too readily into restricting the few options available to the highway maintenance manager in the scheduling and performance of maintenance activities. Responsiveness, however, is becoming increasingly difficult for equipment programs to sustain. Periods of fiscal constraint tend to drive states into deferring equipment replacement, often without making appropriate provision for increased maintenance and repair activity generated by such deferrals. As a consequence, downtime increases and availability suffers to a corresponding degree. In addition to such impact from budget cutbacks, replacement decisions also have been impaired by a relatively recent trend in which the initiation of budget cycles has been stretching further and further back from the commencement of the fiscal years to which they relate. The further ahead of time that issues such as replacement are reviewed, the more inevitable it is that they will be regarded with less urgency, and hence the greater the risk of declination for all or part of the funds requested.

It is evident that this situation can cause the erosion of an equipment program's responsiveness. A device for overcoming this problem, which evidently has reached serious proportions among highway agencies, is the revolving fund. This is by no means new to government administration, having first been used at the federal level in the late nineteenth century. If properly applied, the revolving fund is one of the most, if not the most, promising and practical tools for furthering the reach of progressive management in the government sector, especially with regard to equipment programs.

By resembling a dedicated fund within the highway agency, a revolving fund becomes buttressed from replacement cutbacks that would otherwise apply if monies were sought from the general fund. Furthermore, such a fund provides the kind of fast-moving flexibility that top management needs to secure for highway maintenance managers. A properly constituted revolving fund enables replacements to be made in as short a time as a manufacturer can produce and deliver units requisitioned in accordance with approved criteria.

Notwithstanding these advantages, plus the fact that 40 states declare themselves in favor of them, it was surprising to find that only three equipment revolving funds have been launched in the past 20 years. Following is a distribution by decade of those that are in existence among states and provinces.

Year of Formation	*States*	*Provinces*
Prior to 1930	5	1
1930–1940	3	1
1940–1950	2	2
1950–1960	2	—
1960–1970	—	—
1970–1977	2	—
	14	4

It is important to recognize that a revolving fund is not properly constituted if the highway agency needs to go to another department for approval to replace any equipment included in that fund. In this respect, four of the state funds and one provincial fund in the previous list can not properly be classified as revolving funds.

In summary, replacement presents a problem of significant consequence to most fleets, state and federal alike, for three reasons: inadequate data, rare use of objective evaluation, and outdated funding mechanisms.

STAFFING

A matter known to be of widespread interest to highway agencies relative to their equipment programs concerns the question of how shops should be staffed. Twelve states and three provinces have formulas for this purpose, but details could be obtained for only 10. The 10 fall into three basic methods of computation, the principal difference

among them being the level of detail undertaken to arrive at shop complement. The American Public Works Association has documented these methods in Section 8 of its "Equipment Management Manual."

Level 1: Simple Ratio of Mechanics to Units of Equipment

Five of the 10 agencies use this method, which simply applies a fixed ratio to the total mix and number of units in a fleet. It does not follow that any two agencies should have the same ratio, but it is interesting to note the wide disparity that exists among the 5 that use this method. At one extreme, a ratio of 4 units per mechanic is used; at the other extreme, the ratio is 50 units per mechanic. The remaining three cases are evenly distributed between these two extremes.

Level 2: Point System

Three agencies apply minor variations of this approach, which establishes a relative point value for each type of equipment. These points then are multiplied by the number of units in each type serviced by a shop. The sum of these points is next divided by a point value considered to be representative of normal workload for one mechanic. The latter value is arrived at by taking the total point value of actual workload performed by several normal-performing shops and dividing it by the number of mechanics in those shops.

Level 3: Standard Hours Method

Two agencies use this approach, which, in effect, substitutes standard hours for points. The agencies establish the number of available productive hours per mechanic per year and divide it into an accumulation of standard man-hours per year for each type of equipment, based on historical patterns of repair accrual for that type.

PARTS INVENTORY

Forty-two states and all eight responding provinces retain control of their parts inventories within the bounds of their highway agencies. Thirty states and seven provinces say that their parts inventory systems are essentially of an accounting/record-keeping nature, and 16 states say they have full-fledged inventory management systems.

On the whole, it would appear that staffing, stockroom security, low-bid syndrome, unacceptable incidence of emergency purchases, and audit reviews are all matters that present no problem to any measurable degree. On the other hand, stock outages and parts-chasing emerge as related problems of some significance. Stock outages are reported to occur frequently in 24 states and four provinces. Only three provinces report a frequent occurrence of parts-chasing, but 32 states report having problems in this area.

MANAGEMENT INFORMATION SYSTEMS

The realities of the Maintenance Challenge confronting the highway maintenance manager resemble more of a precipice than a steep incline. As pointed out in Chapter One, the highway maintenance manager needs every possible support from other disciplines, as well as from top management, to succeed in climbing that precipice. It thus seems appropriate that the maintenance manager first plot the most expeditious and least burdensome path to the summit. For this purpose he or she clearly needs to take an unfettered and measured view of each specific obstacle from at least ground level.

Insofar as equipment relates to the Maintenance Challenge, it would not be unreasonable to conclude that the highway maintenance manager is starting the journey shackled, from below ground level at the bottom of a crater.

This synthesis shows that the fleet selection and optimization process probably has led to the maintenance manager's having too much of the wrong mix of equipment; that this individual faces resistance in replacing a goodly portion of it and is buried under a mountainous volume of paper; and that, in the meantime, other disciplines are gathered around the rim of the crater exhorting the maintenance manager, with some impatience, to do something about getting to the summit of the precipice.

It is to be hoped that this analogy is farfetched enough to evoke attention, even ridicule, sufficient to cause the several disciplines involved—and the highway maintenance manager—to pause and reexamine the extent to which they may be contributing to the equipment impasse.

Engineering disciplines are as suspect as any of making a contribution by default because of their tendency to be intimidated by pronouncements on so-called accounting and fiscal principles. On the other hand, the fiscal discipline, which occupies the ultimate driver's seat in government administration, might do well to temper the weight of that authority with a closer appreciation of the privilege the administration bestows on it. With privilege comes a collateral responsibility, and therefore it is never amiss for the fiscal discipline to preserve awareness of the long-standing and far-reaching impact that its pronouncements can have on operations for which it seldom is held directly responsible.

As illustration:

- Those who insist that rental rates *must* be changed on a monthly basis to liquidate costs, and after the fact at that, are aware neither of the negative forces they unleash on operations nor of alternative ways to accomplish their end and also encourage operating personnel to attack the Maintenance Challenge. No human alive, least of all a highway maintenance manager, can juggle price and volume variances around mentally and still come up with meaningful actions to correct the cause of the deviations.
- Those who contend that every vehicle must be charged with only the *actual hours* for all work done on it and be priced at the *actual rate* of the particular mechanic who performed that work are unaware of the polluted data they cause to be pulsed into a system. These data can only lead to invalid decisions regarding that vehicle's cost/performance in relation to others that may be challenging its continued presence in a fleet.

These two illustrations are but a few, seemingly incontestable dictates that go under the guise of established accounting principles but that in fact can be shown to

defeat the purpose of trying to improve productivity. Indeed, they act as self-fulfilling prophecies, because when one attempts to use the information yielded by them to justify recommendations on such as replacement, the information can too easily be declared inappropriate for the purpose by the very discipline that gave it birth.

To suggest that such incongruities should be resolved outside the mainstream of an agency's accounting/fiscal system is to subject the management process to additional costs, delay, and confusion, an environment in which mutual confidence and trust can not survive.

All states and provinces charge labor hours against individual units at the actual hours it took to do the work (Fig. 5). However, only three states (Maryland, New Jersey, and New York) also charge those units with the standard hours it should have taken to do the work. No province does so.

Labor hours are priced by 32 states and three provinces at the actual payroll rate of the particular mechanic doing the work. In contrast, 16 states and five provinces charge labor hours at a standard or average rate that reflects all mechanics in their equipment programs.

All states but one and all eight responding provinces charge repair and replacement parts to units at actual cost. Fuel is charged against units at actual cost specific to districts in which they operate by 25 states and five provinces. In the other three provinces and in 20 states, fuel is charged at actual cost averaged for all districts.

Only three provinces and six states allow credit to a unit for the unexpired life of major components that are replaced and subsequently rebuilt for use on other units. The same number of provinces but somewhat more states (28) deduct an amount for salvage in order to arrive at depreciation value.

As far as depreciation is concerned, 33 states use the straight-line method, 5 use utilization as a basis, and 3 apply the declining-balance method. Not included in those states, and undoubtedly influenced by the interesting work it is doing in replacement efforts, is Louisiana, which is unique in employing actual cash value as a means of arriving at its "loss of market value" for depreciation purposes. Nine provinces are evenly split in their application of straight-line and declining-balance methods (one province reports using both methods), and only one uses utilization as its basis for depreciation.

It makes sense, then, that 33 states say that the data made available by their systems are essentially accounting-oriented and thus inhibit meaningful operating decisions (Fig. 6).

Because only eight states and three provinces use repair time standards, it is clear that all the remaining agencies have no means by which to measure shop productivity.

It is interesting to note a parallel between states and provinces concerning the availability of management information other than that of an accounting nature (see Fig. 6). About 37 percent have ready access to such costs as supervision, training, and building and grounds maintenance, all of which are fixed and easily controllable. However, when it comes to being able to gain insight into aspects that are more deserving of control, such as inter-program assistance, road-call travel, average hours and cost per job by specific types of work, downtime, and so on, the threshold of availability drops markedly, to about 12 percent.

Also significant is the fact that only four states (Kansas, Maryland, New Jersey, and New York) and two provinces (New Brunswick and Quebec) attempt to govern the course of events within their equipment programs by monitoring deviations from planned performance (see Fig. 6).

In terms of having planning mechanisms to assist in developing fleet size, only Louisiana, Maryland, New Jersey, and Washington are active in the field.

Reliable and timely information is a prerequisite to sound equipment management. It permeates every one of its facets and therefore has a significant bearing on how effectively the highway maintenance manager is able to extract maximum benefit from equipment resources. There is thus a widespread need to upgrade both the quality of data flowing into and the form and content of equipment management systems.

"Let it not be feared that erroneous deductions may be made from recorded facts: the errors which arise from the absence of facts are far more numerous and durable than those which result from unsound reasoning respecting true data."—CHARLES BABBAGE, 1791-1871.

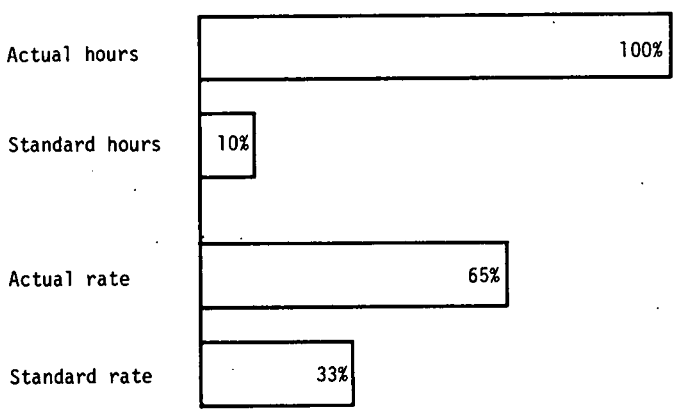


Figure 5. Features of valuation flow used in state equipment management systems.

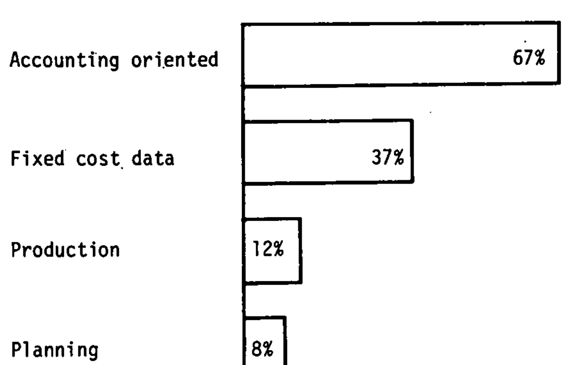


Figure 6. Design characteristics of state equipment management systems.

CHAPTER THREE

CONCLUSIONS

THE ROLE OF EQUIPMENT

Equipment management in state highway agencies is a function that must necessarily be responsive to the best interests of its principal customer, highway maintenance programs.

The Maintenance Challenge of the immediate and far future is considerable. External forces such as inflation magnify it even further. There is thus compelling demand for a significant increase in highway maintenance productivity.

Highway maintenance managers are obliged to look toward improved application of materials and equipment for enhancing the yield of their primary resource—manpower—the cost of which is escalating rapidly in the face of a mounting backlog of work and increased competition for limited funds. Although it is by no means the only alternative, equipment represents one of the more promising potentials with which to address the Maintenance Challenge. Despite this opportunity, this synthesis leads to the conclusion that, on the whole, current equipment management practices are not fitting to the task at hand.

There is no reason to doubt widespread presence of the necessary expertise among state equipment program personnel in a technical or mechanical sense at the daily operating level. Acknowledgment also must be made of the great strides that have been taken over the past 10 years by the highway maintenance community in broadening its management horizons. This significant development, when combined with the deductive discipline of an engineering background and the practical service orientation inherent in the highway maintenance function itself, all support the assertion that the highway maintenance manager of today is well qualified to provide the much-needed impetus for new initiatives capable of extracting better yield from equipment resources.

THE EQUIPMENT IMPASSE

Given that service support for equipment is not wanting in a technical sense, and given that the principal user has both the capacity and the need to effect improvement in the most productive application of equipment, particular attention has been directed in this synthesis toward isolating what may be inhibiting these positive qualities from yielding the necessary momentum on a scale more evident than it is. Ample reason has been found to explain why most equipment programs appear to exist in a state of frustrated suspension.

When 33 states say that equipment information made available to them inhibits meaningful operating decisions and 38 states report that they have been prevented to a significant degree from replacing equipment on average in 6 out of the last 10 years, it becomes evident that a fruitful accord among fiscal, engineering, and administrative managers is not widespread.

Such an accord is an essential prerequisite if any worthwhile inroads are to be carved out of the Maintenance Challenge. A sound basis for communication among all disciplines, therefore, assumes paramount importance. This synthesis discloses that such a basis, essentially, can not materialize from most present equipment management systems. Neither top management nor any of the previously mentioned disciplines can be said to be exposed to information worthy of their consideration for articulating the role that equipment can and should play in the broader scheme of things.

The acid test of an equipment management system must be whether or not it serves to bring about an easy consensus in the management decision-making process. In this sense, highway agencies have little to gain from the current state of the art in other sectors of the economy, including federal government fleet operations. These operations were found to be strong in well-thought-out instructions aimed at ensuring adherence to sound practices at the operating level in very large, highly decentralized fleets. All, however, also were found to share the dilemma of the equipment impasse in full measure.

Most fleets do indeed have computerized systems that list the inventory of equipment they own and that also accumulate utilization and costs attaching to it on a unit-by-unit basis. The fact that these systems are computerized, however, does not necessarily mean that they are useful for making relevant management decisions about over-all fleet size, mix, productivity, replacement, and so on.

Not only are the data inappropriate in many cases, they are invariably cast in such voluminous detail as to prohibit attention from the management levels that can influence and govern the course of events. As a consequence, decisions concerning equipment can be expected to go begging, and highway maintenance managers will be obliged to content themselves with making do as well as they can with what they have.

That this inertia, or impasse, needs to be broken is enforced by the fact that 60 percent of state fleets are estimated to involve investments on the order of $30 million or more each, at current replacement values. Such a level of capital outlay in any enterprise is deserving of close scrutiny with regard to its productive yield. This becomes even more pertinent because a fleet investment, far from presenting the limited options attaching to any fixed plant of comparable cost, represents many mobile elements, each of which enjoys the flexibility to be upgraded or redeployed in the interests of sustaining maximum over-all productivity.

CATALYST NEEDED

Timely and relevant information, properly presented, is concluded to be the catalyst best suited to bridging the present gulf that surrounds equipment programs. It will not suffice simply to purify the quality of data that pulses through existing systems, necessary though this will be. What is needed are more succinct, meaningful impact statements capable of leading all disciplines, as well as top management, to a rapid consensus for effective policy, operating, and funding decisions.

Such insights also should be directly and immediately accessible to the management levels charged with that decision-making responsibility. No delaying intervention of lesser qualified clerical personnel should be necessary to formulate them.

By way of analogy, when the automobile was first introduced, one practically had to be a mechanic to drive it. But over time, Detroit put the complexity into the system, under the hood, giving us automatic starters and automatic transmissions, making the car simpler and simpler to operate.

The capability already exists for achieving a comparable breakthrough to clarify the complexities of management's decision-making task within geographically dispersed, multidisciplinary organizations like highway agencies. No further research is needed.

Such a new dimension in management systems design would provide a readily accessible and economical "exploration probe" capability with which management could assess the probable ripple effect of each alternative. This ability to anticipate the consequence of various options would encourage highway maintenance managers to explore and initiate tightly targeted actions within the context of operating reality, which they are best qualified to judge, while at the same time keeping them attuned to the fiscal impact of each.

It becomes readily apparent that advanced design of this nature would facilitate the interaction of disciplines by bridging the communications gap that presently exists. In effect, it would enable the professional engineer to speak with the confidence and authority on financial matters of any budget examiner, while at the same time permitting the latter to do likewise in translating the technicalities of engineering into commonsense terms of cause and effect.

THE ROLE OF TOP MANAGEMENT

The escalating impact of the Maintenance Challenge is already well in evidence; therefore, the need to unleash the options and potentials available from the equipment sector must be judged as being past due. If meaningful momentum is to be initiated in this respect, it is also clear that nothing short of deliberate attention from top management in highway agencies is likely to break the equipment impasse.

The issue has not attracted appropriate attention because equipment, by its very nature and function within state highway agencies, possesses none of the attributes for exciting the executive mind. It seldom appears en masse in either physical or fiscal form and hence is perceived in individual units of relative inconsequence. Furthermore, its function as a resource naturally tends to catalog it as secondary to the end product of the agency as a whole. And finally, as this synthesis shows, almost all states lack an adequate means with which the collective impact and potentials of equipment can be articulated in a manner concise and credible enough for executive consideration.

Failure to break the equipment impasse within highway agencies can be expected to invite and lend credence to momentum in favor of centralized control of all fleets within a state. Indeed, trends in this direction already have emerged in some states. Although such motivation may be well-meaning, it promises only to further constrict the maneuverability that should be preserved for promoting new initiatives among highway maintenance managers.

The emerging pattern indicates that there is less need for extensive research in any particular area than there is for top management action to sponsor these two initiatives:

1. Where they are not present, negotiate the formation of properly constituted equipment revolving funds that are capable of providing a highway agency with appropriate protection to replenish fleet capacity in a more economical and timely manner without risk of infringing on legislative or fiscal authority.
2. Provide support for the implementation of equipment management systems, but ensure beforehand that they have both the clear purpose and the capability of raising the visibility of significant trends and thus will enable the right information to be brought to the right people at the right time to enhance highway maintenance productivity.

Regarding the second item, the Federal Highway Administration, with participation from 12 states, recently completed a study entitled "Equipment Management System Design." The product of this project is a three-part system design manual that describes a general equipment management system intended to be used by any highway maintenance jurisdiction as a model to develop its own system, incorporating changes to respond to local needs.

To test the management concepts in the manual, FHWA is entering into cost-sharing contracts with states, using the manual as the basis for design and implementation of an equipment management system. Results of these pilot studies may be available in 1980. A brief outline and an introduction to the equipment management principles set forth in the FHWA manual are given in Appendix B.

In sum, what highway agencies need are:

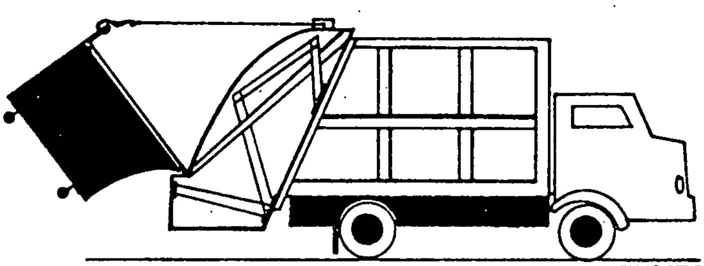
- Systems that eschew the unimaginative, unit-oriented, print-bound products of yesteryear.
- Systems that expose problems and their consequences in terms that all disciplines and levels can comprehend readily.
- Systems that lead ordinary people to practical, reliable, and productive decisions without the need of extensive analysis and review.
- Systems that provide highway maintenance and equipment managers with rapid, economical means for assessing the impact of alternative courses of action in arriving at the optimum size, mix, and age of their fleets and levels of equipment shop service, manning, and productivity.

APPENDIX A

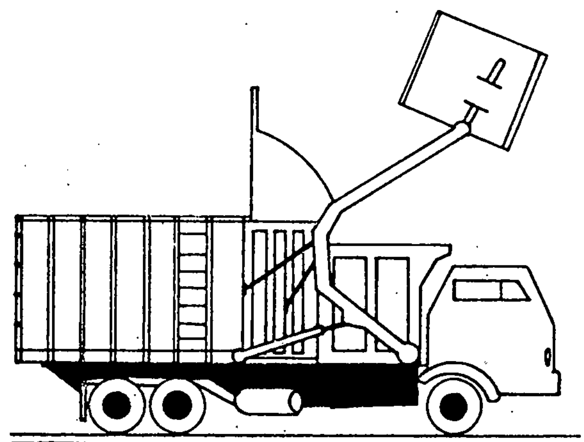
COST-EFFECTIVENESS COMPARISONS

The following is extracted from the Environmental Protection Agency publication entitled "Decision-Makers Guide in Solid Waste Management" to demonstrate a cost comparison method, used in this instance to compare the three alternative types of refuse collecting equipment illustrated.

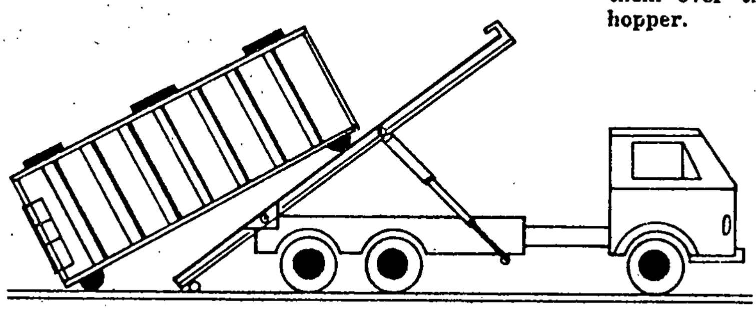
Clearly, the costs included in this appendix are outdated; nonetheless, the methodology provides an effective and simple example for making such comparisons.



Bulk containers can be emptied mechanically into a rear-loading compactor truck (as shown) or a side loader.



The front-loading compactor truck collects waste by picking up bulk containers, lifting them over the cab, and emptying them into the hopper.



Tilt-frame vehicles are used to transport roll-off containers.

For the rear loader, it is assumed that a two-man crew manually collects two loads a day, 5 days a week, working 8 hours per day. The truck's capacity is 20 cubic yards, and it compacts to an average density of 500 pounds per cubic yard (4-to-1 ratio). On this basis, the estimated total yearly cost, including the cost of the truck, labor, overhead, maintenance, fuel, insurance and licenses, would be $49,478, or $19.03 per ton (Table 24).

To estimate costs for a front loader, the following assumptions were made: 2.5 loads per day, 5 days a week, and 8-hour work shifts; an average of six containers are emptied per hour; the average container size is 6 cubic yards; the body capacity is 30 cubic yards, with a 4:1 compaction ratio; and the average weight per compacted cubic yard is 500 pounds. The initial investment in the storage containers is assumed to be covered by a rental fee or sale to the users. On this

TABLE 24

TYPICAL YEARLY COSTS FOR COMMERCIAL COLLECTION WITH REAR LOADER AND 2-MAN CREW*

Item	Cost per year
Truck cost ($30,000 at 6 percent interest amortized over 5 years)	$6,900
Labor, including 20 percent fringes:	
Driver ($5.00/hr)	12,480
Helper ($4.50/hr)	11,232
Consumables:	
Fuel (7,200 gallons × $0.36)	2,592
Oil	480
Tires	1,680
Truck maintenance	4,000
Management and administrative overhead (30 percent of direct labor)	7,114
Miscellaneous (insurance and fees)	3,000
Total	$49,478
$49,478 ÷ 2,600 tons/year† = $19.03/ton	

* Costs are for a 20-cubic-yard packer that is manually loaded. Average compacted waste density is 500 lb/cu yd, and two loads are collected each day.
† 20-cu-yd body × 500 lb=10,000 lb, or 5 tons; 5 tons × 2 trips/day=10 tons per day; 10 tons/day × 260 days=2,600 tons per year.

basis, the yearly operating cost is $48,993, or $9.92 per ton (Table 25).

The assumptions underlying the cost estimates for the roll-off system are as follows: 5 loads per day, 5 days a week, in 8-hour work shifts. The average container size is 30 cubic yards, and the average density of the compacted waste is 500 pounds per cubic yard. The cost of the containers and/or compactors is assumed to be passed on to the user and is not considered as part of this estimate. With these assumptions, the yearly operating cost of the roll-off truck is estimated at $44,293, or $4.54 per ton (Table 26).

The roll-off system, with a cost per ton of $4.54, is clearly the most cost-effective. The next most cost-effective system is the front loader with a cost of $9.92 per ton. The least cost-effective system shown is the rear loader with a cost of $19.03 per ton. It should be noted that the costs of operating a residential-type truck (rear or side loader) with mechanically emptied bulk containers would fall somewhere between those for the front-loader system and the manually loaded rear-loader system on a per ton basis. The more bulk containers are used with the rear or side loader, the closer its costs will come to those of the front loader, but it can never be quite as cost-effective.

TABLE 25

TYPICAL YEARLY COSTS FOR COMMERCIAL COLLECTION WITH FRONT LOADER AND DRIVER-OPERATOR*

Item	Cost per year
Truck cost ($50,000 at 6 percent interest amortized over 5 years)	$11,500
Driver's wages and 20 percent fringes ($6/hr)	14,976
Management and administrative overhead (30 percent of direct labor)	4,493
Truck maintenance	10,200
Fuel (8,400 gallons × $0.36)	3,024
Insurance and licenses	4,800
Total	$48,993
$48,993 ÷ 4,940 tons/year† = $9.92/ton	

* The truck is a 30-cu-yd packer; the average waste density is 500 lb per cu yd; and 2.5 loads are collected each day.
† 30-cu-yd body × 500 lb=15,000 lb or 7.5 tons; 7.5 tons × 2.5 trips per day=19 tons per day; 19 tons per day × 260=4,940 tons per year.

TABLE 26

TYPICAL YEARLY COSTS FOR COMMERCIAL COLLECTION WITH TILT-FRAME (ROLL-OFF) TRUCK AND DRIVER-OPERATOR*

Item	Cost per year
Truck cost ($40,000 at 6 percent interest amortized over 5 years)	$9,200
Driver's wages and 20 percent fringes ($6/hr)	14,976
Management and administrative overhead	4,493
Truck maintenance	7,800
Fuel (8,400 gallons × $0.36)	3,024
Insurance and licenses	4,800
Total	$44,293
$44,293 ÷ 9,750 tons/year† = $4.54/ton	

* The truck takes on a 30-cu-yd container; the average density of the compacted waste is 500 lb per cu yd; and five loads are handled per day.
† 30-cu-yd body × 500 lb=15,000 lb or 7.5 tons; 7.5 tons × 5 trips per day=37.5 tons per day; 37.5 tons per day × 260=9,750 tons per year.

APPENDIX B

EQUIPMENT MANAGEMENT SYSTEM MANUAL

The FHWA equipment management manual describes a general equipment management system that could be used by any jurisdiction responsible for highway maintenance as a model to develop its own system, incorporating some changes dictated by local needs. The manual consists of two parts and a technical appendix, described briefly in the following. More information on the manual is available from the Implementation Division (HDV-22) or the Construction and Maintenance Division (HHO-34), Federal Highway Administration, Washington, D.C. 20590.

Part I—Equipment Management Opportunities and Information System Benefits

Part I describes some current equipment management practices and the effects of a general lack of adequate management information. It describes how the information reported by systems developed in the manual can help to improve management practices and estimates the value of management improvements.

Part I also outlines a role for top management in developing an adequate equipment management system. This part is designed as an executive summary for top officials in a transportation agency.

Part II—Equipment Management Information Reports and Their Use

Part II is the key section of the manual. It illustrates sample reports produced by the model equipment system, describes how these reports are used in normal equipment management decision processes, and describes the operational objectives to which they relate. This part is aimed at equipment engineers and managers and their immediate subordinates, senior data system analysts, equipment user representatives, and fiscal managers.

Appendix—Technical Guide to Equipment Management Systems Development

The appendix describes the structure of equipment management systems, including system flow diagrams and system interfaces, file structures, and processing requirements, and indicates priorities for system development. This section is directed primarily to the project manager whose aim is to develop and implement an equipment management system, and to data system analysts.

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