HRB SPECIAL REPORT 100

MAINTENANCE MANAGEMENT

HIGHWAY
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SPECIAL REPORT 100

MAINTENANCE MANAGEMENT

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The Ohio State University
Columbus, Ohio

Subject Area

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12 Personnel Management
40 Maintenance, General

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PREFACE

This Special Report constitutes the record of a Maintenance Management Workshop held July 22-24, 1968, at The Ohio State University, Columbus, Ohio. The Conference was sponsored by the Departments of Maintenance, and Economics, Finance and Administration of the Highway Research Board with the cooperation of the Department of Civil Engineering, College of Engineering, The Ohio State University. Organization and direction of the Conference was the general responsibility of the Department of Maintenance of the Highway Research Board, and the specific responsibility of an Advisory Committee consisting of Roy E. Jorgensen, Chairman; G. A. Brinkley; L. Mann, Jr.; J. M. Montgomery; and C. H. Oglesby. Kenneth E. Cook and Adrian G. Clary of the Highway Research Board assisted as staff liaison representatives.

With some exceptions the papers in this volume were originally prepared for and served as a basis for subsequent discussion at the Workshop. The exceptions are the paper by L. Mann, Jr., analyzing and reporting on the Workshop, and the summary remarks by J. F. Andrews, R. E. Jorgensen, and C. H. Oglesby.

The Workshop brought supervisors and methods analysts from agencies undertaking or contemplating maintenance management studies into contact with representatives from the organizations most active in developing modern maintenance management systems. Discussions were not recorded although summaries by group discussion leaders are published in this report.

The Highway Research Board gratefully acknowledges the financial assistance of the Automotive Safety Foundation in publishing this volume.

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Analysis and Report on the 1968 Maintenance Management Workshop

LAWRENCE MANN, JR., Louisiana State University

At the Annual Meeting of the Highway Research Board in 1967, it was decided that the Department of Maintenance would sponsor a maintenance management workshop. The agenda and operating details of the workshop were worked out at the 1967 midyear meeting of the department in San Francisco.

The purpose of the workshop was generally informative in nature. It was decided that invitations to all state highway departments would be made and that at least two individuals from each state would be requested to be in attendance. Other interested parties could participate as full working members.

The Highway Research Board in general and the members of the Department of Maintenance in particular were of the opinion that the particular research projects having to do with systematizing maintenance operations, that were being supported in some states, would be of interest to maintenance managers in general. There was a general feeling that state legislators were beginning to question whether or not the considerable funds, being approved for highway maintenance operations, were really necessary or were being spent wisely. The purpose of most of the research projects is to design a system to optimize the use of these funds. The maintenance workshop was to inform all participants of the work that was being done in the particular states that supported such research.

The Ohio State University was chosen as the site for the three-day seminar which was held from July 22-24 of 1968. There were 134 participants representing all but eight states and representing all but two provinces in Canada. The format of the seminar included a day and a half of talks by speakers who were familiar with the latest technology which has been developed for these maintenance research projects.

On the morning of July 22 after initial welcoming speeches, William N. Records, Highway Research Engineer, Bureau of Public Roads, spoke on "An Overview of the Highway Maintenance Management Research Program in the United States." He reviewed maintenance management during the past fifty years and particularly emphasized the studies that had been done in the recent past. Studies included the 1959 Ohio State study, the Louisiana study of the early 1960's, the Oklahoma Department of Highways study, the Illinois, New Jersey, New York, and Wisconsin studies having to do with toll roads authorities, the Los Angeles study, and the Minnesota study. Records singled out the Virginia Department study as the largest single one which had been carried out to date. This effort lasted over a three-year period and was designed to cover nearly every major aspect of maintenance. The uniqueness of this study was its all-inclusiveness. Records noted that currently the maintenance management research program includes thirteen formal studies which are fully active. Eleven of these are being financed through the Federal-aid HPR program. The estimated total cost is over $2 million and the annual expenditure is about $700,000. The nature and scope of these studies vary considerably. Six can be classed as comprehensive because they cover several aspects of maintenance management; five deal with the equipment and methods for specific activities; two are concerned with cost.

Paper sponsored by the Committee on Maintenance Management to be presented at the 48th Annual Meeting.

The next presentation was by Colonel P. J. F. Wingate, Principal Scientific Officer, Road Research Laboratory, Ministry of Transport, London, England. Colonel Wingate spoke on the concept of maintenance management problems insofar as they have been established by preliminary investigations in Great Britain. He reviewed the overall content of the problems and mentioned the specific tools that management was then using to approach the solutions. He felt that in Great Britain they must start logically by getting the maintenance task right, that is, by setting standards correctly. Then they must get administration and organization right so that they can know what is going on so that planning and controlling can be done correctly. Finally, they must ensure that what is being done on the site is being done in the most efficient manner.

H. O. Sheer, Engineer of Maintenance, and Nile Blood, Engineer of Cost and Planning, Illinois Highway Division, next gave a progress report on the Illinois management program. They noted that a short report of the Illinois concept of highway maintenance management and performance rating was presented at the HRB Annual Meeting held in Washington in 1968 and that they were restating a few of the major features of the system. They described the roadway inventory system and the necessary forms used to maintain this inventory. They have attempted to design a simple system, especially in the field report phase. Planning and scheduling of work were encouraged when feasible, although formalized scheduling was not a part of the system. No actual job time studies had been made. They expect to develop performance standards from actual average unit cost which they are recording over a period of time. In summary, they noted that the present status of the Illinois system included the first roadway inventory summary, a basic report from the work accomplishment phases, the first cost reports, and the equipment usage reports.

Allen Leslie and A. P. Cunliffe presented the Ontario approach to maintenance management. Many are familiar with this project since it has been reported from time to time. An interesting approach which seems unique to the Ontario study is the recognition of the system as a dynamic one such that quantity standards, production rates, and methods of performing work come under continuous scrutiny and are revised and reshaped according to changing conditions. Planning is thus based on current information, thereby allowing maximum utilization of all resources in the achievement of the design level of maintenance service at the lowest practical cost.

V. L Dorsey presented the State of Washington's approach to maintenance management. He concluded that the system which was developed and installed has obtained the general acceptance of the employees of the system and that they are very optimistic about the future. A unique aspect of the Washington study is the recent heavy unionization of the Highway Department. At times, there were union representatives attending the training sessions where the maintenance management study was being initiated. Dorsey emphasized the tremendous amount of work required to see such a program through to a successful conclusion. He further emphasized the extreme importance of taking the program to the people and getting maintenance employees directly involved. In his words: "This is absolutely necessary to avoid the resistance that is all too often encountered when new programs are undertaken to displace long established habits."

L. G. Byrd spoke on "The Use of Pavement Evaluation Techniques in Maintenance Management." His thesis was that in order to evaluate maintenance, a systematic and formalized pavement evaluation technique should be developed. He reviewed the existing techniques emphasizing the advantages and disadvantages of each and recommended future work in the field.

John Swanberg gave a presentation on the Minnesota study, "Work Standards and Programmed Budgeting for Maintenance Operations." He also emphasized the difficulty of the transition to the new system. On the other hand, he found the program budget to be a management tool that can improve management's long-range planning, fiscal budgeting, performance evaluation, and decision-making. The program budget achieved benefits in the following ways:

1. It reflected the objectives, goals and policies of the organization;
2. It indicated approved plans and work programs geared to meeting the goals and objectives;

3. It provided a financial picture that indicated the cost as related to the expected result in carrying out the work programs; and
4. It presented results reflecting outputs and cost.

Swanberg's presentation and report included a number of forms, standards, scheduling techniques, and reports.

"The Application of Industrial Engineering to Maintenance Operations in New Jersey" was presented by J. F. Andrews, Director of the Division of Maintenance and Equipment for New Jersey's Department of Transportation. Andrews is the new chairman of the Highway Research Board's Department of Maintenance, succeeding John Murphy of California. It appeared that his argument for inclusion of industrial engineering techniques into highway management work was a strong one. Andrews said that the great strength of bringing industrial engineers in is that they bring a methodology and a freshness of viewpoint. Industrial engineers are usually enthusiastic with zest for improving methods, systems, cutting costs, and training. Entering the world of highways, the industrial engineer has no mental roadblocks induced by tradition worn-out policies, governmental budget processes, and politics. The industrial engineer is willing to challenge the status quo and reprocess it. The weakness that Andrews emphasized was the fact that the industrial engineer is usually trained in the industrial, hard-goods type industry field and that he must reorient his thinking to the highway frame of reference. Andrews emphasized the suspicion among government employees as to what new personnel and new systems were going to do to their entrenched operation. At this point, he mentioned that all of these problems are possibly encountered by the industrial engineer in the industrial atmosphere as well as the highway atmosphere. He says that in his opinion the strength overcomes the weaknesses.

Jim West, Engineer for Maintenance, Utah State Department of Highways, presented "A Scheduling and Performance Evaluation System for Utah's Basic Maintenance Mangement Units." Utah has recently undertaken the development and implementation of a computerized maintenance management system. The components of this system include performance standards, a maintenance management reporting system, planning processes and performance evaluation techniques. West went on to say that their computer system is not designed to schedule their basic management units or provide short-range operating guidances.

The development of the system required an evaluation of characteristics of Utah's particular organization. The major factors considered important in the development of the system follow:

1. First-line supervisors most of whom have high school education.
2. First-line supervisors who have traditionally been working members of crew.
3. Basic management units which are physically separated from each other and from their respective district headquarters by considerable distances.
4. Basic management units most of which require a staff of only 4 to 6 men.
5. Performance standards which have been and will continue to be developed to provide first-line supervision with operating guidelines.
6. First-line supervisors who have traditionally been responsible for need identification, scheduling, and performance of a majority of the maintenance activities.

The resulting scheduling and performance evaluations systems design can best be described as one which is noncomputerized; which continues to place considerable managerial responsibility on the first-line supervisor; which minimizes the time labor between performance and evaluation; and which incorporates performance standards.

The performance evaluation procedure involves a comparsion of actual performance with performance guidelines. Indications of actual performance are provided by data from the reporting system and actual field observation.

C. O. Leigh described some of the problems encountered in developing and installing a maintenance management reporting system in Virginia. His primary problem appeared to lie in the area of computer programmers and in the time lag between the reporting process and receiving reports from the computer. It appears that these problems will not necessarily be encountered by all who enter into a computerized system but make themselves felt when it is difficult to get and retain satisfactory computer programmers.

Forrest E. Crawford and Melvin Jackson, Louisiana Department of Highways, spoke on implementing findings from the Louisiana maintenance research project. Their discussions were divided into two parts. The first part described the project results to date and included a discussion of the background of the project and a report on the results of the major phases. Particular emphasis was given to the management reporting process, maintenance planning and changes in organization. The second section concerned experience in implementing the study. This included a discussion of the performance laboratory where basic data were gathered and methods reviewed. The performance laboratory aspect seemed to be of most interest to the audience. This was not a laboratory in the sense that all work was simulated in a building or within four walls. The performance laboratory merely meant a group of people who studied, mostly in the field, jobs which were of a repetitive nature and which could be "standardized." The Louisiana study was of considerable magnitude and permeated the whole maintenance organization.

Moving from the state highway frame of reference to the county and city approach, David K. Speer, County Engineer for the County of San Diego, California, presented the county's idea of a maintenance management system. That system had been in operation only about 4 months when the conference was held, and it was still too early to recognize tangible quantitative benefits. Dollar savings are anticipated and data are currently being accumulated. He noted that immediate quantitative benefits had been realized in the form of increased efforts on the part of the maintenance personnel to recognize and use methods improvement, priority ratings, and overall planning and scheduling.

One significant difference noticed by the group between the state highway situation and the county and city situation was the significant differentiation in the salary structure. The latter group was compensated considerably better than were the state highway workers.

Lawrence C. Jones, Director of the Bureau of Street Maintenance for the City of Los Angeles, gave that city's approach to maintenance management. It was interesting to note that the Bureau of Street Maintenance employed about 2,300 civil service employees and had a budget for the current fiscal year of over $27 million. It also maintained a fleet of approximately 1,900 units. Although the City of Los Angeles, with only 464 square miles and 7,275 miles of streets and public ways to maintain, was considered geographically small, the size of the street maintenance group approaches that of a state highway. Jones noted that the application of industrial engineering principles indicated 149 maintenance laborer positions (of a total of 472 studied) could be eliminated. Reduction was achieved by attrition in conjunction with an upgrading of 32 field positions. To date, the installation of the program within the bureau has produced a net savings of $4,339,344 for the city. The report also documented other savings. The audience was particularly interested in getting firm improvement figures resulting from maintenance management systems and, as a result, this presentation was of much interest.

The last three presentations concerned satellite problems of the maintenance management system. Charles Diehl of the Stanford Research Institute spoke on "A Researcher Looks at Maintenance Management—in a 'Systems' Context." He described the use of the systems analysis approach in the maintenance management environment. He indicated some general tools that he felt might be helpful in such an analysis and suggested some unanswered questions that engendered a feeling that there still remains a considerable amount of research to be done in order to come up with a really effective highway maintenance management system. The questions raised included: Do we have a reliable way of accumulating our costs so that the designers can look at the total cost of a highway from both a capital and operating standpoint? Are there restrictions on our operations because of funding situations that force us into illogical decisions because we must follow the money chain?

Lawrence Mann, Jr., presented "An Industrial Engineer Looks at Maintenance." The essence of these remarks was that the industrial engineer and his techniques have a real place in highway maintenance management and the training that the industrial engineer gets seems to prepare him for this type of work. Some problems exist as to whether there should be an industrial engineering department in the highway department or whether industrial engineers should be sprinkled throughout the organization so that their technology can permeate the entire maintenance structure. The paper listed some industrial engineering techniques, and with each technique, an application in the highway maintenance field was given.

The last paper was entitled "Cost Effectiveness as a Measure for Setting Maintenance Levels and Priorities." Professor C. H. Oglesby, Department of Civil Engineering, Stanford University, took a preliminary look at how cost effectiveness can be applied to decisions on highway maintenance. He also briefly explored the forms that analyses to measure cost effectiveness will take and the problems that will be encountered in carrying them through. In addition, he examined the question of giving decisions regarding highway maintenance greater sensitivity to the wishes of the public who pay the bill. Professor Oglesby concluded that cost effectiveness was an advanced and valuable aid to decision-making and is a fruitful area for future research and development.

After the presentation of the papers the group was divided into four sections of approximately 30 individuals each. The sections then met individually with teams from Ontario, Louisiana, Los Angeles-San Diego County, and Washington. The purpose of the group seminars was to allow the participants to ask questions of the representatives of those states which were conducting the maintenance management program. The group seminar approach seemed to work very well in that the participants felt no hesitancy in asking questions of the representatives of the above-mentioned states, and actually this was the purpose for holding the program, that is, making known to the states which did not have a maintenance management program the experience of those states which were conducting such a program.

The questions seemed to center around four particular topics: topics included the role of consultants, the source of man power to act as liaison between the consultant and the state highway department, how to sell the program to the highway administration, and how to sell the program to the maintenance people. Another source of discussion was the place of the industrial engineer and industrial engineering techniques in the maintenance management field.

In summary, it is my opinion that the maintenance management seminar was most successful in achieving the goals which were stated as the purpose for the seminar. Each participant went away with a complete set of notes and with a good idea of what such a program can do for his state. Further, he has a list of individuals in the highway field that he can call upon if he wants further information about such programs.

Summary Remarks

J. F. ANDREWS, New Jersey Department of Transportation

The papers presented at the workshop and the group discussions brought out that progress is being made in maintenance management improvement. Approaches vary. States with active programs are all working on substantially the same things: work measurement, planning and scheduling, and work accomplishment reporting. Progress varies with some states moving faster on one element than they are on others.

There appears to be an emphasis on developing reporting systems in order to measure work accomplishment.

It appears that electronic data processing may be delaying progress in several states because data processing sections are hard pressed to keep up with the needs of maintenance systems development. There is some indication of a need to establish data processing programmers in the maintenance department to concentrate on developing maintenance computer programs.

One thing which very much impressed me is the concept of the performance laboratory as used in Louisiana. Such a concentrated study of methods and time factors can be useful in any maintenance department whether or not it has embarked on a comprehensive maintenance systems improvement program. It seems time could be saved and progress made by focusing attention on this work in one location.

The role of consultants was conspicuous in the discussions. Consultants are working in most states reporting progress in maintenance management. Consultants can bring know-how and training to government organizations getting started in this new work.

There is good promise in the possibility of coming up with general time standards which can be employed without the need of making specific time studies. San Diego County and the city of Los Angeles are making use of such standards and it would appear that there is possibility that some day we can work from a manual in an office or laboratory without going into the field for more time-consuming stopwatch studies.

We realize that there are limits to maintenance management work. Highway maintenance must always be subject to emergencies and schedule interruptions. It does not lend itself to the same fixed pattern of daily activity as does work in an industrial plant. We must retain in any maintenance management system the ability to keep operations flexible and mobile. This necessity notwithstanding, we can still go a long way in measuring maintenance work, programming and scheduling it, and reporting accurately our work accomplishment.

Summary Remarks

ROY E. JORGENSEN, Roy Jorgensen Associates, Inc.

A most impressive aspect of the Workshop was the apparent general acceptance of the idea that we are in a process of rapid change in maintenance management. There was frequent comment on the growing pressures to establish program or performance budgeting systems. There was discussion of work measurements and standards, and of scheduling work to fit a plan.

While there is some confusion in terminology, it seems clear that maintenance budgets will, in the future, have to be based on measurable work quantities, such as cubic yards or tons of patching, and acres of mowing. Resources (labor, equipment, and materials) will then be allocated in the budget process to meet the work needs for patching, mowing, etc., based on standard productivity rates.

Associated with the change in budgeting are new guidelines for planning and scheduling work and more useful reporting systems for managers to use in evaluting performance and controlling work. At the present time, no highway agency seems fully to have established a performance budgeting system. Some are committed to so doing but are in prelimiary stages of development.

A number of state highway departments, the city of Los Angeles, San Diego County and Ontario have developed productivity standards for principal work activities. Some of the departments have also developed level of service or quality standards and, on the basis of these, are able to establish work quantity standards. They are now engaged in implementing a management system which utilizes these standards for planning purposes—including development of a performance budget—and for work scheduling and reporting to provide an effective management control system.

From the discussions, it is obvious that the development of the new management system is a big task. It requires the development of new ways of measuring, planning, scheduling and reporting work. It requires training of supervisors in their new responsibilities. It requires the creation and development of a maintenance staff capability for planning that has not previously existed. The magnitude of the job and the personnel requirements associated with it seem to be of real concern to some highway agency representatives—which leads to discussion of how the problem is being met.

There are those who felt industrial engineers were essential to the work measurement and standard setting associated with the new system. Others felt that highway engineers could readily pick up the industrial engineering concepts involved and would be better because of their knowledge of highways. This question was not resolved at the Workshop. However, the experience in several agencies indicates highway engineers and technicians with aptitudes and interests in the systems approach can do the job, provided they get adequate orientation and training. Furthermore, their background and association with the highway work increases the likelihood of their being accepted by operating personnel.

A somewhat parallel question is where in the agency responsibility for development of a new system is placed. There was discussion of experience in which a unit outside of maintenance was responsible. This has some appeal where an agency already has a methods or systems division staffed with individuals specially qualified as systems analysts.

It appears, however, that best results will be attained where the maintenance division itself takes full responsibility both for analysis and implementation, augmenting its existing staff as needed to provide the additional capabilities required.

The general arrangement of the Workshop seems to have been good. However, as a group chairman, I had a feeling of ineffectiveness in bringing a wider expression of viewpoint from the group itself. Understandably, the immediate interest was in interrogating the formal speech makers. And, this the group did, with specific reference to details not covered in the formal presentations or about which elaboration was desired.

The Workshop discussions may be presumed to have served an important function in concentrating attention on the significant changes now taking place in maintenance management. For those already engaged in establishing new management systems, it provided an opportunity for interchange of ideas. For those who have not yet undertaken projects, the Workshop gave some indication of the promise, the problems and the payoff of such an effort.

A List of Questions Posed for Maintenance Management

C. H. Oglesby, Stanford University

Question 1. What about feedback to top management on the effectiveness of new maintenance procedures: Who uses it and how effectively?

Question 2. How effective is maintenance management in getting maintenance problems considered at the time a highway is located, designed, and constructed?

Question 3. What about training programs for maintenance employees and managers: Are they ready to go—or in the dream stage?

Question 4. What can the computer do for a maintenance management program other than create problems?

Question 5. What are the advantages and disadvantages of the various ways for setting performance standards, such as stopwatch, time-lapse photography, M. T. M. ?

Question 6. What are the most effective means for devising improved methods? In particular, how can the interests and ideas of foremen and workmen be brought to bear?

Question 7. How can supervisors, foremen, or workmen who develop good ideas be rewarded?

Question 8. One gets a "feeling" that much of the talk about understanding and motivating people is superficial and is not based on a real knowledge of people and why they behave and react as they do. As a specific example, has any thought been given to defining and publicizing the opportunities ahead for good maintenance people at all levels?

Question 9. Do maintenance managers really know what the public wants and is willing to pay for in terms of standards of maintenance? If not, how are they going to find out?

Maintenance Requirements for the 70's

FRANCIS C. TURNER, Director of Public Roads, Federal Highway Administration, U. S. Department of Transportation

I compliment the Highway Research Board and Ohio State University for their vision and foresight in holding this Maintenance Management Workshop. While to most of the public the maintenance of highways may not be as glamorous as planning and building them, there is nothing more important among the responsibilities of the highway engineer and administrator.

Maintenance is important from many aspects, principally of course, in protection of the substantial investment we have made and are making in our highway plant. Even though the Federal Government does not contribute to maintenance costs, it has an investment of 50 to 90 percent of the capital cost of these highways built under the Federal-aid highway program. The Bureau of Public Roads has a statutory responsibility to see that this investment is maintained properly and, therefore, has a significant and continuing interest in the financial and other aspects of highway maintenance.

But there is much more than economics involved, important as that is. We must always keep in mind not only the safety factor but also the return in the form of good or bad public relations which result from the quality of our maintenance efforts. The traveling public is seldom aware of construction features so long as a highway provides a reasonably fast, direct, and safe route. But it is acutely conscious of such things as potholes, ragged shoulders, thriving crops of weeds, litter, illegible signs, and snow and ice on the pavement. And the traveling public is inclined to be quite vocal about its displeasure with such things.

It is an understatement to say that the 1970's will pose tough new challenges for state maintenance forces. The Interstate System will be in use throughout its length sometime around the middle of the decade—the precise time depending on the availability of financing. The Interstate System involves a different set of standards and more complex problems than most maintenance organizations have dealt with historically.

Maintenance must frequently be performed under conditions of never-ceasing heavy traffic, thus entailing much greater difficulties as well as potential hazards to both workmen and the traveling public. Landscaping on a large scale and the need for systematic mowing go hand-in-hand with Interstate routes. Huge signs and rest areas must be maintained and numerous motorist services must be provided. The motoring public demands a bare pavement year-round on high-speed expressways, and it is necessary to try to accommodate this demand if only on the one ground of traffic safety.

All of this adds up to a required raising of the sights in the maintenance field. It means more and better equipment, more and better personnel and more effective utilization of both. It means more and better materials and, wherever possible, materials which are maintenance-free or have long-durability qualities built into them. As one example, we need a simple and inexpensive traffic stripe that will last longer and have greater visibility in rain and fog. Current experimentation with grooving the pavement in the stripe area appears promising in both regards.

Before getting into the specifics of maintenance requirements of the next decade, a few comments on the expenditures involved may be useful, especially in comparison with construction costs. In 1950 the construction cost index was a composite 78. 3. In 1967 it was 117. 6 or a 39. 4 point rise in 17 years. During the same period, the maintenance cost index rose from a composite 70. 5 for labor, materials and overhead to 137. 4 or a 66. 9 point rise. The relatively low rise in construction costs is probably due largely to greater productivity by reason of improvements in both equipment and construction methods. Conversely, the high rise in maintenance costs is perhaps attributable to a lesser attention to research and development in the maintenance field, combined with the inherent difficulty of improving the maintenance operation.

Most of you are familiar with NCHRP Report 42 on Interstate Highway Maintenance Requirements. This estimates the cost of maintaining the completed Interstate System at $261 million per year or about $6, 400 per centerline mile. The report concedes that this figure is probably conservative and it is likely that $10, 000 per centerline mile will be a more realistic estimate for the overall mileage. The NCHRP report also calculates that pavement and shoulder presently take 15 percent of the Interstate maintenance expenditures, but that this ratio will rise to 45 percent in 1975 because of the increasing age of the Interstate highways as well as the increase in traffic volumes carried by them.

The Bureau of Public Roads, in a report to Congress, has estimated that an annual average of $5. 8 billion will be spent on maintenance during the years 1973-85. It has also been estimated that maintenance needs will rise about 60 percent during this period. Better maintenance management is one of the ways available to us to offset this rise in maintenance expenditures and that is why I complimented you at the outset on your enterprise in holding this timely workshop.

When we get into maintenance requirements of the 1970's, we have to make a necessary division of labor into two categories. One is physical or general maintenance; the other is traffic services. We also have to start out with the fact that 15 percent of our main state system of roads and streets is still unpaved. Most of such mileage is surfaced with soil, clay, gravel or stone, but not concrete or asphalt. These older roads and streets need widening, resurfacing, additional lanes, frequently complete reconstruction. Everyday maintenance needs are always with us on all roads—such routine activities as striping, mowing, cleaning up litter, patching, signing, ditch cleaning, shoulder work, joint sealing, and upkeep of guardrail.

In the urban areas considerable construction emphasis has been given to freeways, but arterial streets and highways still must carry enormous traffic loads exceeding the freeways. We expect that the TOPICS program will help to relieve some of the congestion in the urban areas. Much can be done by maintenance operations to improve capacity by merely striping left-turn lanes and minor channelization.

Routine maintenance operations on urban roads and streets with heavy volume, high-speed traffic will necessarily have to be done to a great extent during off-peak hours. This may involve night work or hours outside the normal working day. Extra pay will thus be involved but even then there is a problem in getting personnel to work these hours. And sometimes in our larger urban areas there is really no such thing as an off-peak traffic flow. This puts a heavy premium on building facilities that are as maintenance-free as possible.

Trees, shrubs and plantings will require a need for men especially well-trained in pruning techniques, fertilization, watering, weeding, grafting, replacement of materials, thinning, and other technical activities involving special expertise.

Bridge maintenance is probably the most difficult and troblesome problem today and as far as we can see into the future. This activity is of tremendous importance and demands highly qualified personnel. Public Roads has recently issued new bridge inspection guidelines to our field offices and the new Federal-Aid Highway Act of 1968 carries statutory requirements for a special effort in this direction. Bridge deck scaling and sometimes even heavier types of deterioration are causing extra maintenance problems. We need to develop ways of constructing more durable decks and to find more effective ways to maintain them.

The hazard of bridge deterioration was brought forcefully and tragically to the attention of the public and Congress by the collapse of the Silver Bridge at Point Pleasant on the Ohio River last December. Fortunately, very few bridge failures are so disastrous but still about 150 of them fail for various reasons every year. We do not have complete centralized information files on all of the highway bridges in the United States, but we are now working toward a nationwide inventory to determine both their number and their condition. It has been estimated, meanwhile, that of the approximately 1 million highway bridges in the country, a very large percentage of them are more than 30 years old and deficient in load capacity for much of today's traffic.

Much deterioration of older bridges is undoubtedly due to overloading and this is essentially a police problem rather than a maintenance problem. However, adequate and regular inspections of bridges are maintenance activities, and if done properly will detect conditions which may signal a possible collapse. Bridge inspection techniques must be vastly improved and new maintenance practices developed which do not in themselves contribute to deterioration of the structures. For example, deicing techniques are needed which do not corrode the floor system of the bridge or its supports.

In the field of traffic services we are being forced into new and additional activities. Rest area maintenance, for instance, is requiring a full-time maintenance man 24 hours a day in the larger rest areas that have all the facilities. Constant manning of this scope actually requires 5 employees. Personnel chosen for these duties must be more than cleanup men. They will be required to furnish information on routes, roadway conditions, historical features and answer other questions from the traveling public. Emergency aid to the stranded motorist is a new field requiring a great deal of attention today. Public Roads has issued an Instructional Memorandum (IM 60-1-66, dated October 18, 1966) on this subject and Federal aid is participating in experimentation with this activity in a number of states.

One of the growing problems of safety in the maintenance field is the disabled vehicle in the high-speed lane or middle lane of an 8-lane facility. Some type of arrangement will have to be developed to remove it from the traffic flow. Some far-out proposals have suggested that possibly a heavy crane traveling on tracks located in the center median can reach out to the disabled vehicle and lift it out or that helicopters might also be used as a possible means of coping with this problem.

Sign replacement and maintenance of large directional units will require a great deal of planning. The average life of the facing material in some cases has been estimated to be from 7 to 10 years after which fading and deterioration will occur, requiring major replacements. Signals require specially trained personnel to maintain electrical circuits, clean fixtures, replace bulbs and perform other similar operations in increasing amounts.

Snow and ice removal is a very expensive maintenance item but a necessary one. Possibly it need not be so expensive if we combine research and development with imagination. Snow removal methods are essentially the same today as they were 30 years ago. But this does not mean that progress is at an end. Whole new varieties of equipment and tools or perhaps materials also, may be required eventually—designed to meet the special requirements of the Interstate and other high-speed roadways carrying heavy traffic volumes.

In the field of highway safety, maintenance personnel must be trained in procedures for summoning aid, protecting others from hazards at accident sites, and removing debris quckly and efficiently. Programs must be developed for preventive maintenance, repair, and daytime and nighttime inspection of traffic control devices. Safety equipment on maintenance vehicles is of increasing importance. Roll-over bars, for example, on tractors and mowers are being used today in some states. Seat belts and effective warning signs and lights on vehicles are also items of importance. Proper control of the movement of traffic through maintenance worksites is a field in which considerable improvement is necessary.

Litter is not only costly and time-consuming to the state and local highway departments, but is repugnant to the great majority of conscientious, law-abiding motor travelers. We do not have any very good answers on this problem yet except manpower and more manpower. New types of equipment are needed to mechanize portions of the trash pickup problem. Or, possibly, some genius will develop self-destruct beer cans and pop bottles. But in the meantime we must continue to rely largely on pulling maintenance forces away from the more constructive work they should be doing to cope with the problem of litter.

I mentioned earlier the need for research, development and imagination in planning and carrying out maintenance programs for the future. Let me add to that cost accounting. As the maintenance operation becomes more complex, so does the need for strict control of the highway dollar. As in the past, there will in the future be just so much money available for highway purposes and any dollar wasted on inefficient maintenance practices is a dollar deducted from the funds available for new facilities.

In other words, I am talking about maintenance management—the very timely subject of your meeting. Even though most maintenance operations do not lend themselves to computerization, your brains are doing a pretty good job in perfecting such practices as properly scheduling maintenance operations and installing maintenance management reporting techniques.

During your brainstorming sessions here you are covering many matters of vital importance to meeting the maintenance requirements of the 1970's.

Many of you are invited to participate because of your knowledge in the systems analysis and management fields, while others are maintenance operators with direct responsibility at the firing line for the results. I do not happen to be one of those individuals who believe blindly in the worship of the systems analysis approach as the beginning and end of all knowledge and that its application to every one of our problems will insure an automated, push-button, easy and infallible answer. But there are variations of the organized approach to a problem which are characteristic of the engineer training which many of us have had, through which we may substantially contribute to the solution of many of these problems which face the highway maintainer both now and in the future. Many of these problems are answerable through the application of improved management practices covering our resources of manpower, equipment, materials, and dollars; while others are in the realm of research into improved materials through chemistry and physics.

We have traditionally given less attention in both the management and research fields to maintenance of our road system than we have to its initial construction, although we are now expending amounts for maintenance which rapidly are approaching the level of capital expenditures. It is time that we gave substantial attention to this area of our responsibilities. I feel strongly that on a relative scale, there is opportunity for much greater payoff, and greater cost-effectiveness application here than in the construction side of our responsibility. I therefore commend this thought to you in the sessions which you hold during this workshop.

An Overview of the Highway Maintenance Management Research Program in the United States

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Historically, highway maintenance management in the United States has experienced many changes during the past 50 years. Most of these changes came about through a process of gradual evolution and were based on intuition and pragmatical considerations rather than factual knowledge and scientific management principles. Results of this process were reasonably adequate during the era between 1920 and 1949. Most maintenance organizations were satisfied with the status of their management and thus had no real reason to adopt a more sophisticated procedure. It is therefore not surprising to discover that maintenance management research was of little consequence during these years. Studies were few in number, limited in scope and uncoordinated. Most were carried out informally, making it difficult to even document their existence. It would definitely be misleading to say either that these efforts had a significant impact or that they constituted any kind of a research program.

In June 1950, an event occurred which signaled the beginning of an organized, formal maintenance management research program in the United States—the initiation of the Connecticut Maintenance Study—a joint venture of the Bureau of Public Roads and the Connecticut State Highway Department. Its principal objectives were to: (a) develop basic facts concerning the performance of labor and equipment on field operations, and (b) appraise management problems. Study results indicated that there were a number of deficiencies and problems associated with field operations and showed the need for continued research. Prophetically, the report stated:

> The further development and extension of the groundwork encompassed by this study can lead to the establishment of units of work and standards of maintenance accomplishment, thus making possible the estimation of labor and equipment requirements to perform the maintenance obligation in a particular area under certain given conditions.

The program continued during the eight years which followed the Connecticut Study primarily because the Bureau of Public Roads retained an interest in such research. About 20 small-scale studies were conducted on the field operations of state maintenance organizations. Results were not extensive enough to fully delineate management problems, but did serve to verify two hypotheses: (a) results of the Connecticut Study provided a good picture of the situation in other states; and (b) many management problems were common, varying only in degree from organization to organization.

The program received an impetus in 1959 when the Bureau of Public Roads and the Iowa State Highway Commission joined to conduct a study which was considerably larger in scope. The Iowa Maintenance Study was primarily designed to produce facts which could be used by management for controlling and improving the economy of maintenance operations. It involved collection of basic data concerning the performance of labor and equipment on field operations, variations in total work-loads, work units, utilization of supervisory personnel, and other aspects of maintenance management. Considerable emphasis was placed on analysis of data to pinpoint problems and develop possible solutions. In a few cases, proposed solutions were tested for practicality.

The Iowa Study received considerable publicity during 1960 and 1961. Its findings were accepted by many maintenance managers as indicative of the situation in their own organizations. About the same time other forces began operating to change these managers' attitudes toward management and management research.

Between 1960 and 1967, maintenance organizations in this country were subjected to a number of external pressures which caused severe internal stresses. Among the most intense pressures were those due to:

1. Addition of new facilities on the Interstate and other systems.
2. Public demands for higher and higher levels of maintenance.
3. Rapid changes in the technology of highway design, materials and equipment.
4. A labor market which could not supply an adequate number of qualified personnel.
5. Constrictions on maintenance budgets to make the maximum amount of funds available for badly needed construction projects.
6. Campaigns to tighten up the fiscal and administrative control of highway organizations.

The type of management which had been getting by for many years was not able to cope with the stresses induced by these pressures. Problems multiplied and managers became painfully aware of what was happening. Many concluded that their organization's management was deficient and needed to be improved. As attitudes toward management changed, there was increased interest in all kinds of management research. The organized, formal program expanded considerably between 1960 and 1967 with studies covering a wide variety of subjects.

In Louisiana, there were three studies which related to costs for maintaining specific types of roads. These studies, conducted by Louisiana State University, were aimed at developing a procedure for estimating costs through the use of mathematical regression models based on historical fiscal records. A study conducted in Idaho by the University of Idaho had a similar objective and used much the same procedure. The Oklahoma Department of Highways also undertook a study of maintenance costs for specific types of roads using a technique which took into consideration both historical fiscal data and deterioration ratings for selected test sections.

A major study of maintenance costs was conducted for the National Cooperative Highway Research Program by a consultant, Bertram D. Tallamy Associates. This study was primarily directed toward developing a method for predicting Interstate System maintenance requirements. The technique used was similar to techniques used for the aforementioned state studies. Cost data from selected test sections across the nation were analyzed to develop mathematical models for seven groups of maintenance activities which could be used to predict "requirement units." A secondary objective of the study was to develop a new maintenance expenditure index.

In Louisiana, the University undertook a study to establish optimum equipment and work methods for mowing highway roadsides. A second study on mowing roadsides was conducted by the Indiana State Highway Commission. Emphasis was placed on developing comparative costs for different types of roadsides and mowing methods. The Ohio State University also carried out a research study to determine the most effective means of caring for Interstate roadsides.

In Illinois, New Jersey, New York, and Wisconsin, Bertram D. Tallamy Associates conducted a series of studies for state highway departments and toll road authorities. They were designed to establish long-range requirements for major maintenance on high-type facilities. These studies utilized new techniques for predicting pavement deterioration in conjunction with detailed field inspection of facilities.

A major study was undertaken by H. B. Maynard and Company and the City of Los Angeles. The objective was to develop a program which would improve the planning, directing and controlling of labor and equipment assigned to various field activities. An important feature of this study was the use of the methods-time measurement industrial engineering technique to analyze each activity and to develop standards for work methods and performance. The same consultant recently worked with the San Diego County on a study which had a similar scope and objectives.

Booz-Allen and Hamilton carried out a study in Minnesota which utilized industrial engineering techniques to develop improved work methods, establish performance standards, and improve the maintenance reporting system. The same firm conducted a similar study of somewhat smaller scope in New Jersey.

The largest single study was carried out by the Virginia Department of Highways with the assistance of Roy Jorgensen and Associates. This effort lasted for three years and was designed to cover nearly every major aspect of maintenance management. It involved collection of data concerning performance of labor and equipment, development and testing of improved work methods; establishment of quality, quantity and performance standards; development and testing of a new reporting system; development and testing of a budgeting system; development and testing of training material; and work in several other areas.

These studies were all started and essentially completed during the eight years ending in June 1968. They provide a good indication of the extent and scope of activities during this period but do not account for the entire research program. Nine other studies started between 1960 and 1967 have not been listed because they are still active and will be described subsequently. A few other studies, generally of limited scope, were omitted because of space limitations.

One other aspect of completed studies deserves mention. More than half were funded through the Federal-Aid Highway Planning Research Program. This program provides for joint state-federal financing of research in areas which have a significant influence on highway transportation in the United States. For many years, maintenance management has been recognized as one of these areas. In 1964, this position was emphasized when a project for maintenance operations and management was included among the 27 top priority projects of the National Program for Research and Development in Highway Transportation. Partly as a result of this emphasis, annual Federal-aid expenditures in this area have more than doubled in the last 5 years.

Currently, the maintenance management research program includes 13 formal studies which are fully active. Eleven of these are being financed through the Federal-aid HPR program. Their estimated total cost is over $2, 000, 000 and annual expenditures are about $700, 000. The other two studies are financed entirely with state funds. Their estimated total cost is over $500, 000 and annual expenditures are about $150,000. The nature and scope of these studies varies considerably. Six can be classed as comprehensive because they cover several aspects of maintenance mangaement, five deal with the equipment and methods for specific activities or functions, and two are concerned with costs. The following summaries present pertinent facts about each study:

<u>Study title:</u> Maintenance Practices

Sponsoring agency: Arkansas State Highway Department (Federal-Aid HPR Program)

Conducting agency: Arkansas State Highway Department

Estimated total cost: $169, 000

Period: July 1967-July 1972

Objectives:
1. Evaluate the maintenance accounting system and revise as needed.
2. Define maintenance standards.
3. Evaluate existing maintenance practices and develop improved practices.
4. Identify training needs; develop and test training materials.

Current status: Work plan approved. Récruiting staff.

<u>Study title:</u> Maintenance Management

Sponsoring agency: Louisiana Department of Highways (Federal-Aid HPR Program)

Conducting agnecy: Joint—Louisiana Department of Highways-Roy Jorgensen and Associates

Estimated total cost: $575, 000

Period:	September 1965-July 1969
Objectives:	1. Define responsibilities and functions for various management levels. 2. Evaluate training needs; develop and test training materials. 3. Develop and pilot test a maintenance work reporting system. 4. Determine the most effective methods and staffing for maintenance activities. 5. Establish maintenance standards for quality, quantity, and productivity. 6. Develop and test an overall maintenance management system.
Current status:	Work on first three objectives nearly complete. Three reports published. Reporting system implemented.
<u>Study title</u>:	Comprehensive Maintenance
Sponsoring agency:	North Carolina State Highway Commission (Federal-Aid HPR Program)
Conducting agency:	North Carolina State Highway Commission
Estimated total cost:	$220, 000
Period:	July 1966-December 1972
Objectives:	1. Determine the adequacy of the maintenance organization to carry out its assigned responsibilities and functions. 2. Evaluate the present maintenance management system with emphasis on reporting. 3. Determine the relationship between maintenance costs and factors such as traffic. 4. Determine major maintenance operations whose efficiency and economy can be improved; develop improved methods, etc. 5. Evaluate maintenance facilities and materials.
Current status:	Work now in progress on first objective.
<u>Study title</u>:	Highway Maintenance Management
Sponsoring agency:	South Dakota Department of Highways
Conducting agency:	Joint—South Dakota Department of Highways-Roy Jorgensen and Associates
Estimated total cost:	About $300, 000
Period:	July 1968-October 1970
Objectives:	1. Develop and test quality, quantity and productivity standards for maintenance activities. 2. Develop and test a maintenance work reporting system. 3. Develop and test a maintenance work scheduling process. 4. Develop and test a maintenance budgeting process. 5. Develop a methods and training unit. 6. Conduct a performance laboratory to test developments.
Current status:	Work just getting under way.
<u>Study title</u>:	Maintenance Management
Sponsoring agency:	Utah State Road Commission (Federal-Aid HPR Program)
Conducting agency:	Joint—Utah State Road Commission-Roy Jorgensen and Associates

Estimated total cost: $285, 000

Period: April 1967-August 1969

Objectives:
1. Establish quality, quantity and productivity standards for maintenance activities.
2. Develop and test a maintenance work reporting system.
3. Design, develop and test an overall maintenance management system.
4. Evaluate the field organization and resource utilization.
5. Prepare a plan for improving maintenance performance.

Current status: Work under way on most objectives.

Study title: Maintenance Improvement Program

Sponsoring agency: Washington State Highway Commission

Conducting agency: Joint—Washington State Highway Commission-Booz-Allen and Hamilton

Estimated total cost: About $250, 000

Period: July 1967-December 1968

Objectives:
1. Develop standards for measuring performance of maintenance operations.
2. Establish procedures for maintenance planning and scheduling.
3. Provide data for improved maintenance budgeting and control.
4. Train maintenance supervisors.

Current status: Work under way on all objectives. Several training manuals prepared.

Study title: Tunnel Cleaning Method

Sponsoring agency: California Division of Highways (Federal-Aid HPR Program)

Conducting agency: California Division of Highways

Estimated total cost: $117, 000

Period: July 1967-June 1972

Objectives:
1. Develop a tunnel cleaning method that is rapid, economical, nonhazardous and nondestructive.

Current status: Work under way on equipment design.

Study title: Cost Effectiveness of Anti-Skid and De-Icing Programs in Pennsylvania

Sponsoring agency: Pennsylvania Department of Highways (Federal-Aid HPR Program)

Conducting agency: Pennsylvania State University

Estimated total cost: $20, 000

Period: July 1968-June 1970

Objectives:
1. Study and evaluate existing snow and ice control practices.
2. Develop improved methods, equipment and materials for snow and ice control.

Current status: Work just getting under way.

<u>Study title:</u>	Winter Maintenance for Bituminous Pavements
Sponsoring agency:	Texas Highway Department (Federal-Aid HPR Program)
Conducting agency:	Texas Transportation Institute
Estimated total cost:	$36, 000
Period:	September 1967-August 1969
Objectives:	1. Evaluate existing practices for winter pavement maintenance. 2. Develop improved methods, equipment and materials for winter pavement maintenance.
Current status:	Work on first objective completed.

<u>Study title:</u>	Snow Removal and Ice Control Techniques at Interchanges
Sponsoring agency:	National Cooperative Highway Research Program (Federal-Aid HPR Program)
Conducting agency:	Bertram D. Tallamy Associates
Estimated total cost:	$50, 000
Period:	September 1967-July 1969
Objectives:	1. Identify and evaluate the factors which influence the efficiency of snow removal and ice control operations at interchanges. 2. Develop operational systems that will provide for efficient snow removal and ice control procedures on interchanges in both rural and urban locations.
Current status:	Field work completed on first objective.

<u>Study title:</u>	Develop Performance Budgeting System to Serve Highway Maintenance Management
Sponsoring agency:	National Cooperative Highway Research Program (Federal-Aid HPR Program)
Conducting agency:	
Estimated total cost:	$250, 000
Period:	September 1968-October 1970
Objectives:	1. Develop and test a model highway maintenance budgeting system.
Current status:	Contractors selected for Phase I preparation of detailed work plan.

<u>Study title:</u>	Maintenance Formula Application
Sponsoring agency:	Louisiana Department of Highways (Federal-Aid HPR Program)
Conducting agency:	Louisiana Department of Highways
Estimated total cost:	$60, 000
Period:	July 1963-July 1969
Objectives:	1. Accumulate accurate cost data for testing and revising mathematical models to predict maintenance costs.
Current status:	Data collected and summarized for 5-year period.

Study title:	Maintenance Cost
Sponsoring agency:	Ohio Department of Highways (Federal-Aid HPR Program)
Conducting agency:	Ohio Department of Highways
Estimated total cost:	$380, 000
Period:	July 1961-July 1972
Objectives:	1. Determination of reliable maintenance costs. 2. Determine the influence of major factors which contribute to maintenance costs. 3. Measurement of the level of maintenance and determination of the extent to which deficiencies exist in the current maintenance and operation of the highway system.
Current status:	Data collected and summarized for 6-year period. Preliminary analysis made and several interim reports published.

The descriptions of the studies which constitute the current program were, of necessity, lacking in detail. However, they do give an indication of its depth and breadth. It should also be recognized that there are other current informal research efforts such as those under way in Illinois, New Jersey and New York which may ultimately become a part of the formal program.

Up to this point, emphasis has been placed on describing the research studies which have been or are being conducted under the program. Now, it is time to look at some of the significant results which have come out of these efforts.

1. It has been clearly demonstrated that management in most highway maintenance organizations is beset by a number of problems including:

   a. Inadequate factual data concerning field activities.
   b. Nonuniform standards or a lack of standards.
   c. Ineffective procedures for planning and scheduling work.
   d. Widely varying quality, productivity and unit costs for field activities.
   e. Ineffectual means of comparing actual and desired quality, service level and unit cost for maintenance activities.
   f. Lack of a reliable means to forecast long-range maintenance requirements.
   g. Lack of a means to evaluate alternative policies.
   h. Shortage of trained personnel.

2. New systems for maintenance field reporting have been developed and proved capable of supplying the kind of information needed for management, fiscal accounting and research purposes.
3. Quality, quantity and performance standards for maintenance activities have been developed and proved practical for operational use.
4. Techniques for planning and scheduling maintenance activities on a long-range and daily basis have been developed and proved practical.
5. A large fund of data concerning the work methods, time utilization and productivity of labor and equipment under typical field conditions has been accumulated and analyzed to determine some cause-effect relationships.
6. Procedures for determining optimum staffing patterns and work methods have been developed.
7. New equipment and methods have been developed and proved practical and economical for several maintenance activities.
8. Performance budgeting systems for maintenance are being developed and tested for practicality.
9. Procedures and data for forecasting long-range maintenance requirements have been developed and proved useful.
10. Techniques to enable management to evaluate alternative policies for investments, resource allocation, staffing and other aspects of maintenance are being developed.

11. Some materials and procedures for training maintenance personnel have been developed and tested.

At the present time it would be unrealistic to state that these research results have been widely translated into improved management. The current attitudes of administrators and managers have created a favorable climate for such use but, unfortunately, each maintenance organization must operate under its own set of conditions and constraints. Thus, it is usually necessary to undertake some additional research just to adapt results for a particular situation. This takes time. Still more time is required for the actual implementation. Hopefully, a significant number of organizations will soon begin to make use of available research results, but even so, it may be five years before there will be widespread improvement in maintenance mangaement and operations.

Finally, everyone involved in maintenance management research needs to keep in mind that the objective is not simply improved management. That is only the key which unlocks the door leading to the ultimate goal—effective and efficient maintenance for the highway systems of this nation.

A Concept of the Maintenance Management Problem Insofar as It Has Been Established by Preliminary Investigations in Great Britain

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In recent years much thought has been given by highway authorities in Great Britain to the improvement of the management of highway maintenance, and individual authorities, especially the County Councils, have introduced new schemes aimed at greater administrative efficiency. The County Surveyors' Society, which represents the highway engineers of rural authorities, has had for some time a committee on highway maintenance, but this is mainly a forum for the discussion of problems of immediate interest and has not so far sponsored extensive research studies. It is recognized that there is a need for a coordinated effort and a major step towards this has been the setting up in September 1967 of the joint Committee on Highway Maintenance by the Ministry of Transport and the Local Authorities (the Marshall Committee), the terms of reference of which include a study of the management of maintenance in all its aspects.

In the Road Research Laboratory, we had already planned to make a long-term study of maintenance, but the start has been delayed by other commitments. Now, with the impetus of the Marshall Committee, we have made a start and are cooperating fully with the Committee by undertaking a part of its field work. In the long term, we shall also be working in cooperation with the rural and urban highway authorities. This paper gives a simplified view of our concept of the problem in Great Britain and of the present organization of highway maintenance.

THE REQUIREMENT FROM A SYSTEM OF MANAGEMENT

It is worthwhile here to restate the obvious—what one basically requires from a system of management. It must be capable of insuring that:

1. The aims of the organization are carried out and that unnecessary work or expenditure is not incurred;
2. The right quality and amount of work are carried out to meet its purposes;
3. Value is obtained for the money spent.

THE RIGHT WORK

A highway consists of a very large number of different parts, playing different roles—engineering, safety, aiding movement, amenity, etc. Their relative importance varies with the importance of the highway, whether it is a national interurban route, a very minor rural road, a residential street, etc. At present, one tends to do something about maintaining everything because it is there, and to go to the extreme, one maintains in good condition every highway whatever its value to the community, just because it is there. These questions are now being faced in Great Britain and some highway authorities are beginning to leave out maintenance of the less important features on roads particularly on those with low cost-benefit. One authority has suggested maintaining only a reduced width of the pavement on such roads, to demote them to single-lane roads with passing places. Another has abandoned white line maintenance and grass-cutting on verges but the latter is troubling farmers because of the weed problem.

THE RIGHT QUALITY AND AMOUNT OF WORK

There is probably little scope for cutting out maintenance functions completely but a great deal in controlling the quality and amount of maintenance, i. e., insuring that the standards of maintenance carried out are no more and no less than are required for the usage and importance of each type and class of highway. One can of course regard cutting out functions as reducing them to a zero standard of maintenance.

Our first priority task, we considered, is to study the standards of maintenance over the whole range of conditions in Great Britain, in order to suggest, in the first instance, subjective maintenance standards. From here we will go on to study objective standards, based upon engineering and safety requirements, etc. Many are already in existence but there tends to be a gap between what is objectively required and what practical considerations including finance, allow. At present objective standards tend to be used only for new construction or in special circumstances such as roads with excessive accident rates. Such standards have been determined for the condition of pavements (expected life can be estimated from the permanent deformation of flexible pavements, from the amount of cracking in concrete pavements, and from the temporary deflection under a standard wheel load), skidding resistance, riding quality, visibility and sight lines, etc. Once standards of maintenence are set, on whatever basis they are determined, then the level of expenditure on maintenance is fixed, within ascertainable limits, and over or under expenditure, due to other faults in the system, is more readily apparent.

VALUE FOR MONEY

Having set one's standards for maintenance and thereby set one's theoretical expenditure level, it is then time to examine the way in which functions are carried out on site to raise productivity and reduce expenditure. Under this rather broad heading, we include not only the use of work study techniques to raise productivity, optimize gang sizes, select the most effective plant, and reorganize the control of gangs but also economic studies such as cost-benefit studies on materials to insure maximum effectiveness. These will extend back to materials used in the basic design of the original construction to see whether the overall cost-benefit of construction and maintenance can be improved. Of course much has already been done using work study but comparatively little on economic studies.

TOOLS OF MANAGEMENT

Management cannot function properly without certain tools, the chief one of which is information and the means of transmitting it. We intend looking at the systems of management that we have in Great Britain to insure that we are getting the correct information back rapidly to the people who need it, that the information is as accurate as possible and that the essentials of it are stored in a readily accessible manner.

The information required is of two broad types: (a) an estimate of the total potential work load, and (b) a record of the work actually carried out and how it was carried out.

In both cases the information needed is varied, covering such things as quantities of materials, man-hours spent on the work, the amount of work actually completed, the quality of the work, and the cost. At present much of this information originates from the lowest level of management—foremen and "gangers"—and much of it is unreliable. One reason for this is that probably they do not appreciate why it is required and how it is used. We must codify and classify the information required so that it is easy to produce and to produce accurately. Any data-processing system is only as good as the quality of the data fed into it. Much of the information required will be produced in the form of expenditure against various accounting heads. While it is always necessary to remember that accounts are kept to show how public money has been spent, engineers cannot control expenditure unless accounts are rendered in a form which is meaningful to them. Too often in the past this has not been so. Our accounting system must meet the needs of the engineer and provide the information rapidly.

The system of management must provide for decision-making at the most effective level. This we will look at, not forgetting financial decision-making at "chief-officer" level and above. Their financial powers are continually eroded by inflation and central government is always slow to increase their powers to keep pace with it. We must provide methods to aid decision-making and insure that they are used, such as critical-path planning and programming, and electronic data-processing and storage. Too often they are regarded mainly as aids to the more glamorous work of new construction. A very necessary aid to decision-making is a method of assessing priorities. Little use is made in Great Britain of sufficiency-rating systems, partly because they involve a large amount of manpower to establish and maintain. We feel that in the first instance, a simplified form of sufficiency-rating applied to maintenance only is needed (most systems cover improvements rather than maintenance and in Great Britain improvements require financial approval and funding separately from maintenance). Management needs simple methods of measuring standards of maintenanee and, thereby, the need for maintenance. For the roadside maintenance functions, this is usually fairly straightforward but, for the pavement itself, measurement is more difficult and often causes serious interruption to traffic. Our aim is to devise methods of measuring all aspects of the condition of pavements by machines traveling with the traffic and, if possible, at the speed of the traffic. This is possible with riding quality—the "bump-integrator" trailer has been in use for many years. We are achieving it with skidding resistance—a prototype machine for continuous automatic readings of sideway-force coefficient is being tried out this summer and will operate at up to at least 50 mph. We are experimenting with a traveling deflection beam but as yet it is slow and not really suitable for inserting into heavy traffic. It seems too that we may need some method of continuous measurement of the transverse shape of the pavement. Some mechanized method of measuring cracking in concrete may come, but at present it seems that visual assessment will be with us for some time yet.

MAINTENANCE MANAGEMENT IN RELATION TO CONDITIONS IN GREAT BRITAIN

We have in Great Britain a comparatively large number of highway authorities, the largest of which are probably small compared with the individual states in America. They are of several different types, with different responsibilities, and the range of size within each type is large. Table 1 gives the types and approximate numbers in England, Scotland and Wales.

All counties are highway authorities, and towns over 20,000 inhabitants can claim to become highway authorities. Other towns and rural districts can have highway responsibilities delegated to them, for administrative convenience. The largest rural county has 7500 miles of road and the smallest 115 miles. The largest urban authority

TABLE 1

HIGHWAY AUTHORITIES IN GREAT BRITAIN

Type	Number	Description	Apportioned Responsibilities
Rural counties	89	Geographical counties excluding urban counties	All roads
Urban counties	106	Major towns known as county boroughs	All roads, but with some exceptions have no trunk roads
Greater London	1	London and its suburbs	All roads
London boroughs	33	Local government divisions of London	Act for Greater London Council on all roads (with some exceptions)
Municipal boroughs	275	Large towns within rural counties	Act for rural counties on all roads (with some exceptions)
Urban districts	480	Small towns within rural counties	Act for rural counties on all roads (with some exceptions)
Rural districts	10	Rural subdivisions of rural counties	Act for rural counties on some or all roads except trunk roads
New towns	18	Special development areas	All roads except trunk roads

TABLE 2

ROAD CLASSIFICATION AND SOURCES OF FUNDS

Type of Road	New Construction and Improvements		Maintenance	
	Central Govt	Local Govt	Central Govt	Local Govt
Trunk roads (including motorways)	100 percent	Nil	100 percent	Nil
Principal roads	75 percent	25 percent from counties	Indirect support	100 percent from counties including indirect support
Non-principal roads	Indirect support	100 percent from counties including indirect support	Indirect support	100 percent from counties including indirect support
District (minor urban) roads	Nil	100 percent from urban authorities	Nil	100 percent from urban authorities

excluding Greater London has over 1000 miles and the smallest only a few miles. Annual expenditure on highways (including new construction) varies from £14½ million in a large rural county down to £130, 000 in a small rural county and from £4¾ million in a large county borough down to a few thousand pounds in small urban authorities. The figures for Greater London are 7, 800 miles and £37 million.

Table 2 shows the road-classification system and sources of funds for highway new construction and improvement and for maintenance, excluding Greater London. Indirect financial support is by means of bulk grants to the local authorities to cover all services (schools, housing, sanitation, highways, etc.), the proportion allocated to each service being left to the discretion of the local authority. However, the highway element of this support depends on the mileage of principal and classified roads in each county's area.

In general, the county highway authorities find all the funds for highway maintenance for all roads in their own areas, including those in the non-county borough urban areas, from their own resources (rates and bulk grants) except for trunk roads and urban district roads. Non-county borough urban authorities contribute to the rural counties' bulk funds. Funds for urban district roads are found directly from rates levied within each urban highway authority area.

Table 3 gives the responsibility of highway authorities and their type. London Boroughs and New Towns have been omitted because arrangements in these authorities are not typical of the remainder of the country.

This system of funding all began in 1867. Previously direct support for the maintenance of all roads other than district roads had been provided from central funds. Now direct support is provided only for trunk roads. This new system has some effect on maintenance policy for principal roads in that it may tend to defer some major maintenance until such time as it can become part of an improvement scheme, e.g., widening, and so gain direct support.

TABLE 3

HIGHWAY AUTHORITIES' RESPONSIBILITIES

Type of Road	Responsible Authority	Agent Authority
Trunk roads (including motorways)	Central government	Rural counties and some county boroughs
Principal roads	Rural counties and county boroughs	Municipal boroughs and urban and rural districts which are highway authorities
Non-principal roads	Rural counties and county boroughs	Municipal boroughs and urban and rural districts which are highway authorities
District roads	County boroughs and other urban highway authorities	

In general highway departments are organized on broadly similar lines. The chief officer or surveyor is directed on policy by a committee of the local government council. His own headquarters department is usually divided to provide separate engineers for planning and control of new construction and of maintenance. His area, except in the case of small urban authorities, is divided into divisions, the head of which is usually responsible for both new construction and maintenance, except that large new construction projects are often run from the head office through an ad hoc site organization. New construction tends to be carried out mainly by contract and maintenance by directly employed labor organized into gangs. The use of specialist rather than all-purpose gangs is becoming more general. With the exception of motorways, the different classes of roads are all maintained by the same gangs. Separate organizations are usually set up for motorways with their own gangs.

Any management system devised must therefore take into account the wide variation in size of highway authority and the different types. (The question of size may be resolved to some extent in the near future because a national study of local government organization is in progress and it may well recommend grouping of urban and even some rural authorities.) Some re-thinking may be necessary on the traditional role of the divisional surveyor, e.g., whether he should be responsible solely for maintenance or whether he is even necessary. However, in large rural authorities some outlying organization would always be necessary for day-to-day control of maintenance gangs. All-purpose gangs have already completely displaced the traditional county roadman. In turn the all-purpose gang is giving way to the centrally controlled specialist gang. Increasing use may be made of contractors for maintenance on functions traditionally carried out by directly employed labor, but this is less likely.

CONCLUSIONS

To sum up, in Great Britain we must start logically by getting the maintenance task right, i.e., by setting our standards correctly. Then we must get our administration and organization right so that we know what is going on and so that planning and controlling are done correctly. Finally we must insure that what is to be done on site is done in the most efficient manner. All three of these aims can and are being pursued simultaneously of course, but the emphasis we feel should be placed in the order given—it is false economy to carry out efficiently work that should not be done at all!

ACKNOWLEDGMENT

Contributed by permission of the Director of Road Research.

A Researcher Looks at Maintenance Management—In a "Systems" Context

CHARLES E. DIEHL, Stanford Research Institute

There are as many definitions of "systems analysis or approach" used today as there are people who use the term. I have my own which stems from my engineering background. Systems analysis, in a simple discription, is an attempt to optimize or improve the system under consideration. It is generally approached through the following steps:

1. Definition of the system under study, including objectives.
2. Identification of the system components, the structure.
3. Definition of the relationships and interactions between the system components.
4. Definition of the problems or conflicts in system component interactions and relationships.
5. Application of technology to the problems or conflicts encountered. It is in this step that the use of operations research, including mathematical models using exact or approximate causal relationships, is brought into action. Through a series of iterations an attempt is made to optimize the variables involved, and come up with at least one best solution, or several best solutions.
6. After the alternatives or best solutions are developed, it is necessary to test these solutions, including the use of judgment in some instances where factual data are lacking. This testing effort also has the side-effect of generating specific knowledge about research or problem solving techniques that are needed for a more complete solution to the problem.
7. Armed with factually developed data, temporized by good judgment where necessary, the decision-makers are then in a position to make a rational choice using the best solution to optimizing or improving the system under consideration.

Systems analysis is not a panacea for all management aches and pains, but it is a rational approach to some of the current problems in optimizing maintenance management. Most civil engineers of my generation were unknowingly introduced to the systems approach by our old friend, Hardy Cross.

If we are to use the "systems" approach to improve highway maintenance management, we must first define the system under study.

RELATIONSHIP OF MAINTENANCE TO THE "HIGHWAY SYSTEM"

Through a system of mandated or dedicated taxes to support highways there has been a tendency to set highway systems apart from the remainder of public environment. Those who live in major central cities, or in states where urban needs are the greatest, are seeing the results of this approach expressed by opposition to plans for highways and the mandating of tax revenues. It is becoming apparent that if we are to "optimize" our urban environment, there is going to be increasing pressure to look at the urban area as a "system" in itself. To tackle the urban area as one system is complex, so we would start to decompose the system. One might depict the urban environment as consisting of some major subsystems as shown in Figure 1.

Within each of these subsystems there are many sub-subsystems; for example, in the public works area, we might define the need for shelter for human activities, transportation of all kinds, natural resources, and, becoming more important, the waste system. As shown in Figure 2 each of these subsystems has forces of optimization which are in conflict in many instances. When we consider that the optimization of one

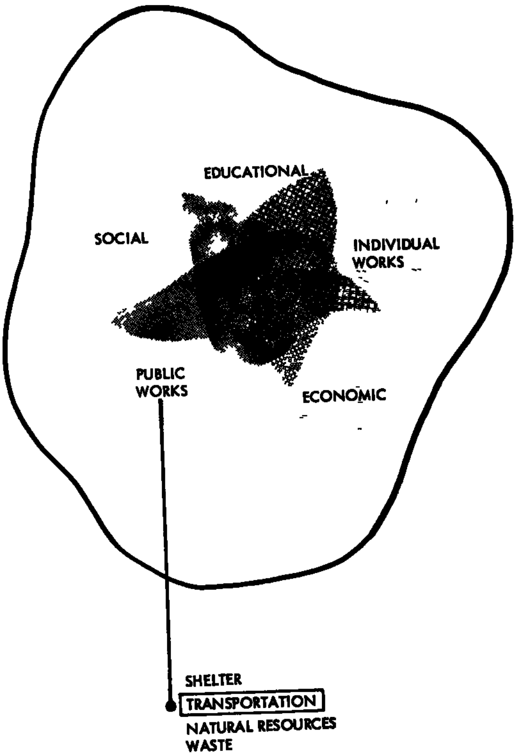

Figure 1. The urban system and its major subsystem areas.

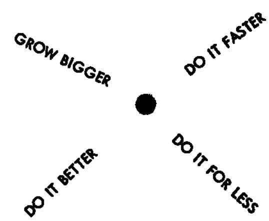

Figure 2. Forces of optimization in conflict with urban areas and systems.

system may detract from or compete with the optimization of another system, the number of solutions to any urban problem approaches infinity. Recognizing the difficulty in trying to approach any sort of valid rationalization across the whole spectrum of the urban environment, we are forced to seek suboptimization. Frankly, we do not have enough knowledge or factual data to do any more than seek suboptimization, and rely on social pressures, political judgments, and, hopefully, common sense to bridge the gap between the major competing urban systems.

Fortunately for highway maintenance people, we are not faced with the problem of th magnitude faced in the whole urban system. The problem in highway maintenance management is a bounded system. Although there are many intangibles involved, we can describe fairly accurately our maintenance world because it is represented by the physical existence of real property—roads, bridges, traffic signals and signs, drainage structures, and buffer land. Each of us could make some fairly valid judgments on the adequacy of maintenance for a particular small segment of a road by observation. Getting this same kind of judgment expressed for a whole state road system complicates the problem significantly. If we were satisfied with our highway maintenance systems, we would not have this workshop. If we are to compete successfully for resources in a changing urban environment, we must have a system that not only makes sense to us, but also carries our message up the line to others, in a way that relates to the whole of our urban environment. I will try to indicate some approaches that I think would help us in improving maintenance management.

All of us are familiar with the life cycle of real property. Figure 3 identifies the major events in the life cycle that have an impact on highway system management. Before maintenance personnel are given the responsibility for the road system, many decisions have been made over which they have no control. Most of these events are controlled by engineers, and, therefore, the opportunity to use the same language in communications exists. Although we can describe the event relationships over the life cycle of the highway system, that does not per se solve the communications problem. Because you must maintain what the designers and constructors build, a good system must provide for feedback. In summary then, we can define the highway system, iden

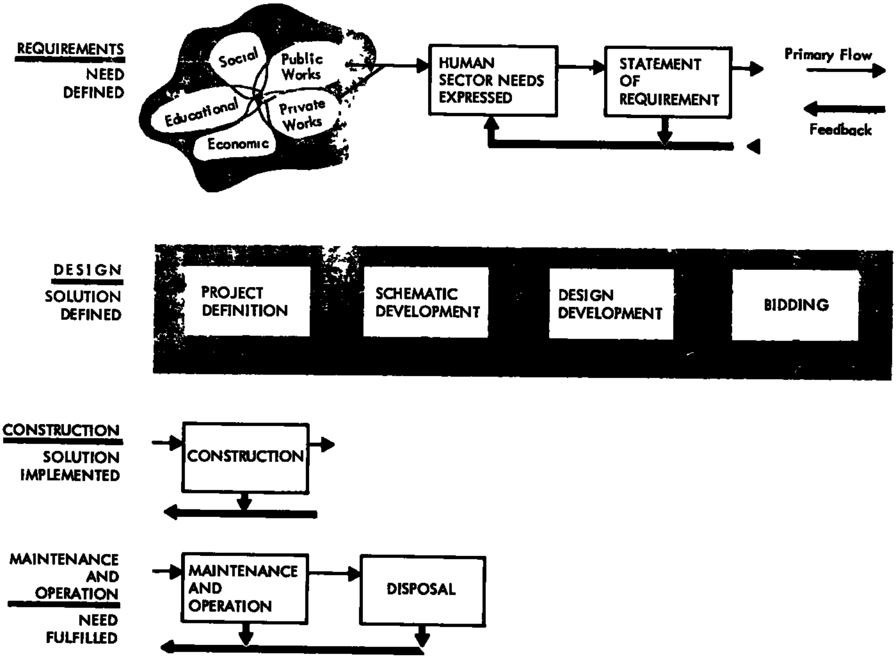

Figure 3. Major process events in the life cycle of real property.

tify its life cycle, and the major events in the life cycle where decisions and management action are possible. We can make a fairly substantial case that it is to a great degree a closed system, once human needs requirements are determined. In short, from a systems approach the highway maintenance management program can be readily rationalized. The next question we might ask ourselves is whether maintenance management is a classic management problem? Can we find mathematical models developed for other management problems that will work?

MAINTENANCE—"CLASSIC" MANAGEMENT PROBLEM?

The functions of management as outlined by authoritative writers are described in different words, but three main word descriptors appear to dominate the literature. These are plan, execute, and appraise. Under planning, we set objectives, organize the effort, and assign responsibility. In execution, we carry out the plan exercising good judgment. Appraisal provides us with the necessary feedback to monitor performance and to provide the basis for replanning. Each of these elements of management is part of every viable maintenance program.

From a modeling standpoint, maintenance could be related to a modified inventory problem. We have an inventory of roads which must be maintained. The roads might be considered to have a "shelf life." Periodically they must be renewed to original or serviceable condition, with the objective of maintaining the inventory in usable condition. If we could predict shelf life expectancy, and the repairs required at the end of the shelf life period, we should be able to establish an effective management model for highway maintenance. Similarly we could consider highway maintenance as a dynamic equipment problem because of its wear characteristics from traffic. Workable mathematical models exist for management decision-making aids in both these cited cases. Both of these models, however, require the ability to determine a failure condition. To make the model work we must be able to describe failure.

It would appear that our first problem in trying to model maintenance management for highways is that we are faced with two contributors to failure, natural deterioration from the elements (akin to the inventory problem), and wear from traffic (akin to the dynamic equipment problem). The problem is made a little tougher in that we must also state what constitutes failure. As we all recognize, a rather bad road from a riding

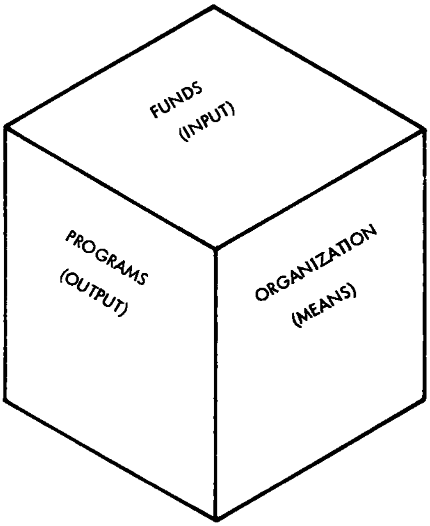

Figure 4. Typical management information matrix for decisions and planning.

standpoint is still usable. Therefore, a clear definition of failure is hard to produce.

Maintenance management on the other hand is a classic problem from the functions of management standpoint—plan, execute, and appraise. To my knowledge no one has developed a mathematical model for highway maintenance using the existing management models that have been developed. So our problem appears to be classic in the functional sense, but atypical in the modeling sense. This by no means indicates that we cannot do a good job of maintenance management, but only that we have to tackle it in another fashion, at least for the time being.

The approach which has been used successfully in maintenance management relies on structuring a management information system to provide historical data as an aid to management decision-making. Figure 4 is a typical management information matrix for structured decisions and planning. Starting with the output of the system, generally stated in programs, the means or organization for accomplishment is

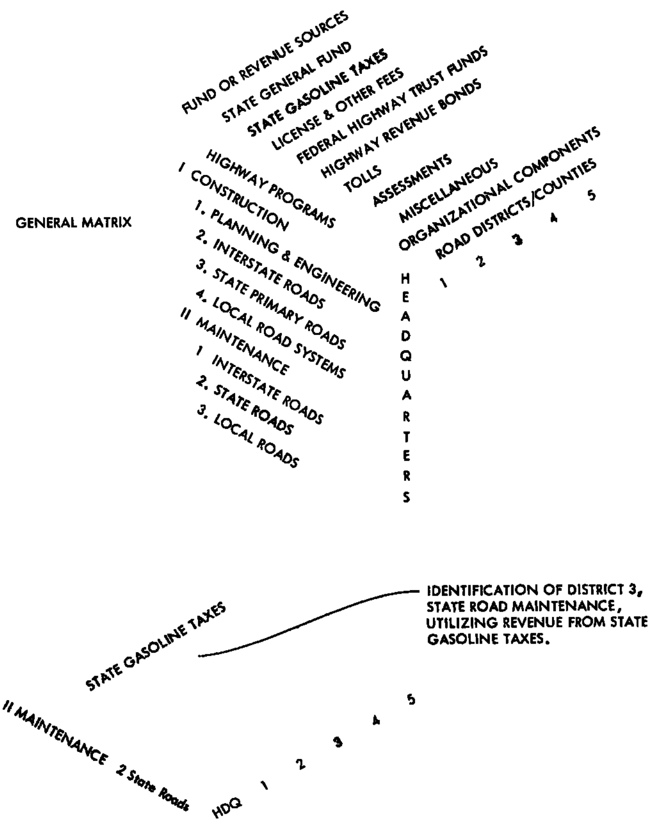

Figure 5. A potential budget framework for a state highway department.

developed, and the input or dollars to support the means determined. In the days before state and interstate roads, one source of funds, one organizational element, and one class of roads described the problem fairly adequately. To be able to approach the same information base today, the amount of information required is compounded significantly as indicated in Figure 5 for a potential state highway budget framework. Prior to the development of electronic data processors such an information system would have been impossible to maintain, much less use for management needs. While the problem is still formidable, the solution is feasible. Until we are able to develop a valid highway maintenance model the use of a historical-based cost and budgeting system appears to offer the best potential for management of the maintenance function at the state level. The development of the budget on a program or output basis, while subject to some assumptions, provides management with a rationalized base for decision-making in the resource allocation process. If we built the best mathematical model possible, the objection would still come up from the field, "But my district is different." With the recognition that we can use a workable budget and information system, for management and information exchange between state and district or county level, there must also be a functional management system in operation.

THE MAINTENANCE MANAGEMENT CYCLE

Because of our inability to predict specific maintenance jobs reliably, the best maintenance management systems are based on inspection generated work identification. Although the program budget and management system should provide overall guidelines for the amount and type of work to be performed, it is still necessary for a trained man to eyeball the road for specific deficiencies. With the deficiencies uncovered, the inspection generated word is planned and estimated for the working supervisor. It is the supervisor's role to manage the men and equipment to accomplish the work outlined. The feedback of costs and accomplishments versus plan provides management with the status of work in hand. This planned approach to maintenance has been widely adopted, and has resulted in reducing the cost and improving the quality of maintenance. Figure 6 shows the typical organizational makeup (administration,

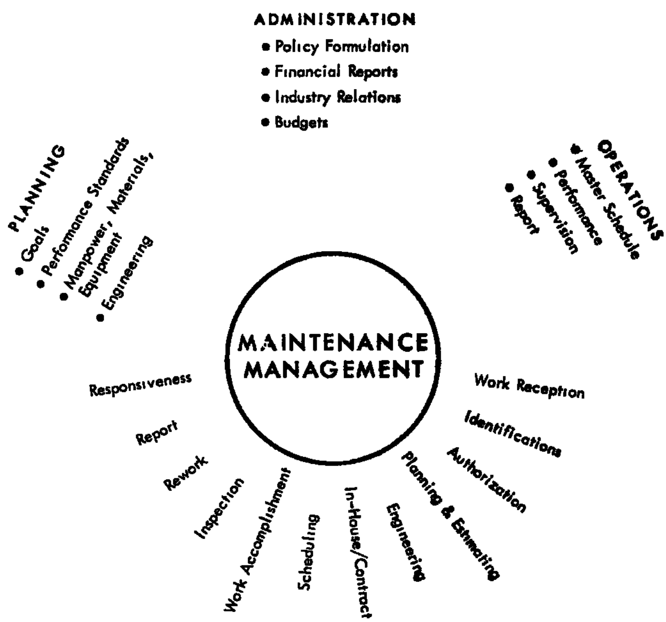

Figure 6. Maintenance management cycle.

FUNCTIONS	LEVELS OF SOPHISTICATION		
POLICY	**VERBAL** none expressed; custom and usage; verbal to key people; brief top level instructions	**WRITTEN — INCIDENT GENERATED** written general guidance; written specific guidance; plus contingent guidance	**FORMAL STATEMENTS AND DETAILED PROCEDURES** printed and published; plus updating; plus contingent guidance
ORGANIZATION	**UNSTRUCTURED BASED ON INDIVIDUAL ASSIGNMENT** craft; shop; function (e g housing utilities etc)	**STRUCTURED** area (geographic); craft or shop; function	**STRUCTURED AND CONTROLLED** plus maint control staff; plus financial management and cost control staff; plus self contained support (supply procurement & transport)
LEVEL OF MAINTENANCE	**UNPLANNED** user (do it yourself); breakdown (at time of occurrence); haphazard or random	**PLANNED** scheduled; plus back log control; partial preventive maintenance; comprehensive preventive maintenance	**PLANNED AND CONTROLLED** plus feedback; plus maintenance engineering
WORK IDENTIFICATION	**UNPLANNED** complaints; emergency service calls; routine service calls; operator inspections; supervisor inspections	**SIMPLE STDS** mfr health, safety stds; scheduled inspections	**PLANNED** planning and estimating; plus preliminary engineering
WORK RECEPTION	**REACTION RESPONSE** individual workers; supervisors; dep t staff	**FORMAL WORK RECEPTION AND CONTROL** dayshift receptionist; screening plus additional clarification and feedback; 3 shift receptionist; screening plus additional clarification and feedback	
PLANNING & ESTIMATING	**WITHOUT STANDARDS** none; rough by journeymen; rough by supervisors	**EXPERIENCE STANDARDS** rule of thumb at any level; published standards by others; P & E group in shops; P & E group at staff level	**FORMALLY DEVELOPED STANDARDS** plus engineered performance standards; plus consulting firms; plus maintenance engineering
WORK AUTHORIZATION	**VERBAL** customer; shop; staff	**LIMITED FORMAL** policy instructions; system standing job order; supervisor approval specific j o	**FORMAL SYSTEM WITH DEFINED AUTHORITY** specific j o approval staff; specific j o approval senior staff; specific j o approval PW director
SCHEDULING	**INFORMAL** none; first in first out; fixed priority by work classif	**PARTIAL FORMAL** major jobs scheduled; scheduled preventive maintenance	**TOTAL SCHEDULED AND FORMAL** all in house work and contract work; by scheduling engineers
WORK PERFORMANCE	**INFORMAL** visual; watch standing; routine patrol and inspection	**PARTIAL CONTROL** service work controlled; major work orders controlled	**TOTAL CONTROL** all work controlled
MAINTENANCE CONTRACTS	**UNSCHEDULED** none; peak work load	**SCHEDULED** periodic	**PLANNED AND BUDGETED** complexity or limited dollars; planned annual
EVALUATION & ANALYSIS	**INFORMAL** none; customer complaints; breakdowns and emergencies; verbal inspection reports	**SIMPLE CONTROLS** written inspection evaluations; rework effort; work sampling	**DETAILED EVALUATION** detailed comprehensive cost effectiveness analysis
BUDGETING	**INFORMAL** level budgets; current payroll plus estimate of materials and services	**FLEXIBLE AND INFORMAL** fixed percent of plant investment; adjusted per cent of plant investment; adjusted historical cost basis	**DETAILED FORMAL AND FLEXIBLE** based on maintenance control forecast for level of facility maintenance; planning programming and budgeting systems

Figure 7. Maintenance management profile.

planning, and operations) that has been adopted by most alert maintenance management organizations. The functions of each of the organizational elements are indicated. The elements of the maintenance management cycle are also shown. The management functions of planning, execution, and appraisal are adequately covered with a system of checks and balances developed by the cycle and the assignment of functional responsibilities.

ORGANIZING FOR MAINTENANCE MANAGEMENT

There are few occasions where one has to start from scratch in organizing for maintenance today. In our work with clients who are trying to improve their maintenance management programs, we developed a maintenance management profile (Fig. 7). In looking at the adequacy of our client's maintenance management programs we felt the need for a simple working tool that would help us identify potential sources of problems, and which would provide a profile of levels of sophistication in management. Our observation is that many systems for the management of maintenance get out of balance. The simplest analogy that I can make is perhaps to use my Volkswagen as an example. I could install a hopped up motor and get the necessary power to use it for road racing. But unless I beefed up the clutch and the suspension gear, it would be a rather dangerous machine. In short, by not balancing the capabilities of the "Bug" I have destroyed the overall system design.

On the left-hand side of the profile (Fig. 7), we have identified the major functions required in a maintenance program. In the columns to the right we have identified the levels of sophistication of the various management functions. In general, we start on the left with an unplanned, loosely structured approach with few controls, and because of the lack of planning, no formal feedback mechanism. As we progress toward the right the management devices that we introduce become increasingly sophisticated. On the far right the most sophisticated devices for management are being utilized. By checking off the appropriate level of sophistication for each of the functions, and then connecting the checks with a line, we develop a vertical profile which provides us with a good overview of the management system balance. From this point we are then able to determine the best way to get balance in the maintenance system, and to suggest the appropriate devices or techniques which should be incorporated. Most highway systems are large enough that they require and can economically support a fairly sophisticated maintenance management system. Each of you might like to evaluate your own management profile to determine your system balance.

With the advent of the computer-aided management systems, we find that there is a tendency to develop extremely sophisticated systems for cost collection purpose, and the handling of the business functions, payroll, purchasing, etc. The management functions that we worried about 15 years ago—policy, organization, evaluation and analysis, and budgeting—have tended to be sidelined. The profile, therefore, tends to look like a curve of normal distribution turned 90 degrees.

As we might surmise, if you cannot hang a computer on your program, or indicate in your position description that your work depends on a computer, you are not "in." For years the way to succeed was to develop new organization charts, new position descriptions, new policies and programs, and fight for control of the budget, or set up management analysis and review functions. In those days, the management opportunist fought a battle of words. Today the objective is to quantify. If you can manipulate numbers your road to success is open.

Most of you would rightfully agree that the case has been overstated by the descriptions just given. All of us who have been observing the management of government enterprises for any length of time recognize that there is a constant pendulum effect in management direction. Fortunately for most operations, the motion is in the center position twice for each time it is at the left or right position of the swing. If we could go from left to right without passing through the middle ground, most of our management systems would be chaotic.

This desire to quantify and rationalize every decision has merit. Hardly anyone would want to get up in front of his peers and present the case for irrationality as a mode of operation. In our approach to rationalization of decision-making, we have to make sure that we recognize that we are working in a total system, and that optimization of a subsystem may defeat our major system objectives.

For example, much of our current stress on numbers is connected with cost control. Cost control was developed in an industrial environment, where profitability could generally be measured. The impact of cost control had an ultimate profit measure in most instances. When we look at the public enterprise organizations we often find that cost control can have some rather negative effects. Our system of management does not provide an ability to determine the impacts of cost reduction across the total system. Let us examine some typical cases where cost control may be detrimental to the overall program, because our system is not geared to the profit motive.

In highway maintenance, we have in many instances two ways of accomplishing our work. We can do it with highway road crews, or we can contract for the work. If we are going to rationalize our decision, most of us would agree that we should do it by the most efficient and economic method. To make the decision, however, our accounting system must provide us with full information on the cost of our direct labor, fringe benefits, overhead for supervision, equipment costs including maintenance and repair with its own overhead burdens, equipment depreciation, and a few others. To the contractor's bid we must include the cost of contract preparation, administration, inspection, billing, and a pro rata share of legal costs for defending contract claims. At this point in time we might be in a position to make an evaluation on a cost basis. The story, as we well recognize, is not complete, however. There are other considerations, intangibles for the point of this particular maintenance job decision. We have to consider whether we have work for the people on our payroll, the impact of the reduction of in-house workload on our budget for next year, perhaps even the impact on our own job. The decision is patently one which involves more than pure costs. For example, depreciation has little actual meaning because we neither have to write off capital assets, nor can we declare depreciation as expense in a tax deduction situation. If we reduce our manpower usage in-house we might lose the numbers for next year when we will need the maintenance people.

In our efforts to control costs, many of us have to rely on central purchasing authorities. They operate on a pure cost basis in most instances. They buy at the cheapest price, sometimes with quality lacking. The fact that our equipment is deadlined for a five dollar part, which they are buying at the lowest price regardless of delivery time, is of no consequence to them in their particular attempt to optimize by buying at the lowest price.

With the pendulum swing that occurs when managers stress one program after another, lower management's attention often gets directed too deeply to one facet of the management system. One of my respected associates called this the "White Knight" syndrome. The White Knights pick up the current fad and charge off after much fanfare to win the current crusade. Meanwhile, back at the castle, the crops go untended, the drawbridge is not maintained and gets stuck, and the castle is overrun by bandits. When the Knight gets home he finds the whole place has gone to pot during his absence. The Knight may have gotten a medal for the crusade, but when the King comes around to collect the taxes, he better be off on another crusade.

Each of us has been exposed to this type of decision-making. Each of these problems is generally the result of not having a balanced management system.

We feel that the only way to get the balanced management system is to evaluate the strengths and weaknesses of your current system. The profile may be of some help in this area. The next step is to pick some of your people who know your current system, but are dissatisfied with its performance, and pull them out of the mainstream. Let them start with determining your objectives and defining your system. Identify the system components, and define the relationships and interactions between these components. If you interface with others, as we do in maintenance, we have to look at the whole real property cycle from planning to disposal. Define the problems or conflicts that are involved in the system, and then, and only then, try to apply technology to the development of alternative solutions. There are too many tools or techniques available to take the approach of pulling one off the shelf and trying to force it into a totally different environment. The technique may have worked in the state next door, and solved many problems. It may not work in your system as effectively, or it may even be a step backward.

It may sound like we are deprecating progress and a willingness to move ahead. Nothing could be further from the true situation. We do feel, however, that too often in our efforts for improving our systems we have not looked at the forest hard enough because of the magnitude of the problem, and instead start worrying about the individual trees.

THE UNANSWERED QUESTIONS

The current political fad is to point out problems, not solutions. It appears to be fairly successful so there is no reason why we in maintenance should not avail ourselves of this new technique. Problems are my bread and butter. I would prefer to solve them, if they are real problems, rather than talk about them, but one must start the definition phase before solution can occur.

Most of us would agree that we do not as yet have the best management structure for our highway system. It works, but there are often questions that we cannot begin to rationalize.

Our objective in maintenance is fairly simple. Maintain what they build. Do we have a reliable way of accumulating our costs so that the designers can look at the total cost of a highway from both a capital and operating standpoint? Are there re-

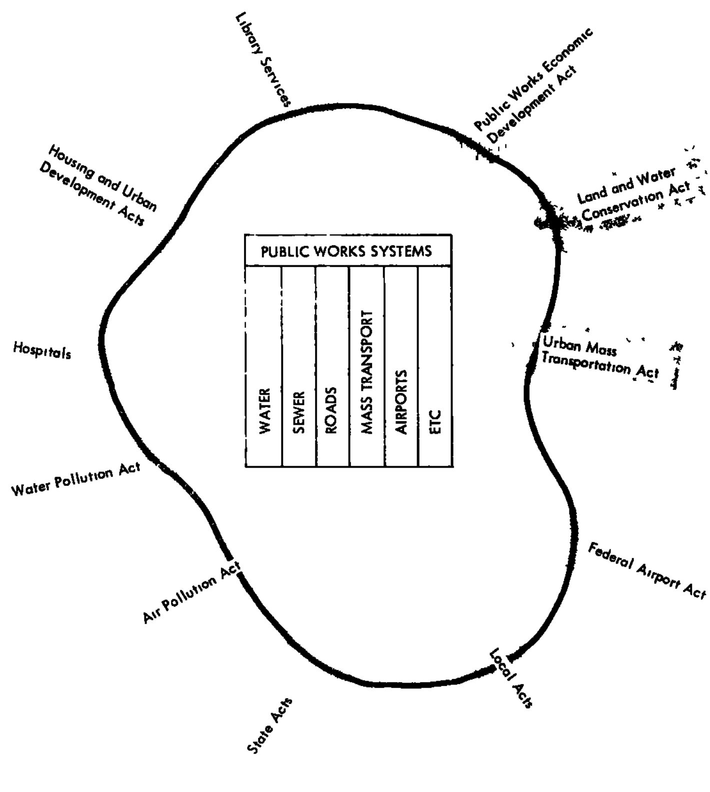

Figure 8. Existing patterns of laws that tend to foster vertical systems of planning, engineering, and construction.

strictions on our operations because of funding situations that force us into illogical decisions because we must follow the money chain? Figure 8 illustrates the problem of multiple funding for the urban environment. Similar problems exist in the maintenance area, and it is often difficult, if not impossible, to plan our work and operate effectively. Through arbitrary rules we have labor money, material money, and contract money. When we try to combine these pots of money we are often unable to make the choices that are rational because of the arbitrary allocation and control process. After much observation and some practical experience the use of a flexible budgeting system, such as an enterprise fund, has merit. If we got one kind of dollar to buy maintenance based on some form of output evaluation, then the day-by-day decisions on make or buy would be far simpler, and our cost collection systems more meaningful. There are many more questions such as these in the area of the management structure, but time does not permit discussion.

In studying the interrelationships within the highway system, one major problem involves getting adequate feedback to the design side of the house. In our attempt to maintain autonomy of the maintenance function have we destroyed our relationships with the designer? The following kinds of situations leave me to question how well this communication system is working. A picture appeared in the New York Times which showed a massive interchange proposed for one of the serious traffic bottlenecks in New York City. How much consideration will be given to maintenance in the design of that structure? What are they going to do with the snow? Are there maintenance turn-offs so that equipment will not block the flow? What was done to prevent deterioration from deicing materials? The designers may have the right answers to the kinds of problems that you and I in the maintenance world might ask, but do they in this case? Some things that I have spotted in the past month in California, New York, Colorado, Virginia, and Maryland make me want to question this premise.

With the current demand for protection on superhighways, guardrails are being installed at a tremendous rate—most of them in grassy areas. We have bridge abutments completely surrounded by guardrails, with no way except to lift the equipment over the rail or use hand tools to cut the grass. The guardrails are in most instances too low for anything but a sickle bar to pass underneath. If we are to maintain appearance we are going to be forced to hand cut around each of the guardrail supports, and also, the number of new signs that are being installed. It might be cheaper to put plastic collars around the posts, killing the grass to make it possible to use machine equipment.

The beautification program is already recognized as an additional drain on maintenance funds. But in a water short state is it rational to put in sprinkler systems at road interchanges so that we can grow flowers and shrubs—particularly when the interchange is surrounded by industrial and shoddy commercial ventures?

With our subspecialization of design, construction, and maintenance within a highway system, have we killed our ability to communicate effectively? Can we build our information system to overcome this difficulty?

In summary, I have attempted to describe the use of systems analysis in the maintenance management environment, indicated some of the general tools that I feel might be helpful in your analysis, and suggested some unanswered questions that make me feel that there is still a need for an in-depth look across the board into highway maintenance management systems.

Cost Effectiveness as a Measure for Setting Maintenance Levels and Priorities

C. H. OGLESBY, Stanford University

Tremendous progress toward effective management already has been made by at least some highway agencies. Such approaches as setting realistic standards, and developing computer-based methods for planning, scheduling, and controlling the maintenance function are in full accord with the best present-day thinking.

The construction industry prides itself on being progressive and claims to be far ahead of governmental agencies in its initiative and in developing new methods. But it can be stated without fear of argument that many of the maintenance techniques and procedures are far more effective than those employed by all but a handful of contractors. Particularly noteworthy is the use of the industrial engineering approach to develop improved methods, standard times to measure job performance, and the attention being given to the "people" side of management.

There is no question that many decisions regarding maintenance policy and procedures require choices on how to use that very scarce commodity, money. But are these decisions money based? Figure 1 is a plot of the responses of the state highway departments to a 1963 questionnaire (1). It shows that formal economic analysis was almost never employed in making maintenance decisions.

It can be argued then: (a) that since many decisions about maintenance expenditures can be money-based, (b) that current decision-making procedures are not money-based, and (c) that there are strong pressures on public agencies to explain and justify how the money entrusted to them is being spent, it is time to get busy developing techniques and procedures for looking at the "cost effectiveness" of maintenance.

WHAT IS COST EFFECTIVENESS?

The term cost effectiveness immediately suggests a comparison between an expenditure and the gains that that expenditure brings. However, the term does not say how that comparison should be made, and at the present, no universal basis for such comparisons is available in the private sector of the economy, let alone in the public sector. In the highway field, Figure 1 suggests how little has been accomplished in any of the divisions of highway practice.

Cost effectiveness is relatively easy to define in the private sector. Here, the aim is to make money or, stated more elegantly, to "maximize profits." This must, of course, be done under certain rules of the game which require observance of the law, payment of taxes, and some degree of recognition of social responsibility. It is admitted that projecting costs and gains into the future is neither an easy nor exact science, but at least, the objective of private enterprise is clear: to deploy the available money and other resources to maximize one thing—profit after taxes.

In the public sector, merely to define cost effectiveness is difficult indeed. Here, the aim is to "maximize the public good," whatever that may be. However, one thing is clear: it is that the aim is not to maximize the "good" of the highway agency or of the maintenance division of that agency. It is an agency developed to spend public money to perform a public service, and it and its employees are stewards (house wardens) charged with a responsibility to make the best possible use of the funds placed in their hands.

In the public works field, as in private enterprise, accounting for costs is primarily a matter of devising and operating a suitable estimating and measuring system. On the other hand, it is extremely difficult to set up measures of the public good that are

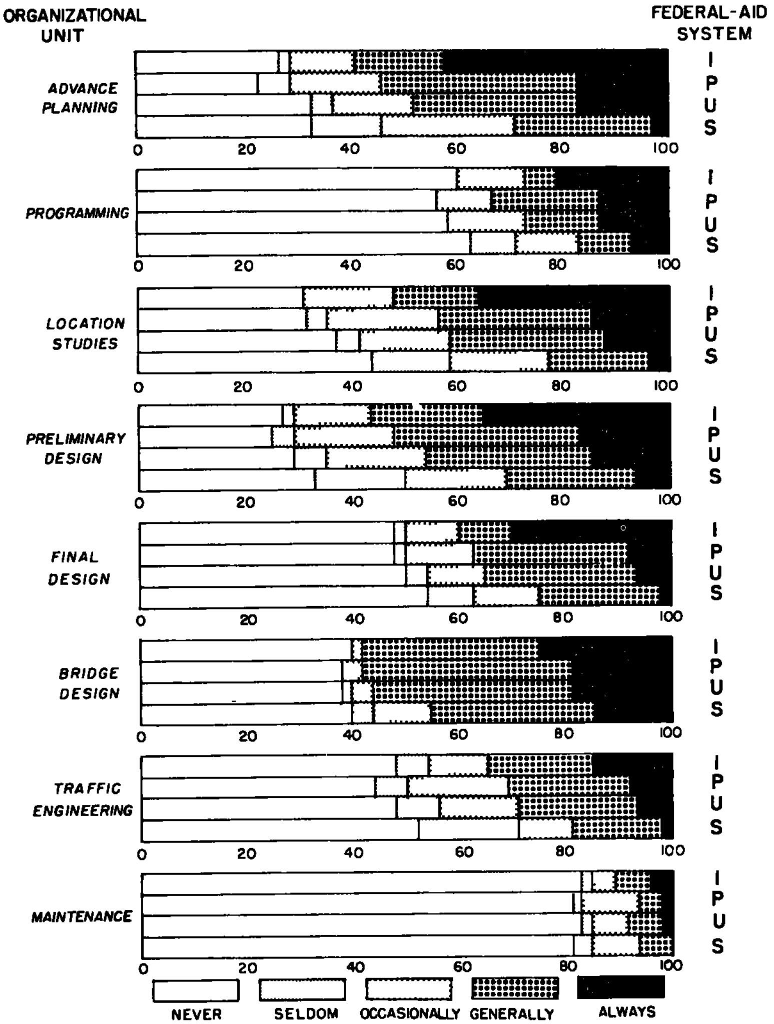

Figure 1. Percentage use of economy analysis by Federal-aid system, organizational unit and frequency category (1).

to be mazimized by public works decision-makers. Possibly the most important of these goods is, however, reflected in the term cost effectiveness. It covers the efficient use of resources, be they money, land, plant and equipment, air, water, or human productive capacity.

In the developing nations where food and shelter are so scarce that human survival is a problem, these economic considerations may well be overriding, and even in the developed nations where resources are abundant, economic comparisons are important. There are many instances where choices among the possible use of resources can be made solely on economic grounds. In other cases, economic comparisons provide a means for weighing the relative desirability of consequences for which money values are either unknown or for which they seem inappropriate.

It must be recognized that in today's world, it is not possible to completely overlook the "other than economic factors" that are affected by public works decisions. Examples in the highway field include the comfort and convenience of motorists, the presence or absence of noise, dust, and fumes, and the suffering and deprivation resulting from highway accidents. Furthermore, the implications of highways to neighborhoods and the community must be weighed.

It follows that, not only must the techniques for measuring cost effectiveness be broad and all-encompassing enough to reflect economic and social costs, but also that, in some situations, other measures that cannot be stated in money terms must be considered in the decision-making process.

THE SYSTEMS APPROACH

One of the most popular words in today's technical jargon is "systems." It means many things to many people, but for the purposes of this paper, it offers a useful concept, and that is "to reach a proper solution to a problem, it is necessary to make the circle encompassing a study large enough to include all relevant factors." Unfortunately, this systems concept has often created confusion rather than clarity because it has been used capriciously and without thought.

In applying the systems approach, it must be recognized that for decisions made at the top, the system must be comprehensive; in other words, the circle encompassed by the study is large. As the decision-making power moves lower and lower in the management hierarchy, the system becomes more and more restricted in scope and the circle gets smaller and smaller. On the other hand, as the system becomes more and more complex, fewer and fewer particulars can be encompassed in it. Applying these concepts to cost effectiveness, it should be clear that no single approach to or set of answers for cost effectiveness will be appropriate for all levels of management.

For example, in the case of snow removal, top administrators will be concerned with broad questions such as the economic and political implications of a bare pavement policy and, within that, deciding which roads to keep open. The equipment manager will be concerned primarily with the relative economy of various types and sizes of snow-removal machinery, and the maintenance supervisor will be looking for economies in, among other things, setting routes for equipment to follow and determining the circumstances under which he begins and carries out snow removal activities. Of course, accurate cost information is needed to make correct decisions at all these levels. However, it is only at the higher levels that the broad policy questions regarding "gains" enter directly into studies of cost effectiveness.

Research now being carried on may have far-reaching effects on how decision-making on more complex problems is carried out. The behavioral scientists have developed strong evidence to show that the human mind can deal effectively only with about six or seven major elements of a problem at one time (2). Yet, many problems have far more than this number of facets. The effort is, then, to find workable means for alternately breaking a problem down to show the detail and then reassembling it into a relatively small number of variables. One very promising approach is to couple a visual display cathode ray tube to an on-line computer. It is then possible to assemble the major variables graphically or in words or to instantly recall and display the details underlying these variables.

APPROACHES TO COST EFFECTIVENESS

In the broadest interpretation, cost effectiveness programs will have the aim of permitting comparisons of the costs and benefits of all expenditures of the governmental agency in question. They will include evaluations in money of long-term investments in capital improvements in such areas as highways and other transportation media, water projects, and air and water pollution. Also, the expenditures for day-to-day governmental services such as a law-enforcement and protection of the public through the licensing of engineers, doctors, lawyers, contractors, and barbers will be rated.

As indicated earlier, it should be possible to determine the costs of providing such governmental services within reasonable limits. Admittedly, there is much uncertainty and argument on investment criteria such as interest rates and useful lives of capital investments, but at least all costs can finally be stated in terms of money.

On the gain side, however, only the beginnings have been made in reaching overall evaluations. For example, in the highway field, reasonable estimates can be made of gains from reductions in vehicle operating and time costs that accompany an expenditure to improve traffic flow, assuming traffic volume projections are fairly accurate. However, money measures of the socioeconomic and certain nonquantifiable effects of highway improvements have yet to be developed, and in a field such as the licensing of professions, what possible measure is there of the gains to society that result because, for example, barbers have passed an examination?

The above arguments are not intended to say that the cost effectiveness approach cannot be implemented. It is, rather, to say that a long road lies ahead. In the meantime, it will often be necessary to "suboptimize," that is to look at only that part of the problem that can be handled. Again, in many instances, it will be necessary to minimize the costs necessary to achieve some arbitrary measure of gain, but the aim will always be to give the public the most for its money, even though the measures are imperfect. It goes without saying that decisions made with as much factual knowledge of costs and benefits as can be assembled will be better than those based solely on opinion or reaction to pressure.

IS COST EFFECTIVENESS BEING APPLIED IN HIGHWAY MAINTENANCE?

It can probably be said truthfully that only a few of the many highway agencies in the United States have meaningful data on either the cost or gain sides of highway maintenance. A recent study sponsored at Stanford University under the National Cooperative Highway Research Program offers some proof to this claim. Almost no data in the depth and form needed to make meaningful cost effectiveness studies in any facet of highway maintenance were found either in the literature or in the records of highway agencies (3). Actually, more meaningful data have been presented at this workshop or have been developed by the agencies making presentations here than were found in all the past literature. So real progress has begun!

CLASSES OF COST EFFECTIVENESS STUDIES

Techniques for making cost effectiveness studies might be put into three general classes as follows:

Class 1—Those situations where a standard of quality or quantity has been fixed by higher authority and where no differences in or factors affecting capital investments are involved. In this case, comparisons based on cost per unit of accomplishment will be appropriate. For example, for patching a bituminous surface, the man-hours and materials per square foot or square yard of patching might be proper units, or both items might be converted to a dollar cost per unit area. This approach would be appropriate whether the aim is to measure the actual performance of a given crew against a standard or to make comparisons between the effect of crew size or some other variable on productivity (this would be true as long as equipment costs are not a factor in the comparison).

Class 2—Those situations where a standard of quantity or quality has been fixed by higher authority, but where capital investments as well as annual expenditures are involved. These investments may be in materials, machines, or facilities any of which may have different costs, performance characteristics, or useful lives. In this case, an economic comparison (economic study) must be made. The most favorable alternative will be the one that had the lowest cost in the long run. Results may be expressed in the following forms: (a) lowest equivalent uniform annual cost, (b) lowest present worth of costs for a specific number of years, or (c) the highest rate of return on the total and also on the last viable increment of investment. An example of a situation where this approach is required would be a comparison of the present method of mowing the roadside with several other machines and procedures.

Class 3—Those situations where the standard of quality of maintenance is subject to question and where, in addition, alternative procedures may or may not be followed to accomplish the different standards. In this case, as in Case 2, an economy study approach is required. Results may be stated as indicated in Case 2, or also as the benefit-cost ratio on total and last viable increment of investment. Case 3 differs from Case 2 in that, for Case 3, a money value for the good or benefit that this particular maintenance operation brings to the public at large must be included in the analysis or the decision. An example of this form of cost effectiveness study would be a determination as to how often, at what height, and how far from the edge of the roadway to mow the roadside.

PROBLEMS WHEN MAKING ECONOMY STUDIES

The purpose of economy studies is to apply fundamental economic principles to making engineering and management decisions. All too often, however, engineers and administrators have assumed that these principles are self evident or that they merely represent an extension of accounting procedures or financial calculations. An added factor is that only about one-third of the civil engineering curricula offer these principles among their subject matter. It is, then, small wonder that many highway economy studies contain fundamental errors. Unfortunately, also, the highway literature is crowded with formulas and solutions to economic problems that are entirely wrong.

The principles underlying economy studies are too complex to be presented here, but it is essential that those involved in cost effectiveness studies understand them thoroughly. The book by Grant and Ireson is a classic; early next year, Robley Winfrey's book devoted entirely to highway economics will be available (5). In addition, most of the papers sponsored by the Committee on Highway Engineering Economy of the Highway Research Board in the last ten years are fundamentally sound. Although these papers are not primarily concerned with maintenance problems, the parallels are close enough to be helpful to one who wishes to develop competence in highway economy.

As indicated above, past highway economy studies have often been in error. Among the more common mistakes are the following:

1. Failure to clearly define the available alternatives and their consequences.
2. Mixing economics, which is the use of resources, with finance, which relates to sources of funds. Decisions on economy and finance are separable; they should be made separately, one following the other.
3. Using accounting data such as book value or allocated costs in economy studies. Neither of these have a place in an analysis of the future consequences of alternate courses of action.
4. Including a factor for inflation in future costs or benefits.
5. Making comparisons involving future costs, gains, or both without using compound interest to reflect the time value of money. Another form of the same error is to adopt the bare cost of borrowed money as the interest rate.
6. Counting the same cost or benefit more than once. This is called "double counting." (A common error is to include the tax on motor fuel when computing vehicle operating costs.)
7. Using the physical life rather than the anticipated service life of a highway element in cost comparisons.

This list of errors is far from complete, but it may be useful as a means for running a rough check on formulas now in use or that are being proposed to solve maintenance economy problems.

DIFFICULTIES IN SETTING STANDARDS AND EVALUATING THEIR BENEFITS

Earlier in this paper it was stated that highways are constructed, operated, and maintained with public funds for the public good. It can be concluded, then, that standards for maintenance should, insofar as possible, reflect the public's wishes when determining how maintenance funds should be used. Cost effectiveness is one measure, but it is also clear that the public has desires that cannot be evaluated in money terms.

To date, few, if any, formal attempts have been made to measure public preferences as to the level of maintenance standards. Neither have public desires been explored systematically in terms of the importance or the various aspects of maintenance, for example, surface maintenance vs litter collection. Of necessity, and for want of legislative or other direction, highway engineers in each agency have aopted standards that, in their opinions, seemed reasonable. These standards have, of necessity, been elastic in order to fit the available resources of money, manpower, and equipment. If the available resources were in short supply, standards were selectively relaxed.

Recently a statement of policy entitled "Criteria for Maintenance of Multilane Highways" was prepared by the Committee on Construction, Maintenance, and Operation of Highways of the American Society of Civil Engineers (6). Among the objectives of the statement was the following: "To promote a uniformly high level of maintenance by the various state and local agencies." This statement presumes that the public wants or demands this high level of maintenance. It also assumes that the public wants this high level across the board, rather than being selectively applied to say, the roadbed but not the roadside.

In some instances, the statement of policy indicates that standards should be lower where traffic volumes are lower; in others, it does not. For example, it recommends that corrective measures to bring skid resistance to a particular level be developed on all roads, regardless of traffic volume. Yet, accident expectation and accident costs should be less on roads carrying lower volumes.

The question being raised here is how, if at all, cost effectiveness and other measures of the public's wishes can be applied to standards for highway maintenance. One possibility is to use modern sampling and polling methods to test public reaction, as has been done in an exploratory way in other public works fields. In any event, since standards are at the crux of all decision-making on highway maintenance, this subject deserves immediate and concentrated attention.

CONCLUSION

This paper has attempted to take a preliminary look at how cost effectiveness can be applied to decisions on highway maintenance. It also has briefly explored the forms that analyses to measure cost effectiveness will take and the problems that will be encountered in carrying them through. In addition, it has examined the question of giving decisions regarding highway maintenance greater sensitivity to the wishes of the public that pays the bill. In sum, it has looked at cost effectiveness as an advanced and valuable aid to decision-making and as a fruitful area for research and development.

REFERENCES

1. Glancy, D. M. Utilization of Economic Analysis by State Highway Departments. Highway Research Record 77, 1965.
2. Miller, G. A. The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. The Psychological Review, Vol. 63, p. 81-97, March 1956.
3. Oglesby, C. H. and Altenhofen, M. J. The Economics of Design Standards for Low Volume Rural Roads. Final Report on Contract HR 63-2-6 of the National Cooperative Highway Research Program.
4. Grant, E. L. and Ireson, W. G. Principles of Engineering Economy. Fourth Edition, The Ronald Press, 1960.
5. Winfrey, Robley. Highway Engineering Economy. International Textbook Co. (in press).
6. Criteria for Maintenance of Multilane Highways. Journal of the Highway Division, Proc. ASCE, p. 43-60, June 1968.

Use of Pavement Evaluation Techniques in Maintenance Management

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Pavement evaluation techniques have important applications in maintenance management. In the determination of present conditions and remaining service life in important pavement systems, managers can eliminate the problems associated with subjective ratings and accomplish management planning on a sound technical basis. Also the ability to determine the future date or dates when major pavement rehabilitation will be required, permits management to accomplish optimum scheduling of the rehabilitation work and of interim maintenance measures as well.

Obviously, this type of evaluation has particular application on important arterial routes and major highway networks such as the Interstate System. It also has proved to be a valuable tool in maintenance programming on a number of major toll road systems throughout the northeast.

PRESENT SERVICEABILITY INDEX

Essentially, the pavement evaluation techniques consist of utilizing the Present Serviceability Index (PSI) concepts and pavement performance curves developed during the AASHO Road Test at Ottawa, Illinois. The PSI is a measure of a pavement's momentary ability to serve traffic. The PSI concept was developed to monitor the effect of axle-load applications on a variety of pavement designs. A pavement serviceability rating panel was appointed to make a subjective judgment of the ability of 138 different pavement sections to service traffic. The panel's judgment was indicated by a rating value ranging from 0 to 5 with adjective designations of very poor (0-1), poor (1-2), fair (2-3), good (3-4), and very good (4-5). AASHO personnel then measured variations in longitudinal and transverse profiles as well as the amount of cracking and patching on each of the pavement sections. Using mathematical analyses, these quantitative measures were related to the mean rating value as established by the rating panel to produce an equation to predict a quantitative counterpart of the mean rating value.

SURVEYS AND ANALYSES

A number of devices are available to measure the pavement profile. A profile measurement system developed at the AASHO Road Test employed the Chloe profilometer. A number of states have acquired this instrument. Its major limitation is in its slow operating speed (±5 mph) and sensitivity to moisture and temperature changes. A more practical instrument for general field operation is the BPR-type road roughness indicator, which measures the accumulated inches of roughness while traveling over the pavement surface at 20 mph. Our firm has purchased a road roughness indicator and is currently using this instrument in pavement evaluation studies.

To establish the PSI of a pavement it is necessary to conduct a survey of the pavement roughness using the road roughness indicator or an alternative instrument and to conduct a visual survey of the patching and cracking conditions on the pavement surfaec.

The roughness survey records the surface deformation resulting from effect of traffic loads, age and environment. This phase of the field survey consists of taking measurements to determine the rideability of the pavement surface recorded in inches of roughness per mile of roadway. The BPR-type road roughness indicator consists of a single test wheel mounted on a towing frame with two single-leaf springs and precision damping devices. As it is towed along the wheelpath of the roadway, the wheel deflects with respect to the towing frame in proportion to the roughness of the road.

Figure 1. BPR-type, road roughness indicator, Model CT-444.

Figure 2. Roghometer test wheel is towed in the outside lane to record most severe condition.

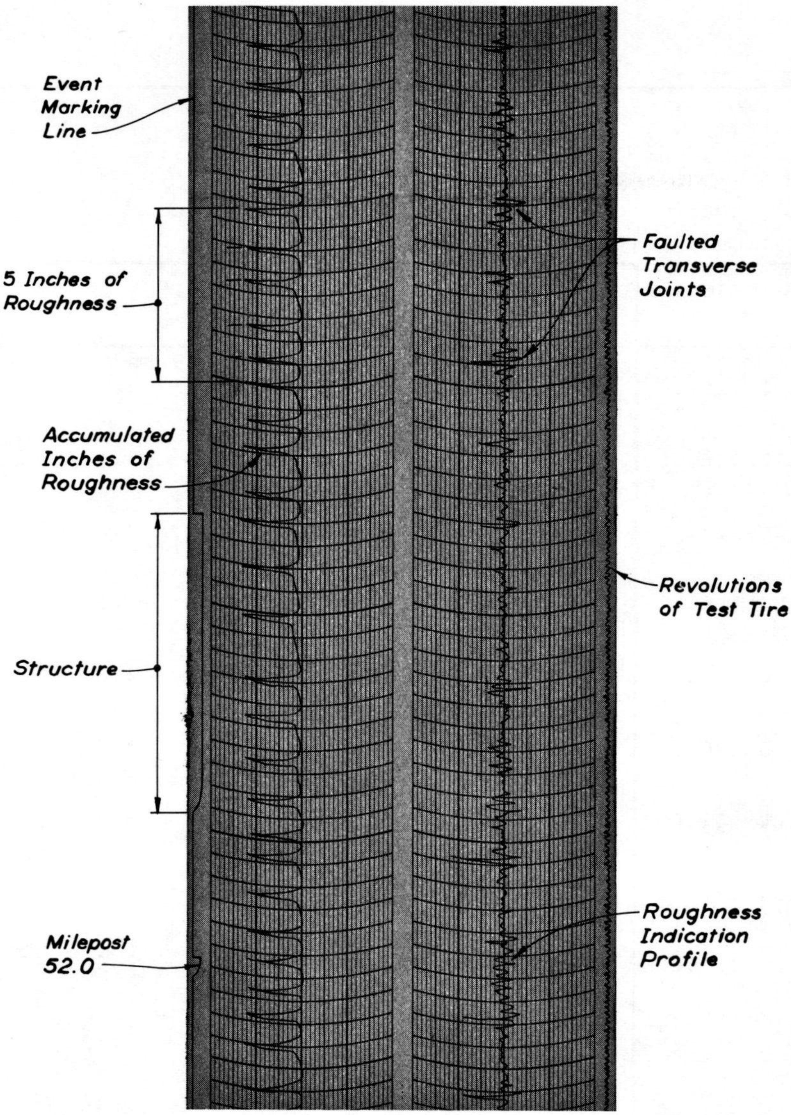

Figure 3. Continuous tape record of pavement roughness survey, electronically registered by road roughness indicator.

The total downward movement recorded in inches per mile of roadway represents the roughness index. The downward movement is electronically recorded on the instruments contained in the towing vehicle. These instruments also provide an accumulative record of the inches of roughness to one 1000th of an inch and a continuous profile of the roughness of the road recorded on tape.

The visual survey consists of observing the pavement surface and recording the quantities of pavement deficiencies noted. While cracking and patching are the only quantitative values required to compute the PSI, it has been our practice to observe and record other conditions which could affect the structural integrity of the pavement, i.e, pumping, faulting, scaling, and other signs of disintegration of the pavement surface as well as defects in shoulders, drainage, and appurtenances. The data are recorded on special forms for each mile of mainline pavement and for each ramp or con-

NEW YORK STATE THRUWAY
1967 PSI VALUES

WESTBOUND MAINLINE

MILEPOST FROM	MILEPOST TO	STRUCTURES DIST	STRUCTURES RI	STRUCTURES PSI	PAVEMENT TYPE	PAVEMENT DIST	PAVEMENT RI	PAVEMENT PSI	AVE PSI
114.CC	115.CC				R	1.00	116	3.12	
						1.00	116		3.12
115.CC	116.CC				R	1.00	103	3.40	
						1.00	103		3.40
116.CC	117.CC				R	1.00	106	3.33	
						1.00	106		3.33
117.00	118.CC				R	1.00	115	3.15	
						1.00	115		3.14
118.CC	119.CC				R	1.00	110	3.25	
						1.00	110		3.25
119.CC	120.CC				R	1.00	105	3.36	
						1.00	105		3.35
120.CC	121.CC				R	1.00	108	3.29	
						1.00	108		3.29
121.CC	122.CC				R	1.00	115	3.15	
						1.00	115		3.14
122.CO	123.CC				R	1.00	118	3.08	
						1.00	118		3.06
123.00	124.CC				R	1.00	113	3.19	
						1.00	113		3.19
124.CC	125.CO				R	1.00	134	2.75	
						1.00	134		2.75
125.CC	125.39				R	0.39	128	2.87	
125.39	125.47	0.08	133	2.59					
125.47	126.CO				R	0.53	126	2.91	
						0.92	127		2.90
126.CC	127.CO				R	1.00	129	2.85	
						1.00	129		2.85

Figure 4. Typical print-out of pavement sections and PSI values from computer program.

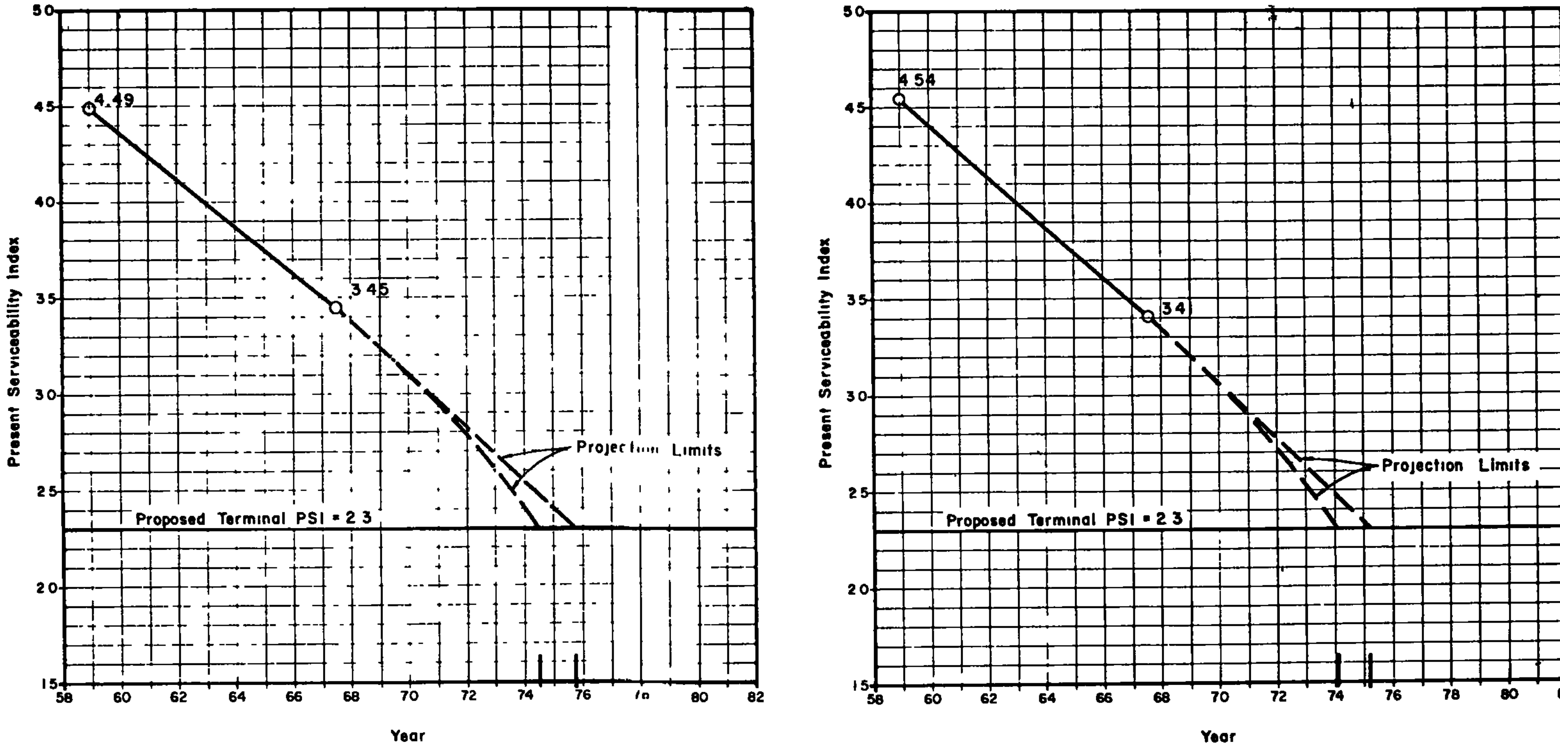

Figure 5. Typical service life curve; projection limits set by alternative future traffic growth estimates.

necting roadway for the pavement section under study. The visual survey can be conducted by a crew operating on the shoulder of the highway where a paved or graded shoulder is available. The visual survey crew consists of a vehicle driver and an observer and recorder riding perferably in the open bed of a pickup truck, traveling at an average speed of 3 to 5 miles per hour.

With the cracking and patching data in hand and the roughness index (RI) values established, the PSI values can be computed for each pavement section using the appropriate equation where the cracking factor (C) is in units of linear feet of cracking per thousand square feet of area and the patching factor (P) is in units of square feet of patching per thousand square feet of area. PSI values can be computed for each segment of highway and plotted on a bar chart to permit inspection and analysis. Generally, it has proved practical to compute PSI values for each half-mile pavement segment and then to average the PSI values over longer pavement sections so that programming of major rehabilitation work can be scheduled for significant pavement lengths.

DEVELOPMENT OF LONG-RANGE PROGRAMS

Service life curves are the graphic illustration of the loss of PSI values as a result of repeated axle-load applications and environmental influences acting over a period of time. In the AASHO Road Test analysis, equations were developed to show the loss of PSI as a result of repeated axle-load applications of a known magnitude for various pavement designs. Because the AASHO Road Test was performed over a relatively short period of time, no relationship with time and environmental factors was established. In evaluating existing pavements, many of which have been subjected to environmental influences over a number of years, it is necessary to account for that loss of service life associated with factors not related to axle loads. Our firm has developed a procedure to identify the influence of time and environment in what we refer to as a K factor. By expressing both the axle factor and the K factor in the same mathematical form, they can be incorporated into a single expression where K is used to convert time and environmental influences into equivalent axle units. For large axle-load applications, the K factor becomes insignificant. Conversely, it may become the primary factor when axle-load applications are relatively small on older pavements.

The AASHO Road Test curves plotted loss of service life against accumulated axle loads. In order to convert axle loads to time, it is necessary to perform an extensive analysis of the character and magnitude of the traffic to which the pavement has been subjected since its opening and to analyze and develop projections of traffic volumes and traffic load classifications over the service life period of the pavement. With adequate traffic information in hand, and through the computation of equivalent 18-kip axle loads for the mixed traffic flow to which the pavement is subjected, it is possible to establish a direct correlation between accumulated axle loads and calender years. Thus the service life curve can be plotted with PSI values as the ordinate and calendar years as the abscissa. The point at which the projected service life curve intersects the minimum acceptable PSI value then identifies the year in which major rehabilitation of the pavement section can be anticipated.

Service life curves can be computed for each of the pavement sections using the PSI values established by the survey as the current point on the curve. Where no prior pavement evaluation studies have been performed on a pavement section, initial PSI values must be assumed in order to determine the loss of service life associated with current values. This assumption can be based on PSI surveys on nearby newly constructed sections of pavement built to comparable standards or it may be established by a purely judgmental assignment of initial values. Obviously, the warrants for periodic PSI surveys and the establishment of additional points on the service life curves are strongly indicated if a high degree of accuracy is to be anticipated in projections of the service life curves over more than a few years in the future.

With pavement service life curves computed for each significant contiguous segment of a roadway system it is possible to identify the year in which each pavement segment can be expected to reach its minimum acceptable PSI value. Resurfacing programs can be scheduled from these data, and practice grouping of sections to provide optimum contact size, to minimize repeated traffic interruption and to balance out annual betterment programs can be accomplished.

Use of Pavement Evaluation Techniques in Maintenance Management by the New York State Thruway Authority

J. P. PENDLETON, New York State Thruway Authority

The engineering report of the resurfacing program is presented to the Thruway's top management with the chief engineer available to expand on the content in areas where questions arise. Top management sets policy by indicating acceptance of the report and its conclusions. The chief engineer and the superintendent of maintenance in conjunction with the finance officer, can now use the pavement evaluation report as a management tool. In our case, a long-term reserve fund has been established with money from operating revenues set aside in an orderly schedule to be available according to requirements of the pavement rehabilitation schedule. On an annual basis, the long-range requirements are used as a framework on which to hang our annual budget requirements.

In its fourteen-year life the Thruway has had two complete evaluation studies. The first one covered the period from 1962 to 1975 and the second one enlarged the period from 1966 to 1982 with the experience in the first four years being used to refine earlier projections. In at least one instance the pavement rehabilitation financing schedule was used in a statement to prospective bond holders.

IMPLEMENTATION OF PROGRAM SCHEDULES

The projections covering long-range maintenance are updated annually by running a roughometer survey over the entire Thruway system. In addition to any wide variation shown on the roughometer graph from year to year, a judgmental evaluation is provided. The service life curves are adjusted if necessary by the following factors:

1. Yearly traffic volumes which are automatically tabulated from toll records.
2. Comparison of the roughometer surveys.
3. Establishment of new PSI values on new overlays.
4. Occasionally new crack and patch surveys are conducted in local areas.

The superintendent of maintenance, a local division engineer and two men from the chief engineer's office make an annual visual inspection each summer to confirm the exact location of major rehabilitation work for the following year. Since this work falls into the categories of resurfacing, installation of additional drainage, and added improvements for safety, most of these projects are handled by contracting firms rather than our existing maintenance organization.

After the inspection and approval of work for contract, Thruway office engineers prepare contract documents during the winter and early spring. These contracts are generally available for bidding in April which gives us the advantage of starting pavement work prior to the busy season. It also generally results in low bid prices because contractor obligations have not yet been made on summer construction work. The contracts are written with definite traffic sequential considerations. It is necessary to allow traffic to pass through the construction area due to the nature of this limited-access highway.

Thruway management of the highway rehabilitation contracts is divided as follows—our Department of Traffic and Services sets overall policy on traffic control; the contract preparation, bidding and inspection is the responsibility of the Bureau of Construction and Design, and the Bureau of Thruway Maintenance provides all designated traffic control devices but is not directly involved in the reconstruction project.

Coordination between the Bureau of Thruway Maintenance and the Bureau of Construction and Design is assigned to the assistant chief engineer.

GENERAL OBSERVATIONS

Why should Thruway experiences be of general interest?

1. Because the entire 559 miles of the Thruway was built in its entirety in a relatively short period of time in the early fifties. The Interstate System in other states has very similar characteristics except that it is 10 to 12 years younger.
2. Normal state budget appropriations dictate a year-to-year program for repair and maintenance of highways which hinders long-range plans. While an annual hand-to-mouth existence must be used on the overall state highway network, some long-range provisions should be made to insure the future value of the Interstate System.
3. Some provision for a 10- to 20-year master plan of Interstate highway maintenance should be developed so that money for major rehabilitation is spread over a number of years even though a considerable mileage will grow old at one time.

On the Thruway, operating funds for normal pavement maintenance are provided on a calendar year basis. By the nature of normal maintenance, there is fluctuation in the amount of money provided annually but a reserve fund for pavement rehabilitation tends to equalize the year-to-year demands.

The pavement evaluation reports and subsequent long-range policy which is established tends to stabilize the pavement maintenance program. Quite often we are able to avoid the waste of maintenance effort which commonly occurs when maintenance programs are strung together on a year-to-year basis. For instance, we avoid such things as putting down a shoulder surface treatment one year and tearing up the shoulder the following year to install underdrains. By noting the progressing signs of age, we are able to predict more closely the need for maintenance repairs and can alter the timetable to our economic advantage. A side effect of having formal professional pavement evaluation reports is that our top management is made aware of specific trends in year-to-year costs. This effect is similar to the in-door out-door thermometer function in that we are able to anticipate and adjust to new conditions without as wide a fluctuation. This is particularly important when you are geared to an income budget where revenues must be in harmony with operating expenses.

continuous observation and detailed study. The advantage of work sampling is that the taking of a few random observations can be done economically, usually as a collateral duty of supervision, while other detailed methods of appraisal are more expensive and may require the full-time services of groups of specialists.

The exact degree of reliability required of any study is dependent upon the end use to which the study will be put.

An essential condition of work sampling is that observations be taken at random. Randomness in the statistical sampling sense means the condition that any given instant of time has an equal likelihood of selection as the time for observation as any other instant, that there is no apparent order to the times of observation, and thus, that one time of observation is independent of all other times of observation. Finally, the entire period of time over which samples are taken must be subject to selection as the random times of observation are drawn. If these conditions are met and enough observations are taken, inferences of known reliability may be made through work sampling. There are several straightforward tests by which the randomness of times of observation may be verified or tested. If careful attention is paid to these tests, the accuracy and reliability of work sampling studies can be developed to within any practical limit. By "practical" is meant the answer, dollarwise, to the question: "How much certainty of results is desired for the expense involved?"

STANDARDS

The logical step after work measurement is the creation of maintenance standards. Many states, for example, Minnesota, Virginia and Louisiana, are engaged in extensive standardization programs. It can readily be seen that maintenance cannot be adequately scheduled unless management has some idea of how long it should take to do a job. Conversely, the time taken to do a job cannot be ascertained unless the job is standardized, that is, unless the job is done in the same manner each time it is performed. The method study and motion technology aspects of industrial engineering help the engineer to design a method which requires the least effort. Once this method has been performed then the time taken to do the job can be ascertained and this used by the maintenance planner in his scheduling work. Additionally, this information can be used to ascertain the long-range manning requirements for any highway maintenance effort.

A modern aspect of the method analysis procedure lies in the area of value engineering. This is but a new name for an old idea. Value engineering identifies a specific system of decision-making which is aimed at the creation of a product or service with the highest possible value to the user at the least possible cost. Instead of looking at the cost production problem from the narrow view point of "how can we produce this service most economically?", a more comprehensive concept is taken by questioning "how can we produce the function that is required for the least total cost?" This is the philosophy underlying the value engineering approach. This approach has already effected the development of the new production and maintenance systems, and it will exert an even greater influence on methods and machines as it permeates the engineering maintenance and manufacturing field more widely. In highway maintenance work, an example of value engineering might be the consideration of the total grass cutting problem, not just how to cut grass better with mowers. The entire system from beginning to end would be formalized, that is written down, and consideration would be given not only to mowers but also to chemical treatment, elimination of grass and replacement with aggregates and any other ideas which in total would minimize the cost of roadside maintenance.

PERSONNEL RELATIONS

Necessary to any industrial engineering curriculum is one or more courses having to do with industrial and personnel relations. Typical of the topics covered in such courses are union and management collective bargaining, recruitment and selection, employee appraisal, promotion, transfer, lay-off and demotion, training, supervision, effective use of meetings, communication, discipline, wage and salary administration, and wage incentive programs. The applications of these topics to maintenance management is so clear that specific examples to the highway maintenance field are not required.

MAINTENANCE CONTROL

In preparing a student for the industrial engineering field, a course in production control is usually included in the curriculum. Some universities, particularly Louisiana State University, are lending greater emphasis to maintenance control than production control merely because most of their students go into work in a chemical or chemical-processing plant where maintenance control is a large factor. Nevertheless, the technology underlying the production and/or maintenance control field is common. The emphasis is on the word "control," whether it be maintenance or production.

Traditionally, these control procedures have included: (a) forecasting, (b) planning, (c) scheduling, and (d) follow-up. To these four traditional areas have been added network analysis known as critical paths scheduling and PERT. In addition, the use of the computer in performing these jobs is now emphasized with all the attendant problems.

The forecasting aspect of control encompasses the ascertaining of what resources will be needed by the maintenance supervisor for some foreseeable future. The resources, of course, are men, material and machines. The planning aspect is the methodology of how the resources will be put to best use. The scheduling function is the determination of when the resources will be used and the follow-up aspect is the feedback mechanism by which the maintenance manager ascertains how well the plan is keeping up to the schedule. The PERT and critical path analysis techniques are used to determine the longest job or endeavor in the maintenance system and the shifting of idle resources to this longest path function so as to cut down on the total time and cost required for the function.

ENGINEERING ECONOMY

Engineering economy differs from classical economy in that the engineer learns about the value of money rather than price theory. Most engineers do not receive the financial motive emphasis in their undergraduate curriculum. This concept permeates the entire industrial engineering curriculum in that the student is constantly made aware of the fact that the engineer is a person who can do with one dollar what any other damn fool can do with five dollars. The newer concepts of engineering, and this is particularly emphasized in industrial engineering, include the idea that a product or system should not merely just work but it should be the most economical method of doing the particular effort. A logical question at this point might be: How do you teach students to be economy minded? In industrial engineering this is done by subjecting the student to a course in engineering economy early in his career and making frequent use of engineering economy principles in other courses.

This typical engineering economy course might include the following topics:

1. Interest, equivalence, and depreciation
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down to an average length of 28 men and an average waiting time of 58 minutes. In each hour, then there would be 28 man-hours lost in waiting. Further calculations show that one extra store man will reduce the average to 0.28 man, releasing 27.3 men for productive work. Addition of a third man, however, will only cut the average to 0.04 and might not be justified when weighing the third man's salary against the production time gained.

There are other techniques in operations research such as game theory, dynamic programming, and simulation techniques, but these techniques are so theoretical that there are not many examples in highway maintenance work. This does not mean that the techniques are useless. It merely means that our state of knowledge has not reached the point where we can apply these techniques to the specific problem that we have in highway maintenance.

In summary, I have attempted to give an idea of how some industrial engineering techniques can be useful in highway maintenance operations. The list of applications is a long one, and only a few of the techniques which could be useful in this type of work have been covered.

There is much need for industrial engineers in state highway departments in general, and in maintenance operations in particular. Tradition dictates that state highway departments hire mainly the civil engineer. It is difficult to understand why this practice persists, when, in a number of positions, the job demands knowledge in the scheduling, planning, and budgetary fields much more than a knowledge of concrete and reinforcing rods.

The Application of Industrial Engineering to Maintenance Operations in New Jersey

J. F. ANDREWS, New Jersey Department of Transportation

New Jersey established a Bureau of Industrial Engineering in October 1964. A staff of seven industrial engineers and technicians was recruited from outside state service. The designated mission and function of the Bureau was and is "... to plan, direct, and supervise industrial engineering practices in the analysis of work, the development of methods improvements, the establishment and application of work standards, the standardization of methods and procedures, and the development and implementation of cost control techniques, to insure the optimum utilization of the manpower, facilities and equipment of the various divisions and bureaus of the State Highway Department."

The Bureau's initial project was to develop work planning and scheduling systems for both roadway maintenance and equipment supervision. Better manpower and equipment utilization were the objectives.

You cannot plan and schedule without having standards of work performance, because planning can only go on when you know how long it takes to do a job. The industrial engineers, early in the planning and scheduling project, set up a companion project to develop work standards for both equipment and road maintenance.

A third project was to design and install an equipment preventive maintenance program which is mainly a complex scheduling project.

These planning, scheduling, and work measurement projects are long range and will continue to be developed. There have also been special study projects concerned with equipment replacement needs, chemical ice control, and specialty crew organization.

The great strength of bringing trained industrial engineers in is that they bring a methodology. If we can bring from industry men who have been trained in analysis of work, the setting up of work standards, techniques of production and waste control, cost analysis and control, training, these men can bring us skills and activities we need at this time and in the immediate future. It seems that we shall have to move into these activities just as industry did when it became time and cost conscious.

Another strength in bringing industrial engineers into highway activities is the freshness of their viewpoint. Industrial engineers are usually enthusiastic individuals with zest for improving methods, systems, cutting costs, and training. Coming into a world of highways, they find much to challenge them. Tough old problems to the highway engineer are new challenges to the industrial engineer. He has no mental roadblock induced by traditions, worn out policies, governmental budget processes, and politics.

A trained ability to question any going system is another useful characteristic of industrial engineers. Whereas highway engineers are often brought up in a school of the status quo, industrial engineers are willing to challenge the status quo and reprocess it.

What are the weaknesses of traditional industrial engineering when applied to highway maintenance? Obviously, the industrial engineer entering the highway field meets a technology, environment and organization new to him. In any one industrial plant where an industrial engineer works he meets a more limited technology than the full spectrum of materials, equipment, and methods he finds in a statewide highway maintenance operation. He can learn this technology over the years, given time. Theoretically, he should have no problem with organization, because organization and people are basically similar in all organizations. But, there is an important difference when one enters government, namely the governmental or bureaucratic way of doing things. We are circumscribed by law in many of our operations, we carry out our work in constant contact with the public, we have the political factors, and we have the bureaucracy

An Industrial Engineer Looks at Highway Maintenance Operations

LAWRENCE MANN, JR., Louisiana State University

The title of this paper would indicate that I am an outsider looking in on maintenance problems. However, I have been working with maintenance operations for nearly 20 years and have been working specifically with highway maintenance operations since 1962. The importance of making maintenance operations more efficient is well recognized. It is my purpose to indicate what industrial engineering has to offer to further the aim of making more effective use of our maintenace resources.

Industrial engineering became popular around the turn of the century when it became evident that industrial enterprises had grown so large that individuals could no longer control the enterprise. Since individuals could no longer control the enterprise, some system had to be created in order that information be readily available for decisions which must be made periodically for the enterprise to remain competitive. Thus, industrial engineering is a child of the capitalistic system. If there were no competition and if we were not worried about making the operation more efficient, there would be little use for industrial engineers. The text definition of industrial engineering is as follows: "Industrial engineering is concerned with the design, improvement, and installation of integrated systems of men, materials and equipment. It draws upon specialized knowledge and skill in the mathematical, physical and social sciences together with the principles and methods of engineering analyses and design to specify, predict, and evaluate the results to be obtained from such systems." I shall attempt to relate each of these facets to the highway maintenance problem.

Because of certain abuses in the principles of industrial engineering, the "efficiency expert" name was tacked on to early industrial engineering efforts and the resulting prejudices have carried over until today. Many older practicing engineers think of a stopwatch when industrial engineering is mentioned. The stopwatch to the industrial engineer is sort of synonymous with the transit to the civil engineer. The transit gains information for the civil engineer; the stopwatch gains information for the industrial engineer. Many civil engineers pursue their career with little or no contact with the transit. This is particularly so in the areas of soil mechanics, traffic, transportation, structures and the like. Similarly, many industrial engineers perform their day-to-day work without seeing or using a stopwatch. The stopwatch-efficiency expert idea of an industrial engineer is no more valid today than is the idea that mechanical engineers work mainly with steam engines or the accountant is the individual who sits on a high stool with a green shade penning figures into a ledger.

Many highway departments consider only civil engineers when seeking technical employees. Occasionally, a mechanical or electrical engineer is tolerated. This thinking fails to take into consideration the makeup of a modern curriculum in other engineering disciplines. The chemical engineer knows as much or more about the makeup of asphalt as does the civil engineer; the electrical engineer is certainly in a position to advise on the design of modern highway traffic control systems; the industrial engineer is in the position, where the optimum use of resources available to the highway department, can be realized.

WORK MEASUREMENT

Perhaps the area which most highway maintenance people are involved in at the present time is that of work measurement and work simplification. Up to a short time ago, maintenance jobs were performed by an all purpose crew who were sent out to the site, performed the necessary work, and returned to a central collecting point. Under this system management had advocated the responsibility of how a job was to be done to the craftsman himself. No attempt was made to inform the craftsmen of how the work should be done and how long the crew should be involved in their work. They merely returned when the job was finished. In addition to making a very inefficient system, this situation precluded any effective scheduling effort. Since the crews could not be adequately scheduled, efficient use could not be made of them. In addition to this, different crews did things in different ways, not always the best way. No data were available with which to justify additional mechanical equipment in terms of savings in man-hours.

Today, many states have embarked on programs to measure all or nearly all of the jobs that are done by maintenance crews. This measurement not only includes the number of hours required to do the job, but also includes the optimum number of craftsmen and equipment which should be available. In this way, the maintenance dispatcher can plan ahead for the groups to do more than one job in the future. Work measurement efforts as used today in highway work usually take two forms. The first is the stopwatch study and, in my opinion, this effort should be minimized since the length of time of most of the elements that we are trying to measure are much longer than those which require stopwatch studies. Whereas in the hard goods productive plant we are talking in terms of a hundredth of an hour, in highway maintenance operation if we could peg down our jobs to the nearest five minutes, we would be very happy. Because of this, the normal type of wristwatch can be used to try and create a set of standards for the work of the highway maintenance craftsmen. I have just mentioned the work "standards" for the first time. Standards is simply a word which includes the determination of how long a job should take and the use of that length of time in designing a maintenance system for future operations.

By far the best tool for the analyses of highway maintenance operations is the work sampling technique. Work sampling is a measurement technique for the quantitative analysis, in terms of time, of the activity of men, machines, or of any observable state or condition of operation. Work sampling is particularly useful in the analysis of non-repetitive or irregularly occurring activity, where no complete methods and frequency description are available. It is also an extremely useful device with which to make an inexpensive overall survey of office, shop, or service activity. Such a preliminary study can help evaluate the need for further study, and it may serve to establish a benchmark for managerial purposes because it is extremely convenient, possesses known reliability, and because it operates without recourse to the stopwatch or to subjective judgments of "effort" or "performance."

A work sampling study consists of a large number of observations taken at random intervals. In taking the observations, the state or condition of the object of study is noted, and this state is classified into predefined categories of activity pertinent to the particular work situation. From the proportions of observations in each category, inferences are drawn concerning the total work activity under study. As an example, if a group of maintenance men are observed to be "waiting" in a third of the observations made of their activity, we might draw the inference that better scheduling or supervision, rather than increased crew size, represents the most fruitful area for improvement

The underlying theory of work sampling is that the percentage of observations recording a man or machine as idle, working, or in any other condition reflects to a known degree of accuracy the average percentage of time actually spent in that state or condition. If observations are randomly distributed over a sufficiently long period of time, this theory is held to be true, regardless of the nature of the observed activity. Work sampling observations may be likened to a series of photographs taken at random times, with the added advantage that the observer is capable of on-the-spot interpretation and classification of what he sees.

Work sampling utilizes the well-established principle of drawing inferences and establishing frames of reference from a random sample of the whole. In this case the "whole" is the total activity of the area, persons, or machines observed during the entire period of time over which observations are made. Work sampling is a practical compromise between the extremes of purely subjective opinion and the "certainty" of continuous observation and detailed study. The advantage of work sampling is that the taking of a few random observations can be done economically, usually as a collateral duty of supervision, while other detailed methods of appraisal are more expensive and may require the full-time services of groups of specialists.

The exact degree of reliability required of any study is dependent upon the end use to which the study will be put.

An essential condition of work sampling is that observations be taken at random. Randomness in the statistical sampling sense means the condition that any given instant of time has an equal likelihood of selection as the time for observation as any other instant, that there is no apparent order to the times of observation, and thus, that one time of observation is independent of all other times of observation. Finally, the entire period of time over which samples are taken must be subject to selection as the random times of observation are drawn. If these conditions are met and enough observations are taken, inferences of known reliability may be made through work sampling. There are several straightforward tests by which the randomness of times of observation may be verified or tested. If careful attention is paid to these tests, the accuracy and reliability of work sampling studies can be developed to within any practical limit. By "practical" is meant the answer, dollarwise, to the question: "How much certainty of results is desired for the expense involved?"

STANDARDS

The logical step after work measurement is the creation of maintenance standards. Many states, for example, Minnesota, Virginia and Louisiana, are engaged in extensive standardization programs. It can readily be seen that maintenance cannot be adequately scheduled unless management has some idea of how long it should take to do a job. Conversely, the time taken to do a job cannot be ascertained unless the job is standardized, that is, unless the job is done in the same manner each time it is performed. The method study and motion technology aspects of industrial engineering help the engineer to design a method which requires the least effort. Once this method has been performed then the time taken to do the job can be ascertained and this used by the maintenance planner in his scheduling work. Additionally, this information can be used to ascertain the long-range manning requirements for any highway maintenance effort.

A modern aspect of the method analysis procedure lies in the area of value engineering. This is but a new name for an old idea. Value engineering identifies a specific system of decision-making which is aimed at the creation of a product or service with the highest possible value to the user at the least possible cost. Instead of looking at the cost production problem from the narrow view point of "how can we produce this service most economically?", a more comprehensive concept is taken by questioning "how can we produce the function that is required for the least total cost?" This is the philosophy underlying the value engineering approach. This approach has already effected the development of the new production and maintenance systems, and it will exert an even greater influence on methods and machines as it permeates the engineering maintenance and manufacturing field more widely. In highway maintenance work, an example of value engineering might be the consideration of the total grass cutting problem, not just how to cut grass better with mowers. The entire system from beginning to end would be formalized, that is written down, and consideration would be given not only to mowers but also to chemical treatment, elimination of grass and replacement with aggregates and any other ideas which in total would minimize the cost of roadside maintenance.

PERSONNEL RELATIONS

Necessary to any industrial engineering curriculum is one or more courses having to do with industrial and personnel relations. Typical of the topics covered in such courses are union and management collective bargaining, recruitment and selection, employee appraisal, promotion, transfer, lay-off and demotion, training, supervision, effective use of meetings, communication, discipline, wage and salary administration, and wage incentive programs. The applications of these topics to maintenance management is so clear that specific examples to the highway maintenance field are not required.

MAINTENANCE CONTROL

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Perhaps the most valuable of these topics is the evaluation of alternatives and, in truth, this is what an engineer does in every case. He is always deciding what materials to use, what size to use, what type to use, etc. This type analysis attempts to give the engineer a background in the financial portion of the picture so that he might construct the most economical system—not just a system that works.

It is obvious that there are many examples of engineering economy in highway engineering and maintenance work. We do not have to go far afield to find examples of how the highway maintenance engineer would use engineering economy. Probably the most common application would be in the justification for new equipment. The engineer would list the alternatives of not having the equipment. These alternatives may include doing the work with manual labor, doing the work with other types of equipment, doing work with the equipment that is on hand. The engineer would then draw up the alternatives and cost of the alternatives would thereby give the decision-maker all the information he needs to decide which would be the most economic course of action to take. There are many other examples of engineering economy in highway maintenance work but these are too obvious to require illustrations.

PLANT LAYOUT—MATERIALS HANDLING

Traditional plant layout courses teach the industrial engineer the most efficient way to place production equipment within the plant. This usual course is heavily slanted towards the hard goods industry, thus the problems faced by the industrial engineer include situations involving lathes, drill presses, etc. At LSU, we recognize that our graduates will be more interested in the process-type industry; therefore, we slant our courses more toward the chemical-type industry. Part of any plant layout course includes techniques and methodology in materials handling. Materials handling is of great interest to highway maintenance engineers. A large percentage of highway maintenance cost includes the transportation and handling of material and the most efficient ways to perform these operations should be of great interest to all involved.

Applications of plant layout by itself are relevant to highway maintenance in that most maintenance districts have a central shop or repair area where the principles of plant layout can yield a more efficient system. My experience indicates that shop areas merely grow and no overall plan or thought is given to their layout.

Aggregate, asphalt, concrete, steel sections for bridge repair and railings, mulches, fertilizers, water, and sign material are examples of the types of material with which highway people must cope. It is therefore essential that highway maintenance people be familiar with the latest types of equipment so that the most economical materials handling system can result.

STATISTICS AND OPERATIONS RESEARCH

The preceding technologies are more or less traditional approaches to the field of industrial engineering. Most of the new work and horizons in this area are in the field of statistics and operations research. Statistics is both an art and a science, and it deals with the collection, tabulation, analysis and interpretation of quantitative and qualitative measures. It is concerned with the classifying and determining of actual attributes as well as the making of estimates and the testing of various hypotheses by which probable, or expected, values are obtained. It is one of the means of carrying on scientific research in order to ascertain the laws of behavior of things. Statistics is the technique of the scientific method.

Statistics is a branch of applied mathematics. It differs from so called pure mathematics in that the values in statistics are approximations or estimates, but not mere guesses.

Statistics deals with problems that fall into two general categories. The first has to do with characterizing a given set of numerical measurements or estimates of some attribute or set of attributes applying to an individual or a group of individuals. In highway maintenance work, the statistical situation might be characterized by our making estimates on the probable use of materials for a particular district or a particular state.

The other category has to do with characterizing an attribute or attributes belonging to all individuals of the group one is investigating. In highway maintenance engineering, this might be an attempt to predict overall maintenance costs for the whole country or the creating of standards which would apply to the entire Interstate System and problems of this nature.

Statistics, then, is the science of obtaining more information out of a set of data than we would normally obtain. If there is one word which characterizes statistics, that word is prediction. If we want the ability to predict the future behavior of any situation then we must use statistical methods to try and ascertain the degree of consistency with which we can predict; therein lies the secret of why we use statistics. We can put a number in it to indicate the degree of consistency we have in the data which come from any sample large or small.

One branch of statistical methods which appears to be having a field day in the field of highway maintenance work is that of regression analysis. In regression analysis we take a group of variables and try and find out the effect of those variables on what we are trying to measure. For instance, if we are trying to measure total maintenance cost for the highway system, variables such as traffic right-of-way width and surface width are all characteristics which may or may not affect the cost of maintenance. The regression appraoch will tell us to what extent each of these variables affect maintenance costs. Therefore, if we had limited funds to spend on maintenance and we had a regression analysis of our system we would find out where each dollar would do the most good. Th results of regression analysis are mathematical models. Many people have the feeling that mathematical models are a very popular thing and many of us deplore the fact that they perhaps have been overused. This is only natural where a group of scientists or engineers discover a new technique. The technique may be overworked in its initial stages. I will not dwell further on statistical techniques, but the time spent here in discussing them is not proportional to their value. There are many more applications of statistical methods in highway maintenance work.

Closely related to statistics is the emerging field of operations research. This tool represents a very significant advance in the engineer's ability to try and appreciate the environment with which he is working. Operations research tackles large-scale problems which normally are not solved manually, but need electronic data processing equipment.

Operations research involves the application of mathematical techniques to the front-line, nuts and bolts problems of industry, operational problems as diverse as, but not restricted to, labor distribution, profitable inventory levels, price quotations, production planning, maintenance planning, etc. It consists of correlating all available data on a problem and providing management with factual, quantitative reports on the relative merits of all potential courses of action.

There are a number of techniques which are generally recognized as being the core of any operations research study. The first is linear programming. Linear programming is a mathematical technique whereby the best allocation of limited resources may be determined by manipulation of a series of linear equations. This technology, of course, has every widespread use in the highway maintenance field and is being used today. Some problems which could be solved in this manner are problems such as where to locate a highway maintenance storage area for the minimization of travel time to the possible points of use of the material which is stored there. Also, the technique that could minimize the travel time for trucks and other roadbuilding equipment.

Another technique is called queuing theory. This situation takes place when the flow of materials or people is bottlenecked at a particular servicing point. Here, losses occur in the form of lost time, idle equipment, and unused labor. Minimizing such costs is the job of queuing theory. In the highway maintenance example, this could take place where people had to wait because the number of trucks or pieces of mechanical equipment was not satisfactory in order to keep everyone busy.

Another example is the following: What is the expected length of a line when 29 workmen arrive randomly each hour at a tool store where the store man takes an average of two minutes to serve each man? Queuing theory predicts that the line will settle down to an average length of 28 men and an average waiting time of 58 minutes. In each hour, then there would be 28 man-hours lost in waiting. Further calculations show that one extra store man will reduce the average to 0.28 man, releasing 27.3 men for productive work. Addition of a third man, however, will only cut the average to 0.04 and might not be justified when weighing the third man's salary against the production time gained.

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Governmental operations have more inertia to overcome in changing directions and it may take some time for the industrial engineer to appreciate this. This can result in his taking more time to accomplish his objectives because he may fail to dot all the "i's" and cross all the "t's" in setting the stage for his work. He may fail to appreciate from the start that the line organization may be more restricted in its authority than its counterpart in industry. Failing to appreciate this, the industrial engineer may become impatient and sometimes overbearing with the people with whom he is working. I think he has to nurse the situation and personnel more in governmental work. If he fails to do this, it is unlikely that the line organization has the incentive or the pressure against it to keep pushing the innovations industrial engineering is supposed to be bringing about. His lack of knowledge of the system may cause him to lack seasoned judgement in how he furthers his projects.

Still another disadvantage of the traditional industrial engineering approach, and particularly of hiring people from the outside, is the suspicion among government employees as to what the new personnel and the new system is going to do to them and their entrenched organization. Actually, this problem is not much different than what the industrial engineer finds in industry when he initiates an industrial engineering program in a plant which has not had one before. But, operating in the extended geographical scope of a maintenance organization, he finds it difficult to get close to the entire maintenance organization. Suspicions can be kindled and resistance can be created before an industrial engineer even appears in a maintenance district.

Are not all of these problems those which would be encountered if a highway department undertook to improve maintenance management by training its own people and having them introduce the work improvements, standards, and cost controls that the industrial engineer is trying to bring about? My guess is that the same problems of innovation face the long-time highway-oriented individual who would bring about a methods improvement. However, the methods man trained from within is likely to know more of the technology and the ways the organization works, so that he holds an advantage over the outside industrial engineer. On the other hand, the inside man has to be trained in methods and standards work. So, there are compensating values whichever approach one takes.

There is, of course, the important question of engineer availability for this work. In New Jersey, there were just not any engineers around who might have been singled out in sufficient numbers for this. Once we had gained agreement that a Bureau of Industrial Engineering should be established and that people should be recruited from outside, we did benefit by the addition of these new people to our total staff.

What is the total value of this operation and its prospect for the future? The chief accomplishment of our industrial engineering staff has been to give our foremen and supervisors a good course in planning and scheduling. In doing this, much paperwork was generated which built up resentment among our foremen against the industrial engineering approach. In the equipment area where we have moved on to scheduling work operations through the computer, this resentment is breaking down and prospects of future improvements and relationships are good. We hopefully expect that in the area of road maintenance the same will prevail as we move into computer scheduling.

In equipment, we have benefited by institution of a preventive maintenance program that seems to be working with increasing assurance and less friction as we move along in time. Progress might have been faster in all projects had we been able to establish better coordination between industrial engineers and the line maintenance organization. Our industrial engineers too often took things on their own and went off on their projects without appreciating that it requires the line supervision to make the projects work. The line supervision, on the other hand, lacked sufficient farsightedness to take warmly to the new approaches without being cultivated.

To do justice to both groups though, we could have made faster progress had we been further along with our computer organization which has been developing concurrently with industrial engineering. This meant that the computer center could not take on the work needed to develop our planning and scheduling and work order programs.

Another problem has been the diversion of the industrial engineering group to other departmental divisions and problems. Initially, industrial engineering confined itself to maintenance projects, but very soon their skills were applied to other projects around the department, lessening their availability for maintenance. They have carried out industrial engineering training programs, prepared office-space layouts, initiated program budgeting, made cost-effectiveness analyses. The very fact that these industrial engineers can be used on so many projects in itself speaks well for recruiting industrial engineers from outside the highway industry.

In my opinion the strengths overcome the weaknesses. One of the weaknesses in our setup has, in my opinion, been the placement of industrial engineering in respect to maintenance outside the Division of Maintenance and Equipment. This has resulted in a sense of competition where cooperation would have been the better motivator.

We are finding that if we do maintain a separate Bureau of Industrial Engineering, it is important to have on the maintenance staff at least one engineer to work in liaison with the industrial engineers. We did this early in equipment projects and we seemed to make more progress there. More recently we have done this in roadway maintenance.

I believe industrial engineers find themselves more at home in our equipment shops which are more akin to the four walls of an industrial plant. Garage repair operations are more identifiable with those found in industry. Road maintenance, with its far-flung activities, its uncertainties with the weather, and its interruptions for emergencies is a production scheduler's nightmare. Anyone working in this field, whether the most experienced industrial engineer or a young highway engineer trained for this work, is handling a complex problem.

There is one final word which should be said for the industrial engineer who comes from industry and tries to work in the field of highway maintenance. In manufacturing industry the 50 years or more over which industrial engineering has developed has been mainly confined to production. For many years industrial engineers did not venture into plant maintenance because it was long felt plant maintenance could not be standardized and controlled as production could. While progress has been made in applying industrial engineering to plant maintenance, this is still considered a more nebulous field for industrial engineering.

Therefore, to ask the industrial engineer to come out from industry where maintenance engineering within the walls of one plant seems to be a special problem and operate in the wide spectrum of highway maintenance with its variety of operations, geographical spread and governmental problems, is to ask a great deal of the man trained in a particular tradition. He needs time to get acquainted and adapt himself. An ideal setup would be to place him with matching numbers of men who have grown up in a highway department and who have the aptitude for learning and adapting themselves to new ideas. This combination of experience brought together on a maintenance team which includes the line supervision, should produce the kind of results that maintenance must have in the future.

Problems Encountered in Developing and Installing a Maintenance Management Reporting System

C. O. LEIGH, Virginia Department of Highways

In the five years we have spent in the development, implementation and operation of the maintenance management reporting system in Virginia, we have encountered a variety of problems. My task is to condense five years of problems into a short paper. Some of the problems encountered are universal and would be encountered in making any operational change; other problems were unique to the project. The problems I wish to discuss are primarily those of installation rather than development because I feel that many of our development problems would be somewhat unique to Virginia.

First, I would like to present a brief timetable and enumerate a few steps in the development and installation of our maintenance management reporting system. The Virginia Maintenance Study began in June 1963 and extended until December 1966. During the first two years the primary development of the system occurred and during the last 18 months of the study we were pilot testing the management system. To put the system into operation required that several new positions be created to properly administer the maintenance function, operating personnel be trained in the operation of the system, maintenance sections be revised, maintenance activity codes be revised, and computer programs prepared and report forms revised.

To implement the system with the least amount of confusion and difficulty, we decided to implement in stages. Early in 1966, the additional maintenance positions were filled and training began. On July 1, 1966, we changed to our new maintenance activities, and on July 1, 1967, we put the entire reporting system into operation. We have now been in operation for slightly more than a year and while we still have problems we are well pleased with the results.

The first problem and one that is common to any new idea or change is selling the idea or concept. We did not have any particular problem securing the approval of the top management for the installation of the system; however, we did have and still do have problems with the acceptance of the system by a few field operating personnel. We recognized at the beginning of the study the necessity of having all levels of management sold on any new concepts developed. To promote endorsement and the solid support of field operating personnel, we tried to involve these personnel in the development of the system as much as possible. Field operating personnel were given committee assignments such as the committee which developed maintenance standards. Many were invited to attend the quarterly advisory meetings of the study. Some field personnel were directly involved in the data-gathering phase and analysis. Several orientation sessions were held with the field managers, and members of the study staff made many individual contacts to explain the system.

With all the effort put forth we still have a few who do not believe the system is worthwhile. I might add that experience with the operational system has reduced the number who were not originally sold on the idea.

While this lack of support from certain field managers did not appreciably hamper the development and installation of the reporting system, these managers are not effectively utilizing the reports. They are not encouraging their subordinates to utilize the reports or to participate to the fullest extent in the management system. I do not mean to suggest they are actively opposing the system, but they are apathetic.

We believe that securing the participation and involvement of many field personnel in the development of the system eased the problems of selling the concept and installing the system. As we all know however, one hundred percent acceptance and support is a dream and we can expect to find in any proposal a few people who will disagree entirely with, or with portions of, the proposal.

A number of orientation sessions with field personnel at all levels were held. These sessions presented a number of problems. To get good audience participation and subsequent understanding, and satisfy differences in informational needs as to details, it was necessary to hold several sessions in each area of the State with different groups of personnel. One series of sessions was with the district engineer, resident engineers, and residency maintenance supervisors. Another series of sessions was with the maintenance superintendents, foremen and timekeepers. In order to cover the whole State, holding these orientation sessions with one team of instructors, we had to start several months before the implementation date. In some cases, problems arose where the benefit of orientation was lost due to resignations or promotions. In some cases, people forgot. Also since we held these sessions near the end of the fiscal year, some of the personnel were occupied with preparing budgets for the next year, revising five-year plans, or other duties related to the close-out of the end of the year.

We feel now that we would have made a smoother transition by covering the State with several teams a few weeks before the implementation date to discuss the working details of the reporting system. We also should have had a series of meetings with superintendents, foremen, and timekeepers about a month after the implementation date to further discuss the system, answer any questions and review the feedback reports. We planned to do this; however, the next problem interrupted our plans.

The problems mentioned so far are all related to personnel or training personnel. While I do not want to minimize these problems, the problems that have been by far the most troublesome involve the computer programs to handle the data and furnish the feedback reports. I mentioned that we pilot-tested the management system. The pilot test involved only testing the management aspects of the system. While a computer program was written to handle the pilot test, this program could not be used when we put the system into operation. Consequently, we began operations with a virtually untested program. We anticipated having our first report for the month of July 1967 back to the field by mid-August. At this time we planned a series of sessions with field personnel to discuss the reports and their use in the management system. Actually we got our first report back to the field in November 1967 and this report was for the month of August.

Our first major setback occurred when half the tapes for July were accidentally erased. Due to errors in reporting and other factors, it was decided not to try to duplicate these tapes; so we forgot July. With the processing of the August data, program errors in the computer program became very apparent. The computer program has now been corrected, however, we are still finding minor changes which should be made in the program to improve reporting and the usefulness of the feedback reports.

The necessity of having tested computer programs before beginning operations cannot be overstressed. The long delay in getting the first report back to the field somewhat dampened the field personnel's enthusiasm for the system and when the first few reports contained obvious errors due to the computer program errors, enthusiasm further waned. It has taken a number of months to build back up to the original enthusiasm

All of our computer programs producing reports for maintenance, construction, administration, and other special items are part of one integrated computer system. In devising the reporting forms and the computer program to handle the maintenance management reporting system, we were required to adjust our program to fit the existing system. In adjusting our program to fit the existing system, we had to compromise some of our original goals. To have revised the existing system would have required at least a year and we would have been delayed accordingly in getting our reporting system into operation.

We in Maintenance are convinced that it would have been desirable, solely from a maintenance standpoint, to have been able to start new with our reporting forms and computer programs designed specifically for the maintenance management reporting system. The administration of the Department, however, decided that the changes and additional flexibility Maintenance desired did not justify the disruption and cost of changing all of the accounting programs.

I do not mean to imply that our program for the maintenance management reporting system falls short of that desired; however, if we could have started new with little or no restrictions in reporting format or computer programs, we could have tailored a reporting system to better fit our needs and desires.

The requirement that our reporting format conform to the existing computer system did have its benefits however. The small changes made in the existing reporting format made the installation and operation of the system easier. If we had drastically revised our reporting forms the timekeepers would have had quite an adjustment to make and consequently the number of reporting errors would have been much greater.

We ran into one additional problem with reporting forms. We found that we had about a six months' supply of an old reporting form which was to be replaced. Being a very conservative and financially conscious State, it was decided to use the old reporting forms until the supply was exhausted. Needless to say, this posed a problem and I would suggest if you are planning a change in a reporting format that you keep a close tab on your supply of existing report forms. Also you should allow ample time for revising, printing, and distributing reporting forms. We found that for the first month or two, we had problems with the printer in furnishing an adequate supply of report forms, and getting the forms distributed to locations where they were needed.

Some of the problems of a lesser nature affecting the implementation are employee turnover, accuracy of reporting, and measurement of work quantities.

Employee turnover in the timekeeper position has contributed to many of our lesser problems. When a trained timekeeper resigns or is promoted, it takes a month or two for the new timekeeper to become acquainted with his duties. We can just about review the edit report and tell where the new timekeepers are. To aid in this problem, we found it necessary to develop a comprehensive timekeeper's manual which we believe will help the new timekeeper quickly adjust to his duties.

Accurate reporting was an initial problem. Prior to July 1, 1967, no continuous checks were made on whether charges were being prorated between routes and activities, and in general, accuracy of charges was not stressed. Another factor contributing to inaccuracies is the fact that while the timekeeper prepares the report documents, he can only report what the superintendent or foremen tell him.

Promoting accurate reporting from the timekeeper's position was not too difficult. Input data go through an edit program where such items as prorated charges to route and activities, wrong units of measure, and no reported accomplishment are kicked out. These items are then sent back to the timekeeper for correction. During the first months, the timekeepers decided it was much easier to prepare accurate reports initially than have to correct the errors.

Getting the superintendents and foremen to report accurately and completely to the timekeeper has been more of a problem. This is particularly true in reporting work accomplishment which is not material, such as acres, miles or feet. However, through indoctrination and the use of a foremen's daily report card, accurate reporting to the timekeeper has improved. I am told that accuracy in reporting has now progressed to the point where errors are running less than one percent.

Our experience during our short operational period has indicated that there could be problems related to the use of feedback reports. In developing and implementing the system, we spent a considerable sum of State and Federal funds. After a few months of operation, all levels of management began to ask such questions as, Is the system worth the cost? Where have we shown improvement? What is the magnitude of the improvement? These are logical questions and need to be answered. However, if we become too impatient for the answers and try to force answers to these questions, we can adversely affect the acceptance and operation of the system.

Many of our first-line supervisors originally looked upon the system as another "ball bat" that higher management would have to work them over. So far, particularly from the maintenance engineer's office, we have used the soft sell approach in bringing performance deficiencies to their attention.

We feel that this approach has contributed to the acceptance of the system and has contributed to improving the accuracy of the reports. Since management to date generally has not made an issue over specific work items that need improvement, the first-line supervisor has concentrated on improving performance rather than just doctoring input data to reflect improved performance.

We expected many problems to arise in the development and installation of our maintenance management reporting system. From our experience, however, I feel that many of our problems were minimized by adequately selling the concept, adequately orienting personnel, and once operational, by not pressing for immediate results. Further we feel that some of our problems could have been eliminated or reduced in scope by allowing more time for the orientation, by better timing of the orientation with relation to implementation, by having tested computer programs available at the beginning of the implementation and by conducting timely follow-up conferences with operating personnel.

Even though we have had many problems during the past five years and I am sure we will have more in the future, none have been insurmountable and the results of the system appear to be worth all our efforts.

Maintenance Management System

DAVID K. SPEER, County of San Diego, California

San Diego County is about 4,260 square miles in size, measuring approximately 80 miles from the Pacific Ocean to the east boundary and about 60 miles from the Mexican border to the north boundary (Fig. 1). The topography varies from coastal hills and inland valleys, to 6,000-foot mountains in the central portion of the county, and to the Imperial Valley floor in the eastern portion. Climate varies as does the topography, and requires maintenance of roads in mild, sometimes foggy, coastal areas, in heavy rainfall and snow removal areas in the mountains, and in desert areas subject to flash floods and high temperatures. Because of the high growth rate and urbanization of the unincorporated areas surrounding metropolitan San Diego, our road maintenance function also involves many miles of city-type streets and their inherent needs such as sweeping, pedestrian control and sophisticated channelization and signalization.

COUNTY ENGINEER DEPARTMENT

The San Diego County Engineer Department, with an annual budget in excess of $13 million and over 500 permanent employees, has the prime responsibility of operating and maintaining approximately 2,100 miles of roads, ranging in types from less than two-lane dirt-surfaced facilities to major eight-lane expressways.

Activities are not strictly limited to road maintenance, but include road planning, road design and construction, contract services to cities, land subdivision and grading administration, county-wide mapping, building inspection, and county-wide communications responsibilities (Fig. 2).

The Road Operations Division (Fig. 3) primarily performs those central administrative services necessary for operation of the three road maintenance divisions. Each road maintenance division centrally operates an equipment repair and maintenance shop and various division-wide specialty crews such as traffic operations, construction and repair crew, road oil and pit crew, tree-trimmers and motor sweepers (Fig. 4). Road Maintenance Divisions are further subdivided into twenty road maintenance stations. Each Road Maintenance Division, including its road maintenance stations, has approximately 75 personnel assigned.

EARLY MAINTENANCE MANAGEMENT PRACTICES

Early efforts in routine maintenance management took the form of scheduling according to need, of the division-wide specialty crews. A more comprehensive cost accounting program was instituted with the development of maintenance reporting codes. Work orders were issued for projects previously reported as routine maintenance but that in reality constituted a road betterment. A pilot program was initiated in six road maintenance stations to schedule routine maintenance one week in advance and to report actual man-hours and equipment use on each scheduled maintenance project.

DEVELOPMENT OF FORMAL MAINTENANCE MANAGEMENT

In October 1967, in an effort to formalize and improve road maintenance scheduling, planning, and the cost accounting system, a management consultant was retained.

Included as part of the program was the selection and training of a technician team to develop necessary data, apply time standards, and aid in the planning and scheduling process. Twelve individuals, four from each maintenance division, were interviewed for possible assignment as maintenance technician. Six of the twelve were selected to undergo special training under the guidance of the management consultant representative.

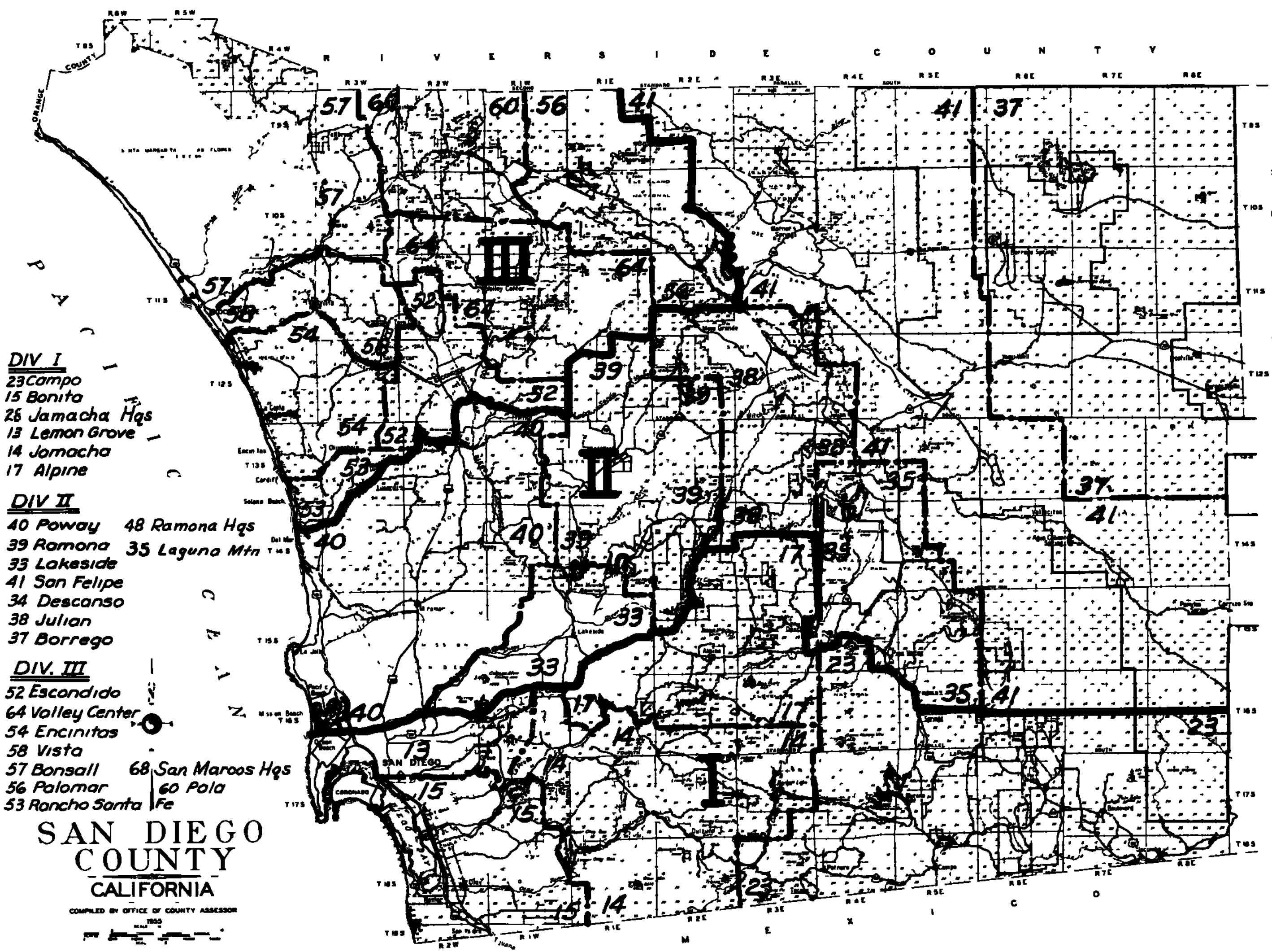

RIVERSIDE COUNTY
MEXICO
PACIFIC OCEAN
DIV I
23 Campo
15 Bonita
26 Jamacha Hqs
13 Lemon Grove
14 Jamacha
17 Alpine
DIV II
40 Poway
39 Ramona
33 Lakeside
41 San Felipe
34 Descanso
38 Julian
37 Borrego
48 Ramona Hqs
35 Laguna Mtn
DIV. III
52 Escondido
64 Valley Center
54 Encinitas
58 Vista
57 Bonsall
56 Palomar
53 Rancho Santa Fe
68 San Marcos Hqs
60 Pala
SAN DIEGO COUNTY
CALIFORNIA
COMPILED BY OFFICE OF COUNTY ASSESSOR
SAN DIEGO
CORONADO

Figure 1.

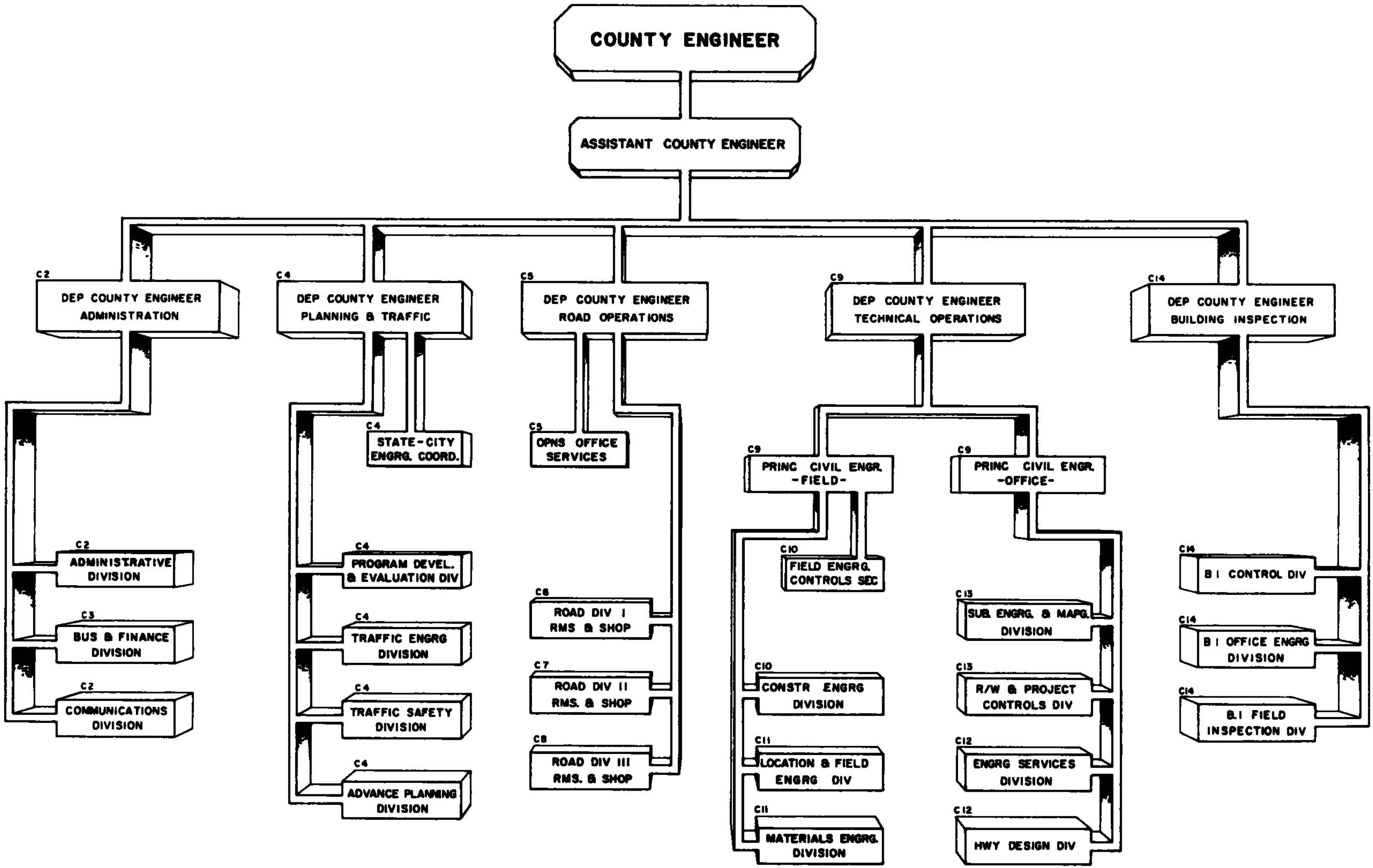

COUNTY ENGINEER
ASSISTANT COUNTY ENGINEER
C2 DEP COUNTY ENGINEER ADMINISTRATION
C4 DEP COUNTY ENGINEER PLANNING & TRAFFIC
C5 DEP COUNTY ENGINEER ROAD OPERATIONS
C9 DEP COUNTY ENGINEER TECHNICAL OPERATIONS
C14 DEP COUNTY ENGINEER BUILDING INSPECTION
C2 ADMINISTRATIVE DIVISION
C3 BUS & FINANCE DIVISION
C2 COMMUNICATIONS DIVISION
C4 STATE-CITY ENGRG. COORD.
C4 PROGRAM DEVEL. & EVALUATION DIV
C4 TRAFFIC ENGRG DIVISION
C4 TRAFFIC SAFETY DIVISION
C4 ADVANCE PLANNING DIVISION
C5 OPNS OFFICE SERVICES
C6 ROAD DIV I RMS & SHOP
C7 ROAD DIV II RMS. & SHOP
C8 ROAD DIV III RMS. & SHOP
C9 PRINC CIVIL ENGR. -FIELD-
C9 PRINC CIVIL ENGR. -OFFICE-
C10 FIELD ENGRG. CONTROLS SEC
C10 CONSTR ENGRG DIVISION
C11 LOCATION & FIELD ENGRG DIV
C11 MATERIALS ENGRG. DIVISION
C13 SUB. ENGRG. & MAPG. DIVISION
C13 R/W & PROJECT CONTROLS DIV
C12 ENGRG SERVICES DIVISION
C12 HWY DESIGN DIV
C14 B I CONTROL DIV
C14 B I OFFICE ENGRG DIVISION
C14 B.I FIELD INSPECTION DIV

Figure 2.

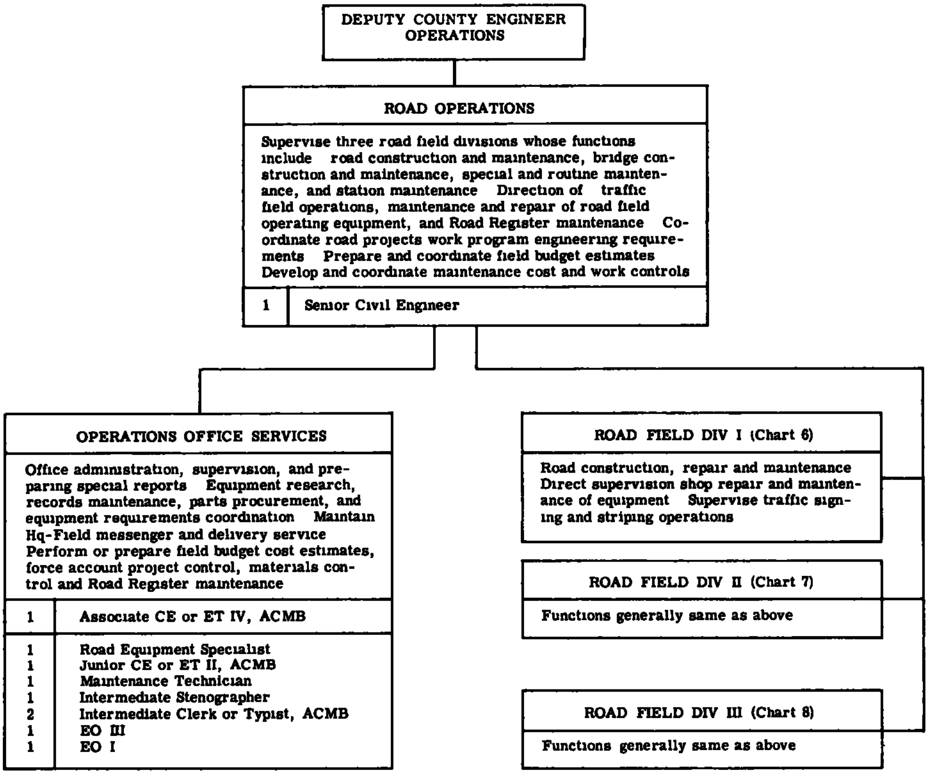


Figure 3.

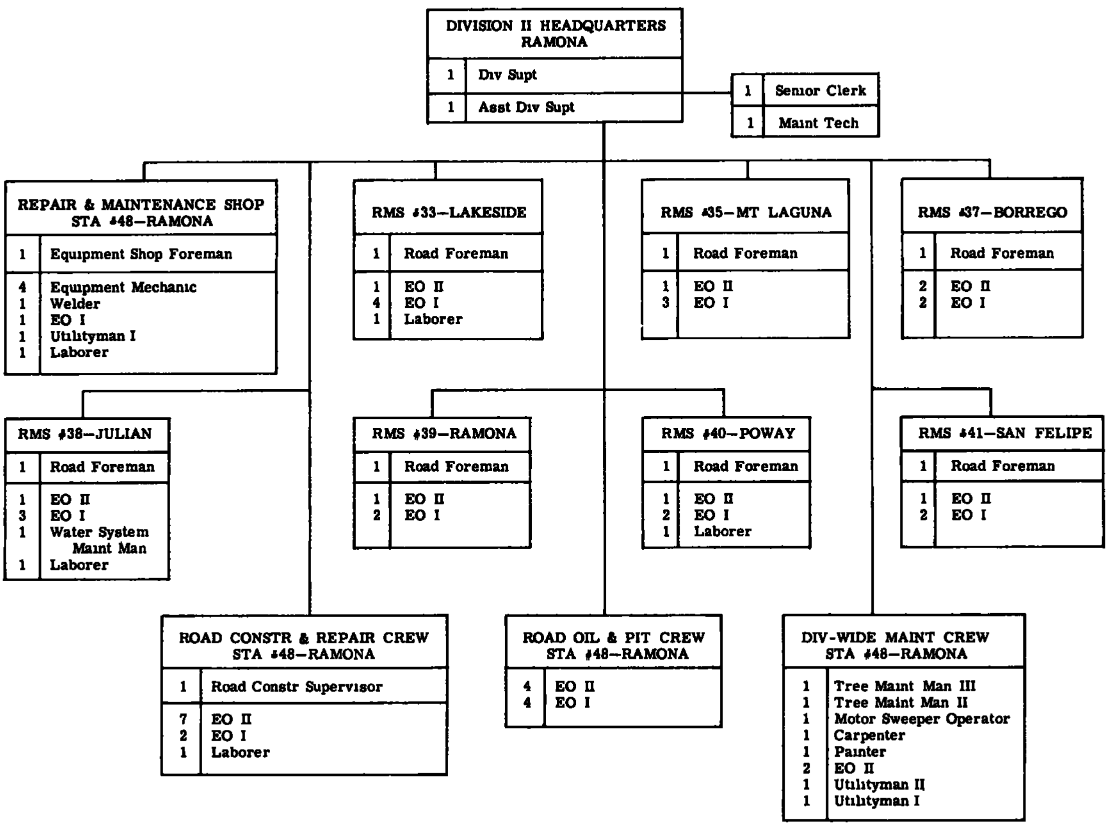


Figure 4.

COUNTY OF SAN DIEGO

COUNTY ENGINEER DEPARTMENT

ROUTINE MAINTENANCE WORK ORDER

NO 04800

UNSCHEDULED ☐

DIVISION ______ PRIORITY ______ STD. HOURS

STATION OR CREW NO. ______ OPEN →

DATE INITIATED ______ COMPLETE →

WORK DESCRIPTION DATE ______

ROAD OR STREET	WIDTH	LIMITS FROM	LIMITS TO	WORK CODE	CREW MEMBERS	QUANTITY OR DISTANCE	STD. HRS	ACT. HRS.
	TOTAL HOURS BY WORK CODE				→			
	TOTAL HOURS BY WORK CODE				→			
	TOTAL HOURS BY WORK CODE				→			
	TOTAL HOURS BY WORK CODE				→			
						TOTAL HOURS		

EQUIPMENT USE AND TRAVEL TIME

EQUIPMENT NUMBER	METER READING END	METER READING BEGIN	EQUIPMENT HOURS/MILES	ACTUAL HOURS

RENTAL EQUIPMENT AND MATERIAL REQUIRED AND USED

KIND	QUAN-TITY	UNIT COST	TOTAL COST	ORDERED BY	DATE REQUIRED

TECHNICIAN USE ONLY	STANDARD	ACTUAL
TOTAL CRAFT HOURS		
TOTAL TRAVEL HOURS		
TOTAL JOB PREPARATION		
TOTAL		
% PERFORMANCE		
APPROVED BY	DATE	

REMARKS (USE BACK AS REQUIRED)

______

______

______

______

______

______

Form ER 708(7/68-OS9)

Figure 5.

COUNTY OF SAN DIEGO — COUNTY ENGINEER DEPARTMENT

WORK ORDER SHOP REPAIR

Open ☐ Complete ☐ Std Hours ____ Unscheduled ☐

DIVISION	EQUIPT NO	MILEAGE/HOURS	DATE INITIATED	DESCRIPTION	PRIORITY	DATE IN	DATE OUT	NO. 01249

CODE	REPAIR MADE	DATE	EMPLOYEE	STD HRS	ACTUAL HOURS

REMARKS

TECHNICIAN USE ONLY

PERCENT PERFORMANCE	STD	ACTUAL
TOTAL HOURS ON STANDARD		
PERCENT PERFORMANCE		
TECHNICIAN	DATE	

HOURS BY W/C	WORK CODE	STD	ACTUAL
TOTAL HOURS			

Figure 6.

COUNTY OF SAN DIEGO - COUNTY ENGINEER DEPARTMENT
WEEKLY OPEN WORK ORDER REPORT
WEEK ENDING 5-17-68

DIV	STATION OR CREW NUMBER	WORK ORDER NUMBER	DATE INITIATED	WORK CODE	STANDARD HOURS REQUIRED	PRIORITY I	PRIORITY II	PRIORITY III
1	12772	03412	5/13/68	07	7 0			7 0
1	12772	03412	5/13/68	06	6 0			6 0
	WORK ORDER TOTAL				13.0	00		13.0
	STATION TOTAL				13 0	00		13 0
1	14-0	754	5/13/68	BR-3	7 0		7 0	
1	14-0	754	5/13/68	RS-2	1 0		1 0	
	WORK ORDER TOTAL				8.0	00	8 0	00
	STATION TOTAL				8 0	00	8 0	00
	DIVISION I TOTAL				21 0	00	8 0	13 0

Figure 7.

The first four weeks were spent in a self-teaching program on methods time measurement. This involved learning the basic practices needed to develop standard times for the simplest of movements.

The technicians were then exposed to a series of maintenance standards developed by the consultant. These were then used to develop new standards conforming to the department's operations. Additional standards were and are continuing to be developed.

As the present system was taking form, necessary reports and forms were developed by the consultant and technician team.

Training sessions were given by the consultant's representative to acquaint management personnel with the proposed maintenance management program and the principles and techniques of planning, scheduling, and method time measurement.

Four of the six technician trainees were then selected for promotion to maintenance technician and assigned one to each road maintenance division and one to the operations division. The primary purpose of the maintenance technician assigned to operations is threefold, (a) continue the development of additional standards to reduce non-ratable projects to a minimum, (b) coordinate the activities of the division technicians to maintain standard and uniform practices throughout, and (c) act as a fill-in for other maintenance technicians when they are absent.

OPERATION OF PRESENT SYSTEM

The backbone of the present system is the combined use of the routine maintenance work order and the shop work order (Figs. 5 and 6). The work orders are of two types: "Open" (scheduled) and "Closed" (unscheduled or completion of a previously scheduled one).

Open Work Order Procedure

An Open work order is conceived by recognition of a project in need of doing. The road foreman identifies the project and assigns a priority for the work. Priority I is work that should be accomplished within one week, Priority II work should be done within four weeks and Priority III should be completed in less than four months. The shop foreman, upon recognition of the need for repairs or maintenance, fills out the work order similarly. Project identification must be complete and as accurate as possible in order to facilitate the next step—project time insertion.

Upon completion of project identification and priority, the foreman passes the Open work order to the maintenance technician assigned at the division headquarters. Project time is then entered. The time is based on developed standards. If a standard has not yet been developed, project time is estimated.

At this stage a backlog is created. The backlog is available in two formats. The first is present in the form of work order files at division headquarters and secondly as an Open-order report produced by the data processing section (Fig. 7). This report is the direct result of data accummulated by routing a copy of each work order to data processing. The material is keypunched and inserted into the IBM 360 system. The report is issued weekly and distributed to upper management and others directly connected with the scheduling process.

The Open order report presents a listing of routine maintenance or shop repair projects identified by road maintenance division, station, crew or equipment number, work order number, date initiated, and type of work by code. Also indicated, and totaled by station and division, are the standard hours required for the work order. Project standard hours are further broken down by priority and totaled by station and division.

Scheduling

Using this knowledge of backlogged projects, with standard times and priorities inserted, weekly, and sometimes monthly or longer, schedules of work are produced. Each road maintenance foreman schedules the work under his supervision. In addition, all of the specialty crews operating out of division headquarters are scheduled by the division superintendent or his assistant. The maintenance technicians are used to aid in the scheduling.

All of the road maintenance divisions have equipment boards that are used to indicate reservations for and locations of pool equipment at all times. Although somewhat different in physical makeup between divisions, they all accomplish the same purpose. Integration of the equipment board and the routine maintenance scheduling and planning is necessary and easily accomplished. A work order will frequently request a piece of pool equipment for the project. Priority rating of the project then enables proper scheduling of the equipment. The maintenance technician keeps the board up to date based on the superintendent's decisions concerning the pool equipment.

Closed Work Order Procedure

A Closed work order either completes a previously scheduled or Open work order, or is initiated upon completion of a project not previously scheduled. This applies to routine maintenance and shop projects alike.

The road foreman inserts the actual times required for the work, the equipment use and travel time, materials used, and any remarks that are necessary to explain delays, obstructions or other items that would affect the standard times previously filled in or to be applied by the maintenance technician. This information is inserted on a retained copy of an Open work order, or, in case of unscheduled work, a new work order is initiated and an indication is made that it is unscheduled.

Initiation of the Closed work order for unscheduled work affords an opportunity to rate project and crew performance and, additionally, to accumulate data on types of work for which no standards have as yet been produced.

COUNTY OF SAN DIEGO - COUNTY ENGINEER DEPARTMENT
WEEKLY CLOSED WORK ORDER REPORT
WEEK ENDING 5-10-68

DIV	STATION OR CREW NO	SCHED. WORK ORDER	UNSCHD WORK ORDER	WORK CODE	STANDARD HOURS REQD.	ACTUAL HOURS USED	PERFORMANCE PERCENT	NON-STANDARD HOURS
1	14-0	2814		SC	4 2	5 4	77%	
				ME1	7	1 1	63%	
				14B	0		****	1 5
	WORK ORDER 002814 TOTAL				4 9	6 5	75%	1 5
	STATION TOTAL				4 9	6 5	75%	1 5
1	23-0		534	TW1	5 4	6 3	85%	
				ME1	1 4	1 8	77%	
	WORK ORDER 000534 TOTAL				6 8	8 1	83%	0
	STATION TOTAL				6.8	8 1	83%	0
	DIVISION 1 TOTAL				11 7	14 6	[illegible]	1 5

Figure 8.

When the Closed work order is received by the maintenance technician, the remarks section is first acknowledged for adjustment of standard time. Craft and travel hours are totaled and performance is calculated.

Transmittal of the Closed work order to data processing ultimately creates the weekly Closed-order report (Fig. 8). The format of this report is somewhat similar to the Open-order report. Division, station, crew, or equipment number, work order number and work code all serve to identify the project. Standard hours required and actual hours used determine performance percent. The last column, non-standard hours, indicates those reported hours that the maintenance technician was unable to rate because of the absence of developed standards for those types of projects. These three columns are totaled by road maintenance station and division.

As indicated before, continued development of new standards is necessary to reduce non-standard hours to a minimum. One of the prime objectives of a management program of this type is to reduce the number of non-ratable and unscheduled projects to a minimum. Only in this manner can one ascertain true available time for unforeseen emergencies. Progress in this direction will be reflected in the balance of the scheduled and unscheduled columns and in the totals under the non-standard hours column of

METHODS IMPROVEMENT PROPOSAL

(Attach Routine Maintenance Work Order for Betterment Projects)

NAME ____________________ DATE OF REPORT ____________

SUBJECT ____

Note If improvement will result in an elimination of a safety hazard or better service to the County, rather than dollar savings, state details in Method Descriptions.

PRESENT METHOD DESCRIPTION

PROPOSED METHOD DESCRIPTION

SAVINGS CALCULATION (Use Other Side For Calculation Details)

	*Yearly Cost Of Present Method	Installation Cost	Yearly Cost Of Proposed Method
Labor	________	________	________
Equipment	________	________	________
Material	________	________	________
TOTAL COST	(A)________	(B)________	(C)________

PRESENT METHOD (A)________ LESS INSTALLATION (B)________ LESS PROPOSED (C)________

EQUALS NET FIRST YEAR SAVINGS ____________________

APPROVED BY FOREMAN ____________ DIV SUPT ____________ DEP CO ENGR ____________

*May be yearly and reoccurring or a one-time savings

Figure 9.

the Closed-order report. Progress is also periodically illustrated using a simple graph indicating percentage of total reported hours covered by standards and, additionally, overall performance of reporting units.

Betterment Work Orders

Early efforts in routine maintenance management involved issuance of work orders to cover projects that were primarily routine maintenance, but also resulted in a betterment to the road and reduction or elimination of maintenance problems. Normally, projects of this type exhibit a project cost somewhat in excess of the normal routine maintenance projects and usually involve installation of new material such as culverts and other drainage installations and extended areas of paving instead of spot patching.

This system has not been formalized with the use of the "Methods Improvement Proposal" (Fig. 9). This proposal summarizes present and proposed maintenance procedures or methods, tabulation of present annual cost, installation cost, and annual maintenance cost after improvement. The proposal is usually initiated by the road foreman who fills in a normal routine maintenance work order and routes it through the maintenance technician for application of standard hours and subsequent cost determination. Necessary approvals are then obtained and an authorization issued to proceed with the project.

CONCLUSION

Our maintenance management system has to this date been in operation only about four months and, as yet, it is still too early to recognize any tangible quantitative benefits. Dollar savings are, however, anticipated and data have been and are currently being accumulated from which to make this determination.

Immediate qualitative benefits have been realized in the form of increased effort on the part of our maintenance personnel to recognize and use methods improvements, priority ratings, and overall planning and scheduling.

Although this management system is currently only in effect in our road operations and maintenance divisions, the program has been widely publicized in the department. Our ultimate plan is to apply this new tool, scientific measurement of project time, and subsequent development of standards as widely as possible to aid in the planning and scheduling of all San Diego County activities.

A Progress Report on the Illinois Maintenance Management Program

NILE R. BLOOD and H. O. SCHEER, Illinois Division of Highways

A short report on the State of Illinois' concepts of highway maintenance management and performance rating was presented at the Highway Research Board meeting in January 1968. This paper briefly restates a few of the major features of the system and discusses the present status of the project, including progress made and problems encountered.

A primary objective of the project is the development of reliable maintenance cost and accomplishment data. From the data, management reports are developed for the various supervisory and administrative levels concerned with highway maintenance, enabling them to make comparisons of costs and of work crew accomplishments for like units, or areas, under their jurisdiction. They may also compare their own area against similar areas, against statewide averages and against an established standard of performance.

The Illinois system includes a "roadway inventory" which is a count, or measure, of the significant items that make up the physical maintenance work load in a unit or area. This enables us to compare the potential work load of similar units. In conjunction with the unit costs we develop, this is expected to be a very useful aid in budgeting.

Management reports generated by our system are as follows:

1. Roadway inventory listings and summaries.
2. Monthly work accomplishment reports, which are a measure of work crew performance and develop unit costs from direct labor and equipment usage; overhead labor and material costs are not included since the work crew normally has little control over these items.
3. Quarterly and annual cost reports showing total charges against the maintenance appropriation, by work items and for the various breakdown of geographical units.
4. Monthly equipment usage reports giving a summary of hours used, and related costs, for all major items of equipment.

The inventory summaries, work accomplishment reports and cost reports are printed for the following. maintenance sections, field engineer's areas, districts, and state total. Costs are reported to 47 individual work items in 11 general categories.

The system is designed to provide for a flow of information and reports back to the various management levels within a relatively short time. The electronic computer is used to achieve timely processing of the large volume of data and feedback of management reports.

While the basic planning for the new system was done within the Bureau of Maintenance of the Illinois Division of Highways, Meiscon Division of Control Data Corporation, Chicago, was retained to aid in the development of the system. This company has done the programming, designed reporting forms, developed procedures, and generally, has made an extensive study of operations of other bureaus affected by our work so that all operations will be compatible.

We have strived for simplicity in our system, especially in the field reporting phase. Maintenance is a complex operation at best and we have tried to avoid an additional paperwork burden on our field personnel.

While planning and scheduling of work are encouraged when feasible, formalized scheduling is not a part of the system. No actual job-time studies have been made. We expect to develop performance standards from actual average unit costs achieved over a period of a year or more.

The field reporting phase of the system was initiated on July 1, 1967. While most phases of the system are now operational, progress has been slower and effort required has been greater than anticipated. Much of this problem was related to the overlap of our work into the areas of payroll processing, general accounting, etc., where we disrupted many existing procedures and had to develop new ones to replace them.

Collecting and recording of cost data were changed from, essentially, a manual operation in 10 districts to a central, computerized process. This, in conjunction with new time-reporting forms and other documents, required new procedures and training for many people. It takes time to get all this operating smoothly again.

We feel that it would be preferable to have the processing of the time cards in the districts with a teleprocessing link to the central computer. The necessary checking and correcting of coding errors on the time cards would be easier for district personnel who are much more familiar with the field operations and have closer contact with the field employees.

One of our initial problems was the lack of an adequate number of trained people to check the time cards and to make the necessary corrections when processing was changed from a district operation to a centralized operation. A substantial backlog of cards had accumulated before anyone was assigned to this task and this, coupled with a considerable number of reporting errors in the beginning, made progress very slow.

The many capabilities of electronic computers are well advertised. Indeed, they sometimes are attributed to have almost magical abilities. In spite of all this, they are also very intolerant of any errors in input and programs. Electronic data processing is a bit like air travel. The "trip" through the computer, like the actual flight on the plane, is quite rapid. It is all the other problems and preparations on each end that consume the time and cause much of the frustration. There are many programs in our system and it has been difficult to get them all functioning properly.

The added load due to our maintenance management programs has taxed the capacity of our data processing section. Program refinements to improve the running time have helped in some cases. A proposed changeover to third-generation computer hardware should alleviate this problem.

The present status of our system of management reports is as follows:

1. The first roadway inventory summaries have been received recently. A few revisions in the inventory were found desirable. The inventory instructions have been rewritten and program revisions are being prepared. To be useful, an inventory must be kept up-to-date and provision has been made for this.

2. The basic reports from the work accomplishment phase are now being received on a monthly basis. Presently, these reports are being received 60 days, or more, after the end of the subject month. This is a longer period than desired and we hope to reduce this time to approximately 30 days. One report in this phase of the program will compare actual unit costs achieved against established "standards." These standards will be based on statewide average unit costs over a period of time, probably one year. Once these standards are established, they are expected to remain unchanged except for an annual correction due to changes in labor rates and costs of equipment and parts. In this way, the performance of an area, or unit, can be compared to its own performance in past years as well as being compared to similar areas on a current basis. This particular report is not yet being printed pending development of the standards from data received in other reports.

3. The first cost reports were received in July 1968. They will be printed on both a quarterly and an annual basis. In addition to the basic cost report form, annual reports will be issued to show costs per lane-mile for three basic highway categories: Interstate, regular and urban expressways. Also, we develop lane-mile costs for a special sampling of pavement surface types and costs per lineal foot for a sampling of bridge types.

4. Equipment usage reports are issued monthly in conjunction with the work accomplishment reports.

As a project like this progresses, the viewpoint may change a bit. One occasionally sees revisions, or additions, he would like to make. Sooner or later, this results in the problem of sufficient time or money to develop everything one might wish. In the contract with our consultant, we reached that point all too soon. Due to the effort required to complete, to our satisfaction, the basic system of data collection and reporting, we have not done as much work as we would like in the analysis of that data. However, if the foundation of our system is good we can continue to build on it.

Development of our basic system is essentially complete. We now want to make it operate a little smoother and a little faster. We also must learn to use, to greatest advantage, the information we now have available.

A Scheduling and Performance Evaluation System for Utah's Basic Maintenance Management Units

JIM WEST, Utah State Department of Highways, and
JOHN JORGENSEN, Roy Jorgensen Associates, Inc.

Utah has recently undertaken the development and implementation of a computerized maintenance management system. Components of this system include performance standards, a maintenance management reporting system, planning processes and performance evaluation techniques. However, the computerized system is not designed to schedule the basic management units or provide short-range operating guidance.

This paper presents a technique which we feel allows our maintenance field organizations to formalize scheduling processes and conduct more timely performance evaluations. The scheduling and performance evaluation technique began operating on a statewide basis July 1, 1968, after trial on a more limited scale. We anticipate further revisions in the procedures but are convinced that the general approach will continue to prove itself.

The development of the system required an evaluation of characteristics of our particular organization. The major factors considered important in the development are the following:

- First-line supervisors most of whom have high school education.
- First-line supervisors who have traditionally been working members of the crew.
- Basic management units which are physically separated from each other and from their respective district headquarters by considerable distances.
- Basic management units most of which require a staff of only 4 to 6 men.
- Performance standards which have been and will continue to be developed to provide first-line supervision with operating guidelines.
- First-line supervisors who have traditionally been responsible for need identification, scheduling, and performance of a majority of the maintenance activities.
- A computerized maintenance management information system.

The resulting scheduling and performance evaluation system design has the following characteristics:

1. It is non-computerized.
2. It continues to place considerable managerial responsibilities on the first-line supervisor.
3. It minimizes the time lag between performance and evaluation.
4. It incorporates performance standards.

Although there is a definite tie between the scheduling process and the evaluation process, for discussion purposes they are treated separately.

SCHEDULING

A flow chart of the scheduling process is shown in Figure 1. Three distinct scheduling relationship phases are apparent: general scheduling, specific maintenance need identification, and resource scheduling.

The general scheduling phase involves the establishment of guidelines for scheduling maintenance activities which, out of necessity or desirability, are best performed during specific times of the year. Figure 2 represents the results of this determination in the form of an annual schedule for major maintenance activities. Its purpose is to provide a general planning framework for the first-line supervisor. Start and completion dates indicated on the schedule are not absolute. The intent is to direct the attention of the first-line supervisor towards those activities and programs which are to receive primary attention during the general periods indicated. It was decided that the distinction between those maintenance activities which are the total responsibility of the first-line supervisor for need identification and scheduling and those activities which require district authorization prior to performance should be made on the annual schedule. This distinction is designated in Figure 2 by the categories "routine shed maintenance activities" and "special shed maintenance activities," respectively.

The specific maintenance need identification phase (Fig. 1) consists of the process during which specific maintenance activities, programs or projects are identified and detailed for future accomplishment. Responsibility for need identification of routine shed maintenance activities falls to the first-line supervisor and is carried out during the weekly inspection tour of his road system. During this inspection particular attention is paid to those activities noted on the annual schedule. Additional guidance is provided by reference to the pertinent performance standards. Figure 3 is a copy of a typical performance standard and illustrates the format developed for use by the first-line supervisors. A pad of the form in Figure 4 is carried by the first-line supervisor for making note of the item requiring attention.

Identification and detailing of special shed maintenance activities and betterment projects is the responsibility of the district-level managers. Scheduling is performed by the first-level supervisors with necessary district coordination. The inspection trips are conducted semiannually by district-level supervisors in the company of the first-line supervisors. Upon completion of the inspection, the first-line supervisor is provided with an itemization of the special maintenance and betterment jobs to be accomplished during the coming six-month period. Figure 5 is an example of a completed itemized special maintenance activities form provided the first-line supervisor. As additional special items arise, they are added to the list.

The resource scheduling phase (Fig. 1) involves the development of a weekly schedule by the first-line supervisor. Items scheduled include those noted for need during the weekly inspection as well as those listed on the itemized special maintenance activities form. Figure 6 is an example of a weekly schedule which indicates what work is to be done, where it is to be done, how much is to be done, what is to be used, when it is to be done, and who is to do it. Alternative activities are listed in anticipation of inclement weather, or other situations which require deviations from the scheduled activities.

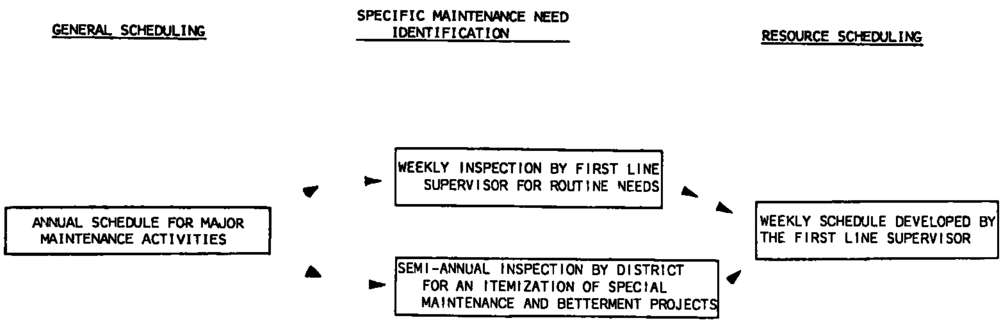
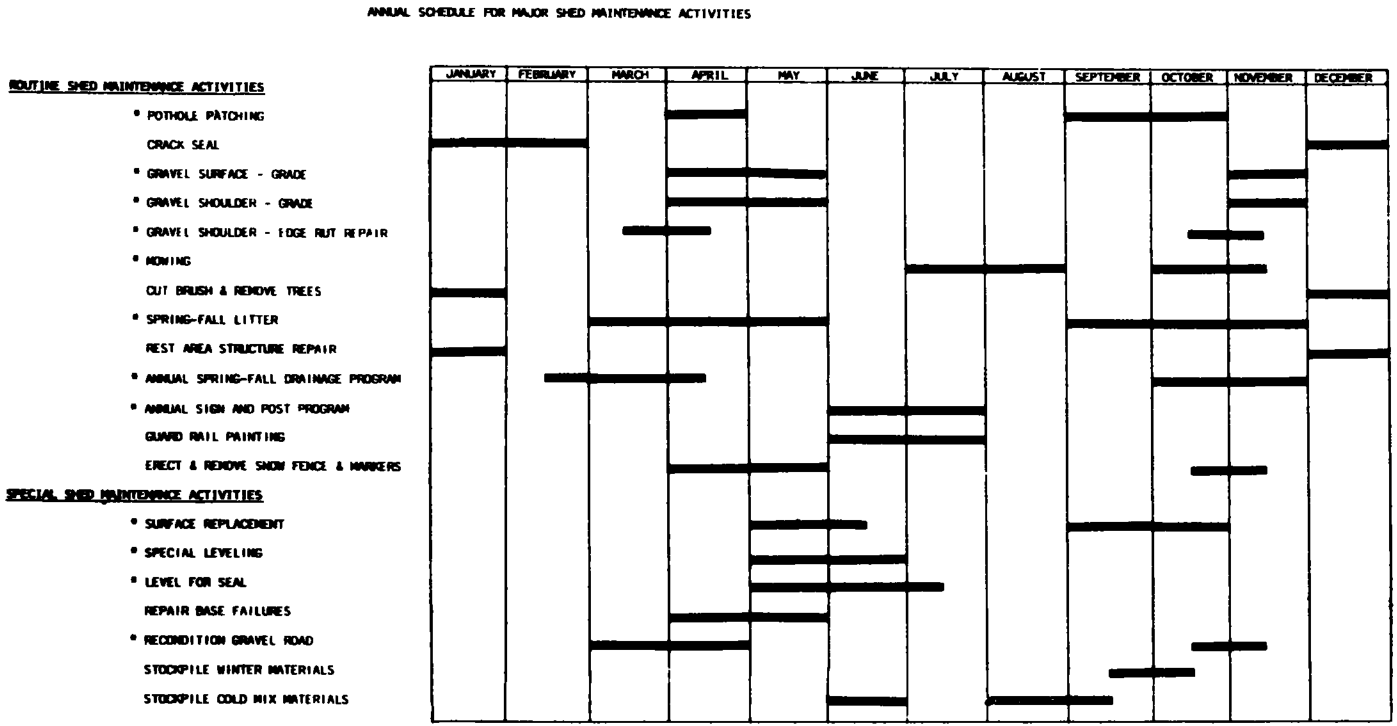


Figure 1. Scheduling process flow chart.



* Refer to PERFORMANCE STANDARDS for desired methods and prodecures

NOTE

This schedule indicates those months during which the Shed Foreman shou d direct his attention to the Maintenance Activities which can be anticipated and should be scheduled and performed weather permitting, during specific months

Those activities classified as "Special Shed Maintenance Activities" require District approval prior to the scheduling and performance by Shed Foreman

Figure 2.

PERFORMANCE STANDARD
JUNE 1, 1968

ACTIVITY 171-100

ANNUAL SIGN AND POST MAINTENANCE PROGRAM

RESPONSIBILITY - Shed Foreman

DEFINITION - The specifically planned and scheduled annual maintenance of all signs, sign posts and marker posts throughout the State's road system. To include the conduct of a night reflectivity survey, replacement, painting and straightening of signs and or posts as performed as a part of the annual program.

SCHEDULING CONSIDERATIONS - The annual sign and post maintenance program is to be performed during the months of June and July. Surveys of sign, reflector and post replacement requirements should be conducted early enough to provide ordering lead time.

QUALITY AND WORKMANSHIP - During the conduct of the Annual Sign and Post Maintenance Program, the required maintenance should be given to the listed observed conditions.

Required Maintenance	Observed Conditions
1. Paint post in accordance with standard	1. Paint peeling 2. Post superficially scarred or scratched.
2. Peplace post	1. Post broken 2. Post unsound 3. Post badly scarred.
3. Replace sign or delineator	1. Sign or delineator damaged 2. Loss of reflectiveness

METHOD AND PROCEDURE -

1. Conduct night survey to determine and mark signs and delineators in need of replacement.
2. Conduct day survey to determine needed sign replacements.
3. Order signs and delineators.
4. Perform replacements, painting and straightening as needed.

CREW ARRANGEMENT - 2 Men, 1 Truck - 0101

EXPECTED PERFORMANCE -

Daily Production - 20-26 sign, marker post or delineator installations.

Productivity - .6 - .8 man hours/installation

Figure 3.

MAINTENANCE NEEDS

date June 7

ACTIVITY DESCRIPTION

Mowing

LOCATION Salina south to Aurora Jct

ESTIMATE of AMOUNT of WORK

56 acres

COMMENTS (priority, scheduling considerations, etc)

- make arrangements to get batwing mower
- need to cut weeds before they go to seed - [illegible]

(FRONT)

ADDITIONAL COMMENTS

we should get them in the next two weeks

(BACK)

Figure 4.

PERFORMANCE EVALUATION

The performance evaluation procedure involves a comparison of actual performance with the performance guidelines provided. Indications of actual performance are provided by data from the reporting system and actual field observation. Because the system is to provide performance indicators with a minimum of time lag between performance and evaluation, the reported data are manually tabulated in the district offices by the district maintenance analyst. This manual field evaluation process does not eliminate the need for or desirability of a quarterly, semiannual or annual, computerized summary performance report. The utilization of manually tabulated data enables corrective assistance to be provided on a more timely basis.

Figure 7 is an arrow diagram of the evaluation procedure. The guidelines provided to the first-line supervisors consists of the annual maintenance schedule, performance standards, and an itemized list of special projects (Figs. 2, 3, and 5). Quantitative reflections of actual performance are provided by the maintenance management reporting system every 15 or 16 days. A copy of the period activity record formed used by the reporting system is shown in Figure 8.

In order for the system to direct efforts towards corrective actions, it needs to be able to answer the following questions:

1. What crew arrangements are being used?
2. What productivity rates are being attained?
3. Are the itemized activities being accomplished?
4. Are efforts being directed towards accomplishment of the maintenance activities and programs indicated on the annual schedule?
5. What methods and procedures are being used?
6. What levels of quality and workmanship are being attained?

SHED OR CREW 334 MT PLEASANT

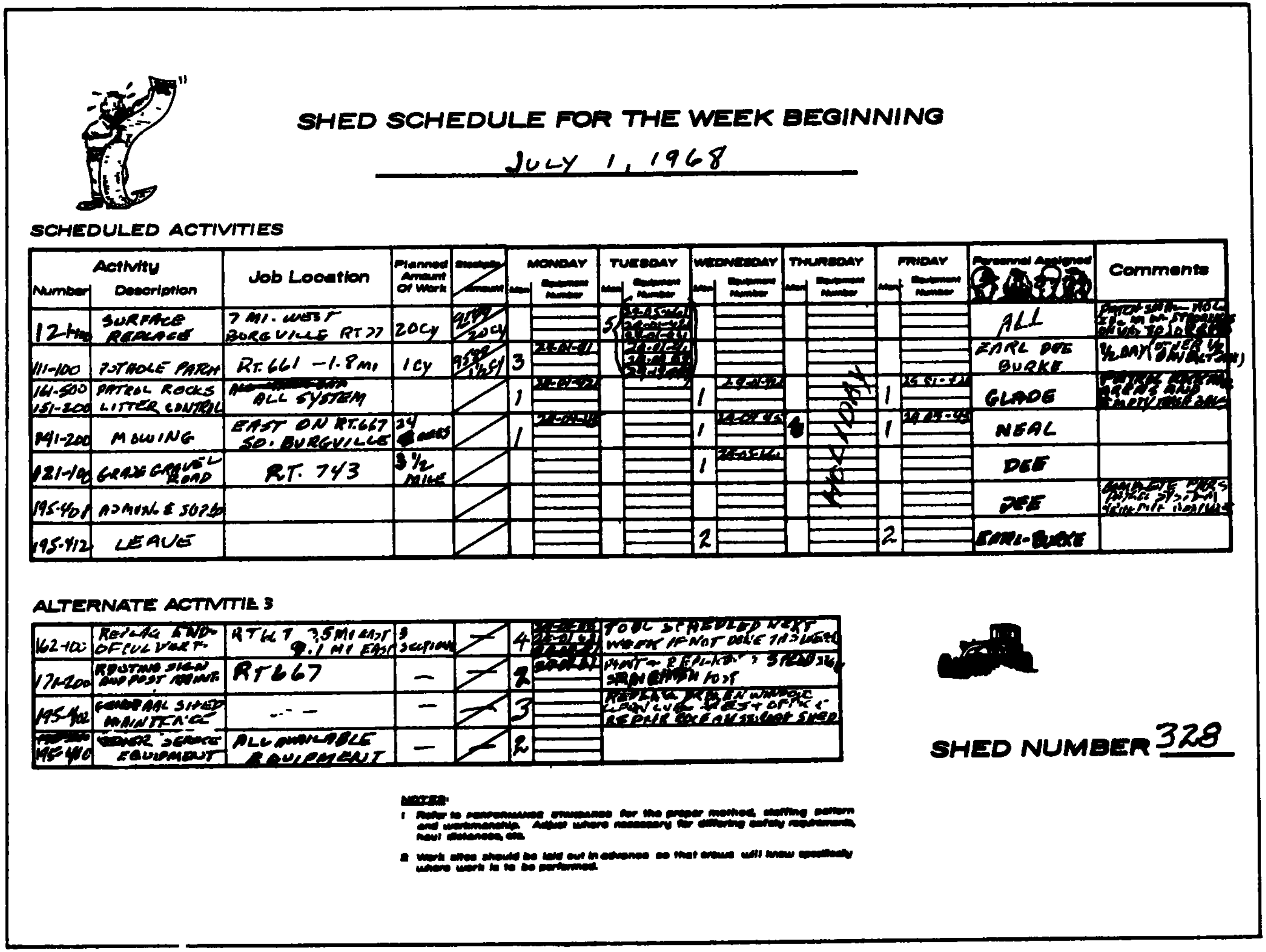
FOR PERIOD MAY 1 TO OCT. 31, 68

ITEMIZED SPECIAL MAINTENANCE ACTIVITIES

ACTIVITY NUMBER	ACTIVITY	LOCATION	ESTIMATED AMOUNT OF WORK	MATERIALS REQUIRED	CREW ARRANGEMENT	ESTIMATED CREW DAYS
112-100	SURFACE REPLACEMENT	NORTH OF SALINA	50 YDS	1/2" BITUMINOUS	STANDARD	1
112-200	LEVEL (FOR SEAL)	FAIRVIEW TO MILK BARN	24 YDS	1/2" BITUMINOUS	STANDARD (-) 1 MAN & 1 DUMP	1
112-200	LEVEL	U-11 NORTH OF FT GREEN	1300 YDS	1/2" BITUMINOUS	STANDARD (-) 1 MAN & 1 DUMP	18
191-900	EXTRAORDINARY REPAIR	FAIRVIEW CANYON	----------AS REQUIRED----------			
163-900	DRAINAGE REPAIR	WEST OF CHESTER			6 MEN, 1 GRADER, 1	10
					LOADER AND 4 TRUCKS	
153-900	R/W CLEARING	U-11 WEST OF CHESTER			3 MEN, 1 TRUCK, 1	2
					LOADER AND 1 GRADER	
153-900	R/W CLEAN, SHAPE AND SEED	U-116 NORTH OF FREEDOM			3 MEN, 1 TRUCK, 1	3
					LOADER AND 1 GRADER	
153-900	R/W CLEAN, SHAPE AND SEED	U-11 SOUTH OF FT GREEN	(IN PROGRESS)			
153-900	OPEN SIGHT DISTANCE	STRAIGHT JCT. (89 & U-117)			4 MEN, 2 TRUCKS, 1	4
					GRADER AND 1 LOADER	
SPEC. AUTH 8760	RESURFACE	NORTH OF WALES	---------- AS REQUIRED----------			
SPEC AUTH. 9012	UP GRADING SIGNS	ALL ROADS	----------AS REQUIRED----------			
SPEC. AUTH. 7081	GREEN THUMB PROJECT	MANTI TEMPLE	---------- AS REQUIRED----------			
	BUILD COLD-MIX STOCKPILE	FOUNTAIN GREEN		1400 YDS	HAUL-4 MEN & 4 TRUCKS	5
					MIX-1 MAN & 1 GRADER	4
	BUILD COLD-MIX STOCKPILES	MT PLEASANT STATION (SHED)		600 YDS.	HAUL-4 MEN, 3 TRUCKS,	
					AND 1 LOADER	1-1/2
					MIX-1 MAN AND 1 GRADER	3

Utah Maintenance Management Project

Figure 5.



SHED SCHEDULE FOR THE WEEK BEGINNING

JULY 1, 1968

SCHEDULED ACTIVITIES

Activity Number	Activity Description	Job Location	Planned Amount Of Work	Stockpile Amount	Monday Men	Monday Equipment Number	Tuesday Men	Tuesday Equipment Number	Wednesday Men	Wednesday Equipment Number	Thursday Men	Thursday Equipment Number	Friday Men	Friday Equipment Number	Personnel Assigned	Comments
12-[illegible]	SURFACE REPLACE	7 MI. WEST BORGVILLE RT 77	20 CY	[illegible] 20 CY			5	[illegible]				HOLIDAY			ALL	[illegible]
111-100	POTHOLE PATCH	RT. 661 - 1.8 MI	1 CY	[illegible]	3	[illegible]									EARL DEE BURKE	½ DAY (OTHER ½ [illegible])
161-500 151-200	PATROL ROCKS LITTER CONTROL	ALL SYSTEM			1	[illegible]			1	[illegible]			1	[illegible]	GLADE	[illegible]
141-200	MOWING	EAST ON RT. 667 SO. BURGVILLE	24 [illegible]		1	[illegible]			1	[illegible]	[illegible]		1	[illegible]	NEAL	
121-100	GRADE GRAVEL ROAD	RT. 743	3½ MILE						1	[illegible]					DEE	
195-401	ADMIN. & SUPV.														DEE	[illegible]
195-412	LEAVE								2				2		EARL-BURKE	

ALTERNATE ACTIVITIES

Activity Number	Activity Description	Job Location	Planned Amount Of Work	Stockpile Amount	Men	Equipment Number	Comments
162-100	REPLACE END OF CULVERT	RT 667 3.5 MI EAST 9.1 MI EAST	3 SECTIONS	—	4	[illegible]	TO BE SCHEDULED NEXT WEEK IF NOT DONE THIS WEEK
171-200	ROUTINE SIGN AND POST MAINT.	RT 667	—	—	2	[illegible]	PAINT & REPLACE 7 STOP SIGN [illegible] POST
195-402	GENERAL SHED MAINTENANCE	—	—	—	3		REPLACE BROKEN WINDOWS [illegible] REPAIR [illegible] SHED
195-410	MINOR SERVICE EQUIPMENT	ALL AVAILABLE EQUIPMENT	—	—	2	[illegible]	

SHED NUMBER 328

NOTES:

1 Refer to performance standards for the proper method, staffing pattern and workmanship. Adjust where necessary for differing safety requirements, haul distances, etc.

2 Work sites should be laid out in advance so that crews will know specifically where work is to be performed.

Figure 6.

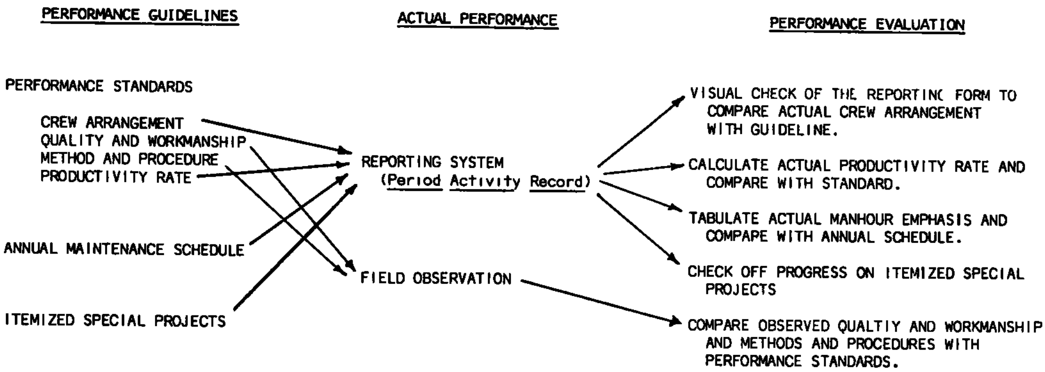


Figure 7. The performance evaluation process.

Answers to these questions, as provided by the reporting system and field observations, are compared with the guidelines in the form of performance standards, annual schedule, and itemized activities. Analytical determinations are made in the following manner.

Crew arrangements on the various activities are determined by a visual inspection of the portions of the period activity record which indicate the number of men and number and types of equipment. It is readily apparent to the district maintenance analyst that the two operations in Figure 9 were staffed with 3 men, 1 truck and 1 loader, and 2 men, 1 truck and 1 loader, respectively.

Productivity rates are manually calculated for each pertinent activity by utilization of the manhour and accomplishment data on the period activity record. Figure 10 is the form used to maintain a cumulative calculation of the rates for each organizational unit. Cumulative data are used in order to compensate for unusual circumstances that may affect the rate for any single period.

Progress with regard to the itemized special maintenance activities is continually maintained by striking them off the list as they are completed.

Conformity with the maintenance effort desires expressed on the annual schedule is determined by the district maintenance analyst through use of the form in Figure 11. The manhours expended during each period on the listed activities are tabulated from the period activity record and posted on the form (Fig. 11). To the extent the major efforts as represented by manhours generally coincide with the shaded periods, the annual schedule is being followed.

Determinations of method and procedure, quality and workmanship require on the spot observations before, during, and/or after the performance of the specific activities. To some extent gross method, quality or procedural deviations will reflect themselves in the productivity rates in the long run. However, when possible, actual observations are desirable.

Substantial deviations from the performance standards and annual schedule or lack of expected progress on the itemized activities without apparent cause are called to the attention of the district maintenance engineer or district maintenance supervisor by the district maintenance analyst. District managers then direct their efforts towards establishing cause and providing corrective assistance as required.

PERIOD ACTIVITY RECORD

PAR

Management unit	Activity	Road Class	Authority Number	Road Section or Project Number	Period ending Year	Month	Day

Day of the month

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Comments

RECORD OF LABOR USED

																TOTAL	Planned
Total Number of Men Used on This Activity																	
Regular Hours of Salaried Employees																	
Regular Hours of Temporary Employees																	
Total Overtime Hours																	

RECORD OF EQUIPMENT USED

Code	Class	Hours or Miles	TOTAL	Planned

RECORD OF MATERIAL USED

Stockpile Number	Inventory Number	Unit	Quantity	TOTAL	Planned

RECORD OF ACCOMPLISHMENT

Measure of Accomplishment	Quantity	TOTAL	Planned

Figure 8.

PERIOD ACTIVITY RECORD

PAR

Management unit	Activity	Road Class	Authority Number	Road Section or Project Number	Period ending Year	Month	Day
321	1110C	4			68	7	15

Day of the month

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	
16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31

Comments

RECORD OF LABOR USED

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	TOTAL	Planned
Total Number of Men Used on This Activity				3				2									
Regular Hours of Salaried Employees				24				16									
Regular Hours of Temporary Employees																	
Total Overtime Hours																	

RECORD OF EQUIPMENT USED

Code	Class	Hours or Miles															TOTAL	Planned
01	04				7				7									
09	02				1				1									

RECORD OF MATERIAL USED

Stockpile Number	Inventory Number	Unit	Quantity														TOTAL	Planned
3316	6-95041	cy				3				2								

RECORD OF ACCOMPLISHMENT

Measure of Accomplishment	Quantity															TOTAL	Planned
Cubic Yds.				3				2									

Figure 9.

Calendar Year 1968
Maintenance Crew Number 321

MAINTENANCE ACTIVITY PERFORMANCE ANALYSIS

Activity 112-200 Level
Unit of Measure Cyds

Period	Cumulative Man Hours	Cumulative Quantity	Productivity Rate	Comments
January 1st	–			
January 2nd	–			
February 1st	–			
February 2nd	–			
March 1st	–			
March 2nd	–			
April 1st	–			
April 2nd	–			
May 1st	124	52	2.4	
May 2nd	–	–	–	
June 1st	244	198	1.2	
June 2nd	481	648	0.7	
July 1st	605	795	0.76	
July 2nd				
August 1st				
August 2nd				
September 1st				
September 2nd				
October 1st				
October 2nd				
November 1st				
November 2nd				
December 1st				
December 2nd				

Figure 10.

SUMMARY OF SHED MAINTENANCE EFFORT BY PERIOD
(IN MAN HOURS)

Shed *MT. PLEASANT*

	JAN. 1ST	JAN. 2ND	FEB 1ST	FEB 2ND	MAR 1ST	MAR 2ND	APR 1ST	APR 2ND	MAY 1ST	MAY 2ND	JUN 1ST	JUN 2ND	JUL 1ST	JUL 2ND	AUG 1ST	AUG 2ND	SEP 1ST	SEP 2ND	OCT 1ST	OCT 2ND	NOV 1ST	NOV 2ND	DEC. 1ST	DEC. 2ND
ROUTINE SHED MAINTENANCE																								
POTHOLE PATCHING		6	18	60	106	240	40																	
CRACK SEALING	204		172		56																			
GRADE GRAVEL SURFACE				12	12		88	32		82														
GRADE SHOULDER							56																	
EDGE RUT REPAIR																								
MOWING										18														
CUT BRUSH AND REMOVE TREES		136	152				22																	
SPRING-FALL LITTER PICK-UP						26	40	136	[illegible]	88														
REST AREA STRUCTURE REPAIR		16	12																					
SPRING-FALL DRAINAGE PROGRAM								24	76	8														
ANNUAL SIGN & POST MAINT PROG.									24	52														
ANNUAL GUARD RAIL MAINT PROG																								
SNOW FENCE, SAND BARREL & DELINEATORS																								

SPECIAL SHED MAINTENANCE																								
SURFACE REPLACEMENT																								
SPECIAL LEVELING																								
LEVEL FOR SEAL																								
REPAIR BASE FAILURE																								
RECONDITION GRAVEL ROAD																								
BUILD WINTER STOCKPILE	204																							
BUILD COLD-MIX STOCKPILE																								
ALL ADMINISTRATIVE ACTIVITIES	56	120	149	168	142	72	152	196	120	83														
SPECIAL AUTHORITY WORK	64	104	48	56	68	8	76	8																
ALL OTHER ACTIVITIES		46		232	44	182	54	132	228	197														

Utah Maintenance Management Project

Figure 11.

Work Standards and Programmed Budgeting for Maintenance Operations

JOHN H. SWANBERG, Minnesota Department of Highways

I am sure that everyone is familiar with Parkinson's Law which states, in effect, that the number of employees increases at a rate which has no relationship to the amount of work to be done. Governmental agencies, in particular, are often accused of applying this law and, we have to admit that some of the examples set by government indicate some validity in the law.

For us, however, as we look at the increased demand for service on the part of the public, as we look at the vacancies in our complement as a result of low national unemployment rate, and as we look at the constantly reduced maintenance budgets, we cannot help but feel that for Parkinson's Law to be correct for maintenance operations, it must work in reverse and could be stated: "As the amount of work increases, the number of men available per unit of work decreases."

Whatever the case, there is no denying the need for use to place greater emphasis on redefining objectives in maintenance and to study, analyze, develop and implement new ways and means to better utilize the human and other resources which are required to achieve these objectives.

This approach, commonly known as management by objectives, has been discussed within the Minnesota Highway Department for quite a number of years. Until recently, however, our maintenance objectives were not divided into countable work units, and we had no established criteria or standards against which actual work performance could be compared. We were on a line item accounting system and were forced to budget entirely on historical data and engineering judgment. In other words, we spent X number of dollars on snow and ice control last year, but last year was a mild winter so therefore, we will need X-plus, say, 20 percent more money for this work next year. The judgment factor is difficult to apply because we must budget on a biennium basis to tie in with legislative sessions.

The last few years, however, have brought new developments in the area of maintenance management. Phrases such as "management by objective," "work standards," "levels of performance," and "program-budgeting" have now come into everyday management conversations.

Two and a half years ago, Minnesota as one result of a department-wide management study performed by consultants, decided to take a new approach to maintenance management. A consultant was retained to direct this new approach—a maintenance work improvement study.

The project could be called a feasibility study because what we were really trying to find out was whether or not certain time-honored principles of industrial engineering, such as work measurement, could be adapted to maintenance operations in an effort to improve the utilization of available manpower and skills. We felt that if these techniques could apply, we could greatly improve our operations through such things as standardization of methods and better planning and scheduling of work, and thereby obtain better control of operations in general.

The management consultants required state personnel to assist in the study. A task force set up for this purpose consisted of five engineers, a shop foreman, a field foreman, a stock supervisor and an administrative analyst—a total of nine people. Two of the engineers were experienced maintenance engineers; the other three were younger engineers with varied background in materials, design and traffic. This task force continued its work following the expiration of the six-month consultant contract.

To begin with, we concentrated on developing work standards which would employ a standard work method, production rates commensurate with this method, optimum crew size and proper equipment for the job. We developed these time standards on various field and shop operations within a pilot district and our central shop.

In order to provide time standards for the activities, work measurement was necessary. A decision was made to use time-study observation, as opposed to some other type of work measurement, as the source for data to be used to develop the time standards.

The time study approach was chosen for various reasons, mainly because of its adaptability to the type of operations involved in field and equipment maintenance. This study technique was used as opposed to "borrowing" standards from other agencies or from equipment manufacturers because standards based on our own operations, using our own personnel, our own methods, our own equipment and our own conditions were desired.

We chose time study rather than historical data to develop standards because we were also interested in methods improvement, and we wanted to be assured that the standards were based on the best methods at the time rather than simply averaging together production rates of existing methods. The study produced time standards covering slightly over 35 percent of our field and equipment shop operations within the first six-month period.

Also, as part of the project, a daily scheduling and reporting form for the maintenance men was developed. The scheduling portion of this form led to magnetic scheduling boards which are being used in our larger maintenance stations. The scheduling procedure has been one of the major benefits of the program in that we are saving a significant amount of time by scheduling men and equipment in advance. Previously, in most cases, our men did not know what they were going to be doing that day until they reported for work.

Before the six-month study was actually completed, we began implementing the system statewide. The study had proved that it was feasible to apply this approach to maintenance operations. Since the standards were to be an indication of better methods, optimum crew size, etc., the standards did, in fact, provide for some standardization. The standards provided production rates that could be used for planning and scheduling. The work reporting system provided for better control in that we had recorded the operation, where it was done, how it was done, who dit it, how the time was distributed, and how much was accomplished.

Weekly reports were developed for all levels of maintenance management. These reports give the performance, coverage by standards and percent of productive work. Lower level reports break down unproductive work into hours spent on travel, safety, delays, supervision and meetings.

We would be the last, however, to deny that we ran into some problems during this study but we also experienced a great deal of success and the successes outnumbered the problems. Within nine months after the beginning of the project, a new type of reporting system and a new technique of scheduling and planning was in operation statewide.

Our progress in this work had been slowed by lack of personnel until only recently. At present we have a permanent staff of 15 employed on the project, including nine time-study men. We have raised our coverage of standard operations but we have a long way to go to reach our goal of 80 percent. We have been concentrating on improving what we have developed thus far rather than stressing increased coverage. We have redesigned every form we initially developed during the study. We have spent a great deal of time training personnel for industrial engineering technician work. Our most pressing area of endeavor at present, is to transform the vast amount of pertinent data now being recorded into usable summaries using data-processing methods. Only then will we realize the full benefit of this program.

One factor which we have found to be an absolute requirement for the success of a program such as this is the cooperation and backing of management, from the foreman up. It is absolutely necessary to explain the program, what it is, what it is intended to do and why it is being done. The maintenance workers and their immediate supervisors must thoroughly understand the scheduling and reporting system and what is expected of it. It has been our experience that these precautions will limit problems due to misinformation, fear, mis-use and lack of cooperation.

We have received, what I consider, less than expected resistance but it has probably been the result of taking action from the very beginning to circumvent any trouble through keeping the men aware at all times of our intent, progress and results. This is extremely important.

Before the maintenance work improvement study was actually completed, our thoughts began to turn toward a sister project: research in program budgeting and development of a top management reporting system. Although there were similarities between the two projects, they were conducted separately because the improvement study was maintenance oriented while the second study was geared to encompass the entire Highway Department.

The program-budgeting and management information study was initiated in February 1967 with two primary objectives in mind: (a) the department desired to transform its budget into a significantly more effective tool and (b) it wanted to improve the availability of information for top management decision-making and cost control. The two objectives were combined into one project because an effective reporting system is essential to capture the benefits of an improved budgeting system.

This project was in keeping with the Bureau of Public Roads' desire to have research performed on structuring program-budgeting and information systems to improve highway administration in the United States. The study was, therefore, partially financed with Federal funds.

To further emphasize this trend toward program-budgeting, attention is called to NCHRP Project 19-2 scheduled to be placed under contract later this year: "Develop Performance Budgeting System to Serve Maintenance Management." This study is designed to accomplish essentially the same thing in the field of maintenance on a national level as we are attempting to do on the state level. It is anticipated that Minnesota's study will yield new knowledge and methods of applying program-budgeting to the entire field of highway administration.

In order to obtain the forementioned objectives, we divided our study into four major phases of effort.

<u>Phase I</u>—Steps were taken to develop a concept of program-budgeting appropriate for the Department of Highways. During this phase, necessary liaison with the Commissioner and officials of the department led to identification of major programs and work activities of the department and their relationship to one another. In addition, units of work output were identified and major costs associated with each program were determined. We then devised budget documents necessary for the department's internal budget in a format suitable for presentation to the Legislature.

<u>Phase II</u>—Steps were taken to develop a concept for reporting data to top management. First, the type of reporting best suited for the Department was determined. Next, the management information requirements of the Commissioner, the Deputy Commissioner and the five assistant commissioners were defined. During this step, the format and frequency of reports were determined.

<u>Phase III</u>—Appropriate procedures for the program-budgeting system were developed. The timetable for preparation of the department's budget was established as well as the design of the budgeting request forms. Procedures were developed to provide for budget request review, revision and approval. Items that should be included in each chapter of a budget manual were identified so that the budget and financial planning office could prepare an effective manual outlining the program budgeting process.

<u>Phase IV</u>—The actual system for reporting data to management was designed. This phase provided for a listing of accounts to meet internal and external requirements. The method and frequency for collecting and processing source data were then developed. In addition, data-processing output forms were developed to provide necessary information for the various levels of management. To complete this phase, the comprehensive systems design manual was prepared.

Throughout the entire course of the study, considerable emphasis has been placed on continually consulting with all levels of Highway Department management, particularly the Commissioner and his staff. In addition, a number of meetings have been held with the Governor, members of the Highway Legislative Interim Commission, the State Commissioner of Administration and representatives of the Bureau of Public Roads. These contacts alerted the study team to required budgeting information and assured them that their revised procedures would meet these needs.

The Governor and his Commissioner of Administration have expressed a strong interest in this subject and have announced as their goal the indoctrination and installation of program-budgeting methods in all departments of state government.

Concurrently, the Governor, through his state planner, has strongly oriented his near and far term overall state planning to automation and the concept of planning programs on a program basis. This latter effort on the part of the state planner is currently awaiting approval of a rather comprehensive program to be partially funded with Federal money.

In summary, I assure you that the transition to this new system was not as simple as this presentation may make it appear. On the other hand, we have found the program budget to be a management tool that can improve management's long-range planning, fiscal budgeting, performance evaluation, and decision-making. The program-budget achieves these benefits in the following ways:

- It reflects the objectives, goals, and policies of our organization;
- It indicates approved plans and work programs geared to meeting these goals and objectives;
- It provides a financial picture that indicates the cost as related to expected results in carrying out the work programs; and
- It presents results reflecting work output and cost.

In this paper, I have mentioned forms, standards, scheduling techniques, reports and budgeting several times. Examples of forms and other controls are given in Appendices A through I.

Appendix A

Maintenance Standards Manual—Field (5-792)

The Maintenance Standards Manual—Field is a loose-leaf manual which includes the work time standards for field maintenance operations for the Minnesota Highway Department.

All field maintenance operation standards have been divided into sections according to the cost control numbers listed under the subactivities (see Appendix I for example). The standards within each section are assigned an operation number for reporting purposes.

A summary of pertinent information regarding the standards for snow and ice control are given on the sample index sheet 5-792.42-00.

A description of each operation which has been standardized is given on standards sheets in each section of the manual. A sample from section 42, Snow and Ice Control, is shown on sheet 5-792.42-01.

The information in this manual is used basically to plan daily and longer range activities. The standards are based on time study work measurement. The figures in this manual are also used to develop performance reports.

DEC. 1, 1967 MAINTENANCE STANDARDS - FIELD 5-792.42-00

42 - SNOW AND ICE

Operation No.	Operation Description	Crew Size	Units Per Crew Hour	Unit of Measure	Standard Man Hours Per Unit
42-01	Snow Removal - Truck Plow				
A		2	17.7	Lane Mile	0.11
B		1	14.2	Lane Mile	0.07
42-02	Snow Removal - Motor Grader	1	5.2	Lane Mile	0.19
42-04	Snow Removal, Shoulders - Truck Plow and/or Wing				
A		2	14.0	Shldr. Mile	0.13
B		1	12.9	Shldr. Mile	0.08
42-05	Snow Removal, Shoulders - Motor Grader	1	7.1	Shldr. Mile	0.14
42-06	Snow and Ice Removal - Motor Grader	1	7.7	Lane Mile	0.13
42-07	Snow and Ice Removal - 10 Ton Truck	2	6.0	Lane Mile	0.32
42-08	Crush Ice - 10 Ton Truck	2	11.0	Lane Mile	0.17
42-09	Snow Removal - Bridge				
42-10	Snow Removal - Rotary Plow	2	3.0	Mile	0.71
42-11	Snow Removal - Crossovers	1	5.9	Crossover	0.17

OPERATION.	SNOW REMOVAL - TRUCK PLOW		OPERATION NUMBER: 42-01
Description·	Load sand and chemicals. Plow snow from roadway, use wing plow and chemicals if necessary Make equipment adjustments and change cutting edges as required. This standard is not to be used for shoulder plowing (see Standard 42-04).		
Reference·	Maintenance Manual 5-791.360, 362 and 364		
Equipment:	Section truck with plow, wing (optional) and sand spreader. Wrenches (for cutting edges)		
Material.	Sand and chemicals for ballast or spreading Spare cutting edges		
Method.	A	B	
Basic Crew:	Two	One	
Unit of Measure:	Lane Mile	Lane Mile	
Man Hours Per Unit:	0.11	0.07	
Crew Hours Per Unit·	0.06	0 07	
Units Per Crew Hour.	17.7	14.2	

OPERATION:	SNOW REMOVAL - MOTOR GRADER	OPERATION NUMBER: 42-02
Description.	Plow snow from roadway using wing plow when necessary. Make equipment adjustments and change cutting edges as required. This standard is not to be used for local cleaning operations or shoulder plowing.	
Reference.	Maintenance Manual 5-791.360, 362 and .364	
Equipment:	Motor Grader equipped with wing plow. Wrenches (for cutting edges)	
Basic Crew.	One	
Unit of Measure:	Lane Mile	
Man Hours Per Unit:	0.19	
Units Per Man Hour:	5.2	

Appendix B

Maintenance Standards Manual—Shop (5-793)

The Maintenance Standards Manual—Shop includes the work time standards for equipment shop maintenance operations.

Included in this appendix are sample sheets from the manual. Sheet 5-793.00-02 is the preface to the manual and explains the purpose and basis for the shop standards.

Sheet 5-793.01-00 is a sample index sheet of the inspection, lubrication and service section. In cases where a standard has not yet been written due to insufficient time study analysis, the standard manhours column is left blank. If an operation does not apply to a particular classification of equipment, a dash (-) has been entered.

Sheet 5-793.01-01 shows sample shop standards.

SEPT. 15, 1967 MAINTENANCE STANDARDS - SHOP 5-793.00-02

PREFACE

The Maintenance Standards - Shop Manual has been prepared to assist the shop foremen in the scheduling and reporting of shop operations. The time standards in this manual are based solely on time studies that were conducted in all of the seventeen shops. The standards attempt to represent the most efficient methods observed in actual shop operations. The standards reflect the time it should take for a qualified operator with normal skill and expending normal effort to do a particular job under normal conditions and surroundings during a full eight hour day. Sufficient time is allowed to complete an operation without any sacrifice in the quality of workmanship.

The standards include allowances for personal and rest time. These allowances are quite liberal and even the least fatiguing jobs are allowed more than twice the time set for the morning and afternoon breaks by department policy. It has been determined by industrial engineering experience that these allowances are not only fair, but necessary for maximum efficiency on the job.

It is expected that there will be variations in the types and availability of shop tools and equipment from shop to shop as well as differences in the shops themselves. These variations will cause corresponding variations in the performance of the area shops. Variations will also occur due to the differences in pace among the mechanics. One may expect higher performance from experienced mechanics than from apprentices because of differences in familiarity with the operations.

The standards listed in this manual are based on an average of observations in many shops, on many types and ages of units and under varying working conditions; therefore, there is no warrant for classifying any of the standard operations as non-standard based on the variations discussed in the previous paragraph. The only work to be labeled non-standard is work not yet included in the manual, extensive (longer than normal) diagnosis time and work not directly related to normal shop activity. There is some work that will not be standardized since it is performed too infrequently or the time required for the operation varies too much to justify writing a standard.

The standards can be used to schedule operations. If the foreman knows that a certain operation is to be performed on a given number of units, he can compute from the standard the total number of hours required to complete the job. The number of men required to complete inspections on all units in a district can be computed in the same manner. The standards can also be compared to the work output to develop more efficient shop operations. It should be remembered, however, that quantity must not be substituted for quality and that very high performance may indicate a lowering of quality standards rather than improved efficiency. Similarly, low performance may indicate that more than necessary emphasis is being placed on quality.

The standards should not be used to compare the work of individual mechanics as the standards are not intended to be a rating guide for merit. The differences in the shops referred to above make fair ratings of individuals difficult if not impossible.

Revisions and supplements for this manual will be issued periodically. As the standards are used, all employees are encouraged to offer suggestions for their improvement. Any information concerning obsolete methods, discrepancies, deletions or additions should be forwarded to the Maintenance Standards Engineer on the form provided on the following sheet.

01 - INSPECTION, LUBRICATION SERVICE

Operation No.	Operation Description	Standard Time Man Hours Per Unit					
		A	B	C	D	E	F
01-01	Lubrication and Service (with Grease Fittings)	1 2	1.3	2.2	0.4		
-02	Lubrication and Service (with Grease Plugs)	1.3	–	–	–	–	–
-03	Lubrication and Service (without Greasing)	1.1	–	–	–	–	–
-04	Wash Unit	0.7	0.7	1.2			
-05	Clean Unit Complete (for Inspection)				1.0		
-06	Steam Clean Unit Complete						
-07	Clean Engine in Chassis			0.6			
-08	Clean Engine Out of Chassis						
-09	Daily Service	0.4	0.4	0.4			
-10	Engine Tune Up	2.1			1.4		
-11	Preventive Maintenance Inspection	4.0	4.1	5.5			
-12	Annual Maintenance Inspection				8.2		
-13	Road Test	0.4	0.4	0.4			
-14	Air Cleaner (Dry), Service	0.1	0.1	0.1			
-15	Air Cleaner (Oil Bath), Service		0.2	0.2			
-16	P.C.V. Valve, Service		0.3	0.3			
-17	Transmission (Manual), Drain and Refill	–					
-18	Transmission (Automatic), Drain and Refill	0 2	0.2				
-19	Transmission and Torque Convertor (Automatic), Drain and Refill	0.7	0.7				
-20	Differential, Drain and Refill	0.4	0.4	0 4			
-21	Transmission Drop Gear Case, Drain and Refill						
-22	Transfer Case, Drain and Refill						
-23	Strip for Trade (Central Shop)	0.5	0.5				
-24	Strip for Trade (District)						
-25	Strip Patrol Car for Trade (Central Shop)	2.9	–	–	–	–	–

A - Cars, B - Pickups or Carryalls, C - Trucks, D - Tractors, E - Motor Graders, F - Four Wheel Drive Loaders

OPERATION:	**LUBRICATION AND SERVICE (WITH GREASE FITTINGS)**				**OPERATION NUMBER: 01-01**	
Description:	Change oil, filter, general inspection and service, lubricate as required. For a complete description, see Maintenance Manual 5-791.416 or Lubrication and Service Instructions, Form No. 17234.					
Classification:	A	B	C	D	E	F
Man Hours Per Unit:	1.2	1.3	2.2	0.4		
Units Per Man Hour:	0.8	0.7	0.5	2.5		

OPERATION:	**LUBRICATION AND SERVICE (WITH GREASE PLUGS)**	**OPERATION NUMBER: 01-02**
Description:	Change oil, filter, general inspection and service, install and remove grease fittings, lubricate as required. Use manufacturers' recommended lubrication interval. For a complete description, see Maintenance Manual 5-791.416 or Lubrication and Service Instructions, Form No. 17234.	
Classification:	A	
Man Hours Per Unit:	1.3	
Units Per Man Hour:	0.8	

OPERATION:	**LUBRICATION AND SERVICE (WITHOUT GREASING)**	**OPERATION NUMBER: 01-03**
Description:	Change oil, filter, general inspection and service, lubricate as required except sealed lubrication fittings. For a complete description, see Maintenance Manual 5-791.416 or Lubrication and Service Instructions, Form No. 17234.	
Classification:	A	
Man Hours Per Unit:	1.1	
Units Per Man Hour:	0.9	

OPERATION:	**WASH UNIT**				**OPERATION NUMBER: 01-04**	
Description:	Wash exterior, clean interior, clean windows.					
Classification:	A	B	C	D	E	F
Man Hours Per Unit:	0.7	0.7	1.2			
Units Per Man Hour:	1.5	1.5	0.8			

OPERATION:	**CLEAN UNIT COMPLETE (FOR INSPECTION)**				**OPERATION NUMBER: 01-05**	
Description:	Wash complete unit including underside with solvent and Graco cleaner or equivalent in preparation for inspection.					
Classification:	A	B	C	D	E	F
Man Hours Per Unit:	1.0			1.0		
Units Per Man Hour:	1.0			1.0		

Appendix C

Field Daily Schedule and Report (Form 17223)

This form is used by all field maintenance personnel and is a daily report of all operations performed, locations, crew members assigned and equipment utilized. In addition, all manhours are reported in the proper columns along with work units done.

The form is used as a schedule by preparing columns I through V prior to performing the work. The remainder of the form is completed after the work is performed. (In areas where work is scheduled on magnetic wall boards, this form is used only as a report.)

A separate form is made out daily for each reporting station. All operations performed are reported separately on the sheet. At least eight hours are accounted for each day per employee.

Columns M and N are completed by the office staff, obtaining proper standards hours from the Maintenance Standards Manual—Field (5-792). The totals are carried forward to the Weekly Performance Worksheet (Form 19190) for analysis.

After the office work is completed, this form is returned to the originating station for filing as a diary.

Form 17223 (' 8)

MINNESOTA HIGHWAY DEPARTM· T MAINTENANCE OPERATIONS

FIELD DAILY SCHE··LE AND REPORT

TRUCK STATION CREW OR SUB AREA ____ PREPARED BY ____ DAY OF WEEK ____ DATE ____

I	II	III	IV	V	VI ACTUAL MAN HOURS											Office Use Only	
OPERATION DESCRIPTION	OPER NUMBER	CONTROL SECTION TRUNK HIGHWAY AND SPECIFIC LOCATION	CREW ASSIGNED	EQUIP UNITS AS SIGNED	Standard Work	Non Std Work	Travel	Safety	Delays (Explain on Back)	Super vision	Meetings	Vacation	Sick Leave	C.O. Taken	WORK UNITS DONE	Std Man Hrs Per Work Unit	Std Man Hrs (L x M)
					A	B	C	D	E	F	G	H	J	K	L	M	N
1																	
2																	
3																	
4																	
5																	
6																	
7																	
8																	
9																	
10																	
11																	
12																	
WEATHER CONDITIONS				TOTALS													

ITEM NUMBER	EXPLAIN ALL DELAYS, CONTRIBUTING CIRCUMSTANCES AND ANY OTHER NOTES BELOW (MAKE REFERENCE TO ITEM NUMBERS GIVEN ON FRONT SIDE)
○	
○	
○	
○	
○	
○	
○	
○	
○	
○	
○	

SPECIAL INSTRUCTIONS

1 This report shall be prepared daily Reports for a week's period, Wednesday through and including Tuesday, shall be submitted to the Area Office on Wednesdays
2 Men loaned out will be entered only as to name, location and assigned equipment taken with him Also make an entry explaining what reporting station he is loaned out to Men borrowed shall be entered just as permanently assigned personnel
3 Travel time between major job sites as well as travel time to and from job site shall be charged to Column C Travel at the job site shall be charged to Columns A or B
4 Time spent flagging and moving temporary barricades and signs for safety purposes will be charged to Column D
5 Delays over 30 minutes are charged to Column E Delays under 30 minutes can be included in Columns A or B
6 Time spent by a Sub Area foreman or intermittent foreman in a supervisory capacity will be charged to Column F
7 All entries must be complete and accurate Special attention must be given to the entries of control section numbers and work units done These are essential for cost accounting purposes
8 Following processing of the forms by the office this form will be returned to the originating section to be filed as a diary

Appendix D

Weekly Performance Worksheet (Form 19190)

This form serves as a worksheet in computing percent productive work, performance and coverage of field, shop and traffic maintenance operations. Entries for columns A through N are carried forward from Form 17223 and Form 1745. The data are summarized as shown in boxes P through V.

Following the transferring of the weekly totals and summary information from this form to Form 19189, the worksheet is given to the subarea foreman for his records.

Form 19190 (4-68)

MINNESOTA HIGHWAY DEPARTMENT MAINTENANCE OPERATIONS

WEEKLY PERFORMANCE WORKSHEET

☐ Sub Area,
☐ Shop,
☐ Station or
☐ District Crew ________ Maint Area ________ Week Ending ________

DAY OF WEEK	DATE	ACTUAL MAN HOURS										STD MAN HOURS
		STD WORK	N STD WORK	TRAVEL	SAFETY	DELAY	SUPER-VISION	MEET-INGS	VACA-TION	SICK LEAVE	COMP TIME	
		A	B	C	D	F	F	G	H	J	K	N
Wednesday												
Thursday												
Friday												
Saturday												
Sunday												
Monday												
Tuesday												

COMMENTS

SUBTOTALS	A	B	C	D	E	F	G	H	J	K	N

SUMMARY				
	Total Productive Work Hrs A+B P	Total Incidental Work Hrs C+D+F+F+G Q	Total Leave Pay Hours H+J+K R	Total Hours Reported P+Q+R S
	% Productive Work P (P+Q) T	% Performance N - A L	% Coverage A - P V	

Appendix E

Weekly Performance Report (Form 19189)

All the data tabulated on Form 19190 (Appendix E) for an entire maintenance area are tabulated and summarized on this report. This report is submitted to the Area Maintenance Engineer, the Office of Maintenance Standards and other interested people. It serves as a management tool in that it provides information such as percent productive work, percent performance as compared to standards and percent of work performed which was covered by standards.

The Office of Maintenance Standards summarizes these reports and prepares a statewide analysis for top management personnel.

Form 19189 (4-68)

MINNESOTA HIGHWAY DEPARTMENT MAINTENANCE OPERATIONS
WEEKLY PERFORMANCE REPORT

Distribution
☐ Original to Area Maintenance Engr
☐ Copy to Maintenance Stds Rm 316
☐ Copy to District Engineer
☐ Copy to District Foreman

MAINT AREA ____________________ WEEK ENDING ____________________

SUBAREA DISTRICT CREW OR TRUCK STATION	PROD WORK HRS		INCIDENTAL WORK HOURS					LEAVE PAY HOURS			Std Man Hours	TOTAL HOURS				% Prod Work	% Perf	% Cov
	Std Work	N Std Work	Travel	Safety	Delay	Supervision	Meetings	Vac	Sick Leave	Comp Time Taken		Prod Work	Incidental Work	Leave Pay	Total Hours Reported			
	A	B	C	D	E	F	G	H	J	K	N	P	Q	R	S	T	U	V
1																		
2																		
3																		
4																		
5																		
6																		
7																		
8																		
9																		
10																		
11																		
12																		
13																		
14																		
SUMMARY: ROAD MAINTENANCE																		
SUMMARY: EQUIPMENT MAINTENANCE																		
SUMMARY: TRAFFIC SERVICES																		

FORMULAS

P = A+B
Q = C+D+E+F+G
R = H+J+K
S = P+Q+R
$T = \frac{P}{P+Q}$
U = N/A
V = A/P

COMMENTS

Appendix F

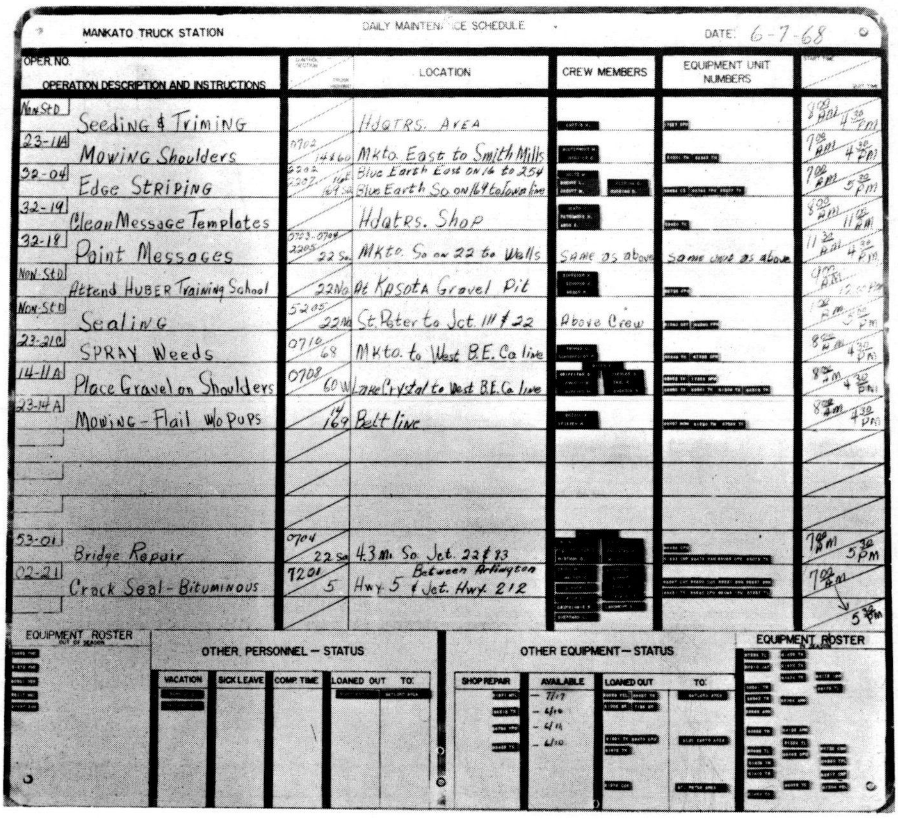
Daily Maintenance Scheduling Board

To facilitate scheduling of field maintenance operations, a number of the Department's larger reporting stations have prepared magnetic scheduling boards. An example of a typical board designed for a 46-man station is attached. The boards are made of sheet steel (approximately 1/16 in. thick) which is covered with white adhesive backed material. Contrasting lines and column headings are placed on the board. The board is then covered with a sheet of clear acetate.

Entries are made for operations and location using grease pencil which can be easily erased with a clean cloth. For the other entries (employee and equipment assigned), labels are made using 1/2-in. magnetized rubber strips. These labels adhere magnetically wherever placed on the board. Only one label is made for each man and piece of equipment. This avoids forgetting to schedule a man or scheduling a certain piece of equipment to more than one job at one time. Labels for equipment not in use but available are placed in the equipment roster boxes, depending on whether it is in or out of season.

Other designs and materials can and have been used in some of the board designs. For instance, blackboard paint and chalk can be used instead of the grease pencil approach.

Whatever the design, the function of the board remains the same. A supervisor can easily schedule and organize his operation in a manner which takes very little time. Verbal orders are necessary only in special cases as the employees merely look at the scheduling board to find out what job they have been assigned to. Scheduling is done the night before and changes resulting from weather condition changes overnight can easily be made in the morning.



Appendix G

Shop Order and Record (Form 1745)

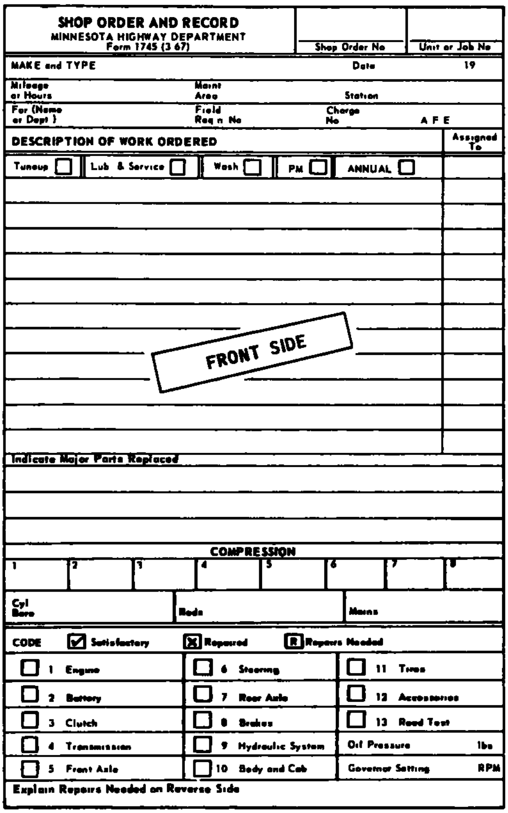
The Shop Order and Record is designed to be used to assign and record all shop work performed on equipment. The card is printed in each of two colors; buff for regular shop work and pink for the Preventive Maintenance and Annual Inspections. This facilitates filing all cards together and still being able to locate with ease records of special inspections or overhauls.

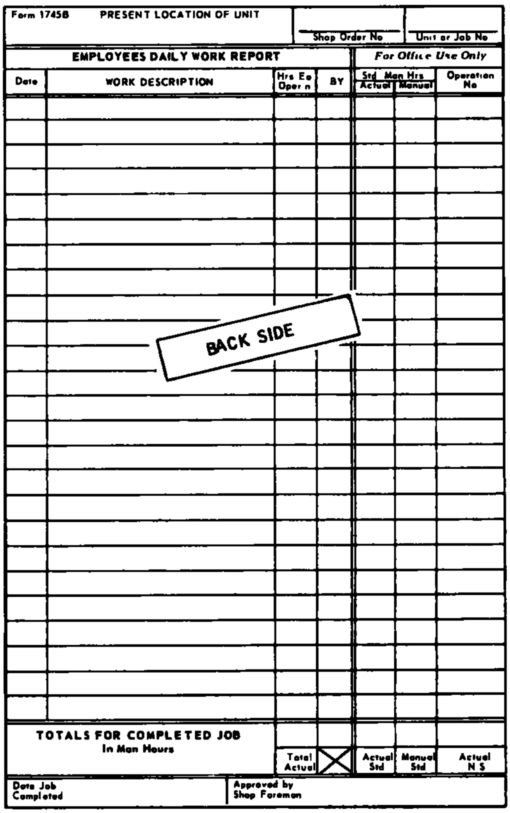
Upon receipt of a Unit Service Request from the Unit Service Book (Form 1743), the shop foreman will prepare the upper portion of a Form 1745. Shop order cards will be numbered consecutively. Descriptions of work ordered will be entered and assigned to mechanics in the spaces provided. The card will then be placed in the assignment box opposite the mechanic's name who is assigned to work on the unit.

The mechanic, following completion of the work, will properly record each operation performed by him on the back side of the card along with date, hours spent on each operation and initials.

Spaces are provided on the front of the card for major parts replaced, compression readings, etc. Notes are made where indicated on the card when a need for further repairs is uncovered.

Upon completion of all assigned work on the card, it is turned in to the shop foreman who approves the work by signing the card, sees that proper entries are made in the unit service book and arranges for placing the unit back into service.


SHOP ORDER AND RECORD
MINNESOTA HIGHWAY DEPARTMENT
Form 1745 (3 67)
Shop Order No
Unit or Job No
MAKE and TYPE
Date
19
Mileage or Hours
Maint Area
Station
For (Name or Dept)
Field Req'n No
Charge No
A F E
DESCRIPTION OF WORK ORDERED
Assigned To
Tuneup
Lub & Service
Wash
PM
ANNUAL
Indicate Major Parts Replaced
COMPRESSION
1 2 3 4 5 6 7 8
Cyl Bore
Rods
Mains
CODE Satisfactory Repaired Repairs Needed
1 Engine
6 Steering
11 Tires
2 Battery
7 Rear Axle
12 Accessories
3 Clutch
8 Brakes
13 Road Test
4 Transmission
9 Hydraulic System
Oil Pressure lbs
5 Front Axle
10 Body and Cab
Governor Setting RPM
Explain Repairs Needed on Reverse Side


Form 1745B
PRESENT LOCATION OF UNIT
Shop Order No
Unit or Job No
EMPLOYEES DAILY WORK REPORT
For Office Use Only
Date
WORK DESCRIPTION
Hrs Eq Oper'n
BY
Std Man Hrs Actual Manual
Operation No
TOTALS FOR COMPLETED JOB In Man Hours
Total Actual
Actual Std
Manual Std
Actual N S
Date Job Completed
Approved by Shop Foreman

The shop foreman or his delegate then applies standard times (Manual) along with standard operation numbers in the proper columns on the back. This information is obtained from the Maintenance Standards Manual—Shop (5-793). Columns are totaled and carried forward onto analysis sheets by office personnel for use in cost accounting and shop performance evaluation.

Before filing the cards into the shop foreman's unit file, proper entries (if needed) are made in the visual Equipment Inspection Schedule and Record card system, Form 17243.

Appendix H

Equipment Inspection Schedule and Record System (Form 17243)

Preventive maintenance inspections, lubrication and service inspections, tune-ups, etc., performed on all motorized equipment are recorded and scheduled on Form 17243 in a visual file. This file is located in the shop foremen's office.

Using a code letter (like L for Lube and Service) an entry is made on the unit card in the date box corresponding to when the service was performed. The mileage reading is entered following the letter code. Each unit has its own card on file. Each card lasts one year although we are now printing both sides of the card so it will last 2 years.

The title card (Form 17243A) is designed to be inserted on top of Form 17243 in the files. This title card will remain in the file for the life of the unit (it will not be replaced every year as Form 17243). This eliminates the need for re-writing the items such as "Make and Type," "Assigned to," "Located at," etc., which generally do not change every year. Space is also provided to enter years of major overhauls.

A unique feature of this system is the scheduling system which this card and filing system provides. Since this is a visual file, colored signals are placed in the proper position over the "month" spaces to indicate when the next inspection, service, etc., are expected to be due. Simply by glancing at a drawer full of these cards, the shop foreman can pick out which units are overdue, which ones are due and which ones are not due yet for preventive maintenance work. Whenever a service is performed, rescheduling is done by moving the proper signal forward.

As a result of this system, the shop foreman has at his fingertips, a complete record of recent inspections and services, a historical account of major overhauls since the unit was purchased and a scheduling system which he can use to plan and control his shop operations. The cards are versatile in that some shop foremen keep track of additional items on the cards such as wheel bearing packing, replacing antifreeze, etc.

Form 17243 EQUIPMENT INSPECTION SCHEDULE AND RECORD MINNESOTA HIGHWAY DEPARTMENT

Day / Mo	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	Day / Mo
JAN																																JAN
FEB																																FEB
MAR																																MAR
APR																																APR
MAY																																MAY
JUN																																JUN
JUL																																JUL
AUG																																AUG
SEP																																SEP
OCT																																OCT
NOV																																NOV
DEC.																																DEC

CODE		COLOR	REMARKS
LUBE & SERV	L		
TUNE UP	T		
PM INSP	PM		
UNIT NUMBER		CLASS	YEAR

CODE		COLOR	INTERVAL	MAKE AND TYPE	DATE OF OVERHAULS (YEAR)	
LUBE & SERV	L				VALVES	CLUTCH
TUNE UP	T				RINGS	TRANS
PM INSP.	PM			ASSIGNED TO	MAINS	DIFF
					ROD BRGS	BRAKES
				LOCATED AT		

UNIT NUMBER	CLASS	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	

Form 17243A TITLE CARD - EQUIPMENT INSPECTION SCHEDULE AND RECORD

(to be placed over lower portion of Form 17243)

Appendix I

Maintenance Program in the Program Budget System

This sample sheet illustrates part of the Maintenance Program and its various levels of effort, outputs and applicable coding.

The levels of effort are indicated in the alignment and relationship under the column headed Sub-program, Activity, Sub-activity, etc. The work output unit to be recorded and summarized accordingly is indicated under the Work Output Unit Identification column. The cost dollars associated and collected for these work output units produces the Performance Measurement Units, as depicted within that column. The process of charging both dollars and output efforts into the system is accomplished by the Program Budget Code, as outlined therein.

PROGRAM BUDGET
MAINTENANCE

PROGRAM BUDGET CODE	SUB-PROGRAM	ACTIVITY	SUB-ACTIVITY	WORK OUTPUT UNIT IDENTIFICATION	PERFORMANCE MEASUREMENT UNIT IDENTIFICATION
XXXX	Program Administration				
3198		Administration			
3199		Fringe Benefits			
3195		Safety, Civil Defense and Training			
3510		Road Permits and Regulations			
XXXX	Field Operations Sub Program				
3201		Sub Program Administration			
XXXX		Roadway Surface			
3212			Surface Repair (01, 02, 62, 63, 65, 66)	Lane miles serviced	Cost per lane mile
3213			Crack and Joint Filling (61)	Lineal feet filled	Cost per lineal foot
3214			Mudjacking (64)	Square yards repaired	Cost per square yard
3220		Shoulder and Approach (14, 62)		Shoulder miles repaired	Cost per shoulder mile
XXXX		Roadside Maintenance			
3232			Drainage Maintenance (22, 67)	Ditch miles cleaned	Cost per ditch mile
3233			Slope Repair (21)	Road Miles repaired	Cost per road mile
3234			Mowing, Weed and Brush Control (23)	Acres worked	Cost per acre

Approach to Maintenance Management

L. C. JONES, Bureau of Street Maintenance, Department of Public Works, City of Los Angeles

The Bureau of Street Maintenance is one of twelve Bureaus which make up the Department of Public Works of the City of Los Angeles. The Bureau is responsible for four major functions which are assigned to four functional divisions:

Street Maintenance Division

Cleaning, repairing, resurfacing, minor reconstructing and remodeling, trench replacing, structural maintenance, and other maintenance activities.

Street Tree Division

1. Trimming, maintaining, regulating of planting, and supervising and administering tree contracts.
2. Maintaining lawns and other plantings in approximately 90 acres of traffic islands.

Lot Cleaning Division

1. Cleaning lots and removing weeds at least once a year on approximately 30,000 parcels of vacant property.
2. Removing brush in hilly areas, along roadsides, and adjacent to improved properties, as requested by the Los Angeles Fire Department.

Street Use Inspection Division

1. Regulating the use of streets and other public ways for any and all purposes other than normal pedestrian and vehicular traffic, including the following: (a) utility substructures, excavation, and backfill; (b) storing of building materials; (c) transportation of overloads and housemoving; (d) banners over streets, advertising benches in public ways, etc.; and (e) serving of notices to repair curbs, sidewalks, driveways, etc.
2. This division is also the enforcement arm of the Department of Public Works.

In addition to the four functional divisions, we have an Equipment and Supply Division which is a service organization that purchases and maintains equipment and supplies for all functional Divisions.

The city encompasses an area of 463.60 square miles, with elevation ranging from below sea level to 5,074 feet. Its street system consists of 7,275 miles of streets and public ways, with grades from practically 0 to 33 percent. It also includes shoestring strips which connect sections of the city. Other areas completely surround incorporated and unincorporated areas. From the northern-most to southern-most points of the city, the distance is 55 miles. It has areas which are changing in character, including the San Fernando Valley which comprises about 40 percent of the city and is rapidly changing from areas comprised of orange groves and agricultural cultivation to fairly dense urban areas. Narrow dirt roads are becoming wide-paved boulevards. The city has a total population of 2,896,100 and a very heavy vehicle registration.

The Bureau of Street Maintenance has a complement of approximately 2300 regular Civil Service employees, a budget for the current fiscal year of over $27 million, and an equipment fleet of approximately 1900 units. The city has two zone divisions, with three maintenance areas in each zone, and four maintenance districts in each area.

In speaking of the Bureau's approach to maintenance management, one could select at random any of a number of our operations. However, I shall confine the subject to a particular aspect of our work, the application of industrial engineering principles to the work of the Street Maintenance Division.

The program had its beginning in 1960 when it was suggested that the Director of the Bureau discuss a possible contract agreement with a consulting firm to undertake a survey of our operations. We were not impressed with this idea; our reaction was that this would be just another survey, and we had undergone many surveys in the past ten years. You might even say that we had surveys of surveys, and all by reputable firms. Our experience was that these firms would come in with their staff, study our operation, publish a report detailing the problems that had been described to them by members of our own staff, and depart. Normally, the approach was always the same, with very little original work on their part. They provided the report and you were then on your own. Therefore, when we were approached with this proposal, we were something less than enthusiastic. However, as this firm explained their program, we recognized that theirs was a fresh approach. They offered to practically live in the Bureau, selecting and then training our employees in the techniques of the work, implementing the work, and then staying on for a period of several months to guarantee that the system they had developed was sound, properly installed, and working. Since the proposed system had never been applied to street maintenance operations, we were still cautious and, instead of buying the entire proposal advanced, only a portion of the program was selected.

This, then, was the start of the application of industrial engineering principles to a considerable portion of the work of the Street Maintenance Division. The first activity of the consulting firm was to select, by special examination, a group of methods and standards technicians composed of our own employees. This appears to us to have been one of the keys to the success of this program. The selection of technicians was made impartially and objectively as the result of a battery of tests supplied and conducted by the consultants and with no interference from management. Following the selection and training, the methods and standards section was activated and work started. There followed a period of 17 weeks of study during which they scientifically analyzed the work assigned to the crews, the work assigned to each man in each crew, and each essential movement of every man in the crew. They then measured and tabulated the enforced delays, or the waiting time, when only one operation can be performed at a given time, and the balance of the crew must wait. Figure 1 is a typical illustration of the studies that were made of crew sizes. Note particularly the "idle time," or enforced delays, which are so prominent in the three- and four-man crews, as compared to the comparatively small amount of such time in the two-man crew.

Figure 2 summarizes the delays (Fig. 1). Note the difference in crew costs per day and the delay cost per day for each crew size. The lower section, relates the crew costs to the cost per individual job.

Following this study, they were ready with charts to prove their points and to present their first recommendation—that 21 four-man crews be reduced to two-man crews. This recommendation was, as anticipated, immediately questioned to varying degrees by many of the supervisors.

After a number of discussions, consultations, and deliberations, the first of a series of crew size recommendations was adopted. The crew sizes were reduced by attrition. A total of 149 maintenance laborer positions were eliminated from a total of 472 employees initially placed under time standards. In conjunction with attrition, there was an upgrading of 32 field positions. With the establishment of two-man crews, it was necessary that one man be in charge and responsible for the paper work, so a special code of crew leader was established, which provided a premium of $1.20 per day for this responsibility.

The reduction of crew sizes is not the sole purpose of a trained staff methods and standards section. Using methods and procedures developed by this staff section, the hours reported by the crew for daily and job site preparation; travel to job sites, asphalt plants, dumps; and return to district yards is compared against a time standard which has been engineered for that or those jobs.

Figure 3 is a typical sample of one of the source documents, showing the miles traveled, material used, locations, and type and amount of work done by a two-man small bituminous repair crew.

Figure 4 shows the standards technician's recap of the crew for a typical day's work. This is the reverse side of the daily work sheet shown in Figure 3. Note that the workman has an example to follow. The actual performance received by the crew for the work recorded is 74 percent.

The weekly performance for each crew is calculated. Thus, although the crews and work in our City cannot be under constant supervision, a form of control has been established and is being extended gradually to all crews engaged in street maintenance work on a city-wide basis.

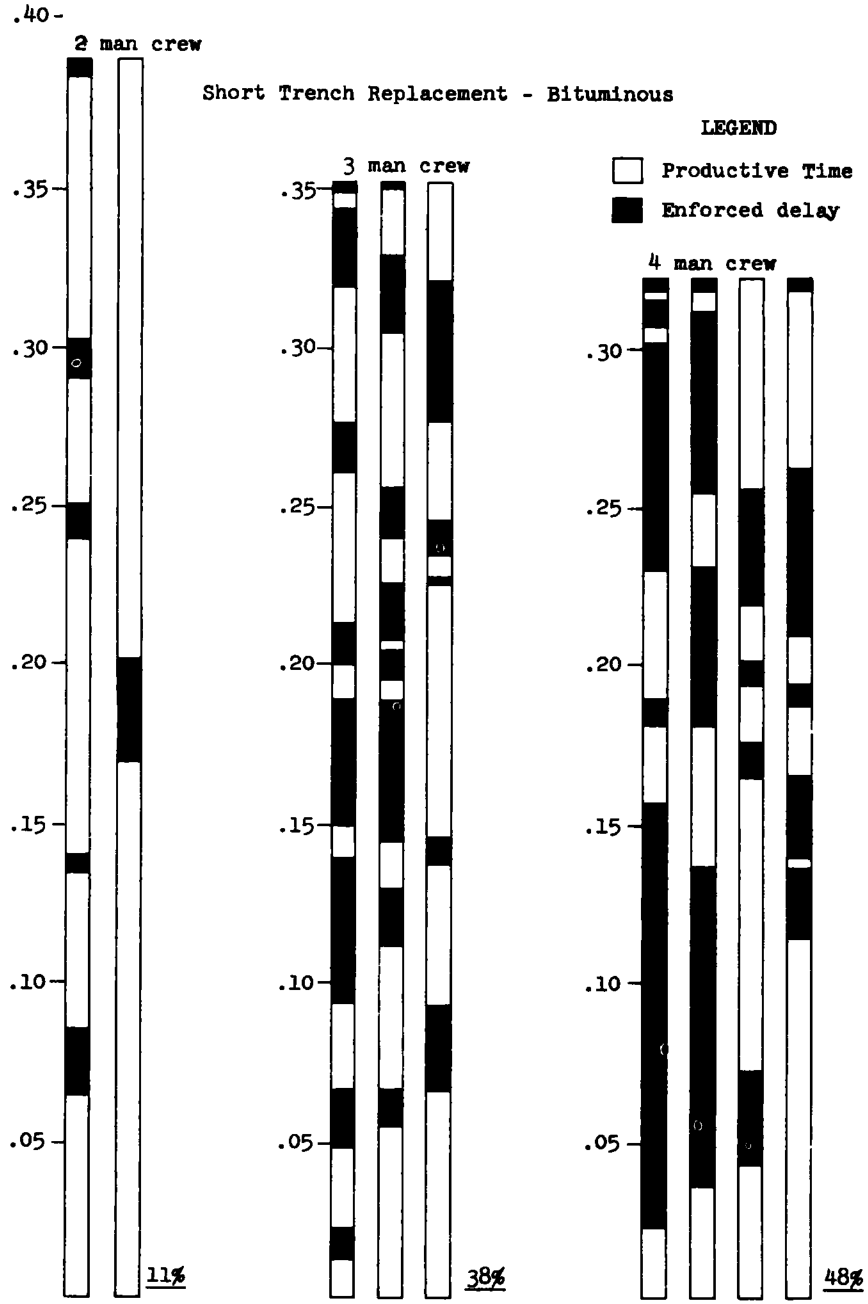


Figure 1. Engineered comparison of different sized crews performing the same operation.

COMPARISON OF DIRECT LABOR COST AND DELAY COST FOR VARIOUS CREW SIZES

CREW SIZE	CREW SIZE PER DAY	DELAY	
		AT___%	COST PER DAY
4	$87 04	48	$41 78
3	$66 72	38	$25 35
2	$46 40	11	$5 10

TYPICAL TRENCH (12 SQUARE FEET)

CREW SIZE	ELAPSED HOURS PER TRENCH	MAN HOURS PER TRENCH	DIRECT COST PER TRENCH
4	0 3225	1 2900	$3 51
3	0 3525	1 0575	$2 94
2	0 3900	0 7800	$2 26

Figure 2. Short trench replacement—bituminous.

This methods and standards section is also used to evaluate new equipment, to compare our methods and procedures with other organizations in similar work, and to suggest crew reassignments due to work backlogs in the various areas and districts. This section prepares and distributes management reports in graph form to all management levels concerning crew performances, hours utilized, and current work backlogs.

Figure 5 is a typical backlog of work report, showing the volume of trench replacing work in Zone I, on April 12, 1968, together with crews assigned, etc.

Figure 6 is a composite report depicting the function of "bituminous short trench" showing utilization of personnel on the assigned function, backlog in crew days of bituminous trenches and, most important, crew performance at that time, as rated by the standards technician. This report is placed in each respective district yard for review by the crew and the district foreman. Composite reports reflecting all crews doing this work and other types of work are compiled for the Director of the Bureau, and for four lower levels of supervision and/or management.

Decisions involving shifting of crews, budgetary needs, requests to meet workload requirements, and many other needs are simplified with this type of current information.

Subsequent to this initial program, additional installations have been made in other departments and bureaus of the City of Los Angeles: Department of Recreation and Parks, Department of Traffic, Bureau of Sanitation, and Bureau of Transportation.

This Bureau entered into a second contract with the same management firm to extend management control coverage to the Equipment and Supply Division. Mechanical repair standards were developed for the following:

1. Heavy-duty equipment: (a) graders, (b) skiploaders, (c) gradalls, etc.
2. Trucks (dumps, flushers, sweepers, etc.), and standards were developed to extend coverage for: (a) tire repair section, (b) auto electricians section, (c) sweeper broom shop section, (d) lubrication and preventive maintenance section, (e) machine shop section, and (f) engine rebuild section.

During fiscal year 1967-68, a third contract between the Bureau of Street Maintenance and the same consulting firm was signed to extend coverage to the resurfacing and special projects section of the Street Maintenance Division. In this third installation, a different approach from either of the first two was employed. At this time, we felt that our methods and standards section personnel were adequately trained to undertake the study, and a similar procedure was followed whereby the new technicians were sent to school for MTM training. Therefore, the management consulting firm was hired for guidance purposes only. In essence, the company made a survey and presented their findings in a programmed plan for controlling the installation.

The resurfacing and special projects section is composed of 351 employees. This section has the responsibility of the resurfacing and minor reconstruction of all streets, the repair of all bridges and tunnels, the operation of two municipal asphalt plants, and the necessary transportation of materials. We know that the elimination of positions from this section will not be as great as the initial installation because, following the initial study, several supervisors took their cue and immediately started to reduce crew sizes. However, we do feel that additional reductions will be made.

Crew Leader fill out and return to Foreman at end of each work day.

DAILY WORK SHEET
SMALL BITUMINOUS REPAIR

Speedometer Reading: Date 12-1-67

End of Day 45500 District No. 07

Beginning of Day 45450

Mileage for Day 50

Truck Number ______

Number of emergencies or radio calls (✓) 2

Dump Site Used Washington

Crew Members

1. Jones
2. Smith

Function No.	#44	#	#
Hours	8		
	8		

Plant Used P. #2

Material Drawn 4 Tons

LOCATION	E	SKIN PATCH			DIG OUT & REPLACE	DEPTH
Ethel and Oak		x	x	x	3 x 3	4'
Fulton and Elm		6 x 10	4 x 4	1 x 1	x	
		1 x 1	1 x 1	1 x 1	x	
		3 x 10	x	x	x	
Orchard and 90th St.		1 x 1	2 x 15	4 x 10	x	
Gaunt and Valerie		2 x 2	2 x 2	2 x 2	x	
		2 x 2	6 x 8	x	x	
11406 Vesper		x	x	x	3 x 2	5"
		x	x	x	4 x 2	5"
Dayton and Elm		7 x 2	6 x 5	5 x 5	x	
Lemon and Noble		4 x 10	3 x 9	4 x 10	1 x 1	4"
		x	x	x	1 x 1	4'
		x	x	x	x	
		x	x	x	x	
		x	x	x	x	
		x	x	x	x	
		x	x	x	x	
		x	x	x	x	

Crew Leader's Remarks and Other Work Section on reverse side.

M&S 240.11
R4 5/16/68

Figure 3.

Additional studies are contemplated, primarily along the lines of our third contract, Our next proposal will include the street cleaning operation, with other sections and divisions to follow.

To date, the installation of this MTM program within the Bureau has produced a net labor savings of $4,339,344. The savings due to increased production has been difficult to ascertain, due to the type of work. However, all crews are using from 25 to 100 percent more bituminous or concrete materials than prior to 1962. One indication of savings that occurred unexpectedly in the third year of management control was that

Crew Leader's Remarks: ____________________

For Use by Standards Technician

Total Miles Driven	50	Daily Earned Travel
Minimum Miles Allowed	30	2.60
Patrol Miles	20	

1. Craft Hours for Skin Patch 5.09
2. Craft Hours for Dig Out & Replace. 1.06
3. Other Work 10
4. Dump Delay Hours(0.20/dump). 20
5. Daily Prep. (0.88) & Plant Delay (0.66). . . 1.54
6. Site Preparation / Site 7 x .08 56
7. Total Craft Hours 8.55

E X A M P L E

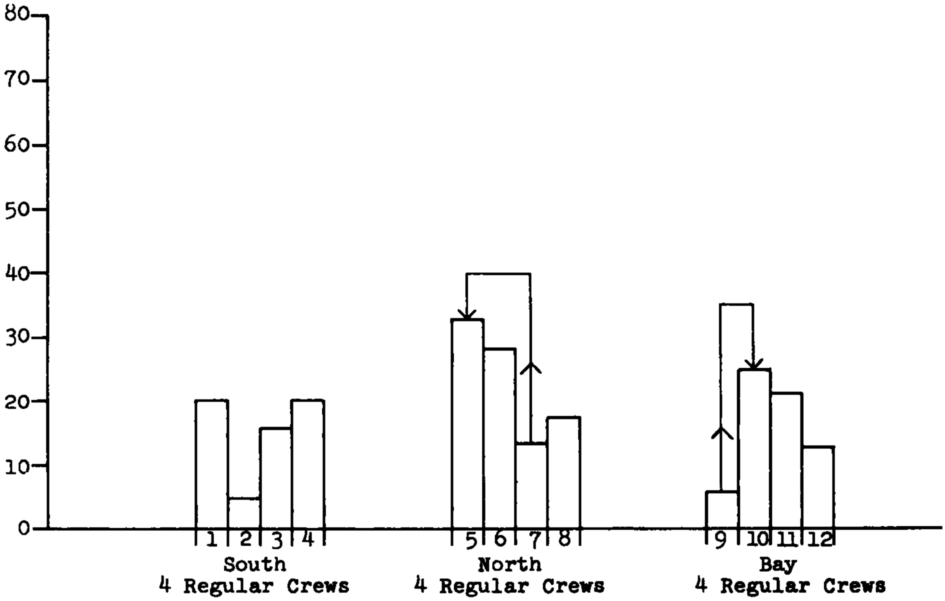
LOCATION	E	SKIN PATCH			DIG OUT & REPLACE	DEPTH
Lemon Ave. & Noble		4 x 10	3 x 9	6 x 7	2 x 1	5"
Fulton & Elm		6 x 10	4 x 4	x	3 x 2	5"
11406 Dayton Ave.		3 x 30	x	x		
90th St. & Orchard		x	x	x	4 x 1	4"
Gaunt & Valerie		2 x 2	2 x 2	6 x 8	x	
3907 Ethyl St.		2 x 16	x	x	1 x 3	4"
3823 Ethyl St.		3 x 6	2 x 18	x	x	
3753 Ethyl St.		5 x 7	x	x	4 x 3	4"
3720 Ethyl St.		3 x 31	2 x 2	x	x	

Figure 4.

Backlog of Work
April 12, 1968

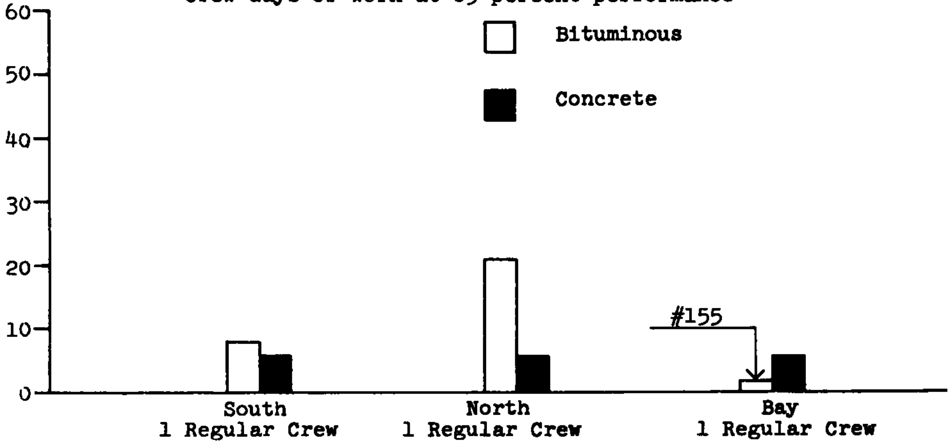
ZONE I

BITUMINOUS SHORT TRENCH
Crew days of work at 65 percent performance



ZONE I

LARGE TRENCH REPLACEMENT
Crew days of work at 65 percent performance



Methods and Standards Section

Figure 5.

the Bureau purchased $23,000 less gasoline, due to the emphasis placed on minimum travel miles. This reduction in equipment mileage would also result in longer equipment life. The second installation in the Equipment and Supply Division has resulted in a net labor savings of $316,841.

Both installations have shown sizable savings; in addition, crews have been provided with engineered standards, and management has been furnished with improved controls and yardsticks by which the Bureau can operate more effectively and with improved efficiency.

I realize that I have described a large operation, and that the amount of dollars saved may not be possible in some cities, but the points I hope you will keep in mind are these:

1. It pays to analyze the work of your crews scientifically, and in minute detail, both as to size of crew and every detail of their work. A considerable saving may be realized.

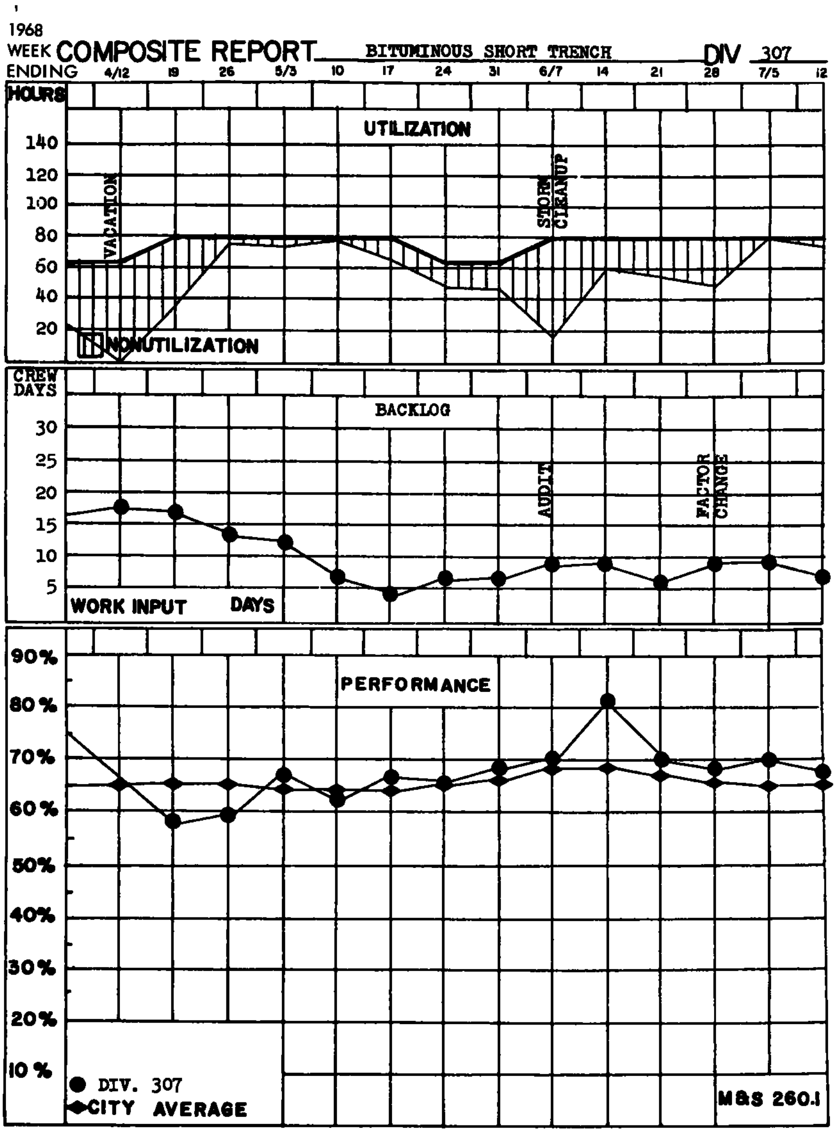


Figure 6.

2. For this type of installation, it pays to train your employees who know the work, and who cannot be misled or fooled, to do this kind of work. There is no substitute for actual on-the-job experience, regardless of formal education, in street maintenance and construction work.

3. By its very nature, our work is not easy to control, but it can be controlled by establishing engineered work standards and scheduling the work of the crews so they are working against time standards as much as possible.

4. Properly-trained, methods and standards technicians can be very valuable administrative assets, and can relieve administration of many problems, headaches, and pressures.

5. The reaction of some of you will probably be along this line—"Los Angeles has lots of money—can afford this type of study and installation, etc.—but my operations do not justify or lend themselves to this type of program." I can only say that all street maintenance work is similar because this work involves movement, motions, and enforced delays; and the potential savings and improvements are so great that the size of your crews and their work methods and procedures deserve study in depth.

The Ontario Approach to Maintenance Management

A. LESLIE, A. GIBSON, and A. P. CUNLIFFE, Ontario Department of Highways

Research has shown that significant reductions can be made in highway maintenance expenditures. The systems approach is directed toward maximization of this reduction. A total system for planning, organizing, directing and controlling of the maintenance function is presented in this paper. The elements of the system are discussed and a model of the system illustrated.

With increasing labor costs and design complexity, highway maintenance is fast becoming a major expenditure for most highway authorities. In Ontario, the Department of Highways is responsible for year-round maintenance of approximately 10,000 miles of paved and 3,000 miles of unpaved roads. The Department employs a maintenance staff of about 6,000 men in the summer, and the maintenance and operation of a huge fleet of snow-clearing equipment requires a further 3,000 men in winter. All this effort costs approximately $30 million for summer maintenance and $25 million for winter operations. These statistics alone establish highway maintenance as truly big business.

Historically, management of maintenance in Ontario has been done principally through the medium of fiscal control by analysis of reported expenditure. Fiscal accounting, however, is useful only to control expenditures from year to year. In terms of today's management information systems, it offers only a small fraction of the data required by modern managers. In reporting expenditure, a second need, that of accounting to the taxpayer, is also fulfilled. However, no matter how costs are analyzed, reported or combined, the end product provides information only on the amount of money spent. With this type of control, it is only possible to allocate resources on the basis of historic cost and to modify these allocations in accordance with changes in labor rates or material prices. It is not possible to allocate on the basis of need.

Recognizing the limitations of fiscal control and desiring to rationalize the operation of the maintenance function, the Department engaged the firm of Roy Jorgensen and Associates, highway engineering and management consultants, to devise a conceptual management system and later to test and, as it turned out, to implement the recommended system.

THE SYSTEMS APPROACH

A number of approaches to managing highway maintenance functions have been developed by government agencies. One approach appears to offer considerable potential for economic benefit through increased efficiency. This concept—the systems approach—is defined as follows:

> The systems approach to maintenance management anticipates the development of an integrated system of procedures in order to provide an objective basis for the planning, organizing, staffing, directing and controlling of all maintenance activities for which an organization is responsible.

FUNCTIONS OF MANAGEMENT

The systems approach to maintenance management is built around the basic functions of management—planning, organizing, directing, and controlling.

- Planning—the selection, from among alternatives, of courses of future action. This is the function by which management determines what goals are to be accomplished (objectives for the organization) and a timetable for reaching these goals.
- Organizing—the establishment of a grouping of activities and authority relationships in which people know what their tasks are, how their tasks relate to each other, and where authority for decisions needed to accomplish these tasks rests—includes staffing to carry out tasks.
- Directing—the issuance of policies, procedures, instructions, and plans in order that organizations' efforts can be directed toward the accomplishment of established goals.
- Controlling—the measuring and correcting of activities of workers to ensure that these activities are contributing to the achievement of planned goals.

These basic management functions are, in fact, decision-making functions. Decisions can be made subjectively—based on opinion, emotion, and incomplete information—or they can be made objectively—based on facts and complete information. This does not imply that managers (the decision-makers) should necessarily make decisions based only on the facts, but they should have complete information so that their decisions are made with complete knowledge of the facts.

One way to interject a higher degree of objectivity into decision-making in the highway maintenance function is to implement a maintenance management system which provides for:

1. The setting of measurable objectives.
2. The allocation of resources to meet those objectives.
3. Reporting of performance related to the objectives.
4. Management actions to assure the attainment of desired modifications to objectives.

SYSTEM INPUT

The basic input requirements for the highway maintenance system are specific operation definitions, accomplishment units, quality standards, and standard values.

Operation Definitions and Accomplishment Units

Uniform, specific operation definitions are the first requirement of any management system. In highway maintenance work, specific operations, such as spray patching, crack sealing, and machine mowing, need to be defined so that the amount of work accomplished and the resources utilized—man-hours, materials and equipment—can be accurately reported by field personnel. The definitions of operations must be in enough detail to allow the resource requirements to be easily related to the required work and the work performed for planning and controlling purposes.

Once maintenance operations are clearly defined, quantitative units of measure (accomplishment units) must be established for the major operations in order that management can establish how much of a particular operation will be performed and, in turn, how much was actually accomplished (Fig. 1).

Some common accomplishment units for highway maintenance operations are tons of patching, acres of mowing, and miles of ditching.

Operation Number	Description	Accomplishment Unit	Code
	SURFACE		
1001	PATCHING with pre-mixed asphaltic materials (hot mix or cold mix). Potholes, depressions, bumps and pavement edge defects. Materials spread by hand and compacted with hand tools and/or truck wheels.	TONS of Hot Mix or Cold Mix Used	23
1002	PATCHING with pre-mixed asphaltic materials (hot mix or cold mix). Potholes, depressions, bumps and pavement edge defects. Materials spread and compacted with grader and/or roller.	TONS of Hot Mix or Cold Mix Used	23
1003	CRACK SEALING using asphalt kettle or pouring can. Include minor repair of distressed areas of pavement and pavement edge defects when this is done during the main activity.	Number of LANE MILES on which crack sealing carried out	32
1004	SPRAY PATCHING distressed areas of pavement and pavement edge defects. Include minor crack sealing when this is done during the main activity.	GALLONS of Asphalt Used	15
1005	JOINT SEALING on concrete pavement using hot poured bituminous material.	GALLONS of Bituminous Material Used	15
1006	JOINT SEALING on concrete pavement using neoprene jointing material.	LINEAL FEET of Neoprene Used	31
1007	GRADING gravel roads Include picking up stones. N. B. Where one pass is made on one mile of gravel road, the accomplishment is one pass mile. Where two passes are made on one mile of gravel road, the accomplishment is two pass miles. Where three passes are made on one mile of gravel road, the accomplishment is three pass miles.	PASS MILES of grading	32

Figure 1. Section of an activity definition list.

Quality Standards

Quality standards must be established for the major areas of maintenance such as surface, shoulders, and roadside for the various classes of highway. By establishing quality standards, the levels of service to be maintained on these classes of highway are specifically defined.

The essential features of quality standards are that quantitative limits are established whenever possible and common goals, for all similar management units, are established. By setting these quantitative limits, objective decisions, based on measurable factors, can be made by field supervisors who must decide whether or not work should be performed, and if so, how much work. [For a typical example of a quality standard, see Highway Research Record 241, p. 9-15, 1968.]

Standard Values

Standard values are of two types—quantity standards and production standards (Figs. 2 and 3). These values must be related to the types of highway on which operations are performed, since workloads and subsequent maintenance costs vary for different highway types. To obtain information by highway type, it is necessary to classify each

ACTIVITY	ACCOMPLISHMENT UNIT	QUANTITY PER MILE OF ROAD		
		ROAD TYPE A	ROAD TYPE B	ROAD TYPE C
Premix Patching	Tons Mix	10.0	1.5	0.1
Shoulder Grading	Miles Graded	4.5	7.0	10.0
Shoulder Patching	$Yds.^3$ Aggregate	5.5	13.0	2.0
Roadside Mowing	Acres	3.0	6.0	10.0

Figure 2. Example of quantity standards.

highway according to its characteristics, such as surface type, surface width and traffic volume.

The quality standards establish the objectives for the maintenance effort. While they describe the objective desired, they do not define the kinds or the amount of maintenance effort required to achieve the objective. It is necessary, therefore, to convert the quality standards to quantity standards, which reflect, when related to different highway types, the amount of maintenance work by specific operation which is required to achieve the quality level desired. For example, the quantity standard for the surface operation hot-mix patching might be established at 5.0 tons per miles per year for a certain type of highway. The quantity standard for the roadside operation machine mowing for a specified highway type might be expressed in terms of mowing frequency, such as three mowings per season.

The quantitatively expressed standard values, related to specific highway types, provide the bases for determining the workload for each defined operation performed by an organization. For example, if an organization has 100 acres of roadside which must be mowed three times per season to attain the desired quality, the workload for the roadside operation machine mowing would be 300 acres. Or, if there are 100 miles of a highway of a certain type which require hot-mix patching, and it is established that 5 tons of hot-mix material is the quantity of work required annually per mile to attain the desired level of maintenance, then 500 tons of hot-mix patching would be the workload for this operation to be performed on the highway type. To determine quantity standards, it is necessary to conduct intensive analyses of actual performance data and of the quality levels achieved and desired.

ACTIVITY	ACCOMPLISHMENT UNIT	MAN-HOURS PER ACC. UNIT		
		ROAD TYPE A	ROAD TYPE B	ROAD TYPE C
Premix Patching	Tons Mix	5.30	6.70	6.70
Shoulder Grading	Miles Graded	0.45	0.45	0.45
Shoulder Patching	$Yds.^3$ Aggregate	0.23	0.23	0.23
Roadside Mowing	Acres	1.33	1.33	1.00

Figure 3. Example of production standards.

Production standards express the resources required to produce a quantity of work. They are normally expressed in man-hours or dollars per unit of work. Ideally, production standards for each operation should be determined on the basis of an analysis of the methods of performing that operation. In this way, the most efficient methods for performing work can be identified, operating personnel can be trained to utilize the prescribed methods, and standard production rates based on these methods can be established. For example, if it is determined that one man using one machine is the best method of performing roadside mowing, and that one acre of roadside should, on the average, be mowed in an hour by a trained operator using the prescribed method and equipment, the standard production rate would be one man-hour per acre.

Once the production standards have been established, the manpower required to perform the workload of each operation can be determined. For example, it was postulated that the workload for the roadside operation 'machine mowing' was 300 acres. Thus, if the mowing production rate is one man-hour per acre, the manpower required to accomplish the planned workload would be 300 man-hours. Expenditures can be forecast in a similar manner. For example, if the cost of mowing an acre of grass was calculated to be 5 dollars (cost of manpower and equipment), the budgeted expenditures for the mowing operation in this case would be 1500 dollars.

Standard values are established on the basis of reported data by highway type. The reported values of a particular highway will vary considerably due to such factors as distance from the work site and length of haul for materials. Specific standard values for planning and controlling each operation on each type of highway is selected on the basis of values that are readily achievable by a majority of the work force and on the basis of available methods studies. Understandably, selection of standard values on the basis of methods studies is the most ideal since inefficiencies and waste are detected during study and improved procedures are developed and disseminated as a result.

DESCRIPTION OF THE SYSTEM

Once the basic input requirements of a system—specific operation definitions, measurable accomplishment units, quality standards, quantity standards, and productivity standards—are established, a highway maintenance management system can be designed around the basic functions of management.

The basic management functions can be more specifically related to a highway maintenance management system.

- Planning—Standard values, related to different highway types, provide a basis for determining the workload in each management unit necessary to achieve the desired level of quality. Budgets prepared on this basis provide sufficient resources to maintain the desired level of service.
- Organizing—Production rates based on methods analysis provide bases for establishing the most effective organization structure and for determining the amounts of manpower, equipment and materials necessary to achieve the planned workload.
- Directing—Planned workloads and allocations of resources provide supervisors with a firm plan to be used as a basis for scheduling the efforts of their work units according to established policies and procedures. Scheduling the performance of maintenance operations throughout the year gives direction to organizational units and enables maximum utilization of manpower, equipment and materials.
- Controlling—In order for management to control maintenance operations, it is necessary to have an information feedback system which provides information on how the

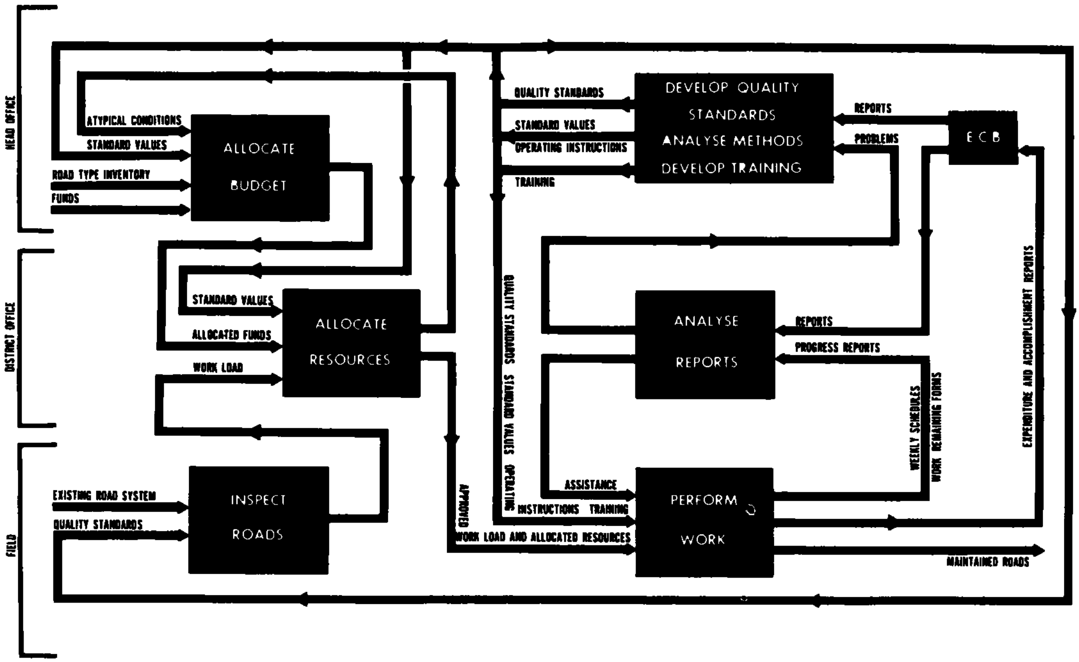


Figure 4. Model of maintenance management system.

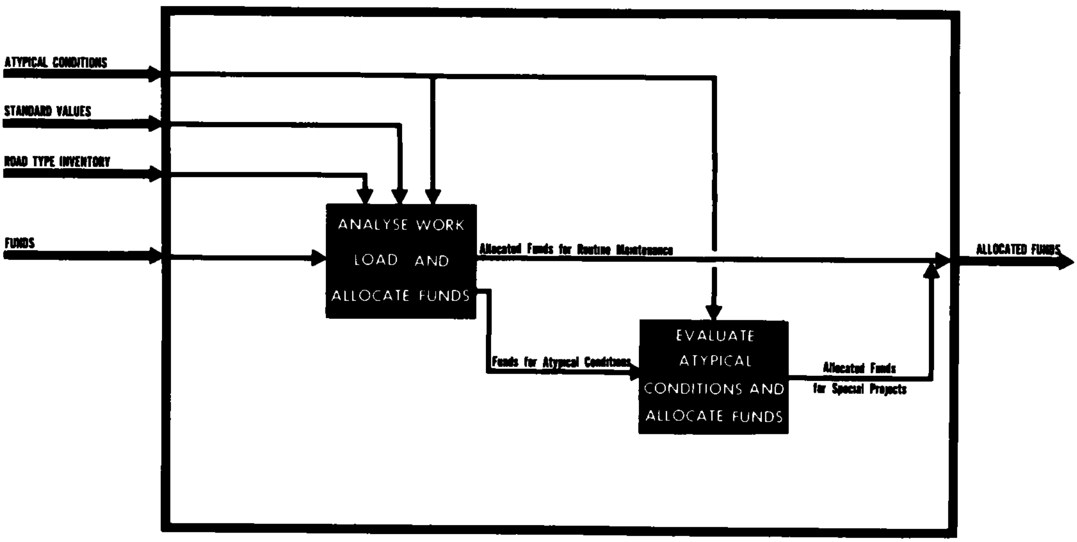


Figure 5. Model of "Allocate Budget—Head Office" function.

> organization actually performed each maintenance operation. Information feedback should assure timely reports to management in terms of the man-hours, equipment, hours and material quantities used in performing each activity, and the amount of work accomplished with these resources. In addition, it is necessary for work accomplishment by operation and highway type to be identifiable with the organizational units responsible for performance.

A simplified illustration of the Ontario Highway Maintenance Management System, designed to provide for the basic management functions, is shown in Figure 4. The main functions in the total system are identified and the inputs and outputs of each defined. The interrelationships between the inputs, outputs and functions of each are also shown.

The main functions in order of performance are:

1. ALLOCATE BUDGET—Head Office
2. ALLOCATE RESOURCES—District Office
3. PERFORM WORK—Field

The supporting functions are:

4. DEVELOP STANDARDS, ANALYZE METHODS, DEVELOP TRAINING } Head Office
5. ELECTRONIC COMPUTING BRANCH (ECB)—Head Office
6. ANALYZE REPORTS—District Office
7. INSPECT ROADS—Field

ALLOCATE BUDGET (Head Office)

Figure 5 shows a model of the "Allocate Budget—Head Office" function.

Input

Funds—representing total maintenance budget for the province.

Outputs

1. Funds for routine maintenance, allocated by district.
2. Funds for special projects allocated by project.

Process

1. The road type inventory and standard values are used to determine the work load for each district, by patrol, highway and activity, and the funds to be allocated for routine maintenance
2. Atypical conditions reported by districts are evaluated and funds allocated for special projects. Atypical conditions are those to which the standard values do not apply, e.g., on highways in poor state of repair or those which have been recently reconstructed.

ALLOCATE RESOURCES (District Office)

Figure 6 is an example of a resource allocation summary; Figure 7 shows a model of the "Allocate Resources—District Office" function.

DATE OF REPORT JUNE 3 , MAINTENANCE MANAGEMENT SYSTEM DISTRICT 1

PERIOD 3/31/68 TO 12 1/68 MAINTENANCE RESOURCE REQUIREMENTS

PATROL SUPERVISOR AARAM WRIGHT REPORT 9

Patrol	High-Way No.	Road Type	Equiv. 2-Lane Miles	Code	Operation Description	Acc/ Equiv. 2-Lane Mile	Acc Unit	Acc Upp Lim	Man-Hours /Accom Unit	Dollars /Accomp Unit	Man-Hours /Equiv. 2-Lane Mile	Man Hours Upper Limit	Dollars Equiv. 2-Lane Mile	Total Accomp.	Total Man-Hours	Total Dollars
1	2	26306	19.2	1001	Mix Patch Manual	0.4	Tons		6.700	28.40				7.7	51	218
1	39	27306	11.3	1001	Mix Patch Manual	0.2	Tons		6.700	28.40				2.3	15	64
1	Opern. Total		30.5	1001	Mix Patch Manual	0.3	Tons		6.600	28.20	2.2		9.25	10.0	66	282
1	2	26306	19.2	1002	Mix Patch Grader	1.0	Tons		0.480	8.83				19.2	9	170
1	2	26306	19.2	1003	Crack Sealing	1.0	Mile		8.000	36.00				19.2	154	691
1	39	27306	11.3	1003	Crack Sealing	0.5	Mile		8.000	36.00				5.6	45	203
1	Opern. Total		30.5	1003	Crack Sealing	0.8	Mile		8.024	36.05	6.5		29.31	24.8	199	894
1	2	26306	19.2	1011	Other surface work						2.0		7.00		38	134
1	39	27306	11.3	1011	Other surface work						1.6		6.00		18	68
1	Opern. Total		30.5	1011	Other surface work						1.8		6.62		56	202
1	2	26306	19.2	2002	Shouldering	3.0	Cu. Yd.		0.320	3.40				57.6	18	196
1	39	27306	11.3	2002	Shouldering	3.0	Cu. Yd.		0.320	3.40				33.9	11	115
1	Opern. Total		30.5	2002	Shouldering	3.0	Cu. Yd.		0.317	3.40	1.0		10.20	91.5	29	311
1	2	26306	19.2	2003	Should. -Grader	10.0	Cu. Yd.		0.230	3.06				192.0	44	588
1	39	27306	11.3	2003	Should. -Grader	10.0	Cu. Yd.		0.230	3.06				113.0	26	346
1	Opern. Total		30.5	2003	Should. -Grader	10.0	Cu. Yd.		0.230	3.06	2.3		30.62	305.0	70	934
1	2	26306	19.2	2004	Dust Laying						0.3		3.00		6	58
1	39	27306	11.3	2004	Dust Laying						0.3		3.00		3	34
1	Opern. Total		30.5	2004	Dust Laying						0.3		3.02		9	92

Figure 6. Example of resource allocation summary—see Appendix A for list of road type codes.

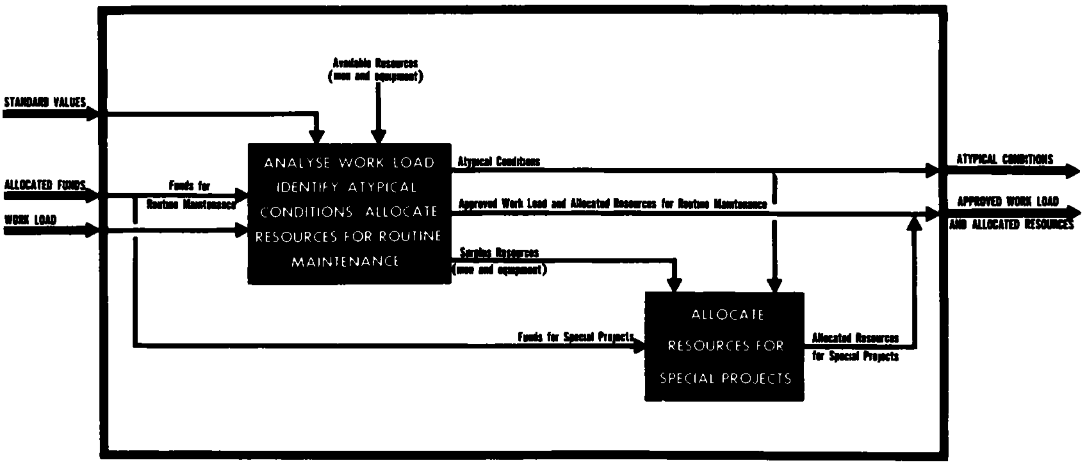


Figure 7. Model of "Allocate Resources—District Office" function.

Inputs

1. (a) Funds allocated by head office for routine maintenance, as determined from road type inventory and standard values.

   (b) Funds allocated by head office for special projects.

2. Work load required to maintain roads to level specified in quality standards, as determined from road inspections.

Outputs

1. Approved work load and allocated resources—men and equipment.

2. Atypical conditions identified in road inspections as being inconsistent with standard values.

Process

1. The work load derived from the road inspection for each patrol is evaluated and adjusted in order that:

   (a) The cost of maintenance work proposed is consistent with the funds allocated to that patrol.

   (b) The number of man-hours required for proposed maintenance work are consistent with those available.

   Where the proposed maintenance work on a patrol is insufficient to utilize the available men and equipment and the excess capacity cannot be reduced by transferring same to adjacent patrols, special projects are set up to improve the existing facilities. Additional funds for these special projects are requested from head office (see Fig. 8).

2. Head office is advised of atypical conditions where excessive resources are required to maintain roads to the level specified in the quality standards or where maintenance requirements are minimal due to recent reconstruction.

Year 1968 | SUMMER MAINTENANCE | District 19

REQUIRED MAN-HOURS AND COSTS

Staff Men (4) Ptlm (1) Other (–) | Patrol 8

Oper. No.	Unit	Road Insp. Qnty.	Mn-hours / Accomp. Unit	Total Man-Hours	Dollars per Acc. Unit	Total Dollars	Remarks
1001	Tons	170	6. 7	1139	28. 40	4828	
1002	Tons		0. 48		9. 84		
1003	Lane Miles	180	8. 0	1440	26. 00	6480	
1004	Gal.	2620	. 28	734	1 38	3616	
1005	Gal.						
1006	Lineal Ft.						
1007	Pass Miles		. 40		3. 30		
1008	Cu. Yd		. 89		4. 20		
1009	Cu. Yd.		. 23		3. 34		
1010	M. H.		3/mile		3. 30		
1011	M. H				4. 00		
1201	M. H.				4. 00		
2001	Miles	479	. 45	216	2. 25	1078	
2002	Cu. Yd.	362	. 32	116	3. 40	1231	
2003	Cu. Yd.	1599	. 23	368	3. 34	5341	
2004	M. H.		. 2/mile		10. 00		
2006	Lineal Ft.		. 016		05		
2007	M. H.				4 00		
2201	M. H.				4. 00		
3011	Acres		1 33		5. 45		
3012	Swath Mi.	105	. 53	56	2. 15	226	
3013	Acres		62		2. 50		
3014	Lineal Ft.		. 0042		. 014		
3015	M. H.	68		68	3. 33	226	
3023	M. H.				3. 33		
3024	M. H.	40		40	3. 33	133	
3031	M. H.	406		406	3. 50	1421	
3050	M. H.				4. 00		
3990	M. H.				4. 00		
4101	M. H.				4. 00		
4204	M. H.				4. 00		
5011	Lineal Ft.	17850	02	357	11	1964	
5012	Lineal Ft.		. 01		. 11		
5013	Lineal Ft.		. 04		. 56		
5014	Lineal Ft.		. 04		. 37		
5015	Lineal Ft.	2700	. 02	54	17	459	
5016	M. H.	8		8	3. 33	27	
5030	M. H.	96		96	4. 00	384	
5040	M. H.	174		174	4 00	696	
5060	M. H.				4 00		
5990	M. H.				4 00		
5201	M. H.				4. 00		
6041	M. H.				9. 00		
6042	M. H.				4. 00		
6061	# Posts	158	1. 33	210	5 30	837	
6062	# Posts	1116	14	156	. 50	558	
6063	M. H.				4. 50		
6064	M. H.				4 50		
6265	M. H.				4. 00		
7017	M. H.				4. 00		
7024	M. H.	72		72	4. 00	288	
7041	Rolls		1 0		3. 00		
7042	Rolls		. 5		1 50		
7043	M. H.				4. 00		
9000	M. H.		M. H. Reqd.	5710	Total $	27793	
9000	M. H.		M. H. Avail	2324	(/man) 581	3460	+ ($865/man-ove.hd)
9000	M. H.		Difference	-3386		2905	+ ($5 00)(Hrs. Avail.)
9000	M. H.		(±)			$36158	(Patrolman Cost) Cost

Figure 8. Summary of man-hours and funds required.

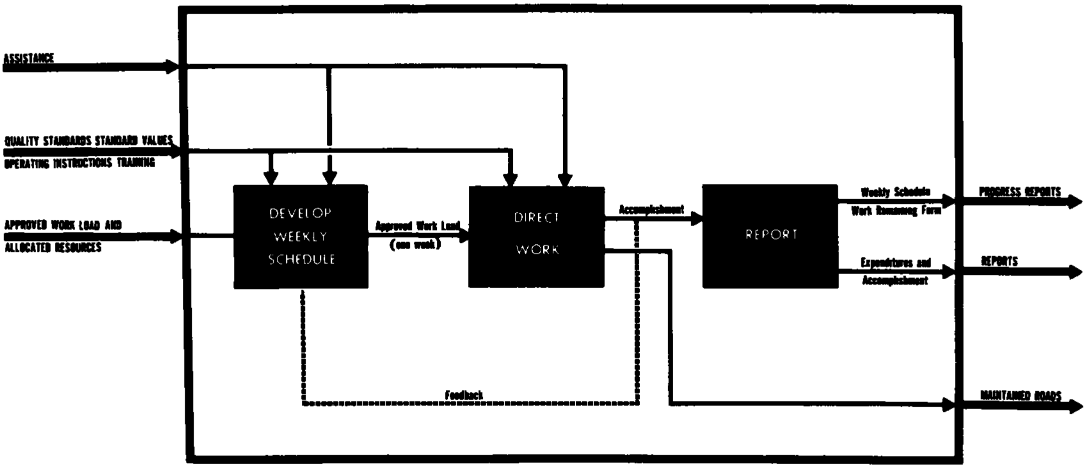


Figure 9. Model of "Perform Work—Field" function.

Effective 5 JUNE to 9 JUNE 1967

DEPARTMENT OF HIGHWAYS, ONTARIO
WEEKLY OPERATIONS SCHEDULE

District 15 Pat Supv 4 Patrol 15

MONDAY

Oper No.	Hwy No.	Equip	Crew Size	Est Accom
½ DAY 3040 4101	–	3 TON	1*	–
½ DAY 6062	88	–	3	78 ~~85~~ POSTS
½ DAY 6062	88	3 TON	4*	126 ~~120~~ POSTS

* PATROLMAN

Wet Weather Activity 3961 – 3972

No Assigned to Patrol	+ 4
No Absent	- 0
No Loaned to Other Patrols	- 0
No Transferred from Other Patrols	+ 0
Todays Crew Size	4

TUESDAY

Oper No	Hwy No	Equip.	Crew Size	Est Accom
1003 LOAN TO PAT. #6	77	5 TON	1	–
6062	88	3 TON	3*	237 ~~250~~ POSTS

Wet Weather Activity 3961-3040-3972

No Assigned to Patrol	+ 4
No Absent	- 0
No Loaned to Other Patrols	- 1
No Transferred from Other Patrols	+ 0
Todays Crew Size	3

WEDNESDAY

Oper No	Hwy No	Equip	Crew Size	Est Accom
1003 LOAN TO PAT # 6	77	5 TON	1	–
6062	88	3 TON	2*	192 ~~175~~ POSTS
8003	–	–	1	–

Wet Weather Activity 3961 – 3972

No Assigned to Patrol	+ 4
No Absent	- 1
No Loaned to Other Patrols	- 1
No Transferred from Other Patrols	+ 0
Todays Crew Size	2

THURSDAY

Oper No	Hwy No	Equip	Crew Size	Est Accom
2002	88	5 TON LOADER	3*	132 ~~125~~ CU YDS
2002 TRANS FROM PAT #6	88	5 TON	1	–
3012	88	MOWER	1	18 ~~20~~ MI

Wet Weather Activity 3961-3040-3972

No Assigned to Patrol	+ 4
No Absent	- 0
No Loaned to Other Patrols	- 0
No Transferred from Other Patrols	+ 1
Todays Crew Size	5

FRIDAY

Oper No	Hwy No	Equip.	Crew Size	Est Accom
½ DAY 2002	88	5 TON LOADER	2*	60 CU YDS
3012	88	MOWER	1	11 ~~20~~ MI
~~½ DAY 3040 4101~~	~~88~~	~~3 TON~~	~~1*~~	~~–~~
½ DAY 3014	88	DROPPED OFF AT 3 TON	1	1000 YDS
8003	–	–	1	–
RAINED 3 HOURS IN PM MEN USED AS FOLLOWS				
3961	–	–	2	–
3040	88	3 TON	*	–
3972	–	5 TON	1	–

Wet Weather Activity 3961 – 3972

No Assigned to Patrol	+ 4
No Absent	- 1
No Loaned to Other Patrols	- 0
No Transferred from Other Patrols	+ 0
Todays Crew Size	3

Figure 10. Example of weekly operations schedule.

PERFORM WORK
(Field)

Figure 9 shows a model of the "Perform Work—Field" function.

Inputs

1. (a) Routine maintenance work load approved by district office.

   (b) Non-routine maintenance work load approved by head office as special projects.

2. Resources—men, material and equipment.

Outputs

1. Roads maintained, where practicable, to level specified in quality standards.
2. Detailed reports of labor, equipment, material used and work accomplished.
3. Progress reports of work accomplished.

Process

1. A weekly operations schedule is developed for each patrol. The work to be performed is selected from the approved work load shown on the work remaining form. Men and equipment are allocated, and accomplishment estimated, using information contained in the typical crew size tables (see Appendix B).
2. Work is performed in accordance with the weekly operations schedule (Fig. 10), except when inclement weather or emergency situations intervene.
3. Labor and equipment time sheets, material used reports and accomplishment reports are submitted biweekly for data processing by the electronic computing branch.
4. The work remaining form (Fig. 11) is up-dated and the weekly operations schedule altered to reflect the work accomplished on the patrol during the previous week. These documents form the bases of weekly progress reports submitted to the district office, where analysis of the patrol's performance indicates areas where assistance is required.

DEVELOP STANDARDS, ANALYZE METHODS, DEVELOP TRAINING
(Head Office)

Figure 12 shows a model of the "Develop Standards, Analyze Methods, Develop Training—Head Office" function.

Inputs

1. (a) Historical data from previous years' operations.

   (b) Current data.

   (c) Observed data obtained from study of field operations.

2. Problems referred by districts.

Outputs

1. Quality standards, used by:

   (a) Field units, to determine the total work load during the road inspection.

   (b) Field units, as reference during maintenance operations.

DEPARTMENT OF HIGHWAYS, ONTARIO

15 Dist | 4 Pat Sup | 15 Pat

Date Inspected APRIL 26, 1967

WORK REMAINING FORM

Hwy No 88

Oper. No	Unit	Road Insp Qty.	Actual Accomplishment For Week/Accomplishment Remaining														
			MAY 5	MAY 12	MAY 19	MAY 26	JUNE 2	JUNE 9	JUNE 16	JUNE 23	JUNE 30	JULY 7	JULY 14	JULY 21	JULY 28	AUG 4	AUG 11
1001	Tons	40	22 / 18	8 / 10	– / 10	– / 10	2 / 8	– / 8									
1002	Tons	–	–	–	–	–	–	–									
1003	Lane Miles	36	– / 36	– / 36	38 / -2	– / -2	– / -2	– / -2									
1004	Gal	230	– / 230	– / 230	– / 230	120 / 110	90 / 20	– / 20									
1005	Gal	–	–	–	–	–	–	–									
2001	Miles	64	– / 64	32 / 32	– / 32	– / 32	– / 32	– / 32									
2002	Cu Yd	200	– / 200	– / 200	– / 200	– / 200	– / 200	192 / 8									
2003	Cu Yd	901	– / 901	– / 901	– / 901	– / 901	– / 901	– / 901									
2004	Bags	240	– / 240	– / 240	– / 240	– / 240	100 / 140	– / 140									
2006	Feet	5230	– / 5230	1400 / 3830	– / 3830	– / 3830	– / 3830	– / 3830									
3011	Acres	103	– / 103	– / 103	– / 103	– / 103	– / 103	– / 103									
3012	Swath Miles	352	– / 352	– / 352	– / 352	– / 352	– / 352	30 / 322									
3013	Acres	–	–	–	–	–	–	–									
3014	Man-Hours	42	– / 42	– / 42	– / 42	8 / 34	– / 34	– / 34									

Figure 11. Example of work remaining form.

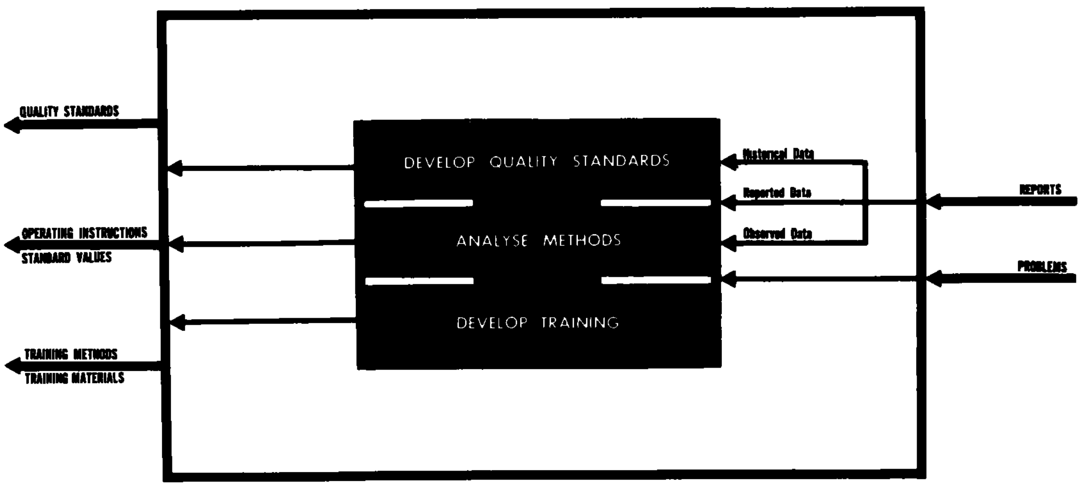


Figure 12. Model of "Develop Standards, Analyze Methods, Develop Training—Head Office" function.

2. Standard values, used by:
   (a) Head office, to allocate funds to districts.
   (b) District office, to allocate resources to field units and to evaluate performance of same.
   (c) Field units, to prepare weekly operations schedules and to evaluate own performance.
3. Operating instructions, used by field units in the conduct of specific maintenance operations.
4. Training materials and methods, used by the district office to train field units in methods and procedures.

Process

1. Quality standards are developed and modified, using historical and current data, to quantitatively specify the level of service to which the various facilities are to be maintained on each type of highway.
2. Standard values are developed and modified using data extracted from reports of expenditure and accomplishment submitted by field units and processed by ECB.
3. Operating instructions are developed using data obtained from field studies to define the procedures to be followed by field units in conducting specific maintenance operations.
4. Training programs and training aids are developed:
   (a) As solutions to problems referred by the district office.
   (b) To meet training needs usually associated with the implementation of new methods and procedures.

ELECTRONIC COMPUTING BRANCH
(Head Office)

Input

Labor and equipment time sheets, material used and accomplishment reports.

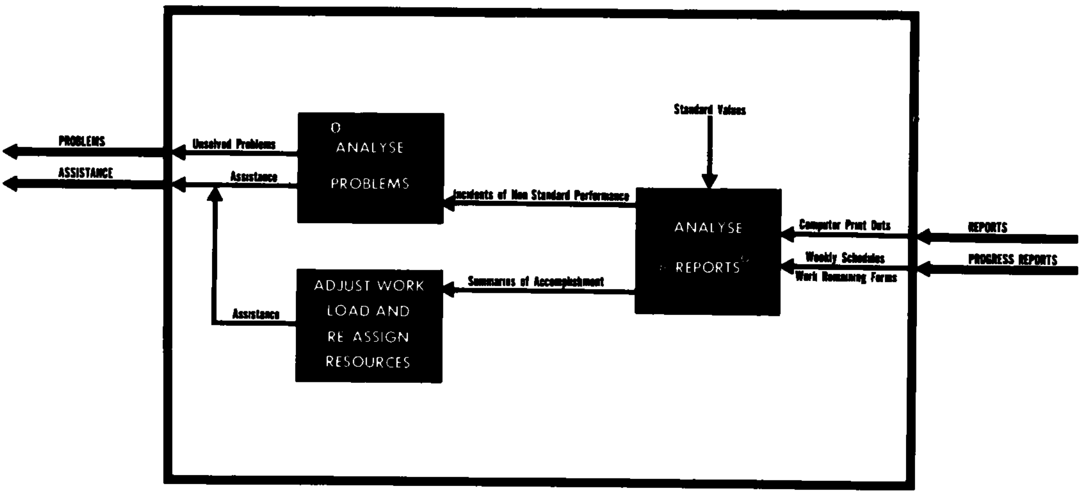


Figure 13. Model of "Analyze Reports—District Office" function.

DATE OF REPORT July 16 1968. DISTRICT NO. 7

COMPARISON FOR EACH ACTIVITY OF PLANNED DOLLAR AND MAN HOUR EXPENDITURES, ACCOMPLISHMENT QUANTITY, UNIT COST, AND PRODUCTIVITY
REPORT 1 (B)

PATROL SUPERVISOR R. MACLEAN TEN WEEK ACCOUNT PERIOD ENDING JUNE 7 1968

Patrol	Code	Operation Description	Expenditure Dollars	Expenditure A/P	Man Hours Hours	Man Hours A/P	Accomplishment Quantity	Accomplishment A/P	Unit Cost Dollars	Unit Cost A/P	Hours	Rate A/P	
6	1001	Mix Patch Manual	325		80.0		8.0		40.63		10.00		ACTUAL
			494	0.66	116.0	0.69	17.3	0.46	28.55	1.42	6.70	1.49	PLANNED
6	1002	Mix Patch Machines											ACTUAL
			54		3.0		6.1		8.25		0.49		PLANNED
6	1003	Spray Patch Cracks	935		240.0		16 0		58.44		15.00		ACTUAL
			1254	0.74	279.0	0.86	34.8	0.46	36.03	1.62	8.02	1.87	PLANNED
6	1004	Spray Patch Areas	1326		338.0		544.3		2.44		0.62		ACTUAL
													PLANNED
6	1011	Other Work											ACTUAL
			168		37.0								PLANNED
6	1000	Surface	2586		658.0								ACTUAL
		Operation Group Total	1970	1.31	435.0	1.51							PLANNED
6	2001	Grading	863		151.0		341.0		2.53		0.44		ACTUAL
													PLANNED
6	2002	Shouldering											ACTUAL
			47		4.0		13.8		3.40		0.29		PLANNED
6	2003	Shouldering Grader											ACTUAL
			603		46.0		197.0		3.06		0.23		PLANNED
6	2004	Dust Laying	380		36.0								ACTUAL
			74	5.13	7.0	5.14							PLANNED
6	2005	Washouts	80		24.0								ACTUAL
			627	.13	173.0	0.14							PLANNED
6	2006	Gravel Windrow	364		134.0		12808.0		0,03		0.01		ACTUAL
			216	1.68	69.0	1.94	4332.0	2.96	0.05	0.57	0.01	0.66	PLANNED
6	2007	Other Work	44		8.0								ACTUAL
			69	0.64	17.0	0.47							PLANNED
6	2000	Shoulders	1731		353.0								ACTUAL
		Operation Group Total	1636	1.06	316.0	1.12							PLANNED

Figure 14. Example of a monthly report from ECB.

Outputs

1. Reports to head office containing data from which standard values are developed and modified.

2. Reports to district office itemizing expenditures and productivity for each field unit.

ANALYZE REPORTS
(District Office)

Figure 13 shows a model of the "Analyze Reports—District Office" function.

Inputs

1. Weekly progress reports from field units—weekly operations schedules and updated work remaining forms.

2. Monthly reports from the ECB, itemizing expenditures and productivity for each field unit (Fig. 14).

Outputs

1. Assistance to field units.

2. Unsolved problems referred to head office.

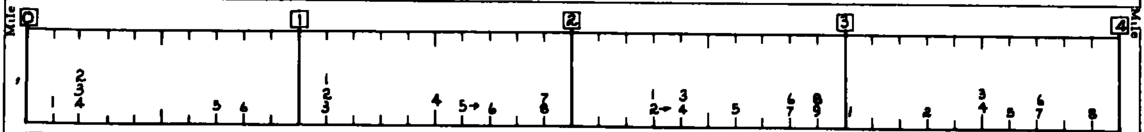
Process

1. The weekly progress reports submitted by field units and the monthly reports from the ECB are analyzed to ascertain if work is being carried out as planned and if production rates are consistent with the standard values:

Date Inspected APRIL 17, 1967
Starting Point GLEWFIELD CITY LIMITS
Miles to End 29 4 MILES

DEPARTMENT OF HIGHWAYS, ONTARIO
ROAD INSPECTION
HIGHWAY NO 15 SOUTH SIDE

Sheet 1 of 16
Dist 15 Pat Sup 4 Pat 15
Road Type 2-LANE



	Miles from Start	Oper No	Qnty	Accomp Rate	Miles from Start	Oper No	Qnty	Accomp Rate	Miles from Start	Oper No	Qnty	Accomp Rate	Miles from Start	Oper No	Qnty	Accomp Rate	
1	0 1	1004	2 GAL	–	1 1	6062	38 POSTS	–	2 3	2002	36 YDS	–	3 0	1005	4 GAL.	–	1
2	0 2	2002	18 YDS.	–	1 1	6061	5 POSTS	2.5 MAN HRS	2 3→2 5	7000 SHOULDERING A M PATCH	80 YDS	–	3 3	6062	20 POSTS	–	2
3	0 2	6062	63 POSTS	–	1 1	5011	120 FT	2 HRS	2 4	2002	6 YDS	–	3 5	5011	100 FT	2 HRS	3
4	0 2	6061	3 POSTS	3 MAN-HRS	1 5	2002	24 YDS	–	2 4	6062	40 POSTS	–	3 5	6061	3 POSTS	1.5 MAN HRS	4
5	0 7	2004	10 BAGS	–	16→39	3011	1 5 ACRES	–	2 6	1001	3 TONS	–	3 6	2002	24 YDS	–	5
6	0 8	6062	27 POSTS	–	1 7	2002	100 YDS	–	2 8	1004	3 GAL	–	3 7	1001	.5 TON	–	6
7					1 9	5060	7 CATCH BASINS	7 MAN HRS	2 8	6062	12 POSTS	–	3 7	6062	23 POSTS	–	7
8					1 9	5016	300 FT	4 MAN HRS	2 9	4101	6 BARRELS 8 TABLES	1 MAN-HR MON-WED-FRI	3 9	6064	100 FT	–	8
9									2 9	2002	6 YDS	–					9
10																	10
11																	11
12																	12
13																	13

Figure 15. Example of road inspection form.

(a) Incidents of substandard performance are investigated. Assistance is given, where necessary, to rectify the situation.

(b) Incidents of consistent above-standard performance are referred to head office for study.

2. Performance problems which cannot be solved at the district level are referred to head office.

INSPECT ROADS
(Field)

Input

Existing road system.

Output

Total work load necessary to maintain roads to level specified in quality standards.

Process

Prior to the start of the summer maintenance season each field unit conducts a detailed road inspection in which all work necessary to maintain the road to the level specified in the quality standard is recorded, by activity, on road inspection forms (Fig. 15).

SUMMARY

The system is dynamic because work quantity standards, production rates and methods of performing work come under continuous scrutiny and are revised and reshaped according to changing conditions. Planning is thus based on current information, thereby allowing maximum utilization of all resources and the achievement of desired level of maintenance service at the lowest practical cost.

Establishment of a highway maintenance management system gives purpose and direction to the highway maintenance function. Without such a system, field managers lack guidance as to what to do, how much and when. With the establishment of a system, they have guides and a reporting mechanism that enables them to know how they are doing.

A highway maintenance management system provides highway management with a basis for setting a maintenance program on level-of-service criteria—quality standards. It gives assurance that the program objective will be uniform throughout the highway department and provides a reporting system that will measure performance. Highway management is able to evaluate organization performance in relation to the objectives by comparing actual production rates and work accomplishment to standard production rates and planned workloads for each operation, and to take appropriate remedial action. In addition, actual expenditures can be compared to planned or budgeted expenditures. Poor performance may indicate such things as the use of improper methods, a need for training, improper scheduling, improper allocation of resources, and poor supervision.

Finally, the highway maintenance management system permits the maintenance function to support highway maintenance budget requirements in terms of measurable and definable work programs.

Appendix A

LIST OF ROAD TYPE CODES

CODE	HIGHWAY TYPE
1	2 Lane (less than 22 ft. width)
2	2 Lane (22 ft. width or greater)
3	3 Lane
4	4 Lane undivided
5	4 Lane divided
6	6 Lane undivided
7	6 Lane divided
8	Other 6 Lanes
9	Other
CODE	**SURFACE TYPE**
1	Gravel
2	Primed Gravel
3	Surface Treated Primed Gravel
4	Mulch
5	Hot Mix
6	Hot Mix on Concrete
7	Concrete
CODE	**SHOULDER TYPE**
1	No Shoulder
2	Up to 4 ft. Shoulder - Gravel
3	Over 4 ft. - Gravel
4	Paved Shoulder
5	Other (Curb and Gutter, etc.)
CODE	**MOWABLE WIDTH OF RIGHT-OF-WAY**
1	None
2	0 to 50 ft
3	51 to 100 ft.
4	101 to 150 ft.
5	151 to 200 ft.
6	201 to 250 ft.
7	Over 250 ft.
CODE	**A. A. D. T.**
1	1 - 100
2	101 - 250
3	251 - 500
4	501 - 1,000
5	1,001 - 2,500
6	2,501 - 5,000
7	5,001 - 10,000
8	10,001 - 25,000
9	25,001 - 50,000
0	More than 50,000

Appendix B

TYPICAL CREW SIZE TABLES

The following 7 pages contain typical crew size tables.

TYPICAL CREW SIZES, EQUIPMENT AND APPROXIMATE ACCOMPLISHMENT PER DAY

OPERATION	1001 2 LANE ROADS	1001 3 LANE ROADS & ABOVE	1002	1003	
DESCRIPTION	PATCHING with PREMIX using hand tools and/or truck wheels	PATCHING with PREMIX using hand tools and/or truck wheels	PATCHING with PREMIX using Grader and/or Roller	CRACK SEALING using asphalt kettle or pouring can	
CREW SIZE Add or delete Flagmen according to manual of "Instructions for Traffic Control at Highway Work Areas". TOTAL	1 - Driver 2 - Shovellers 1 - Flagman 4	2 - Drivers 2 - Shoveller - Rakers 4	1-Grader Oper. 1-Roller Oper 1-Shoveller-Raker 2-Flagmen 1-4 Drivers (refer Table 1) 6-9	Kettle: 1-Spray Bar Op. 2-Sand Spreader 2-Drivers 2-Flagmen 7	Pouring Can: 1-Driver 1-Pourer 2-Sand Spreaders 2-Flagmen 6
EQUIPMENT	3T or 5T Dump	2-5T Dumps (1 truck for traffic control)	1-4 5T truck (refer Table 1) 1-Grader 1-Roller (double roll, width 4')	1-Asphalt Kettle 1-3T (or ½T) to tow kettle 1-5T (or 3T) to carry sand	1-3T Dump (or 5T) to carry emulsion and sand
ACCOMPLISHMENT UNIT	Tons	Tons	Tons 1/	Lane Miles	
NOTES			1/ If less trucks assigned than in Table 1, accomplishment will be less.		

TABLE 1
TRUCK COMPLEMENTS FOR 1002

Ave. Distance of Patch Areas from Premix Plant	No of 5 Ton & 3 Ton 4/ Trucks to Fully Utilize Grader & Roller
4 Miles	1 - 5T
8	1 - 5T, 1 - 3T
12	1 - 5T, 1 - 3T
16	2 - 5T, 1 - 3T
20	2 - 5T, 1 - 3T
24	3 - 5T
28	3 - 5T, 1 - 3T
32	4 - 5T
36	4 - 5T, 1 - 3T
40	4 - 5T, 1 - 3T

Basis;

Roller capacity per day	= 100 Tons
Time available for work per day	= 6 0 Hours
Hauling capacity of 5 Ton Truck	= 9 0 Tons
Hauling capacity of 3 Ton Truck	= 6. 0 Tons
Truck time to dump load & load at plant (or stockpile)	= 17. 0 Min.
Truck travelling speeds (ave full and empty)	= 35 0 mph

4/ If 3 Ton trucks not suitable or unavailable, use 5 Ton trucks

TYPICAL CREW SIZES, EQUIPMENT AND
APPROXIMATF ACCOMPLISHMENTS PER DAY (continued)

OPERATION	1004	1007	1008	1009		1010
DESCRIPTION	SPRAY PATCHING	GRADING - Gravel Roads - include picking up stones	BUILD-UP patching with gravel, grader and patrol truck only	BUILD-UP WITH GRAVEL - Additional DHO (and/or Hired) Trucks		DUST LAYING - Calcium Chloride on gravel roads
CREW SIZE Add or delete Flagmen according to manual of "Instructions for Traffic Control at Highway Work Areas".	1-Spray Bar Oper. 2-Sand Spreaders 2-Drivers 2-Flagmen	1-Grader Operator	1-Driver 1-Shoveller-Raker 1-Flagman	4-Drivers 1-Loader Operator 1-Grader Operator 2-Flagmen	6-Drivers 1-Loader Operator 1-Grader Operator 2-Flagmen	1-Driver 2-Spreaders 1-Flagman
TOTAL	7	1	3	8	10	4
EQUIPMENT	1-Asphalt Kettle 1-3T (or ½T) to tow kettle 1-5T (or 3T) to carry sand 1/	1 - Grader, approx. 100 h. p.	1-3T Dump (or 5T) 1-Loader (as required)	4-5T Dumps 1-Grader (100 h. p.) 1-Loader (approx. 1.0 cu. yd.)	6-5T Dumps 1-Grader (100 h. p.) 1-Loader (approx. 1.0 cu. yd.)	1-3T Dump (or 5T)
ACCOMPLISHMENT UNIT	Gallons	Pass Miles	Cubic Yards	Cubic Yards	Cubic Yards	
NOTES	1/ For heavy patching, add extra driver and 5T Dump					

TYPICAL CREW SIZES, EQUIPMENT AND
APPROXIMATE ACCOMPLISHMENTS PER DAY (continued)

OPERATION	2001	2002		2003		2004	2005	2006	
DESCRIPTION	GRADING - Routine grading of gravel shoulders	SHOULDERING with GRAVEL - No Grader		SHOULDERING with GRAVEL - Grader Included		DUST LAYING Calcium Chloride on shoulders	WASHOUTS	GRAVEL WINDROW between Guide Rail Posts	
CREW SIZE Add or delete Flagmen according to manual of "Instructions for Traffic Control at Hwy. Work Areas" TOT.	1 - Grader Op 1	1-Driver 1-Flagman - Sweeper 2	2-Drivers 1-Flagman - Sweeper 3	4-Drivers 1-Loader Op 1-Grader Op 1-Flagman 1-Sweeper 8	6-Drivers 1-Loader Op. 1-Grader Op. 1-Flagman 1-Sweeper 10	1-Driver 2-Spreaders 3	1-Driver (assist Shoveller) 1-Shoveller 2-Raker-Flagmen 4	1-Driver (assists) 2-Shoveller-Rakers 3	1-Driver (assists) 3-Shoveller-Rakers 4
EQUIPMENT	1-Grader (50-75 hp) with berm leveller	1-5T Dump 1-Loader as required	2-5T Dumps 1-Loader as required	4-5T Dumps 1-Loader (approx. 1.0 cu. yd.)	6-5T Dumps 1-Loader (approx. 1.0 cu. yd.)	1-3T Dump (or 5T)	1-3T Dump (or 5T) 1-Loader as required	1 - Patrol Truck	
ACCOMPLISHMENT UNIT	Shoulder Miles Graded	Cubic Yards	Cubic Yards	Cubic Yards	Cubic Yards	-	-	Lineal Feet	Lineal Feet

TYPICAL CREW SIZES, EQUIPMENT AND
APPROXIMATE ACCOMPLISHMENTS PER DAY (continued)

OPERATION	3011	3012	3013	3014			3031		3041	3042
DESCRIPTION	MOWING with tractor - MORE THAN 2 SWATHS	MOWING with tractor - 1 or 2 SWATHS ONLY (adjacent to shoulder)	MOWING with tractor - MEDIANS ONLY	MOWING with hand mower or scythe around guide rail.			ROUTINE MAINTENANCE		ROUTINE INSPECTION	NON-ROUTINE INSPECTION
							Ave. roadside width 1/ less than 50'	Ave roadside width 1/ greater than 50'		
CREW SIZE	1-Mower Oper.	1-Mower Oper	1-Mower Oper	2 Men with Scythes	3 Men with Scythes	4 Men with Scythes	1-Driver 2-Pickup Men	1-Driver 3-Pickup Men	1-Driver (Patrolman)	1-Driver (Patrolman) 1-Labourer
TOTAL	1	1	1	2	3	4	3	4	1	2
EQUIPMENT	1-Tractor Mower with 5' Sickle or Rotary	1-Tractor Mower with 5' Sickle or Rotary	1-Tractor Mower with 5' Sickle Bar or Rotary	1- Patrol Truck (or 3T) Scythes			1 - Patrol Truck Garbage Pails		1-Patrol Truck (or 3T)	1-Patrol Truck 1-Power Mower (or Tractor Mower when required)
ACCOMPLISHMENT UNIT	Acres	Swath Miles	Acres	Lineal Feet	Lineal Feet	Lineal Feet	-	-	-	-

TYPICAL CREW SIZES, EQUIPMENT AND
APPROXIMATE ACCOMPLISHMENTS PER DAY (continued)

OPERATION	5011	5012	5013	5014	5015	5040	5060	6042
DESCRIPTION	DITCHES - GRADALL, Waste Material hauled away	DITCHES - GRADALL, No hauling of waste	DITCHES - LOADER-BACK-HOE, waste hauled away	DITCHES - LOADER-BACK-HOE, no hauling of waste	DITCHES - GRADER only	MAINTENANCE and repair of culverts and catchbasins, etc attached to culverts	MAINTENANCE and repair of storm sewer systems	REPAIRING and straightening signs
CREW SIZE Add or delete Flagmen according to manual of "Instructions for Traffic Control at Highway Work Areas"	1-Gradall Driver /Flagman 1-Gradall Oper. 2-Truck Drivers	1-Gradall Driver /Flagman 1-Gradall Oper.	2-Truck Drivers 1-Loader-Backhoe Operator 1-Grader Oper. (if required) 1-Flagman	1-Loader-Backhoe Operator	1-Grader Oper	1-Driver (assist) 2-Labourers	1-Driver (assist) 1-Labourer	1-Driver (assist) 1-Labourer
TOTAL	4	2	5	1	1	3	2	2
EQUIPMENT	1-Gradall 2-5T Dumps	1-Gradall	2-5T Dumps 1-Loader-Backhoe (1.0 cu yd.) 1-Grader (100 hp) (if required)	1-Loader-Backhoe (1.0 cu. yd.)	1-Grader (100 h.p)	1-Patrol Truck (or 3T)	1-Patrol Truck (or 3T)	1-Patrol Truck (or 3T)
ACCOMPLISHMENT UNIT	Feet	Feet	Feet	Feet	Feet	-	-	-

TYPICAL CREW SIZES, EQUIPMENT AND
APPROXIMATE ACCOMPLISHMENTS PER DAY (continued)

OPERATION	6061	6062				6063	6064
DESCRIPTION	CABLE GUIDE RAIL - Straighten and/or Replace Posts	CABLE GUIDE RAIL - Clean and Paint Guide Rail Posts				CABLE GUIDE RAIL - OTHER - -Replacing or tightening cable -reflectorized strips	STEEL BEAM GUIDE RAIL - All Work
CREW SIZE Add or delete Flagmen according to manual of "Instructions for Traffic Control at Highway Work Areas"	1-Driver 2-Labourers	1-Scrape & Paint 1-Paint	1-Scrape Only 1-Scrape & Paint 1-Paint only	1-Scrape Only 1-Scrape & Paint 2-Paint only	2-Scrape Only 3-Paint Only	1-Driver 2-Labourers	1-Driver 4-Labourers
TOTAL	3	2	3	4	5	3	5
EQUIPMENT	1 - Patrol Truck	1 - Patrol Truck				1-Patrol Truck	1-Patrol Truck (or 3T)
ACCOMPLISHMENT UNIT	Posts	Posts	Posts	Posts	Posts	-	-

TYPICAL CREW SIZES, EQUIPMENT AND
APPROXIMATE ACCOMPLISHMENTS PER DAY (continued)

OPERATION	7017	7041			7042		
DESCRIPTION	ERECTION AND REMOVAL OF SNOW PLOW MARKERS	SNOW FENCE ERECTION			SNOW FENCE REMOVAL		
CREW SIZE	Erection: 1-Driver (assist) 3-Erectors 4 Removal: 1-Driver (assist) 2-Removers 3	2-Drive posts 2-Unravel & position rolls, set up fence & attach wire clips	2-Drive posts 1-Unravel & position rolls 2-Set up fence & attach wire clips	2-Drive posts 1-Unravel & position rolls 3-Set up fence & attach wire clips	2-Unclip wire from posts & joints 1-Pull out posts 1-Assist in pulling out posts, rolling fence, roll to R O W fence Rolls & posts stacked at ROW fence	2-Unclip wire from posts & joints 2-Pull out steel posts, assist in removing wire, rolling up fence 1-Roll up fence & roll to ROW fence Rolls & posts stacked at ROW fence	3-Unclip wire from posts & joints 2-Pull out steel posts & assist in rolling up fence 1-Roll up fence & roll to ROW fence Rolls & posts stacked at ROW fence
TOTAL	3	4	5	6	4	5	6
EQUIPMENT	1-Patrol Truck (or 3T)	1- Patrol Truck			1-Patrol Truck		
ACCOMPLISHMENT UNIT		Rolls	Rolls	Rolls	Rolls	Rolls	Rolls

Approach to Maintenance Management

V. L. DORSEY, Washington Department of Highways

It is evident that maintenance costs are rising sharply due both to inflation and the steadily expanding highway system, which, by nature of modern design, becomes increasingly expensive to maintain. The Washington Department of Highways and probably all of our counterparts are becoming more concerned with this phase of our activities. This is contrary to past history, in which maintenance was generally ignored or shoved into the background.

It is easy to conclude that our maintenance forces and facilities are not well organized—like Topsy, they just grew. With changes in the system, due to new construction, legislative additions, and the superimposing of the Interstate System upon the older structure, many of our facilities are poorly located, some of our equipment is obsolete, and our forces are not organized or located so as to lend themselves to the most efficient operation. If someone today were charged with the responsibility for establishing a maintenance system in our state and none of the present system existed, obviously the resulting organization would bear only a superficial resemblance to the existing one in all too many areas.

In bygone years, because of the difficulty of travel and the necessity for maintaining roads in remote areas, most sections were maintained by a leadman-maintenance man team, frequently living in state-constructed cottages in the immediate vicinity of their work. Today, as travel is less of a problem due to better roads and higher speed vehicles, the increasing population, which has tended to do away with the isolation of many areas, and the complexity of the highway system itself (quite often several roads meeting in or near a common point), we are shifting slowly from the two-man section to a foreman-supervised gang operation. We are closing out many remote stations and are moving toward consolidation of forces and equipment. We will, undoubtedly, continue to reorganize slowly in this manner, which makes for easier control of employees, scheduling of work, and better utilization of labor.

There are four major reasons, not controllable by local management, which bring about increasing maintenance costs:

- Increased labor costs
- Increased equipment costs
- Increased material costs
- Increased area and facilities to maintain

The elements, which make up the total cost of the normal maintenance operation, are shown in Figure 1. Records for our department show that for the year 1967, our maintenance dollar was divided approximately as follows:

Labor	63 percent
Equipment	23 percent
Materials	14 percent

It becomes obvious then that the area in which the most savings could be made would be in the better utilization of labor. Our initial study showed the conditions in Figure 2 to exist.

We noted that, statewide, there was wide variation in the equipment, methods being used, materials being used, and the makeup of crews. Also, the exchange of information on new methods and materials was poor and, if one district had adopted a most efficient way to perform a piece of work, it was quite likely that other districts were

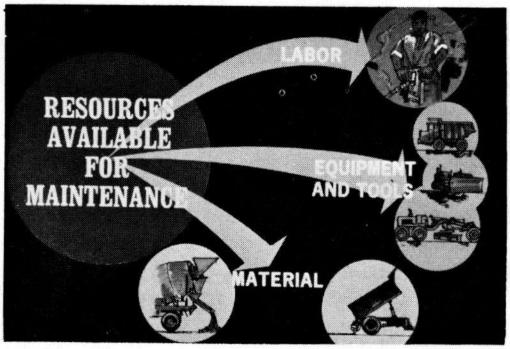


Figure 1.

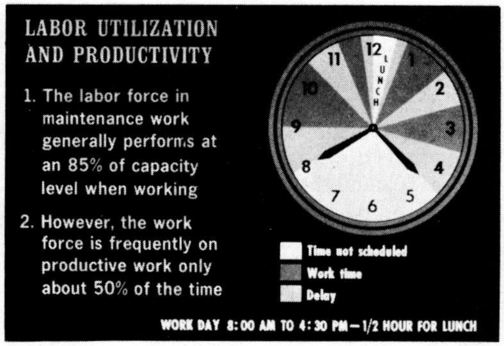


Figure 2.

not aware of it. A very large portion of our work was being carried on by time-honored methods, often not the best, and frequently, for no other reason than that "we have always done it this way." We came to the conclusion that simple modern management tools and techniques are not being applied to the maintenance work. These include:

- Planning and scheduling
- Standardization

As a result, the decision was made to enter into a comprehensive study of maintenance activities to devise better methods of planning, scheduling, and organizing work, and to carry on a statewide program of education and exchange of information. This led to an agreement with a consultant to develop and install a program for the improvement of the control of maintenance forces, establishing uniform methods statewide, and also fixing levels of maintenance to be uniformly applied. The consultants were charged with the responsibility of providing industrial engineers, preparing the training documents, and advising the department; however, it was planned to have ample department representation.

Before discussing the procedures followed, a brief discussion of the organization of that portion of our department concerned with maintenance seems appropriate. The State is divided into six highway districts (the seventh is the metropolitan district in the Seattle area, concerned only with planning and construction and has no maintenance function). Each district has a district maintenance engineer, who reports directly to the district engineer, and he is aided by an assistant district maintenance engineer. Each district, in turn, is divided into four divisions, which are under the supervision of a highway maintenance superintendent. There are, in addition, two special divisions in the Seattle area: one concerned solely with the maintenance of our floating bridges; the other, the signal division, concerned with maintenance of electrical traffic controls.

Each district also has a shop, supervised by an equipment superintendent. These are located at the district headquarters. All fabrication, modification, and major repairs are performed in the district shops. Each division has two mechanics located at the division office to perform minor repairs, tune-ups, and troubleshooting to keep the equipment in the field operating. In the headquarters office, the maintenance staff is supervised by the assistant director of highways for maintenance. His staff consists of an assistant maintenance engineer, roadway maintenance engineer, landscape maintenance engineer, equipment engineer, radio engineer, the management analyst team, and an engineer of capital outlay and inventory.

As the study group was set up initially, the consultant provided two full-time industrial engineers, who were supervised and guided through frequent visits by representatives of the consulting firm, plus a group of departmental management analysts, based on a ratio of two department employees for each representative of the consultant. When the study was extended to the district shops, the consultant provided one additional industrial engineer, specializing in this area, and the department two additional employees. Every effort was made to work as closely as possible to achieve near integration of these two elements.

It was planned to have a major portion of the work done by permanent Highway Department employees, who would remain members of the headquarters staff after the consultant's services were terminated. We felt then, and experience has confirmed, that our maintenance employees work better and talk more freely with departmental employees and every effort was made to avoid the appearance of adopting a plan designed independently by an outsider.

While our department has had members who belong to various employee organizations, we have recently moved into heavier unionization and we, therefore, called in employee representatives to discuss the planned program in advance of undertaking the studies. One union representative spent an entire day at one of our training sessions in order to obtain an understanding of what we were undertaking so that he could report back to his organization better informed. Some union members expressed a fear that once work norms were developed, an employee failing to meet his quota would be discharged. If low productivity shows up in the reports, it is more logical to study the standard to see if it is correct and then to look at the methods being used by the crew in question, not the effort of the individual. It is the opinion of the writer that nearly all of our employees are willing workers if they are told what to do. This reduces to a matter of preplanning and scheduling. There was, initially, some little adverse reaction since a few people, understandably, are nervous about being under all-day observation; however, this was minimal and apparently disappeared completely in a short period of time.

The maintenance work improvement program is divided into five major steps:

1. Training the team;
2. Studying and analyzing present operations;
3. Supervisory work management training;
4. Implementing the controls; and
5. Benefiting from the program.

The first step taken by the consultant was the development of an analyst training manual. This included an introduction to the theory of industrial engineering, with specific instructions for its application to highway maintenance. As soon as the necessary analysts were recruited for the headquarters staff, a training program was conducted at headquarters to indoctrinate these employees. Once the training of these analysts was completed, they and the consultants made up the team to carry on the necessary studies in the field.

The maintenance control system is designed to assist those responsible for carrying out the objectives of the department to utilize manpower, equipment, and resources more effectively. The specific objectives of the system were as follows:

1. Planning of work requirements in terms of manpower, equipment and materials.
2. Budgeting adequately to meet these work requirements.
3. Scheduling to achieve budget objectives.
4. Completing work in accordance with standard times and methods.
5. Reporting of accomplishments and resources used.
6. Evaluating the department's accomplishments against known objectives.

To accomplish our goal, we arrived at the following conclusion that the success of a program such as this was based upon two major factors beyond the system design itself:

- Taking the program to the people and involving them in it;
- The educational-comprehension level of the supervision and work force.

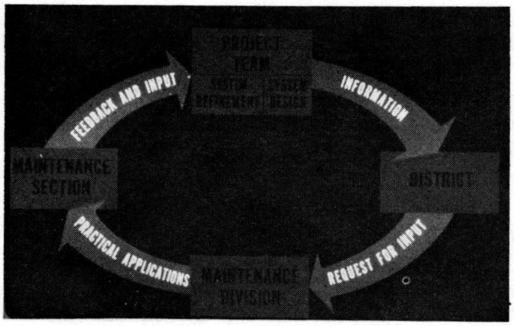


Figure 3. Taking the program to the people.

Figure 3 is indicative of the consultant's concept of the procedure to follow in this program; however, the program, as developed, came very close to being the exact contrary of the procedure shown.

In an enterprise such as a large factory, with a ratio of production workers to maintenance employees in the neighborhood of 1 to 1, it could be expected that supervision would be giving these two areas equal attention and would willingly devote considerable time to improvement in the maintenance program. If the ratio of maintenance employees drops until it approaches that of a highway department, where approximately 25 percent of the employees are engaged in this work, it demands a decreased portion of the supervisor's attention. It does not appear to him to be a major problem area. Engineering studies have shown that some segments of industry, such as chemical plants, are using a very high proportion of maintenance employees to production employees, generally being over 20 percent and sometimes the ratio approaches 1 to 1. In these instances, the supervisor will give maintenance a great deal of attention, whereas, in an industry which may have one maintenance employee for each 100 production employees, so little could be saved by improving maintenance that attention approaches the minimum. While it is true that the maintenance forces in this Highway Department represent somewhat more than 25 percent of direct State employees, if a ratio were to be established, we would have to consider the employees of all contractors as production workers. A look at the budget confirms this conclusion. For the current biennium, the maintenance dollar in the State represents only 6.8 percent of the total budget. On this line of reasoning, we concluded it best to go directly to the people immediately concerned and demonstrate to them the benefits of the program, before requesting recognition from the higher supervisory group. We believe that the results have verified this line of reasoning and, in fact, that this approach was critical to the success of the program. Initially, the study team visited each District in turn to explain the purpose of the study and the procedure we would follow to the district engineer, his maintenance engineer, and the division superintendents. This allowed the study team to be introduced to supervisory personnel in each district and to make arrangements for follow-up meetings with the affected superintendent and his foremen in the pilot areas. Insofar as possible, we also explained to the maintenance people involved the purpose of the study and the type of information we were seeking. We repeatedly emphasized that our studies were not intended to evaluate the performance of an individual but rather to establish, in writing, procedures by which an operation was carried out. Reasoning that the district staff at the higher level was very heavily involved with day-to-day problems, we then concentrated on the collection of data by studying our work at the section level and the group of analysts' contacts were with the superintendents and employees directly below them. In all cases, the districts were kept informed of the work in progress and were invited to attend all sessions.

For the initial studies, we selected three maintenance divisions we felt contained all classes of highways and all types of terrain. This was done to get the broadest possible sampling of the work methods with a minimum of travel for the team. The three divisions were Chehalis, in southwest Washington; Enumclaw, which includes the southern portion of the city of Seattle with a heavily urbanized area and also a mountain pass to the Cascades; Wenatchee, in central Washington, which includes much rural and farming territory; and the Yakima District Shop in central Washington, which has almost a complete range of highway equipment. Also, at the request of the district, we undertook a study of the Seattle signal division. We were greatly encouraged and became more sure of our success when we began to encounter such chance remarks in the field as [from a foreman], "at last I can go home and sleep tonight without worrying about what the crew is going to do tomorrow." [From a Division Superintendent], "Does the Chehalis Division get to be first again?". There were many other indications of acceptance contained in overheard remarks, inquiries from others at higher staff levels concerning our studies, and requests for specific studies from the districts.

We felt one favorable condition existed when a review of the educational level of our employees indicated a surprisingly high average years of schooling. While we have 241 maintenance employees with no high school education, the average for maintenance employees, statewide, is 2.5 years. Also, among our maintenance employees, particularly at the supervisory level, we find many with some college training—106 of these people have a total combined college education of 655 years, for an average of 2 years beyond high school for this particular group. We found the same condition to exist among the other trades, that is, mechanical, electrical, warehouse, and equipment operation. These groups average very close to high school graduation. It is evident, also, that the lack of any high school education exists, in general, among the oldest employees. In a very few years' time, with their retirements, the average of the group will be much higher. There are as many high school graduates among the group hired since January 1962 as there are among all other employees. It is evident, then, that the increasing average level of education among our populace, combined with our civil service procedures, which have been in effect since that time, has resulted in the hiring of the type of employees who can be expected to understand and utilize modern planning methods.

In order to make use of the time standards developed, it was necessary that a set of standards be devised to specify the desired level of maintenance, this to assure that it is done uniformly, statewide, but it is also critical to the scheduling and budgeting purpose. For example, once it has been determined the units of mowing that can be accomplished by an employee with a given machine in a given time, it is necessary to establish the maintenance level for mowing. This department was fortunate enough to obtain an advance copy of maintenance standards developed by the Subcommittee of the AASHO Maintenance Committee, headed up by Darrell Vail, Maintenance Engineer of the State of Colorado Highway Department. These Standards were quite broad in order to be acceptable to all 50 states. It was necessary that we be more specific in many instances; however, we were guided by them and desired our standards to meet with their requirements. For example, these tentative standards specify that mowing on the Interstate highway shall be carried out 20 ft and maintained between a height of 3 and 12 in. As we establish the work that can be accomplished by an employee for the item specified then a determination of the number of mowings per year to maintain this condition and, of course, the total acres to be mowed are necessary.

The roadway maintenance engineer was charged with the responsibility of developing these quality standards. This work was started in July 1967 and completed in May 1968. They are currently being issued statewide as a guide to foremen and leadmen in establishing a uniform level of maintenance. These standards are currently regarded as tentative in nature and we expect that they will be modified somewhat after their application has been tested in the field. They are to be used also in the budgeting process and it follows that, if the funds available are less than indicated, the standards will have to be altered to reduce the level of maintenance. They were, in every instance, reviewed by the districts prior to implementation and acceptance was indicated. All major items of maintenance work have been covered.

One of the most difficult standards to express in writing is that involving the surface of the roadway, both traveled lanes and shoulders. We considered the use of the PSI rating and decided to apply a subjective method developed by our own research people some time ago for making a statewide condition survey.

It was also apparent then that a statewide inventory of the system was necessary in order to compile the total maintenance work load. This inventory was a critical part of the maintenance work improvement program and required such an expenditure of effort that it was completely beyond the capability of the team, which concluded that the best possible way to do this was to spread the work as widely as possible, therefore, the districts were requested to make this inventory, using our maintenance forces. Many of the data had been previously collected and existed in logs but retrieval called for so much clerical effort that it was easier to obtain directly in the field. Accurate, current sign logs were available. The man-hours involved in taking such an inventory are considerable; however, many of the employees accomplished it while on patrol. A computer program has been designed to print out these and to provide for updating these through addition and deletion, as the highways change.

In conjunction with collecting methods data in making time studies, it was necessary to establish a job list. Initially, a tentative list of several thousand was established and it was obvious that this was unmanageable. By elimination then the list was reduced to those activities which occur repeatedly and/or have an appreciable impact upon the budget. At the present time, the team has identified 400 activities in the highway and signal maintenance area and 350 activities related to the maintenance of equipment. In man-hours, we estimate that we can cover 80 percent of the former by standards and 75 percent of the latter. The remainder can largely be attributed to down time or enforced idleness, flagging time and other maintenance activities. As of the first of June 1968, we have established 51 work standards for highway and signal work and 106 standards for equipment maintenance. We plan to expand this to cover 280 activities in highway and signal work and 310 activities involving equipment. It is estimated that we expended in excess of 6,000 man-hours developing, analyzing, and completing standards data. Although, originally, these studies were confined to the pilot areas, they have now been expanded statewide in order to obtain better coverage. Also, the assistant district maintenance engineers have completed their training and are now aiding in the collection of standards data. It is expected that this will be a continuing operation since new materials and new equipment will always be coming on the market.

The chart of accounts used by this department is patterned after AASHO's recommendations, although not in strict conformance. It became evident early in the study that an additional function would be required and we have, therefore, added "4600 - Maintenance - General Functions." While other activities may be charged to this function, it was necessary to the plan to cover enforced idleness. If an employee's nonproductive time, such as that brought about by equipment breakdowns, were charged to the activity he had been working on, a misleading figure for productivity would result and, in many instances, the employee (or work group) being reported on might be made to appear inefficient through circumstances entirely beyond his control.

It was apparent early in the study that the concept of work scheduling offered an opportunity for laying the groundwork for the overall program at an early stage, hence the team concentrated on developing a simple method by which the first line supervisor, either foreman or leadman, could easily and comprehensively schedule his work for the next day. To introduce the concept of scheduling, a simple daily scheduling form was developed and introduced to the pilot areas on September 12, 1967. Initially, three forms were developed—one for an informal daily maintenance schedule, an informal shop schedule, and, in the mountainous areas, a winter operation schedule. After some experience with the scheduling process, the winter operations schedule was abandoned as it was found that the informal daily schedule could be used for this purpose. After several months' experience in the various pilot areas, daily scheduling was established statewide in April 1968. Maintenance sections are now scheduling their work on a daily basis. Implementation of this required a concentrated effort from March 7 to April 3. To be sure that the daily schedule was aimed at accomplishing work that conformed to the basic objectives of the department, a monthly schedule was developed.

The maintenance control system anticipates that a yearly schedule will be established by the division superintendent and confirmed by the district. The schedule will eventually become the basis for a budget and the statewide maintenance program. We are, at the present time, preparing our budget for the ensuing biennium and have not, as yet, developed the system to where it can be used for this purpose; however, we will expect the division superintendents to prorate their allocations so as to stay within the funds available. While we are presently working on this part of the program, we anticipate it will be late this year before it can be installed.

The key to implementing the program statewide has been the extensive training program prepared and conducted in every division. This involved the preparation of three additional training manuals, as well as related exhibits and training aids. Approximately 3,200 man-hours were required for the training of district personnel. Approximately 3,500 man-hours were involved in district implementation and follow-up work by the headquarters staff, bringing us to an approximate total of 6,700 man-hours for training purposes alone. This figure does not include hours spent by team members in informal contacts with foremen and superintendents, it not being feasible to keep a record of these many meetings.

Volume I of the Training Manual explains in simple terms how a work standard is developed. Volume II details in simple form the concept of the overall system. Volume III is essentially an elaboration of Volumes I and II and repeats in more detail many of the aspects previously discussed. The latter also emphasizes the practical application and daily usage of fundamentals covered in Volumes I and II.

While we now believe that the district personnel are advanced in training to the point that they can carry this work on and prepare their own schedules, we will continue frequent visits during the course of our statewide studies and will aid the districts directly later in the year in preparing the annual plan. We believe that this program is succeeding and has been accepted and feel that rapid implementation had much to do with this. In every instance, the division superintendents, foremen, and leadmen were personally contacted by team members within two weeks after the completion of the formal training. Generally, they were accompanied by the assistant district maintenance engineer and ample time was taken to discuss any problems generated. Headquarters assistance was provided in the preparation of daily schedules, monthly schedules, completion of the time cards, and all other phases of the program.

The study team found ample evidence that many of our employees have devised local variations in work methods, of considerable value to the department, which were not known statewide. To overcome this, we have developed a maintenance newsletter, which will be published bimonthly, and, although the initial material was furnished by the headquarters office, we expect shortly that the submission of ideas from the field will make this self-sustaining.

As an aid to the understanding of the development of the system, a "Log of Significant Events" follows:

1967	Event
June 6	Initial meeting of team members
June 14 - 27	Analyst training for team members
July 5	Program orientation for Chehalis personnel
July 6	Time studies began in Chehalis Division
July 24 - 31	Analyst training for additional team members
August 2	District 1 program orientation
August 3	District 2 and District 5 program orientation
August 7	Time studies began in Wenatchee Division
August 14	Consultants assigned an additional consultant to the Yakima Shop
August 15	Time studies began in Yakima Shop
August 22	Time studies began in the Seattle Signal Division
Setpember 12	Started daily scheduling in Chehalis Division
September 13	District 3 program orientation
September 18	Started daily scheduling in Enumclaw Division
September 22	Started daily scheduling in Seattle Signal Division
Setpember 25	Started daily scheduling in Wenatchee Division
September 26	District 6 program orientation
October 9	Started daily scheduling in Yakima Shop
October 24	Chehalis, Enumclaw, and Signal Division training session—"How Time Standards Are Established"
November 2	Wenatchee and Yakima training session—"How Time Standards are Established"
January 29 thru February 2	Began monthly scheduling and work unit reporting on time cards in pilot areas
February 12-23	Assistant maintenance engineers received analyst and maintenance control system training

February 26 - March 9	Conducted Volume I, "How Time Standards Are Established," training sessions in all districts
March 4 - 15	Conducted Volume II, "Maintenance Control System," training sessions in all districts
March 7 - April 3	Conducted initial statewide implementation. Topics included daily schedules, monthly schedules, and time card reporting. Two days allotted for each division and shop
April 1 - 12	Conducted Volume III, "How To Use Time Standards," training sessions in all districts
April 8	Districts began work unit inventory
April 16	Pilot area superintendents approved first group of final standards
May 9 - 27	Follow-up implementation statewide. Topics included: use of standards manual, new time card procedure, new job lists, and monthly scheduling. One day allotted to each division and shop
May 22	First volume of "Maintenance Newsletter" distributed
May 23 - 24	Maintenance engineer training session and progress report given in Yakima
June 1	Began reporting on new time card system.

The Appendix includes a discussion of informal shop scheduling and the work order used, an illustration of the scheduling box, and instruction sheet for completing daily work schedules for routine highway maintenance, a daily maintenance schedule, a minor job list, a procedure for completing a monthly work schedule, and a monthly work schedule—highway maintenance. Also included in the Appendix is a flow chart showing the "Sequence of Activities in the System Operation." It should be understood that local supervision is expected to override the schedule whenever conditions require it, this being a matter of personal judgment and initiative. Also, the minor job list is fill-in work, which does need to be done but not necessarily at any given time. It can be used to supplement when the days work runs short of the schedule or whenever changing conditions, such as unfavorable weather, make it necessary to temporarily suspend any schedule.

We believe that Figure 4 realistically illustrates the benefits which can be obtained from the program. Figure 5, for example, shows what standardizing should accomplish. Scheduling in advance the plannable work should improve our operations as shown in Figure 6. It is expected that our studies will aid the superintendents in pre-planning equipment and manpower requirements (Fig. 7).

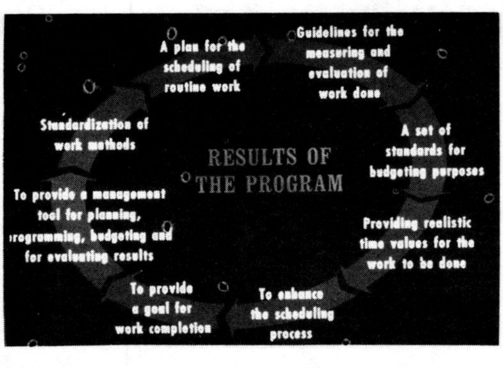


Figure 4.

Figure 5.

Figure 6.

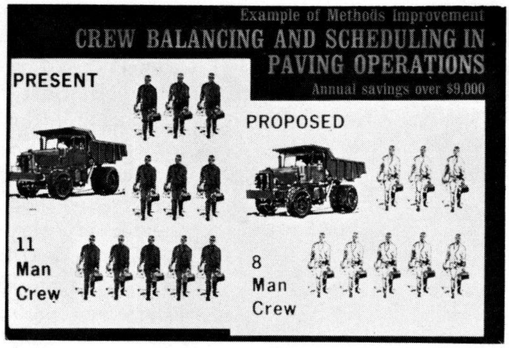


Figure 7.

To make daily reporting possible, each division office has been equipped with an IBM 1050, linked by leased telephone line to the computer section in headquarters. While the data are processed by the maintenance field clerk during the day, transmittal is by automatic call-up by night. This system went into effect on a trial basis in June, but since it was recognized that there will be many problems to be solved, it is being run in parallel with the previous system of hand-posting reported monthly. Assuming that all equipment is on line and that the trial program is successful, it is expected that full implementation will take place in July or August of this year. This will be expanded so that, in addition to the daily labor report, usage for all equipment will be reported daily, by equipment number, as well as all major items of stores. It is planned, in the not too distant future, to expand this further to include a running stores inventory, kept current daily, and also an inventory of parts for all vehicles and equipment. Because of the purchasing procedure we follow, there is a tendency to overstock supplies and parts, with a resultant loss to stores of material being kept beyond its shelf life or the parts remaining in stock after a particular make and model of car has been sold. We believe that through close observation of these inventories in Headquarters, we can develop an interdistrict exchange of surplus items.

In conclusion, the system has been developed and installed, general acceptance among our employees statewide is excellent, and we are very optimistic for the future. No one should undertake such a project lightly. There is a tremendous amount of work required to see such a program through to a successful conclusion, once it has been initiated, At the risk of overemphasis, I would like to repeat at this point the extreme importance of taking the program to the people and getting the maintenance employees directly involved. Stimulate their interest by soliciting help and practice good salesmanship to win their support. This is absolutely necessary to avoid the resistance that is all too often encountered when new programs are undertaken to displace long established habits.

Appendix

INSTRUCTION SHEET FOR COMPLETING DAILY WORK SCHEDULES FOR ROUTINE HIGHWAY MAINTENANCE

Highway Maintenance

There are three types of daily schedules for highway maintenance operations.

a. Daily Work Schedule for Highway Maintenance
b. Highway Maintenance Minor Job List
c. Daily Work Schedule for Highway Maintenance Winter Operations

Daily Work Schedule for Highway Maintenance

The Daily Work Schedule for Highway Maintenance will be the Predominant or typical Schedule for Highway Maintenance. The Daily Work Schedule is developed to insure that all personnel in the Maintenance Section are scheduled to a job, that each job is part of a yearly plan, and that realistic thought and preparation have been given to each assignment to assure proper balance of men, equipment and material.

The Schedule form will be completed as follows:

a. From Monthly Work Schedule for Highway Maintenance determine jobs to be accomplished for the day in question and mark on the Daily Work Schedule for Highway Maintenance. The Daily Work Schedule will be prepared the day before the work accomplishment day.
b. Identify specific location where job is to be accomplished.
c. Assign men by name who are to accomplish each job.
d. Assign equipment to each job by equipment number.
e. Specify material required by type and amount.
f. Complete accomplishment expected column through review of Monthly Work Schedule-Highway Maintenance and Time Standards Manual.
g. Add additional comments on possible changes or problems.
h. Post one copy of Daily Work Schedule for employee information and guidance. The foreman keeps a second copy with him at all times to serve as a guide and ready reference point.

Highway Maintenance Minor Job List

The Highway Maintenance Minor Job List supplements the Daily Work Schedule for Highway Maintenance. It is a list of minor jobs that have been identified for accomplishment on a fill-in or substitute basis to round out the Daily Work Schedule. It is in effect a "running list" having jobs added or subtracted on a daily basis. The types of jobs that will appear on the Highway Maintenance Minor Job List will be generated from sources such as:

a. Work requirements reported by men from section patrol.
b. Reports of minor roadway damage-sign knockdown and guardrail damage.
c. Work needed to be accomplished, but which can be accomplished any time as fill-in work.
d. Request for assistance from other areas such as construction.

The jobs as listed on the Highway Maintenance Minor Job List will be transferred to the Daily Work Schedule for Highway Maintenance as time is available each day. Consequently, the Highway Maintenance Minor Job List is prepared in exactly the same format as the Daily Work Schedule for Highway Maintenance.

INFORMAL SHOP SCHEDULING/WORK ASSIGNMENT

To insure complete service records and effective utilization of all shop personnel, the basic procedure for shop work assignment and accomplishment will be as follows:

1. The foreman receives all incoming work requests.

MAINTENANCE SCHEDULING

Foreman ______________________ Month __________ Day __________

Type of Job	Specific Location	Name of Men Assigned	Equipment	Materials	Accomplishment Expected	Comments

HIGHWAY MAINTENANCE MINOR JOB LIST

Foreman __________ Month ________ Day ______

Specific Job	Specific Location: Control Section Route and Mile Post	Name of Men Assigned	Equipment, (vehicle number)	Materials, Type and Amount	Accomplishment Expected	Comments

2. The foreman initiates Garage Service Order in triplicate (see attachment No. 1) highlighting the following:
   a. Basic work to be performed (specific jobs when possible)
   b. Approximate hours for work accomplishment
   c. Employee/s assigned
3. The foreman keeps the original copy of the Garage Service Order and places copies 2 and 3 in the scheduling box (see attachment No. 2) marked "work to be completed" next to the name of the employee assigned.
4. The employee removes the Garage Service Order forms from the scheduling box, places the second copy in the scheduling box marked "work in process," takes the third copy to the equipment and performs the assigned work.

Several Alternatives can Occur at this Point

Work is completed as originally identified on Garage Service Order

a. Employee writes on third copy of Garage Service Order
   - work completed
   - total hours used for each job listed
   - materials used
b. Employee signs third copy and places second and third copies in schedule box marked "work completed."

Additional work or specific work requirements are identified

a. Employee obtains foreman approval by getting foreman to give verbal work requirements on third copy of Garage Service Order.
b. Employee performs work and writes on third copy of Garage Service Order
   - work completed
   - total hours used for each job listed
   - materials used
c. Employee signs third copy and places second and third copies in schedule box marked "work completed."

Material not available

a. Employee places second copy of Garage Service Order in scheduling box marked "await parts" after writing on third copy of Garage Service Order which remains with equipment.
   - work completed
   - hours used for each job listed
   - materials used
b. When again working on equipment, the employee places second copy of Garage Service Order in scheduling box marked "work in process".
c. Employee performs work and writes on third copy of Garage Service Order.
   - work completed
   - total hours used for each job listed
   - materials used
d. Employee signs third copy and places second and third copies in schedule box marked "work completed."

5. The employee will attempt to accomplish jobs in the order available in his scheduling boxes. Garage Service Order on top of each pile in box is most important work.
6. The foreman in determining work assignments will consider all jobs that he has to do and how best he should split up his team.
7. Some work requirements may involve more than one employee or individual employees in sequence.

Several men working simultaneously on one piece of equipment

a. The foreman will complete one set of Garage Service Order forms containing the names of the assigned employees and place them in the schedule box marked "work to be completed" of the first of the several men (assigned mechanic or main mechanic) he expects to be free to work on the work assignment.
b. Assigned mechanic (main mechanic) writes on the third copy of Garage Service Order (without duplicating information written by other employee).
    - work completed
    - total hours used for each job completed
    - materials used
c. Assigned mechanic (main mechanic) signs third copy and places second and third copies in schedule box marked "work completed". If minor additional tasks such as welding are required and these tasks involve additional personnel, the assigned mechanic obtains approval from the foreman prior to work performance.

Several men working simultaneously (apart-different jobs) on one piece of equipment (major jobs)

a. The foreman will complete a set of Garage Service Order forms for each individual.

Several men work in sequence on one piece of equipment

a The foreman will complete one set of Garage Service Order forms containing the names of the assigned employees in sequence.
b. The foreman will place the second and third copies in the schedule box of the assigned employee in the order required as each assignment in turn is due for accomplishment.

8. Department of Highways personnel will be available to help the foreman get started in this routine.
9. This informal shop scheduling/workload assignment will eventually be expanded to include time standards, standardized job lists, work units, reporting and effectiveness analysis.
10. This informal and limited shop scheduling/workload assignment is therefore a basic starting point in a much larger and more formal maintenance work improvement program. In this regard, the foreman is a most important individual, for his skills determine much of what is to follow.

Attachments
Garage Service Order
Layout of scheduling box

PROCEDURES FOR COMPLETING A MONTHLY WORK SCHEDULE-HIGHWAY MAINTENANCE

COLUMN ON MONTHLY WORK SCHEDULE-HIGHWAY MAINTENANCE	ACTION
Column 1 - Major Job Categories Listed in Order of Importance	Foreman reviews the Yearly Planning Schedule for his Maintenance Section to identify Major Job Categories that have been scheduled for accomplishment by the Superintendent. Foreman marks in Column 1 of the Monthly Work Schedule-Highway Maintenance the first Major Job Category scheduled for the month.

WASHINGTON STATE HIGHWAY COMMISSION
DEPARTMENT OF HIGHWAYS

SHOP SERVICE ORDER

MECHANIC

WORK ORDER NO ____________

EQUIPMENT NO. ____________
MILEAGE ____________
DEPARTMENT ____________

DATE RECEIVED ____________
DATE WANTED ____________
DATE FINISHED ____________

PARTS & MATERIALS	QUANTITY	UNIT PRICE	TOTAL
		TOTAL	

STD NO	OPERATION DESCRIPTION	TIME HOURS	TIME STD
	TOTAL		

SUMMARY OF COST

Parts Total $ ____________
Labor Total $ ____________
TOTAL CHARGE $ ____________

SHOP SCHEDULING/WORKLOAD ASSIGNMENT

EMPLOYEE	WORK TO BE COMPLETED	WORK IN PROCESS	AWAIT PARTS	WORK COMPLETED

SCHEDULING BOX EXAMPLE

Column 2 - Control Section	Foreman reviews the Planning Sheet for his Maintenance Section to identify Control Sections that have been scheduled for the maintenance work. Foreman marks in Column 2 of the Monthly Work Schedule-Highway Maintenance those Control Sections that should be worked on so the units associated with these Control Sections approximate the units on the Yearly Planning Schedule for the month.
Column 3 - Specific Job Name and Number	Foreman determines conditions in the Control Section that have been scheduled for work and reviews Job List-Highway Maintenance and Minor Job List to determine specific type of jobs to be accomplished. Foreman marks in Column 3 of the Monthly Work Schedule-Highway Maintenance the Job Name and Number of the Specific Job to be accomplished.
Column 4 - Units (Amount of Work to be Done per Month per Job)	Foreman reviews the Yearly Planning Schedule for his Maintenance Section to identify units per Major Job Category that have been scheduled for accomplishment by the Superintendent. Foreman also reviews the Minor Job List to identify additional units that may have to be accomplished. Foreman marks in Column 4 of the Monthly Work Schedule-Highway Maintenance the units to be accomplished per specific job.
Column 5 - Standard Time per unit per Job (clock hours)	Foreman reviews the Maintenance Standard sheet for the Specific Job identified in Column 3 to determine the Standard Time per Unit. This is the clock hours (elapsed time), without regard to the crew size, that are required for completing one unit. (Travel time to and from work site is not included, however travel time that is involved in unit accomplishment, such as trips to hot mix plant, is included.) Foreman marks in Column 5 of the Monthly Work Schedule-Highway Maintenance the Standard Time per Unit per Job.
Column 6 - Standard Time Required Per Job (Column 4 x Column 5.)	Foreman calculates the Standard Time Required for Specific Job by multiplying the Units in Column 4 per Specific Job times the Standard Time per Unit per Specific Job in Column 5. This gives the clock hours (elapsed time) without regard to the crew size, that are required for completing all units scheduled for the Specific Job. (Travel time to and from work site is not included, however, travel time that is involved in Job Accomplish-

ment, such as trips to hot mix plant, is included). Foreman marks in Column 6 of the Monthly Work Schedule-Highway Maintenance the Standard Time Required per job.

Column 7 - Crew Size per Job

Foreman reviews the Maintenance Standard sheet for the Specific Job identified in Column 3 to determine the Crew Size per job. This is the number of men, not counting flagmen, that are required for job accomplishment. Foreman marks in Column 7 of the Monthly Work Schedule-Highway Maintenance the Crew Size per Specific Job.

Column 8 - Total Standard Time Required per Job Including Travel (Column 6 x 115%)

Foreman calculates the Total Standard Time Required per Job Including Travel by multiplying the Standard Time per Job in Column 6 times a Travel Allowance Factor of 115%. This means that the clock hours (elapsed time) for job accomplishment is increased by 115% to reflect the normal (average) travel time associated with most jobs. (As more data become available and foremen become more familiar with the scheduling, the 15% travel allowance average may be replaced by a more specific travel allowance per type job). Foreman marks in Column 8 of the Monthly Work Schedule-Highway Maintenance the Total Standard Time per Job Including Travel.

Column 9 - Number of Flagmen Per Job

Foreman reviews the Flagging (safety) Manual for the Specific Job identified in Column 3 to determine the recommended Number of Flagmen. Flagging requirements will vary depending upon circumstances, consequently the recommendations for flagging are approximate. Foreman marks in Column 9 of the Monthly Work Schedule-Highway Maintenance the Number of Flagmen per Specific Job.

Column 10 - Total Number Men Required Per Job (column 7 + column 9)

Foreman calculates the Total Number Men required for Specific Job by adding Crew Size per Job and Number of Flagmen per Job. Foreman marks in column 10 of Monthly Work Schedule-Highway Maintenance the Total Number Men Required per Specific Job.

Column 11 - Number of Days Required per Job (Column 8÷8 Hours per day)

Foreman calculates the Number of Days Required Per Specific Job by dividing the Total Standard Time Required Per Job including travel by 8 hours per day. This determines the number of full days that are required for job accomplishment. Foreman marks in Column 11 of Monthly Work Schedule-Highway Maintenance the Number of Days Required per Job.

Foreman repeats the procedure associated with Column 1 through Column 11 until the Man Days Required Per Month approximates the Man Days Available per Month. This will mean that the work requirements for the month will have been firmed up and in line with availability of men. Even though the schedule will be "firmed up" the Foreman must regard it as being flexible—additional jobs may be added or substituted based upon circumstances.

COLUMN ON MONTHLY WORK SCHEDULE-HIGHWAY MAINTENANCE	ACTION
Man Days Required per Month (The sum of Column 10 x Column 11 for each specific job).	Foreman multiplies for each Specific Job the Total Number Men Required Per Job times the Number of Days Required per Job to obtain man days per job. The man days for all specific jobs are added to obtain the Man Days Required per Month. Foreman marks this figure on sub-total line called Man Days Required Per Month.
Man Days Available Per Month (Work Days Per Month x Average Number of Men at Work).	Foreman multiplies the number of work days per month times the average number of men expected to be at work per day to obtain Man Days Available per Month. This indicates the number of man days of work that could be performed. (This figure will approximate the Man Days Required Per Month). Foreman marks this figure on sub-total line called Man Days Available Per Month.
Days on Which Jobs will be Accomplished	Foreman decides on time period (Days of the Month) when Specific Job will be accomplished by analyzing for each job. - Number of men required - Number of days required - Number of men available - Priority of job - Anticipated weather and problems Foreman marks on days of the month the number of men required and portion of day required in half day increments (per job). Foreman continues process—sometimes through trial and error—until all jobs are scheduled and men required per day approximate men available per day.

NOTE: The scheduling procedures per area involved may differ somewhat in detail depending upon varying conditions such as:

- Foreman may have more than one shift
    - may have schedule per shift
    - may put all on one schedule
- Foreman may have to plan on crew availability for winter operations (stand-by or patrol).

In any case, the objective is to plan work requirements for the month considering:

- Yearly plans
- Men available

so that both are maximized

- Yearly plans are accomplished
- Men are utilized doing required work

The information sources and procedures associated with the Monthly Work Schedule-Equipment Maintenance are similar to those for the Monthly Work Schedule-Highway Maintenance. The basic differences are:

- Control Section is replaced by Equipment Number as means for identifying work location.
- Travel Time Allowances and Flagging need not be considered.

In addition, unique schedules may be generated for specialized operations. Following are examples of:

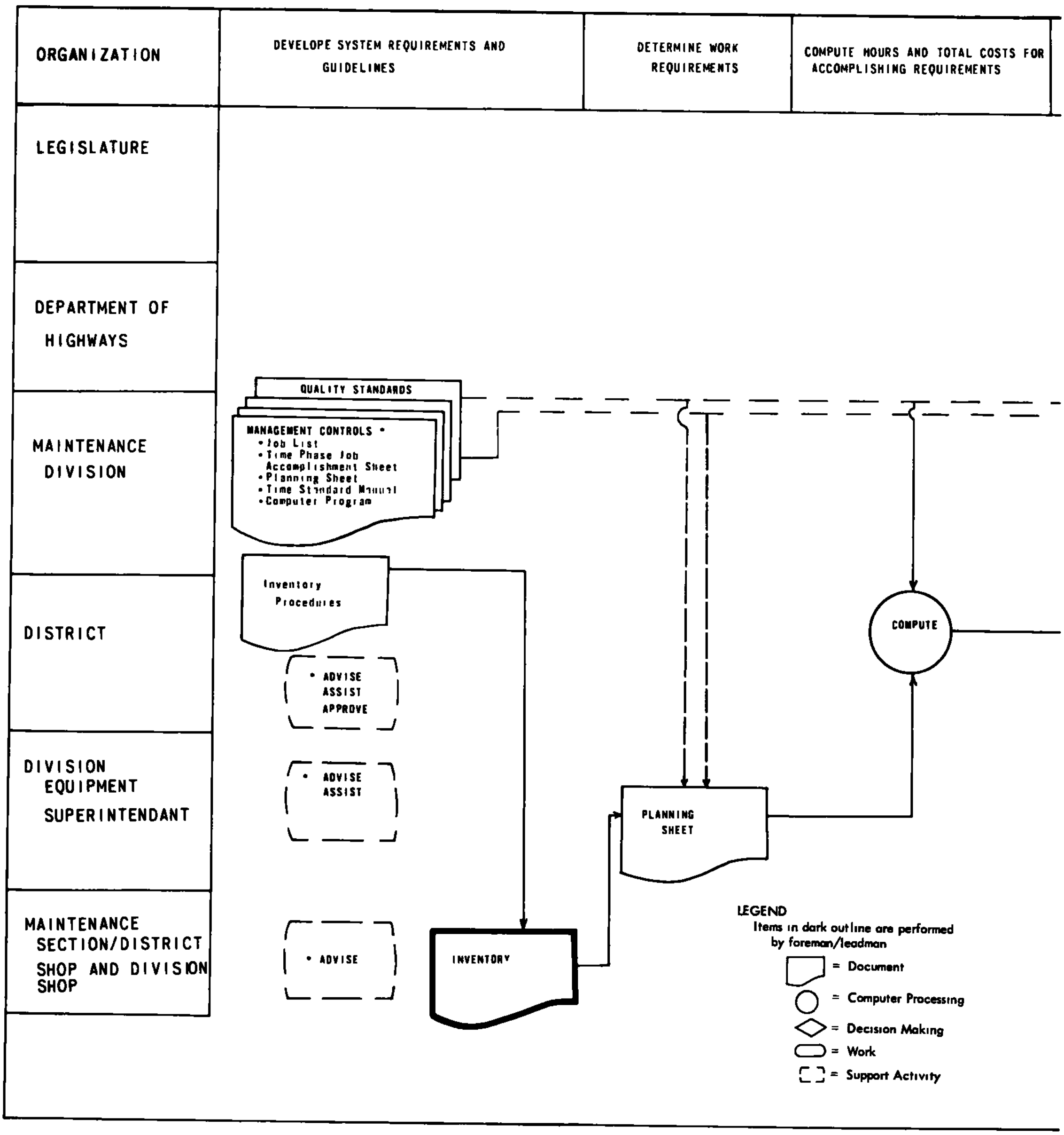
- Monthly Work Schedule-Equipment Maintenance
- Signal Work Schedule and Record

MONTHLY WORK SCHEDULE - HIGHWAY MAINTENANCE

MAINTENANCE SECTION____ MONTH____ YEAR____

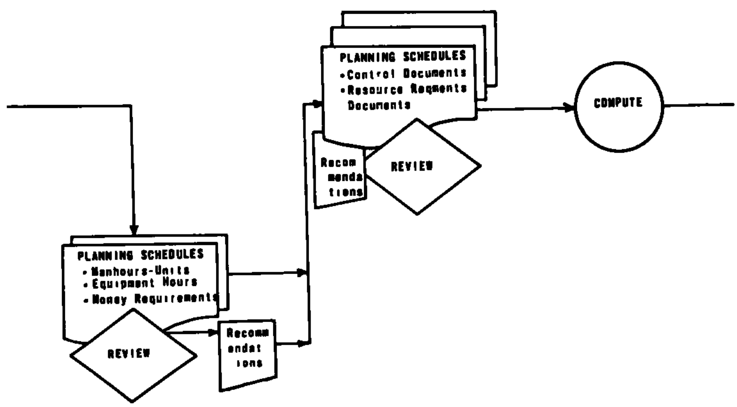
1	2	3	4	5	6	7	8	9	10	11	Days on which jobs will be Accomplished						
Major Job Categories Listed in Order of Importce.	Con-trol Sec-tion	Spec-ific Job Name and Number	Units (amt. of work to be done pr month per job)	Std. time per unit (clock hours)	Std. Time Req. per job (Col. 4 x Col. 5)	Crew Size Per Job	Tot. Std. time req. per job incl. travel (col 6x115%)	No. of Flag-men per job	Tot. No. men req. per job (column 7 + col-umn 9)	No. of days req. per job (column 8 ÷ 8 hrs./day	1	2	3		29	30	31
MAN DAYS REQUIRED PER MONTH (The sum of Column 10 x Column 11 for each specific job)																	
MAN DAYS AVAILABLE PER MONTH (Work days per month x average number men at work)																	

SEQUENCE OF ACTIVITIES IN SYSTEM OPERATION

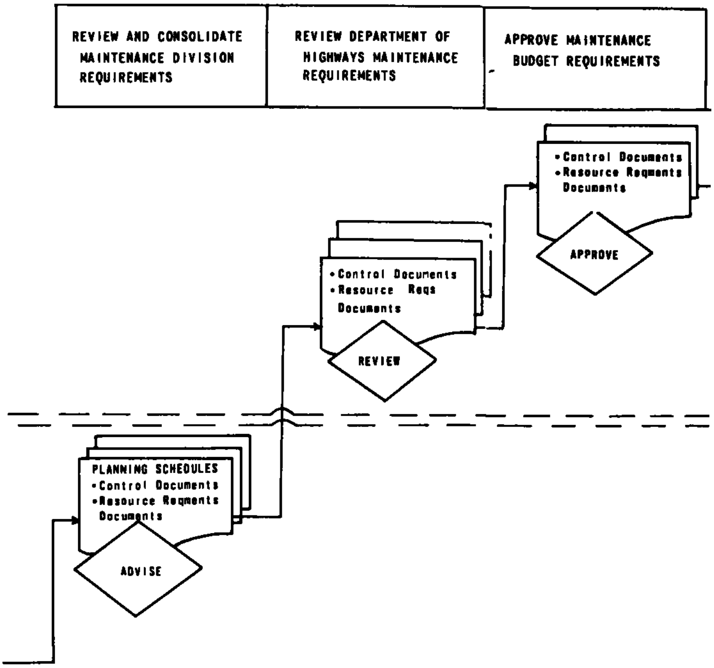


SEQUENCE (Continued)

REVIEW REQUIREMENTS AS COMPUTED AND MADE RECOMMENDATIONS	REVIEW AND CONSOLIDATE DISTRICT REQUIREMENTS	COMPUTE HOURS AND TOTAL COSTS FOR ACCOMPLISHING DISTRICT REQUIREMENTS

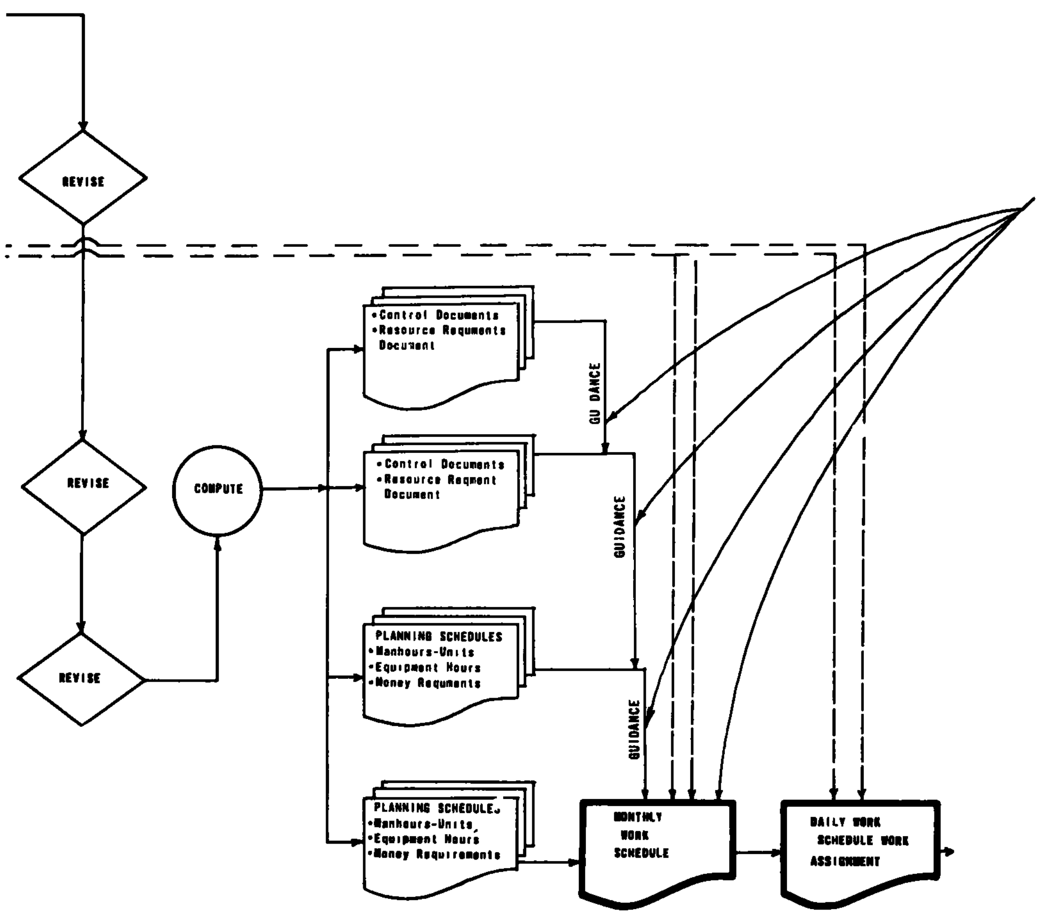


SEQUENCE (Continued)



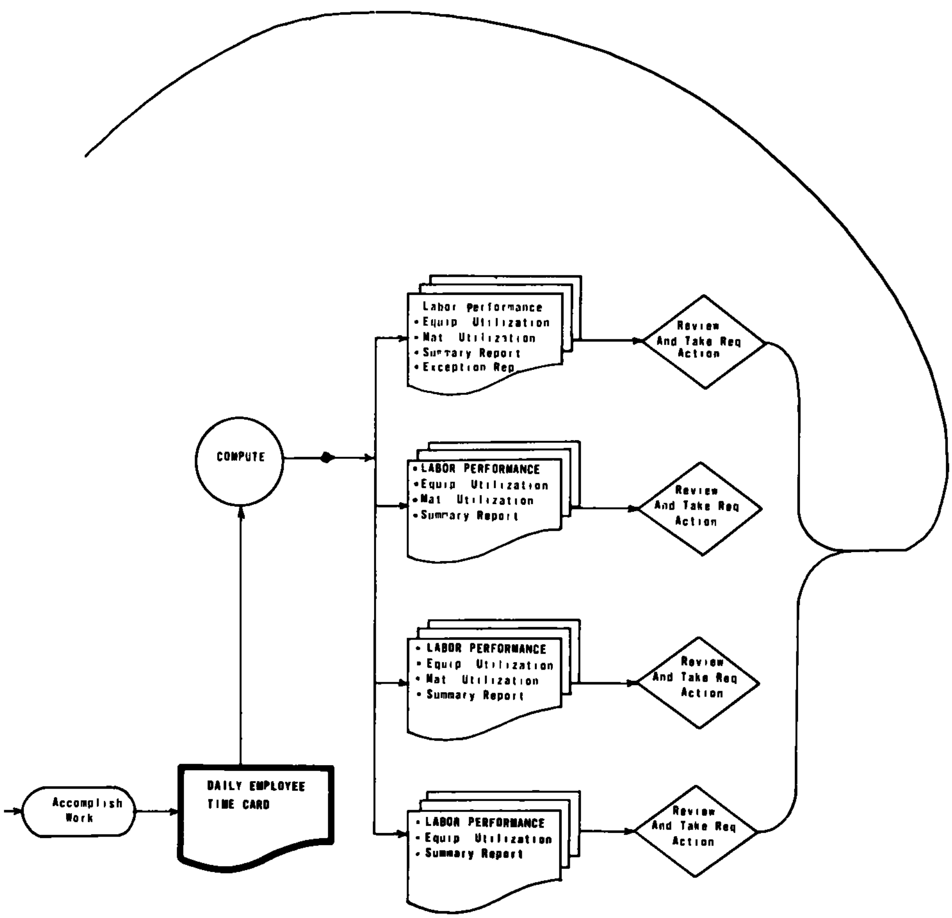
SEQUENCE (Continued)

INCORPORATE LEGISLATIVE MODIFICATIONS INTO PLANS AND COMPUTE MODIFIED REQUIREMENTS	DEVELOPE MONTHLY WORK SCHEDULE	DEVELOPE DAILY WORK SCHEDULE/ WORK ASSIGNMENT



SEQUENCE (Continued)

ACCOMPLISH WORK	REPORT ACCOMPLISHMENT AND COMPUTE PROGRESS	EVALUATE REPORTS AND TAKE REQUIRED ACTION



Implementing Findings From the Louisiana Maintenance Research Project

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The Louisiana Maintenance Research Project was undertaken in September 1965 and will be completed in June 1969. The project is directed toward establishing an operating, modern maintenance management system in the Louisiana Department of Highways. To present the experience of Louisiana in implementing the findings of this research, this paper has been divided into two major sections.

1. Project results to date—a discussion of the background associated with the project and a report of the results of the major phases with special emphasis on the management reporting process, maintenance planning and changes in organization.
2. Experience in implementation—a discussion of the performance laboratory where basic data were gathered and methods reviewed. A discussion of the use of these data, management actions required, training and the results of these efforts in areas other than the performance laboratory.

In addition to the two major sections, the Appendix includes tables and figures which illustrate specific findings, conclusions and procedures.

BACKGROUND

The rapidly increasing cost of maintenance has for several years been of concern to the maintenance engineers of the Louisiana Department of Highways. It was recognized that eventually budget requests to the legislature would have to be documented as to their relationship to actual needs. The maintenance and operations engineer felt that either the Department must install some management system on its own volition or a management system would be forced on it by the legislature. It was decided in 1965 to conduct management research in the maintenance section. The original intent of the research project was to have available a series of recommendations with regard to maintenance management to be brought out at such time as the State legislature began to look at the high cost of maintenance with a jaundiced eye.

In September 1965, the Department entered into a contract with Roy Jorgensen and Associates to conduct the management research. The project was jointly financed by the Department and the Bureau of Public Roads. The original contract was for 18 months.

During the early stages of the project, the main emphasis was placed on data collection and analysis in order to document existing practices of the Department and to define those areas where improvement could be made. The Department's cost records did not have any data showing the relationship of cost to work performed. Also, the AASHO function codes in many cases were so broadly defined that it was impossible to select any one work factor for work measurement.

A pilot reporting system was established in one District for a year. By adding a fourth digit to the AASHO function codes, they were more clearly related to specific types of work. A system code was added to correlate unit quantity to the four highway systems. A measure of work accomplishment was added in order to evaluate man-hour rates for specific work accomplishments. A reporting form was designed for processing by keypunch operators and a computer program was written to summarize the reported data.

Field trips were made to observe the crews at work. Specific types of work were observed in different parishes and districts. Many of the supervisors were interviewed as to why they did work a certain way; as to who gave these working instructions; and as to how they planned their work.

Analysis of the data showed wide differences in performance from management unit to management unit. Figure 1 in the Appendix shows the cost of surface maintenance for bituminous surface-treated roads for each parish. The parishes are grouped according to district and three-year averages were used to level out year to year variations. These roads are all of essentially the same character, carry the same traffic, and should have generally the same maintenance requirements. (The variation indicates the potential for improvement.)

The data from the pilot reporting system and field observations pointed out the causes of the variations. These can be summarized in terms of:

1. Quality—Different supervisors were working toward different levels of service. Some were repairing defects which did not need repair, some were ignoring conditions which should have been fixed.
2. Quantities of Work—Some supervisors predominately used hot pre-mix materials for patching all defects; others used multiple layers of liquid asphalt and cover aggregate of varous sizes. Some patches were extended beyond the immediate area needing repair by as much as ten times for the sake of appearance.
3. Productivity—Many different arrangements of men, equipment and task assignments were noted. All of these had a direct effect on the unit costs of doing work.

From this analysis, it was concluded that the best method of obtaining improvement was to establish better management practices. The key elements involve determining the best way to do work (performance standards), the setting of objectives in terms of good performance and staffing accordingly (planning and budgeting), the developing of simple management procedures for superintendents, and providing information related to standards so they can correct poor performance.

A supplemental agreement was made with the consultant expanding the original research through June 1969. The expanded project has five major phases (the schedule for these phases is shown in Fig. 2 in the Appendix):

1. To develop and test a maintenance work reporting system which will be compatible with existing fiscal requirements and provide management information required for effective planning, execution and control of the Department's highway maintenance activities.
2. To conduct a performance laboratory for the research and testing of maintenance methods and procedures, the testing of performance standards and the testing of management procedures.
3. To form a Department standards panel for the purpose of observing and evaluating the performance laboratory operations and for developing standards of quality and productivity as guides for department-wide planning and control of maintenance operations.
4. To develop a comprehensive maintenance management system and a plan for the implementation of such a system.
5. To develop and test training procedures and training materials appropriate for maintenance personnel.

As each phase of the research is completed, an individual report is prepared. Also, as part of the research in each phase, the new management procedures are being field tested in order to check their validity under actual operating conditions. This means that while the final report for any particular phase has specific recommendations for managment improvement, many, if not all, of the recommendations will have already been implemented in some of the Department's districts through the testing procedure.

At the present time, Phase II, the new reporting system, has been in effect for a year. The performance laboratory and the standards panel have completed their primary job. Reports covering the reporting system and the performance laboratory have been written. Training courses built around the new work standards are being tested. The development of management procedures, a statewide work plan, and control procedures are being tested.

WORK REPORTING SYSTEM

Any work reporting system has to serve two needs: that of fiscal management; and that of management control by the operating personnel. In the past, the work reporting system of the Department was fiscally oriented. The accounting section is mostly interested in documenting where money was spent. The need of management is to know quantities of work, man-hour rates, unit costs of doing work, and how well actual work quantities correlate to the work plan; these items were not a part of the work reporting system. There were three basic types of reporting documents: the payroll, the equipment report and the material-used report. There was, in many cases, poor correlation in the activity reporting on these documents for the same gang in the same period.

A series of meetings was held among the accounting section, the maintenance section and the consultants to design a reporting system that would serve the needs of both the accounting section and maintenance. Consideration was given to several possible approaches to work reporting documents. It was finally decided to have a job-oriented type of reporting where all requred information of man-hours, equipment hours, material and accomplishment would be on one document. This document was designed for data transmission by wire to the accounting 418 UNIVAC computer.

Basically, this new reporting system follows the AASHO Manual of Uniform Accounting Procedures. However, there were some major revisions in the various accounts:

•The highway investment code was eliminated and a system code was substituted consisting of the four basic roadway systems—Interstate, primary, secondary and farm-to-market; two general administrative systems of buildings and grounds and overhead and individual expenses; three off-system codes of rural roads, urban streets and others.

•The use of control sections in work reporting were eliminated except in the case of (a) a project, (b) special test sections, (c) operation of ferries and tunnels, or (d) special instructions such as reimbursable accidents.

•Structures were to be identified as to basic types: concrete, steel, elevated roadway, or ferries.

The function codes were redefined. It was found that 30 work functions covered 96 percent of all work reporting. In this group were several functions that were too broadly defined. Work functions such as patching surface, which covered 21 percent of maintenance cost, were broken into several specific functions to more clearly identify what type of work was being done and on what type of surface. Other work functions such as pumping stations and monument recovery, which accounted individually for less than 0.1 percent of maintenance costs, were lumped into some general catch-all function numbers. Figure 3 (Appendix) illustrates the number of functions related to their size and importance.

The new reporting document, called the "Biweekly Activity Report" (BAR), was basically a summary of all work in a reporting period done under a specific parish superintendent or gang foreman that could be charged to any one combination of work function, parish, system and structure type. Figure 4 (Appendix) shows an example of a BAR completed for surface treatment patching on a secondary road.

Daily work reports are prepared by individual foremen. These are turned into the parish headquarters and summarized on the BAR by the parish clerk. A separate work report is required in any one day for any combination of work function, parish, road system or structure type.

The new work reporting procedures were pilot-tested for four weeks under the supervision of the research staff and district administrative people. A meeting was held with the parish foreman and supervisory personnel. During the first few days of the test, daily visits were made to the parish headquarters to see if any unusual problems developed.

The pilot-testing revealed no major flaws in the reporting procedure or format. Plans were then made for statewide testing with a representative parish and district-wide crews in each district. Key administrative people and teleprinter operators were brought to Baton Rouge from each district. Instruction books were prepared with specific sections devoted to each of the new reporting documents and each new procedure. The Baton Rouge meeting was organized as a workshop. After a general presentation of the new procedures and a question and answer period, the large group was broken up into smaller groups actually using the new documents in trial reporting problems.

Each district then made a pilot test with the new reporting system in a representative parish and in district-wide crews for a biweekly period. The documents were to be processed in the district office and the data transmitted by teleprinter to the accounting section for computer processing. This provided a testing of the complete procedure of handling the work reports from the working crews to the accounting section.

For the last two weeks of the old fiscal year, a statewide test was planned in which all maintenance personnel performed duplicate reporting, using both the old reporting system and the new. At the end of the two week test, the old system was dropped and the new continued. This allowed the highway personnel to become familiar with the new reporting procedure and correct any major reporting errors before the data from the new system was fed into the official records.

The reporting system has now been in effect for a year and is generally well accepted by maintenance personnel. While most supervisors endorse the system, there are a few hard-core areas which are still resistant to the change—but this is to be expected in any major change. The information collected is proving satisfactory for both accounting purposes and management purposes.

The advantages of the reporting system are: (a) more accurate reporting by combining labor, equipment and material relating to a specific work function on one document; (b) a measure of work accomplishment is now included which allows a measurement of performance; (c) the documents are oriented for wire transmission, which relieves the keypunch section of some 50, 000 cards every two weeks; and (d) the job-order-oriented reporting documents have made work reporting more closely related to work scheduling.

PLANNING

Work planning is one of the elements that enables management to manage. By work planning, the highway maintenance administrator is able better to allocate the available resources of manpower, equipment and materials on a basis of needs. Unplanned work, although productive in character, tends to be wasteful of these resources. It results in a maximum number of crises, with most work being done on a "fire fighting" procedure. Also, while most of the work gets done, some needs are neglected, while others are overemphasized. Planning furnishes a guide to the field supervisors in their day-to-day work scheduling. Also, management reports enable middle and top management to compare the plan to actual work and know better how well the job of maintenance is being done.

The values that go into planning are called standards. A later section will detail the development of these standards. The significance of standards is that they are good objectives. The plan is then an objective as opposed to an estimate of what will happen if we sit back and do nothing to improve.

An annual maintenance work plan or program is prepared. This program is the process by which standards are applied to a road system. To prepare a work program, certain basic elements are required.

1. Work Load—The miles of road of different systems and types, the acres of right-of-way to be mowed, the length of bridges in the road system, or some other common denominator upon which to base planning.
2. Quantity of Work—The average amount of work per planning unit for each function. This can be in terms of cubic yards of surface treatment patching per mile of road, times mowed per year, or the miles of seal coat per mile of road.

3. Unit Cost—The cost per unit of work (cubic yard, acre, etc.) which is expected when good methods are used.
4. Production Rate—The number of man-hours required per unit, again based on correct work procedures.
5. Cost Distribution—The breakdown of the unit cost into labor cost, equipment cost, and materials or contractural services cost. This breakdown allows the program to be used in developing a plan along objects of expenditures, which is a valuable guide for budgeting.
6. Annual Distribution—The quarterly amount of work on each function so as to provide an essential guide to supervisors as to when they are expected to do each kind of work.

A planning work sheet was developed in which the elements of planning were tabulated. The sheet was designed for keypunch operation. Columns were established for each component. The actual program is prepared by the computer. Examples of the planning work sheet and the planning summary are given in the Appendix (Figs. 5 and 6).

There are 62 parish maintenance superintendents and each superintendent had a work plan for the area under his supervision. The planning summary is printed with a parish summary, a district summary and a State summary. This planning summary becomes not only a work plan for the fiscal year, but the basis of budget requests for operating funds.

The total of the man-hour column and the total of the cost columns become the man-hour requirements to do the planned work load for one year and the amount of money needed to do the job.

ORGANIZATION CHANGES

The basic geographical unit in Louisiana is the parish, with a superintendent in charge, and the district. The number of men in a parish vary from 20 to 50 with 2 to 6 gangs and the number assigned district-wide averages 240 men per district organized into about 15 to 20 gangs.

Some of the parishes operate from a central parish headquarters. However, in many of the parishes there are two or three outlying unit headquarters. These outlying units are a carryover of the days when the majority of the road mileage was gravel roads. Each small unit patrolled a small circle of gravel roads. With the road system mostly all weather roads and with modern trucks, the need of these outlying units has been eliminated. Now in most parishes the average travel distance from a centralized parish headquarters would be from 20 to 30 miles. Efficiency in work scheduling and overall operations more than offsets the small increase in travel caused by centralization of the parish work forces.

One of the problems encountered in Louisiana in implementing management techniques was the gang organization. The original basic organization unit was a highly specialized gang, such as a concrete gang, asphalt gang, mowing gang or bridge gang. The personnel and equipment staffing of a gang was based on its speciality. If one of these specialized gangs was able to work on its specialty day in and day out, this would not have been too bad a way to organize.

Parish Organization

Basically, the concrete and asphalt crews were 10-man crews with three or four dump trucks. The actual work load of these crews was quite varied. During a year's time, they would perform some 15 or 20 different functions of work. It was evident early in the study that the usual practice was that all men under a specific foreman went to do any job that he was assigned. This meant that whether the job was large or small and required anywhere from 2 to 10 men, all 10 men went along. In most cases, the required crew size for a specific job was under the 10-man assignment. This practice of having people in sets of ten resulted in a waste of about 20 to 25 percent of the available manpower.

It was evident that some type of a work scheduling procedure had to be established in the parishes. Also, it was apparent the men should be assigned to work on the basis of job requirements, not prefixed gang size. If the superintendent was to schedule work and assign men on the basis of needs, it would be necessary to introduce a high degree of flexibility in the parish work organization. The rigid specialized gang organization did not have this degree of flexibility.

The men in the parishes had long been associated with individual foremen, and work patterns are difficult to change. It was decided that the combining of all parish crews into one large gang so that the men would tend to lose identity with individual foremen was necessary. This was tried in a couple of pilot parishes and proved successful. Also, there was a reduction in the number of biweekly activity work reports required, which made the supervisory personnel happy.

The one gang concept of parish forces was then tried in one parish in each of the seven highway districts. Eventually, six of the seven districts renumbered all of their parish into a one gang system. At the present, 43 of the 61 parish superintendents are operating under the one parish gang numbering system. One highway district has actively resisted this change. In the other two districts, one has a parish renumbered and likes it; the other is just slow to make up its mind.

The one gang concept has a large potential in savings from better manpower utilization over the specialized gang concept. Over a year, there are many different work functions performed. The manpower requirements by function vary from 2 to 9 men. The superintendents are scheduling work on a weekly basis. Being able to schedule men to specific work functions, based on the job requirements and any special qualifications the men may have rather than work assignment by gangs, gives the superintendent a high degree of flexibility in work scheduling and personnel assignments. In those parishes where the one gang system is used in conjunction with work scheduling, there has been a noticeable increase in work output. This increase is primarily due to the scheduling techniques, but it is the organizing of the work force as a labor pool that makes the use of scheduling more effective.

This change also tends to make the superintendents job conscious. The specific jobs are analyzed by the superintendent on the basis of standards, manpower requirement, equipment requirements and material requirements. A better utilization of the primary resources of manpower, equipment and material is the result.

District Organization

The Department also has functioning on a district-wide basis and statewide basis specialized work gangs. These gangs do road reconstructions, resealing, bridge repairs, electrical repair and traffic services. On the district level, due to fluctuations in work load and the seasonal character of much of their work, these crews perform routine maintenance on an intermittent basis. When they cannot work at their specialty, they move into routine maintenance. Since most of the routine work is already planned for and staffed in the parishes, the work of these crews is superfluous when used on routine maintenance and usually results in unnecessary duplication of work.

These crews are also used to work on projects off the State system. The Department annually works on many miles of parish roads and city streets. Some of the work is maintenance in nature, but most of it consists of betterment projects. The work has to have prior approval of the Baton Rouge headquarters. The volume of this work fluctuates considerably which makes it extremely difficult for it to be scheduled economically. Since these employees are monthly employees, weather conditions and seasonal variations make these projects more expensive than contract work of the same nature. At the present time, there is some disagreement in thought as to the need of these specialized district-wide crews. It could be that after some additional work analysis and testing is made, that much of the work done by these crews can be phased into the parishes.

MANAGEMENT REPORTS

Out of the data collected in the work reporting system, various management reports are prepared. These reports are designed to let managers at each level of organization receive timely information as to how they and their subordinates are doing. Their actual performance is compared against the planned performance (performance standards) in a series of four reports (the need for all of these is still under examination):

1. Performance Analysis—a monthly summary of production rates and unit costs prepared for each superintendent, district, and the State as a whole.
2. Performance Report—a quarterly report for each manager which emphasizes amounts of work being done.
3. Productivity Analysis—an annual summary organized to help review performance on individual work functions. This report shows the number of organizations which achieve standard productivity and those who do not.
4. Quantity Analysis—another annual report for evaluation of the amounts of work being done. This, as is the productivity analysis, is primarily designed to verify and update standards and to initiate further research where needed.

A sample of each report is given in the Appendix. The first two are shown completed, the third only in blank form inasmuch as the year was incomplete at the time of writing. The fourth is still being reviewed for content.

The performance analysis report was originally planned to be a monthly report for the guidance of the parish superintendents. It listed by gangs, accomplishment, work effort, cost and comparison with standards. This report is now being printed summarizing work by superintendents. It is still a useful report for middle and top management and as a quarterly report does furnish the superintendents some help. However, it has been found to be beneficial for production rates to be computed by the parish clerks and superintendents from the biweekly activity reports and summarized monthly. These summaries are to be brought to a monthly meeting of the superintendents and made part of a group discussion. Those districts using this technique find a greater awareness of the value of productivity standards developing among the supervisory personnel.

It is realized that the continual reassessment of these reports will be needed and that probably future changes will be necessary.

MAINTENANCE POLICIES

In the same way as the planning process sets work objectives, overall management objectives are set through policies. In Louisiana, policies are being developed by an advisory committee composed of major section heads and district engineers.

The basic policies which have been recommended for approval are shown in Exhibit 1. These policies reflect the way the Department intends to handle the management of maintenance. These policies spell out the kinds of standards which will be developed, the use of standards in planning, and the process for continuous performance evaluation and improvement.

Exhibit 1.

BASIC MAINTENANCE OBJECTIVES AND POLICIES

OBJECTIVES

The objectives of the maintenance function are as follows:

1. To preserve the investments made in state highways, bridges and appurtenances.
2. To provide adequate levels of safety, comfort and convenience to the motorists.
3. To ensure economy in the expenditure of resources.

BASIC POLICIES

The three objectives set forth above shall be fulfilled through implementation of the five basic policies set forth below:

1. Standards of performance relative to work quality, work quantity and work methods applicable to maintenance activities shall be established.

Exhibit 1. (Continued)

Quality Standards . . . To define the level-of-service objectives for highway facilities.

Quantity Standards. . . To estimate the volumes, by type, of the maintenance work required to maintain highway facilities at adequate levels of service.

Methods Standards. . . To define the most effective methods developed for doing the work, and to establish productivity rates that can be expected through using these methods.

2. Annual maintenance programs shall be developed and adopted.

Annual maintenance programs shall be developed to define the types and amounts of maintenance required. Programs shall be based on established performance standards and shall reflect estimated requirements for manpower, equipment and materials for each maintenance activity in each District.

Maintenance programs shall be developed under the direction of the Maintenance Engineer, reviewed by the Chief Construction and Maintenance Engineer and by the Chief Engineer, and approved by the Director.

Approved maintenance programs shall be the basis for preparation of maintenance budgets and for the allocation of resources to individual Districts. 1/ Budgetary allotments shall define specific funds for:

+ Routine maintenance and operations
+ Special maintenance programs
+ State force construction and betterment
+ Administration and overhead.

3. A system of performance evaluation and control shall be adopted.

A system of work reporting shall be established to provide a record of work accomplishment in terms relatable to the work programs. Performance reports shall be made available to maintenance managers at all levels in forms best designed to serve their needs.

Performance reports shall be used to guide managers and supervisors in (1) the fulfillment of the planned maintenance program, (2) the evaluation and improvement of performance, and (3) the review and verification of performance standards.

4. A system of long-range planning shall be adopted.

A system of long-range maintenance planning shall be established to provide a basis for estimating long-term requirements for manpower, equipment, materials and money.

Projection of maintenance needs shall be over a period of years sufficient to permit fiscal coordination with long-range highway construction programming.

5. A series of operating policies shall be adopted.

It shall be the responsibility of the Chief Maintenance and Operations Engineer to develop and establish operating policies and procedures within the framework of the basic objectives and policies.

DIRECTOR OF HIGHWAYS DATE

1/ Effective for Fiscal 1969 - 1970 Budget.

EXPERIENCE IN IMPLEMENTING

The results obtained at the performance laboratory with emphasis on findings from methods studies and the development and utilization of management procedures at the operating level are discussed in the following sections. The implementation of these results in other areas of the State is also discussed.

PERFORMANCE LABORATORY

General Results

During 1967, a maintenance performance laboratory was conducted in Natchitoches Parish. The following were the results of the laboratory.

1. The best staffing, equipment assignments, and procedures for work performance were determined. Productivity standards were established based on these methods.
2. Quantity and quality standards were developed for the major maintenance functions for application on a statewide basis.
3. Management procedures necessary for operation of the maintenance management system were developed and implemented.
4. The potential for improved performance of maintenance operations through the use of standardized work methods and management procedures was demonstrated.

The laboratory was conducted as a joint effort between the Department and the consultant. The consultant provided a resident research associate at the Alexandria district as well as specialized assistance from the project manager and consultant staff. Department participation included the assistant maintenance engineer from the Alexandria district who acted as performance laboratory coordinator, a research analyst, and four technicians. Data on maintenance operations were collected, summarized and analyzed to fulfill the objectives of the study. Alternative methods and procedures were tested and performance standards compiled.

Quantity standards were defined in terms of the annual amount of work required per planning unit. Quantity standards were set in three ways. First, standards for certain functions applying to bituminous surfaces were established through an economic comparison of alternative ways of performing work. Next, some standards were set following inspection and observation of maintenance requirements at the Laboratory and analyses of data from the reporting system. Finally, certain quantity standards were established on the basis of a desired service frequency. A summary of the approved quantity standards is shown in Figure 10 (Appendix).

Quality standards were defined by the standards panel for the major routine maintenance functions. Similar standards developed by AASHO, Virginia, and Ontario were reviewed. The final quality standards were based on the collective judgment of experienced maintenance personnel on the standards panel. The approved quality standards were then incorporated in a set of standard work procedures for each function. An example of these work procedures is shown in Figure 11 (Appendix).

Several methods or accomplishment studies, similar to those used on the Iowa and Virginia research projects, were conducted in order to develop detailed data relating to specific maintenance operations. Observers employed wristwatches to obtain a complete record of working time and delays associated with each individual element of work throughout the day. An example of the type of data collected through accomplishment studies is shown in Figure 12 (Appendix).

Findings from the accomplishment studies coupled with field observations of work performance and analyses of data generated under the daily reporting system were used to determine optimum staffing patterns, equipment assignments, and procedures. Once an optimum method was selected, it was implemented as the standard practice in the parish. At the conclusion of the laboratory, a standard production rate—in terms of labor hours per unit work quantity—was derived for each major maintenance function. A standard unit cost when performing each function by the standard method was also derived. Crew staffing and equipment assignments were standardized based on average conditions encountered; the Parish Superintendent has leeway to alter basic staffing if a hauling distance or traffic control problem exists. An example of approved productivity standards is shown in Figure 13 (Appendix).

A standards panel, consisting of a maintenance representative from each of the nine districts in the State, as well as one from headquarters, was formed and met monthly for the duration of the laboratory. The panel reviewed and evaluated the basic approach taken in the laboratory and the conclusions reached. The panel was instrumental in establishing quality standards, setting quality standards, and defining the standard methods and productivity values. Members of the panel established test parishes in their own districts to try out methods and evaluate the management procedures being developed.

The implementation of improved methods and procedures at the laboratory resulted in better utilization of manpower, materials and equipment which was indicated by improved productivity trends. An example of the improved productivity attained at Natchitoches during the laboratory is shown in Figure 14 (Appendix). When improved work methods and management procedures were installed at the laboratory, the parish forces performed betterment-type work. The betterment projects were work items not normally undertaken by maintenance forces that were designated specifically for the laboratory.

As standard methods and productivity values were finalized at the laboratory, they were introduced gradually to other parishes of the Alexandria district as well as statewide in the test parishes. After being developed, the performance standards were incorporated into a "Maintenance Superintendents Manual" which was distributed to all parishes. As mentioned previously, training materials and techniques are being developed which will instruct maintenance personnel in the proper application of the performance standards for the major maintenance categories.

Methods

A number of alternative methods for performing maintenance operations were evaluated at the laboratory. In general terms, the following items were evaluated: (a) crew size, (b) type and number of equipment units, and (c) work procedures.

The methods chosen for testing were selected as the result of a review of methods studies conducted in other states, analyses of data from the accomplishment studies, and conclusions reached following general work observations. The criterion used to accept or reject any particular method was an improvement either in workmanship or productivity. It was necessary, of course, to evaluate subjectively any changes in workmanship that occurred as a result of using different methods.

Crew size or staffing was the single most important factor affecting productivity of operations. The fixed-size gangs virtually dictated the use of a full-sized crew for almost all operations regardless of actual requirements. For example, it was not uncommon to see an asphalt gang of 10 to 12 men used to premix patch and the same gang at a later time used to repair cracks in the road. Aside from those operations where hauling distance for materials became involved it was found that, in general, the fewer men assigned to an operation the better the resultant productivity. For example, when patching with cold premixed material stored at the unit, the smaller crews achieved higher productivity than the larger crews. The relationship between the size of the crew and resultant productivity is shown in Figure 15 (Appendix). If two men were assigned to remove trash from litter barrels, the maintenance supervisor could expect an overall productivity about twice as high as that achieved by a single man. The same held true for blading and reshaping shoulders or gravel roads. A single motor grader functioned more effectively than two motor graders working as a team on the same job.

On those operations where varying haul distances for materials were involved, the absolute size of the crew was not as important as achieving the proper balance between men and equipment for the different distances. For example, in patching nonpaved shoulders it was found that, at times, both small and large crews might attain good productivity values. It was important to have enough trucks assigned to the operation so they could make their trips to and from the pick-up area without causing any major delays in the operation. The number of hauling trucks and men had to vary as the hauling distance was closer or further away from the work site. On the basis of average haul and dump times, Figure 16 (Appendix) was developed as a guide for the parish superintendents when scheduling this activity. So, for this type of activity, a nominal crew size and equipment complement was established and the parish superintendent made adjustments as the occasion demanded. If haul distances were extensive, then the addition of a truck or two to the basic crew would result in better productivity and conversely when haul distances were shorter the trucks had to be eliminated in order to achieve high productivity.

Besides the crew size and amount of equipment taken to a job, the sequence of operations or work procedures were an important aspect of the job if high-quality work was to be expected. Adequate work procedures were developed for the major maintenance functions. Without continual follow-up action by managers, personnel were apt to slip back to their old habits when performing maintenance work. For example, tack coating prior to a premix patch is generally regarded as an essential step to effect a permanent repair. Yet field personnel who had not been in the custom of placing a tack coat found it difficult to adjust to the new requirement.

Another important aspect of methods was the organization of work so that a crew had a full day's job. This was really a part of the scheduling process. It was obvious that if the right number of men and equipment were sent to do a job and the job did not require a full day and if the crew did not have anything else in sight, then, even though they used correct procedures, they were going to dawdle around so that their overall daily productivity for that job would be lower than need be. The supervisor of field operations had to assure that the work was there to be done and that when a crew finished on one road they either had an assignment on another road or some other task to do. Otherwise, they were being used ineffectively and did not attain the desired end result of good productivity.

The best methods were the basis for productivity, unit cost, and cost distribution standards. The standards so selected were thus field tested and attainable by all parishes in the State providing they used the same methods and scheduled work in the same manner as was done at the laboratory.

MANAGEMENT PROCEDURES

Work Emphasis

A chronic problem with maintenance work in the State was that field personnel did more than that which was necessary. Maintenance, of course, falls into two basic categories. Either it is corrective or preventive in nature. Corrective maintenance such as repair of potholes or serious road depressions must be undertaken immediately to provide for safe travel by the public. The area of preventive maintenance is the one where judgment enters the picture. At what point is it necessary to go and correct a minor fault in the road? Must roads be maintained to an as-built condition?

It was found that roads were generally over-maintained although this was probably attributable to the over staffing existing at the field level. Because of the virtually limitless manpower available, the roads were literally being worked to death. All trivial depressions were leveled, all surface cracks, regardless of width, were poured. Nonpaved shoulders and gravel roads were bladed more often than necessary. No guides were available to field personnel as to when work was required.

For corrective maintenance, the decision of when to repair was relatively straightforward—a traffic hazard existed and had to be removed. But with items of a preventive nature, no criteria existed as to when work should be undertaken. It was also found that different supervisory personnel had a tendency to stress different types of activities so that, somewhat paradoxically, it was not uncommon to see some particular maintenance operation neglected. The development and enforcement of quality and quantity standards helped alleviate this situation at the performance laboratory.

Another adjunct of the excess labor force was an emphasis on performing minor daily activities. This was necessary because the men had to be kept busy and, even though it may have been more economical to perform major activities with large work forces instead of the minor activities, this was clearly impractical from an operating level viewpoint. For example, one foreman at the laboratory had been in the habit of using a bituminous mixer (pugmill) every day to keep his assigned road miles in shape. This was what had been done before and his experience dictated that this had to be done almost every day to keep the roads in good condition. But with the same number of men he used for the pugmill operation he could have purchased premix material from a commerical plant and accomplished as much in one day as it was taking him five days to complete. Of course, with the pugmill his men were busy all week, however inefficiently, rather than just one day.

Particularly on bituminous surface activities, a shift will be made from minor daily activities to major work. The prime example is the seal coat program. The cost of surface treatment patching by parish forces is about $15 per cubic yard as opposed to a seal coat cost of $10 per cubic yard. But more emphasis had been placed in the State on the higher-cost surface treatment patching rather than planned seal coats. With the new standards, seal coats of bituminous roads will be programmed to occur on the average of every five years and surface treatment patching will only be used as a stop-gap measure to protect a road in-between seal coats. Thus, the money expended will be more fruitfully employed than it had been in the past.

Planning and Inspections

An annual maintenance program for each parish will be developed from the performance standards specified for routine maintenance functions. An example of the annual program for Natchitoches Parish during Fiscal Year 1969 prepared from approved standards is shown in Figure 17 (Appendix). The miscellaneous category is the contingent plan to take care of work on those functions for which there are no standards. The labor hours for construction and betterment projects represent, in reality, the excess manpower available at the parish when only the proper amount of routine work is done by the best-known methods. As a guide for field personnel, the annual program of the parish will be broken down by quarters according to the recommended seasonal distribution. An example of a quarterly breakdown of the annual program for bituminous surface maintenance is shown in Figure 18 (Appendix).

An annual road inspection was conducted at the laboratory to inventory existing maintenance requirements. This inspection was carried out by a representative from the district and the parish superintendent. Inspection forms are still in a developmental stage but the versions currently being evaluated are shown in Figure 19 (Appendix). The purpose of the inspection is twofold: first, to locate and identify, in general, the routine maintenance work that is required; second, to locate and identify, in detail, the special work to be done during the year such as seal coats, overlays and betterment projects.

Obviously, an annual inspection cannot uncover every maintenance requirement that will develop during the year, but it can pinpoint conditions that exist at the time of the inspection and that will have to be corrected. A road that has already started to ravel seriously will have to be patched, a ditch that is blocked will have to be cleaned. The need for annual inspections is an absolute; without it, the field supervisor will not be in a position to schedule work adequately.

The superintendent relied on annual inspection forms as his general guide for scheduling operations at the laboratory. When work on a road was completed, the superintendent crossed it off the inspection form with a red pencil. To supplement the annual inspection forms, the superintendent made personal inspections of roads prior to scheduling to determine if the maintenance requirements had changed drastically. This pre-scheduling inspection was conducted on an informal basis.

In addition to the annual inspection and pre-scheduling inspections, the superintendent inspected work while it was in progress as well as when it had been completed. The geographical extent of the parish and number of crews set up on any day made it physically impractical for him to check every job every day. He had to exercise judgment and spot-check the high-cost jobs or those that the men were unfamiliar with or those where one crew was not as competent as another. All three elements of work performance—quality, quantity, and productivity—are closely interwoven and, while making inspections the superintendent had to evaluate the adequacy of all three of them.

Scheduling

It was evident from the begining of the project that very little planned scheduling of work was being done at the parish level. Reports of road conditions made by supervisors from the district level or others caused changes in parish operations at the last moment. These reports often caused the parish superintendent to change plans for the day's work with little regard for economics. At best, scheduling of work was sporadic. Job assignments, when made by the parish superintendent, were normally done on a daily basis although most of the time each gang foreman was responsible for scheduling the work for his gang.

Because of the variety of operations that might take place in any one parish, it was recognized that a formal scheduling technique was needed. A written schedule met only partial acceptance by field personnel mostly because of their low education level.

However, the district must assure that parishes develop short-range schedules which fully utilize the capacity of the parish. The type and amount of work scheduled must be in accord with the types and amounts specified in the annual program or uncovered through the annual inspection. Likewise, the labor and equipment scheduled must generally approximate that recommended in the standard methods. Otherwise, the district may find the parish doing work other than that which was necessary or using more labor or material than had been anticipated.

Several techniques for scheduling work were tested in the laboratory; the one finally selected and one that met the approval of most of the parish superintendents was merely a fiberboard, approximately 4 by 8 ft, posted with appropriate entries that hung in the parish superintendent's office where it could be viewed by all parish personnel. The scheduling board is shown in Figure 20 (Appendix). The scheduling board served in a dual capacity, acting not only as a means of formalizing the work schedule, but also as a means of making specific daily job assignments of personnel and equipment. The scheduling board was posted by the parish superintendent, as a minimum, once each week. No permanent record was kept of any weekly schedule; if it ever were necessary for management to know precisely what work was done on a particular day, they could determine this from the daily work reports used in the reporting process.

The scheduling board contained a columnar listing of personnel in the parish, two tables of maintenance activities and codes, and two maps of the parish showing each state maintained road color-coded by road system classification. To the left of the personnel listing were columns where any type of leave could be posted for all personnel. To the right of the personnel listing were two columns, one for normal schedule and one for the inclement weather schedule. Thumb tacks of various colors were used as markers to designate the functions that would be done, the number of specific names of men assigned to each, and the road locations where the work would take place.

The parish superintendent scheduled work on a weekly basis. So, once he set up a repair crew, he tried to keep the basic crew intact for at least a week if there was enough work to do so. The scheduling was done on the Friday preceding the work week. Prior to the superintendent's scheduling, the parish clerk placed markers in the leave columns beside the names of the men who were known to be on leave.

To illustrate how the scheduling board was used, assume a surface treatment patching crew was being set up. The superintendent would place a colored marker in the normal schedule column beside the names of the seven men (standard crew size for this function) he selected to be in the crew. He would then place a similar colored marker in the normal schedule maintenance "Function Table" under Function 411—surface treatment patching. Finally, a similar colored marker would be placed on the parish map on the specific road where work was to commence.

Other crews were scheduled in the same manner but with different colored markers. By using recommended crew sizes, there were usually two to three men left over who would then be assigned some miscellaneous task of low priority. If a member of one of the regular crews was unexpectedly absent on a given day, one of these men could be reassigened to the regular crew with relative ease. Only rarely did it become necessary to readjust the entire schedule because of absentees.

Using the same techniques, the superintendent would then devise an inclement weather schedule for the parish. The superintendent finally reached a point where it took him about an hour to schedule the work for the week. On a daily basis, the only thing that had to be done was to change road markers when a crew completed their work on one road and to make any minor modifications necessary when men were absent or a true emergency had arisen such as an equipment breakdown.

In making job assignments, the superintendent relied on his intimate knowledge of personnel and equipment capabilities. Certain personnel were better at performing some tasks than others. Even when the same equipment and procedures are used, personnel are going to perform differently—not as differently as when they had used non-standard procedures but still a natural variation will exist. For example, older personnel will not perform as vigorously as their younger counterparts. Different items of equipment also will perform differently. There were no standard hitches on trucks, for example, so when the towed air compressor was assigned for an operation the superintendent had to make certain that only a truck with the appropriate hitch was designated to tow it. These, as well as other factors, had to be taken into consideration by the superintendent when making the schedule.

Although it happened infrequently, sometimes the superintendent was not able to inspect the roads prior to scheduling because of the press of administrative details or necessity for him to oversee personally an on-going operation, particularly some of the betterment projects where the men were unfamiliar with the operation. When this happened, the superintendent had to rely solely on the annual inspection forms for his schedule.

Using district and parish supervisory personnel, attempts were made to delineate the actual maintenance requirements in more detail. For example, areas to be patched were outlined on the road with spray paint. But this was more in line with training than scheduling and due to the time and expense involved did not justify the results for routine maintenance activities. When field personnel become well versed with the quality standards, they will be capable of making decisions of this nature by themselves.

Scheduling of maintenance work was generally accepted across the State. Even before the laboratory was completed, most parishes had adopted similiar devices and had begun to formalize work scheduling.

Work Control

Control over maintenance operations, or assuring that performance standards are met, must take place at both the parish and district levels. The criteria for evaluating the quality of work are, for the most part, subjective in nature; for this reason, the district bears a heavy responsibility for assuring uniformity among the parishes in work quality. The quality and quantity standards were designed to guide the undertaking of operations. At the laboratory, district personnel made frequent inspections of parish roads and checked the quality of work that was completed in addition to insuring that only needed work was done. If the standards were not adhered to by the parish, action could be taken by the district to bring the work in line.

Of course, the parish superintendent, foremen and workers did not relinquish their responsibilities for performing high-quality work. Workers had to be conscientious and apply proven techniques when they performed. The foremen had to direct their men so that a quality job was done. Also, the foremen had to make any individual decisions regarding road conditions and the need for work; for example, the specific areas that had to be patched and how far the patches had to extend.

To achieve field control over work quantity and productivity, the superintendent had to be provided with up-to-date information on operations almost instantaneously. This was provided at the laboratory through employment of a work control board (Fig. 21, Appendix). By posting the cumulative results of operations every two weeks, the superintendent had immediate knowledge of the existing situation in his parish with regard to work quantity and productivity for planned maintenance activities.

On the work control board, each planned work function and its numeric code was listed in left-hand columns. For each road system, the planned quarterly work quantity for each function was listed. As work was completed, it was posted in the actual column for the appropriate function and system. Data on the amounts of work done were taken directly from the biweekly activity reports which were submitted to Baton Rouge for processing on the computer. Thus, the parish superintendent could tell at a glance what work, if any, was being neglected and on what road system. The planned work quantities posted were taken from the annual maintenance program and, as such, had to yield to legitimate requirements uncovered during road inspections. If the actual work quantity for a function was higher or lower than that planned because of road inspections, there was a valid reason for the difference and no control action was necessary. However, if it was different because no work had been scheduled or the crews were overworking the roads, then the superintendent had to take action to correct the situation. On entering a new quarter the planned work quantities for that quarter were added to those already on the Board thus providing a cumulative total of the amount of work planned to be done.

Also listed on the board were the planned man-hours necessary to accomplish the work and the standard labor productivity. As work was completed the actual man-hours used and actual productivity attained were posted. The productivity for each operation was computed by the parish clerk, who in fact, bore responsibility for making all entries on the board after he had completed the biweekly activity reports. With the productivity values on the board, the parish superintendent could tell immediately which operations were in line with the standard productivity; those that were not, required some type of action on his part. Thus, with the board, the parish superintendent had the information readily available that he needed to take action to bring work quantities and productivity in line with planned values.

To control operations from the district level, a similar work control board was kept at the district office (Fig. 22, Appendix). The same activities as those listed on the parish work control board were listed. But, in this case, the planned and actual work quantities were not broken down by road system, only the planned and actual total quantities for the district as a whole were listed. For each parish the actual productivity attained to date on each operation was listed. Thus, an immediate comparison of the productivity results at each parish could be made.

Total work quantities were posted on the board by district personnel; productivity values for each parish were posted by parish superintendents. By requiring parish superintendents to post their own productivity values, they were drawn more directly into the control process and displayed more interest in actually achieving standard productivity. The district work control board was posted once a month; a copy of the monthly entries was kept on a form at the district office. The board was reviewed at a monthly meeting held at the district office with parish superintendents. These meetings served as open forums for discussing mutual problems and differences in productivity. The meetings also were useful as informal training sessions for personnel in current methods and procedures. With information from the district board, district managers could take whatever steps they deemed necessary to bring results closer to those anticipated.

The use of control boards at parish and district levels did not obviate the need for computer output reports. But, rather than have field personnel wait for computer reports, the boards provided immediate information for the field. An implicit assumption in using the boards was that labor productivity was a sufficient indicator of efficiency for field use because the boards did not furnish any information on the cost of operations. The computer reports, however, do summarize operations and provide information on costs to district and upper-level management

PERSONNEL TRAINING PROBLEMS

A survey was made to identify the training needs of the personnel who supervise the maintenance and operation of highways, bridges, ferries, and tunnels in Louisiana including: (a) an analysis of the characteristics of the supervisor and potential supervisor forces; (b) an analysis of the work performed and the knowledge, skills, and abilities required to perform that work; (c) measures of the extent to which current and potential supervisors possess the required knowledge, skills, and abilities; and (d) identification of the capacities and the willingness of the current and potential supervisors to learn that which they need to know in order to effectively do their work.

Age

A total of 636 persons are currently employed to supervise the maintenance and operations of highways and bridges. Another 1,662 persons are employed in positions from which promotions to the supervisory level are made.

The supervisors and potential supervisors range in age from less than 25 to more than 65 years, indicating that special steps will have to be taken to insure that all personnel can participate effectively in any training provided.

The average age of the supervisor personnel is 51 years; the average age of the potential supervisor personnel is 49 years. These data indicate that: (a) little difference exists in the age characteristics of the two groups, and (b) both groups are represented principally by personnel who have had little or no formal training exposure for more than 30 years.

Education

Thirty-four percent of the supervisors have had less than eight years of education, whereas 32 percent have graduated from high school. Seven percent of the supervisors have attended college and 3 percent have graduated from college.

Sixty-three percent of the potential supervisors have had less than eight years of education, and 11 percent have graduated from high school.

These differences in educational attainments among persons in the same training population indicate that great care must be taken to insure understanding of the training materials by all personnel without reducing the motivation for training attributable to the better educated individuals. These data further indicate that any training program must consist of basic courses to be taken as prerequisites to technical courses for persons with limited educations.

Experience

The range in experience for both supervisors and potential supervisors is from a few moths to more than 20 years. Sixty-nine percent of the supervisors and 41 percent of the potential supervisors have had more than 10 years of experience. These experience data indicate that: (a) most employees have had considerable exposure to highway operations and can be expected to have strong feelings about how work should be done, and (b) the training approaches will have to recognize that some personnel have had little opportunity to acquire knowledge of maintenance technology while others have learned a great deal through work performance.

Work Force Makeup

The distribution of all personnel employed in the maintenance function of the Department is shown in Figure 23 (Appendix).

1. The total force consists of 4, 852 persons employed at the state, district, and parish levels.
2. The supervisor group consists of 636 persons—13 percent of the total force.
3. The potential supervisor group consists of 1, 662 persons—34 percent of the total force.
4. The non-supervisor group includes 2, 326 persons—48 percent of the total force.
5. The clerical group includes 228 persons—5 percent of the force.

The reaction of those Department personnel already introduced to the new methods and procedures has varied from total acceptance to total rejection. Generally, we found that newer employees with less experience or familiarity with the existing practices in the Department were the quickest to adapt to the new procedures. Older employees, who tended to worry more about job security, were more reluctant to accept the changes. However, as the benefits and advantages of the new practices became evident to these people, they began gradually to accept the changes. We felt that most of the Department employees would be able to adjust to the new system with proper training and follow-through by management.

As mentioned, one phase of the current project is devoted to the research and development of training techniques and procedures appropriate for maintenance personnel. New concepts will be investigated and tested. Examples of training materials also will be developed and tested.

Four basic techniques for training maintenance personnel are being tested:

1. Programmed Instructions—self-instructional material in a printed book form designed so that trainee can proceed at his own pace.
2. Audio-Visual Instructions—self-instructional material in which a regular slide projector and tape recorder will be used.
3. Workshop—a carefully led small group where emphasis is placed on group participation.
4. Conference or Seminar—conventional training utilizing an instructor to present the material.

The subject matter for the first series of training courses covers work on bituminous surfaced roads. This category of work was selected for development of training material because bituminous surface care involves a high percentage of the cash outlay for maintenance. Training materials for other categories of maintenance are also being developed.

The training materials will be evaluated in two stages:

- Short-term—an evaluation directed to the comparative communication ability of the various methods as determined from pre and post testing.
- Long-range—an evaluation from the reporting system which will show performance change and dollar savings.

The training will be administered by the line organization. Primary evaluation of effectiveness will be by district engineers. It is anticipated that all four basic techniques will be used on a permanent basis with the situation dictating which technique is required.

SUPERINTENDENTS MANUAL

The Superintendents Manual was designed as a "working manual" to help field personnel in performing work more effectively. The contents of the manual are based on research work conducted in the performance laboratory. The manual was developed to permit changes to be made readily as new sections are added from time to time as well as revisions made to existing sections.

Contents

A brief description of the contents of each section of the manual follows:

Section 1 Responsibilities

This section informs the superintendent of the basic objectives of the Maintenance Department and tells him of his responsibility as a supervisor. An overview of the entire maintenance management system in terms the superintendent can understand is also presented.

Section 2 Maintenance Standards

A general description of the performance standards, as approved by the standards panel and tested in the performance laboratory is presented.

Quality Standards—These standards provide a tool for supervisors in that they define conditions that are acceptable as well as conditions that are unacceptable. For example, the Quality Standard for mowing says that roadside grass should not be higher than twelve inches. Another example is found in depressions in bituminous surfaces. When these are less than one inch in ten feet they are acceptable, however, depressions greater than one inch in ten feet cause a rough riding surface that is uncomfortable and if they develop into potholes they are a hazard. These are unacceptable and should be corrected.

Quantity Standards—These standards provide the basis for the initiation and measurement of work thus providing a tool for planning and controlling work.

Methods and Procedures—These standards provide guides for staffing arrangements and equipment assignments as well as proper procedures to assist the superintendents in performing work uniformly on a statewide basis.

These standards also provide a production rate and unit cost to enable the superintendent to become aware of what it costs to do the work.

Section 3 Annual Program

This section shows how work is planned in accordance with the standards. The following is an example for premix patching.

Parish Mileage Responsibility

Primary system	-	100 miles
Secondary system	-	60 miles
Farm-to-market system	-	140 miles

Annual Quantity Standards

Primary system	-	2.0 tons per mile
Secondary system	-	4.0 tons per mile
Farm-to-market system	-	4.0 tons per mile

Annual Quantity

Primary	-	100 miles	×	2.0 tons per mile	=	200 tons
Secondary	-	60 miles	×	4.0 tons per mile	=	240 tons
Farm-to-market	-	140 miles	×	4.0 tons per mile	=	560 tons

Total pre-mix required for year. . . . . 1,000 tons

Man-Power Required

The productivity standards indicate a rate of 3.0 man-hours per ton to place pre-mix; therefore, 3.0 man-hours × 1,000 tons = 3,000 man-hours required.

Funding Required

Labor	-	1,000 tons	×	$6.60 per ton	=	$6,600
Equipment	-	1,000 tons	×	2.20 per ton	=	2,200
Materials	-	1,000 tons	×	8.20 per ton	=	8,200

Total $17,000

Section 4 Inspection

This section of the manual covers inspections in the following order:

- Annual inspection
- Pre-scheduling inspection
- On-the-job inspection
- Workmanship inspection

Section 5 Scheduling

This section of the manual stresses the importance of scheduling work. Five questions the superintendent must have answers to in order to schedule his work effectively are:

- What is to be done?
- Where is it to be done?
- How is it to be done?
- Who is to do it?
- When is it to be done?

Section 6 Performance Reports

This section lists and describes sources of information made available to the superintendents, including:

- Biweekly activity reports
- Annual maintenance program
- Performance analysis report
- Quarterly performance report

Section 7 Methods and Procedures

This section presents the performance standards for all major functions. The standards provide the following information:

- Function description
- Recommended crew size
- Recommended equipment complement
- Approximate accomplishment per day

This section also includes the annual work quantity standards and unit costs and productivity standards so as to give each superintendent a complete picture of the management system at his level.

Distribution and Implementation

The Superintendents Manual was distributed to each district for use by all parish superintendents. Training in the use of the manual was handled by district personnel. The intent of the manual is to provide information for employees who are superintendents now and also for those who will be promoted to superintendents.

IMPLEMENTATION OF RESULTS

Certain aspects of the maintenance mangement system have been implemented statewide. For example, the reporting system and scheduling process are being utilized throughout the State and are working satisfactorily. Other aspects of the system, such as the use of standard methods and formalized inspections, have been implemented in several parishes.

A formalized step-by-step implementation of the total maintenance management system will be conducted during Fiscal Year 1969 in the Lake Charles district. At present, implementation of the system or any part thereof in the remainder of the State is at the discretion of the district engineers.

Procedures are being developed for preparing the district annual maintenance budgets on the basis of performance standards. We anticipate that the Fiscal Year 1970 maintenance budgets for all districts in the State will be prepared in this manner.

Appendix

The following pages contain charts, forms, and tables referred to in the text of the paper.

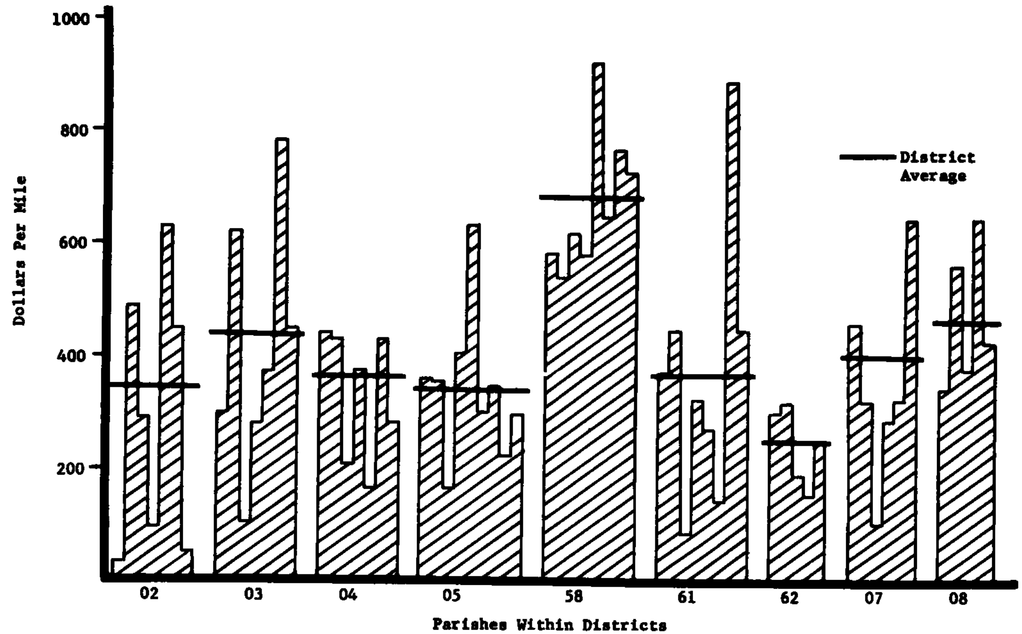

Figure 1. Average annual cost per mile for patching on selected control sections, fiscal years 1963-1965. Data from functional cost reports and system surface logs.

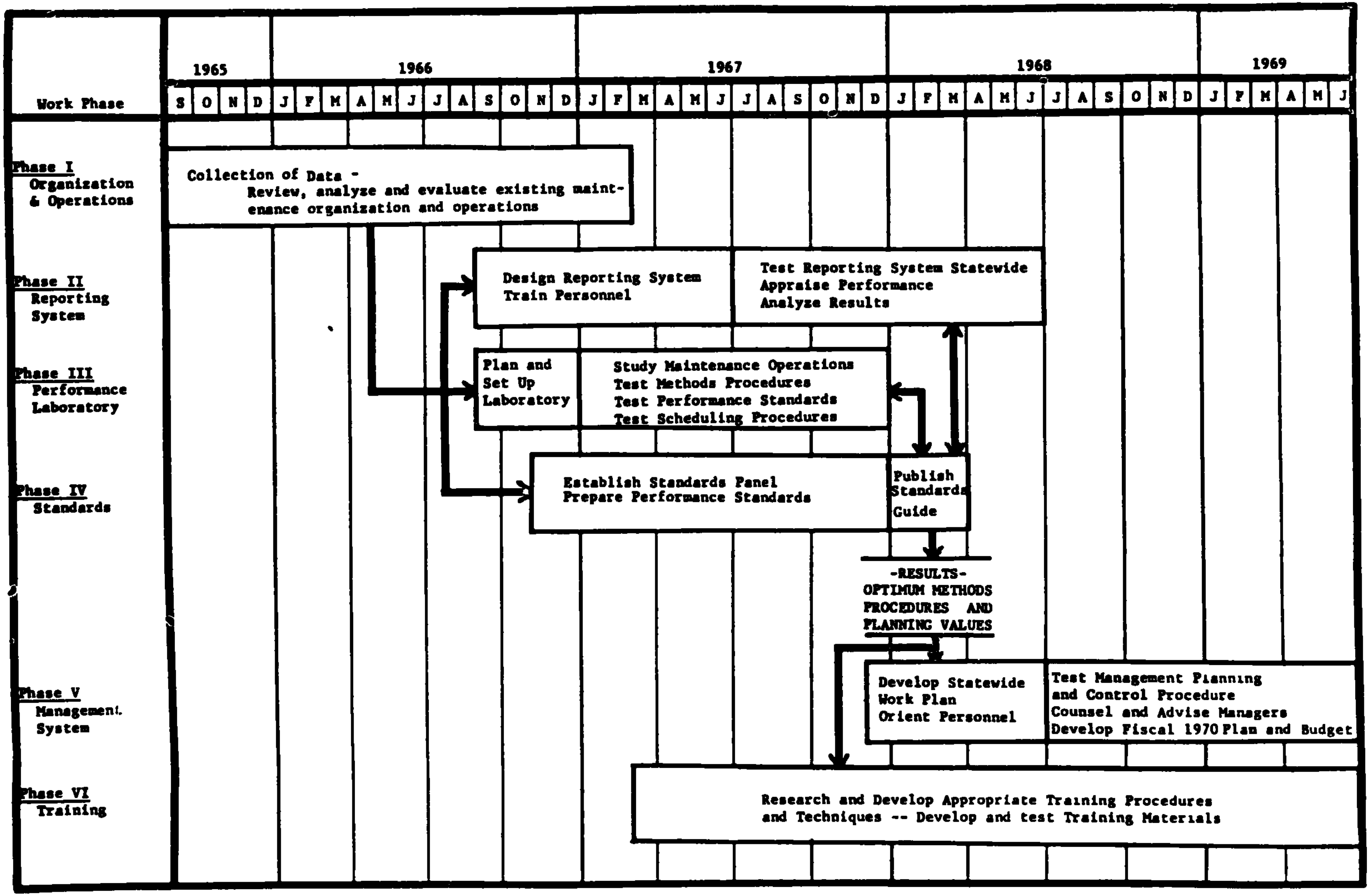

Figure 2. Maintenance research project schedule.

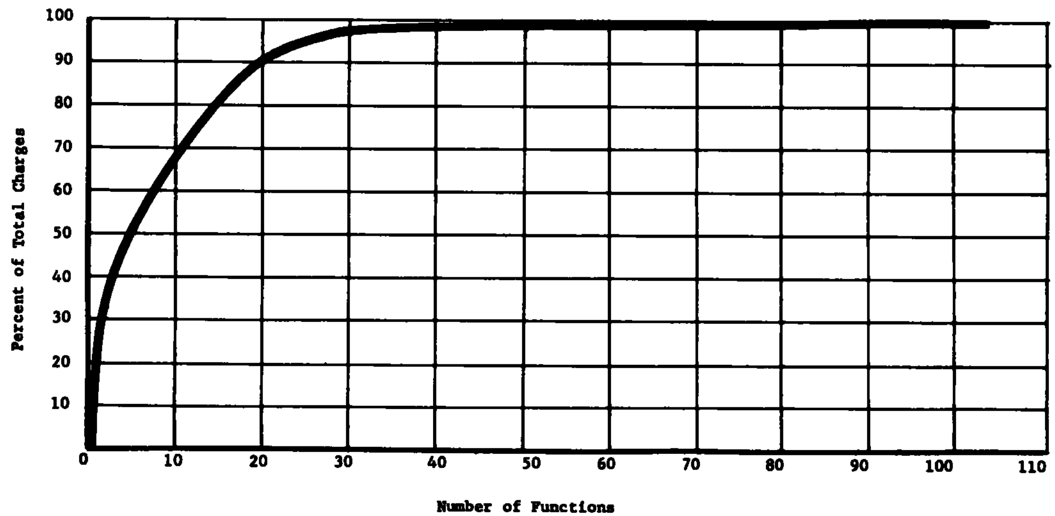

Figure 3. Distribution of charges to maintenance functions, fiscal 1965.

FORM NO 4129

61505

STATE OF LOUISIANA
DEPARTMENT OF HIGHWAYS
BIWEEKLY ACTIVITY REPORT

	Payroll District	Payroll Gang	Period Ending No	Period Ending Day	Period Ending Year
9	07	550	5	22	68

Description of Work

Work Force Identification Dist	Work Force Identification Gang	Parish	Function	System Code	Control Unit or Equip No	Struct Code	Proj No	Ident Code
07	650	10	411	4				

(61505

MATERIALS USED RECORD

Stock Pile Location	Description	Iss Dist	Stock No	Iss Par	1st Wk W	T	F	S	S	M	T	2nd Wk W	T	F	S	S	M	T	Quantity	Unit of Meas
Lake Charles	E-3 Aggregate	07	24-02-6820	10	20	24						22	19	23					108	55
Lake Charles	AC-8 Asphalt	07	2403-1325	10	550	650						600	600	650					3050	20

Transmission Totals 3158

EMPLOYEE TIME & PER DIEM RECORD

$ Employee Name & Number		1st Wk W	T	F	S	S	M	T	2nd Wk W	T	F	S	S	M	T	Total Hours Regular	Total Hours Overtime	Total Amount Per Diem
Labor	PD																	
NO	HR	64	64						56	64	64					312		

Transmission Totals 312

EQUIPMENT USED RECORD

Daily Hours or Miles Charged

/ 1st Wk W	T	F	S	S	M	T	2nd Wk W	T	F	S	S	M	T	Equipment No	Total Hours	Total Miles
8	8						8	8	8					140-650	40	
8	8						8	8	8					140-651	40	
8	8						8	8	8					140-980	40	
8	8						8	8	8					263-562	40	
8	8						8	8	8					250-221	40	

Transmission Totals 200

ACCOMPLISHMENT RECORD

Description

Number of Units Accomplished

? 1st Wk W	T	F	S	S	M	T	2nd Wk W	T	F	S	S	M	T	Unit of Meas	Total Number of Units
20	24						22	19	23					55	108

Jack Smith
PARISH CLERK OR SUPERVISOR

Henry Miller
DISTRICT ADMINISTRATIVE ASSISTANT OR SUPERIOR

ACCOUNTING

Figure 4. BAR for surface treatment patching.

Fiscal Year 1968-69 (1, 6) District No. ☐☐ (7, 8) Parish No. ☐☐ (9, 10) Parish Supt. Gang No. ☐☐☐ (11, 13) Document Code 30 (78, 79) ①

BITUMINOUS SURFACE MAINTENANCE

Function	System	Funct. Code	Sy. Code	System Miles	Planning Units	Q./Plan. Unit	M.H./Q.	Unit Cost $/Q	Cost Distr. - Percent: Labor	Equip.	Mat.	Contr. Serv.	Seasonal Distr.-Percent: 1st. Quar.	2nd. Quar.	3rd. Quar.	4th. Quar.
		15 17	20	21	27	33	39 44	46	52	55	58	61	64	67	70	73
SURF. TR. PATCHING	Interstate	411	1			0.2	2.0	13.50	39	17	44		30	20	10	40
	Primary	411	2			4.0	2.0	13.50	39	17	44		30	20	10	40
C.Y. Aggr. per 2-lane mile of B.S.T.	Secondary	411	3			4.0	2.0	13.50	39	17	44		30	20	10	40
	Farm-to-Market	411	4			4.0	2.0	13.50	39	17	44		30	20	10	40
PREMIX PATCHING	Interstate	412	1			1.0	3.0	17.10	39	13	48		50	20	15	15
	Primary	412	2			2.0	3.0	17.10	39	13	48		50	20	15	15
Tons Premix per 2-lane mile of Bitum. Surf.	Secondary	412	3			4.0	3.0	17.10	39	13	48		50	20	15	15
	Farm-to-Market	412	4			4.0	3.0	17.10	39	13	48		50	20	15	15
PATCHING BASE	Interstate	413	1			2.0	2.0	8.70	45	38	17		35	5	30	30
	Primary	413	2			2.0	2.0	8.70	45	38	17		35	5	30	30
C.Y. Material per 2-lane mile of Bitum. Surf.	Secondary	413	3			5.0	2.0	8.70	45	38	17		35	5	30	30
	Farm-to-Market	413	4			5.0	2.0	8.70	45	38	17		35	5	30	30
CRACK REPAIR	Interstate	414	1			2.0	0.5	1.70	53	42	5		0	50	50	0
	Primary	414	2			5.0	0.5	1.70	53	42	5		0	50	50	0
Gallons Filler per 2-lane mile of Bit. Conc. Surf.	Secondary	414	3			5.0	0.5	1.70	53	42	5		0	50	50	0
	Farm-to-Market	414	4			5.0	0.5	1.70	53	42	5		0	50	50	0
SEAL COAT	Interstate	415	1				5.20	800.00	11	5	84		50	0	0	50
	Primary	415	2			0.2	5.20	800.00	11	5	84		50	0	0	50
Miles Sealed per 2-lane mile of B.S.T.	Secondary	415	3			0.2	5.20	800.00	11	5	84		50	0	0	50
	Farm-to-Market	415	4			0.2	5.20	800.00	11	5	84		50	0	0	50
PREMIX LEVELING	Interstate	416	1				1.3	11.20	21	10	69		50	0	0	50
	Primary	416	2			10.0	1.3	11.20	21	10	69		50	0	0	50
Tons Premix per 2-lane mile of B.S.T	Secondary	416	3			10.0	1.3	11.20	21	10	69		50	0	0	50
	Farm-to-Market	416	4			10.0	1.3	11.20	21	10	69		50	0	0	50
SPOT SURFACE REPLACEMENT	Interstate	417	1			1.0	2.8	16.40	34	20	46		50	20	15	15
	Primary	417	2			2.0	2.8	16.40	34	20	46		50	20	15	15
Tons Premix per 2-lane mile of Bitum Surf.	Secondary	417	3			2.0	2.8	16.40	34	20	46		50	20	15	15
	Farm-to-Market	417	4			2.0	2.8	16.40	34	20	46		50	20	15	15
	Interstate		1													
	Primary		2													
	Secondary		3													
	Farm-to-Market		4													

Figure 5. Maintenance planning worksheet.

Fiscal Year 1968 69 District No 07 Parish No Parish Supt Gang No 081

FUNCTION NAME	NO	ACCOMPLISHMENT UNIT	QUANTITY	LABOR HOURS	COST — DOLLARS LABOR	EQUIP	MATERIAL	CONTR	TOTAL	UNIT COST	RATE MH/Q	SEASONAL DIST % 1 Q	2 Q	3 Q	4 Q
BITUMINOUS SURFACE															
SURFACE TREAT PATCH	411	CY AGGR	560	2138	2991	1303	3374		7668	13 50	2 0	30	20	10	40
PREMIX PATCHING	412	TONS MIX	753	2259	5023	1674	6180		12877	17 10	3 0	50	20	15	15
PATCHING BASE	413	CY MAT	893	1786	3497	2953	1320		7770	8 70	2 0	35	5	30	30
CRACK REPAIR	414	GAL FILL	495	248	446	354	42		842	1 70	5		50	50	
PREMIX LEVELING	416	TONS MIX	1420	1846	3340	1591	10973		15904	11 20	1 3	50			50
SPOT SURF REPLACE	417	TONS MIX	483	1352	2694	1583	3644		7921	16 40	2 8	50	20	15	15
CONCRETE SURFACE															
PATCHING SURFACE	421	CY CONC	650	3900	6523	3374	12593		22490	34 60	6 0	30	50	20	
PREMIX PATCHING	422	TONS MIX	84	252	561	187	688		1436	17 10	3 0	30	50	20	
PATCHING BASE	423	CY MAT	835	1670	3270	2760	1235		7265	8 70	2 0	30	50	20	
CRACK REPAIR	424	GAL FILL	835	418	752	596	72		1420	1 70	5		50	50	
JOINT REPAIR	425	100 LN FT	1040	1457	2925	770	153		3848	3 70	1 4		50	50	
GRAVL-SHELL SURFACE															
PATCHING SURFACE	431	CY AGGR	160	192	382	312	722		1416	8 85	1 2	5	45	30	20
RESHAPE SURFACE	432	ROAD MI	384	614	1244	1521			2765	7 20	1 6	15	25	35	25
RESTORING SURFACE	433	CY AGGR	640	384	749	499	2912		4160	6 50	6	5	45	30	20
SHOULDER + APPROACH															
PATCH NON-PAV SHLDR	441	CY MAT	499	599	1178	883	884		2945	5 90	1 2	5	75	10	10
RESHAP NON-PV SHLDR	442	SHLDR MI	550	825	1682	2058			3740	6 80	1 5	30	15	10	45
RESTOR NON-PV SHLDR	443	CY MAT	1007	705	1417	782	1527		3726	3 70	7	5	75	10	10
SURFACE TREAT PATCH	451	CY AGGR	275	963	1974	790	2172		4936	17 95	3 5	30	20	10	40
PREMIX PATCHING	452	TONS MIX	51	153	338	156	373		867	17 00	3 0	50	20	15	15
PATCHING BASE	453	CY MAT	48	96	188	159	71		418	8 71	2 0	35	5	30	30
ROADSIDE + DRAINAGE															
CLEAN-REP DRAIN STR	462		2796	2796	5595	836			6431	2 30	1 0	15	20	15	50
CLEAN-RESHAPE DITCH	463	DITCH MI	4	960	1916	1508			3424	856 00	240 0	20	40	20	20
MACHINING DITCHES	464	DITCH MI	69	552	1118	1366			2484	36 00	8 0	20	40	20	20
MOWING	470	ACRES	18632	18632	35773	23849			59622	3 20	1 0	50	20		30
LITTER CLEANING	473	LOADS	256	5120	10295	1404			11699	45 70	20 0	10	30	40	20
TOTAL PLANNED MAINT				48915	95871	53268	48935		198074			35	27	14	24

Figure 6. Maintenance planning summary.

Fiscal Year 1967 68
Period From 07 01 67 To 03 31 68

District No 07 | Parish Supt Gang No 081 | Gang No SUPT. SUMMARY

FUNCTION NAME	NO	ACCOMPLISHMENT UNIT	QUANTITY	LABOR HOURS	TOTAL COST	UNIT COST STANDARD	UNIT COST ACTUAL	RATE—MH/Q STANDARD	RATE—MH/Q ACTUAL
BITUMINOUS SURFACE									
SURFACE TREAT PATCH	411	CY AGGR	1076	5452	24475	1882	2275	35	51
PREMIX PATCHING	412	TONS MIX	4923	5329	18898	5439	384	168	11
PATCHING BASE	413	CY MAT	194	1004	3356	1681	1730	39	52
CRACK REPAIR	414	GAL FILL	800	140	492	130	62	5	2
OTHER BIT SURFACE	419			993	2687				
CONCRETE SURFACE									
PATCHING SURFACE	421	CY CONC	104	1455	5614	4633	5398	100	140
PREMIX PATCHING	422	TONS MIX	5	112	340	5440	6800	169	224
PATCHING BASE	423	CY MAT	70	1266	3984	1681	5691	39	181
CRACK REPAIR	424	GAL FILL	800	254	784		98		3
OTHER CONC SURFACE	429			684	1456				
GRAVL-SHELL SURFACE									
PATCHING SURFACE	431	CY AGGR	148	208	898	735	607	13	14
RESHAPE SURFACE	432	ROAD MI	1156	1897	8401	815	727	17	16
SHOULDER + APPROACH									
PATCH NON-PAV SHLDR	441	CY MAT	3190	5945	22488	458	705	14	19
RESHAP NON-PV SHLDR	442	SHLDR MI	122	234	999	1251	819	27	19
SURFACE TREAT PATCH	451	CY AGGR	15	70	314		2093		47
PREMIX PATCHING	452	TONS MIX	17	110	468		2753		65
PATCHING BASE	453	CY MAT	10	24	100		1000		24
OTHER SHLDR + APPR	459			56	180				
ROADSIDE + DRAINAGE									
EROSION CONTROL	461			56	162				
CLEAN-REP DRAIN STR	462			297	1104				
CLEAN-RESHAPE DITCH	463	DITCH MI	12	2159	6932	22560	57767	800	1799
MACHINING DITCHES	464	DITCH MI	11	24	113		1027		22
MOWING	470	ACRES	7680	15430	48971	358	638	10	20
CUTTING BRUSH	471			3392	6820				
LANDSCAPE MAINT	472			216	557				
LITTER CLEANING	473	LOADS	285	7359	15231	6115	5344	317	258
SERV LITTER BARRELS	474	BARRELS	569	510	1139		200		9
OTHER ROADSIDE + DR	479			1301	2749				
STRUCTURE MAINT									
OTHER STRUCT MAINT	499			128	436				
TRAFFIC SERVICE									
SNOW + ICE CONTROL	511			1419	4224				
PUBLIC FACILITIES	542			126	269				
BARRICADES+DETOURS	553			38	84				
OTHER TRAFFIC SERV	559			277	704				
RIVER CROSSING OPER									
OPER OF FERRIES	561			11578	43704				
RIVER CROSSING OPER									
OPER MOVABLE SPANS	563			11882	31760				
DISASTER MAINT									
ACCIDENT DAMAGE	602			7	17				
STATE FORCE CONSTR									
BASE + SURFACE	623			128	351				
SHOULDER IMPROVEMNT	624			8	38				
ROADSIDE DEVELOPMNT	625			6	27				
MAINT OVERHEAD									
FIELD MAINT OH	651			2896	7794				
MATERIAL HANDLING	653			323	605				
STANDBY TIME	655			2412	4464				
ANNUAL LEAVE	656			3474	6373				
SICK LEAVE	657			3672	6755				
COMPENSATORY LEAVE	658			704	1276				
OTHER LEAVE	659			6928	13581				
CLEARING ACCOUNTS									
REPAIRING EQUIPMENT	732			8	18				
SERVICING EQUIPMENT	733			1052	1922				
ADMINISTRATION									
GROUNDS MAINT	884			542	1156				
BUILDING MAINT	885			15	28				
GANG TOTALS				103600	305298				

Figure 7. Performance analysis.

Period From 07 01 67 To 09 30 67

District No 08 — Parish NATCHITOCHES — Parish Supt Gang No 085

FUNCTION NAME	NO	ACCOMPLISHMENT UNIT	QUANTITY PLAN	QUANTITY ACTUAL	%	LABOR HOURS PLAN	LABOR HOURS ACTUAL	%	TOTAL COST PLAN	TOTAL COST ACTUAL	%	UNIT COST PLAN	UNIT COST ACTUAL	%	RATE—MH Q PLAN	RATE—MH Q ACTUAL	%
BITUMINOUS SURFACE																	
SURFACE TREAT PATCH	411	CY AGGR	1212	124	10	2424	1607	66	16968	5792	34	1400	4671	334	20	130	648
PREMIX PATCHING	412	TONS MIX	1084	525	48	3252	1847	57	21680	9283	43	2000	1770	88	30	35	117
PATCHING BASE	413	CY MAT	509	434	85	1019	688	68	3565	2159	61	700	497	71	20	16	79
CRACK REPAIR	414	GAL FILL										180			5		
SEAL COAT	415	SQ YD		54068			344			4792			9				
CONCRETE SURFACE																	
PATCHING SURFACE	421	CY CONC	89			843			2655			3000			50		
PREMIX PATCHING	422	TONS MIX	50			150			1000			2000			30		
PATCHING BASE	423	CY MAT	90			180	7	4	630	20	3	700			20		
CRACK REPAIR	424	GAL FILL										180			5		
JOINT REPAIR	425	100 LN FT										270			9		
GRAVL-SHELL SURFACE																	
PATCHING SURFACE	431	CY AGGR	18	79	439	12	117	975	105	564	537	600	713	119	7	15	212
RESHAPE SURFACE	432	ROAD MI	219	72	33	350	220	63	1313	974	74	600	1353	226	16	31	191
SHOULDER + APPROACH																	
PATCH NON-PAV SHLDR	441	CY MAT	175	373	213	175	667	381	628	2246	358	358	602	168	10	18	179
RESHAP NON-PV SHLDR	442	SHLDR MI	473	97	21	710	444	63	3607	1946	54	762	2007	263	15	46	305
PATCHING BASE	453	CY MAT					6			13							
ROADSIDE + DRAINAGE																	
CLEAN-REP DRAIN STR	462						482			1059							
CLEAN-RESHAPE DITCH	463	DITCH MI	2			360	120	33	1080	297	27	60000			2000		
MOWING	470	ACRES	7294	2996	41	7294	3783	52	25529	12698	50	350	424	121	10	13	126
LITTER CLEANING	473	LOADS	53	15	28	1066	322	30	2399	715	30	4500	4764	106	200	215	107
SERV LITTER BARRELS	474	BARRELS		403			219			569			141			5	
TRAFFIC SERVICE																	
SIGN MAINTENANCE	533						240			464							
DISASTER MAINT																	
ACCIDENT DAMAGE	602						132			375							
MAINT OVERHEAD																	
OTHER GENERAL FUNCT	699						2838			6369							
TOTAL PLANNED MAINT						17435	14083	81	81159	50334	62						
STATE FORCE CONSTR							4286			29891							
LEAVE							4496			8933							
ADMIN AND OVERHEAD							2904			6669							
TOTAL STATE HIGHWAY							25769			95826							
OFF SYSTEM WORK							84			417							
TOTAL							25853			96243							

Figure 8. Maintenance performance report.

Fiscal Year 1967-68
Period From 06-28-67 To 07-25-67

District No 08 | Function SURFACE TREAT PATCH | Function No 411 | Accomplishment CY AGGR

PARISH SUPERINTENDENT LOCATION		GANG NO	QUANTITY	LABOR HOURS	TOTAL COST	PERCENT OF COST LABOR	PERCENT OF COST EQUIP	PERCENT OF COST MAT	PERCENT OF COST CONTR	UNIT COST	RATE MH/Q
ALEXANDRIA		210	9	54	220	44	22	34		2443	60
ALEXANDRIA		211	78	736	2994	48	26	26		3839	94
	ACTUAL		87	790	3214	48	26	26		3694	91
	PLAN		816	1632	11424	29	15	56		1400	20
HESMER		120	100	800	2893	53	20	27		2893	80
HESMER		220	12	104	403	54	19	27		3356	87
HESMER		221	27	312	915	65	13	22		3388	116
	ACTUAL		139	1216	4211	56	18	26		3029	87
	PLAN		783	1566	10962	29	15	56		1400	20
MANY		130	98	440	2010	45	22	33		2051	45
MANY		230	136	408	2107	38	19	43		1550	30
	ACTUAL		234	848	4118	41	21	38		1760	36
	PLAN		870	1740	12180	29	15	56		1400	20
LEESVILLE		140	137	464	2413	37	21	42		1761	34
LEESVILLE		240	78	416	1840	45	21	34		2358	53
LEESVILLE		241	126	464	2328	36	21	43		1847	37
	ACTUAL		341	1344	6580	39	21	40		1930	39
	PLAN		839	1677	11739	29	15	56		1400	20
NATCHITOCHES		550	412	1215	7062	33	19	48		1714	29
	ACTUAL		412	1215	7062	33	19	48		1714	29
	PLAN		1212	2424	16968	29	15	56		1400	20
WINNFIELD		260	137	520	2537	39	23	38		1852	38
WINNFIELD		261	28	160	690	45	23	32		2463	57
	ACTUAL		165	680	3227	41	23	36		1956	41
	PLAN		1029	2058	14406	29	15	56		1400	20
DRY PRONG		170	24	80	385	39	18	43		1605	33
DRY PRONG		270	274	548	3816	28	18	54		1393	20
DRY PRONG		271	30	160	630	45	22	33		2101	53
	ACTUAL		328	788	4832	31	19	50		1473	24
	PLAN		660	1320	9240	29	15	56		1400	20
	DISTRICT ACTUAL		1706	6881	33242	40	20	40		1949	40
	DISTRICT PLAN		6209	12417	86919	29	15	56		1400	20

Figure 9. Productivity analysis.

	FUNCTION	FUNC. CODE	WORK QUANTITY MEASUREMENT	PLANNING UNIT	ANNUAL QUANTITY PER PLANNING UNIT				SEASONAL DISTR. - %			
					INTERSTATE	PRIMARY	SECONDARY	FM-TO-MKT.	July - Sept.	Oct - Dec.	Jan - Mar.	Apr - June
Bituminous Surface Maint	Surface Treatment Patching	411	C Y. Aggregate	Per 2-lane Mile of Bit. Surface Treated Road	0 2	4.0	4 0	4.0	30	20	10	40
	Premix Patching	412	Tons Premix	Per 2-lane Mile of Bit Surface Road	1 0	2.0	4 0	4.0	50	20	15	15
	Patching Base	413	C Y. Material	Per 2-lane Mile of Bit Surface Road	2 0	2 0	5 0	5.0	35	5	30	30
	Crack Repair	414	Gallons Filler	Per 2-lane Mile of Bitum Conc. Road	2 0	5.0	5 0	5 0	0	50	50	0
	Seal Coat	415	Miles Sealed	Per 2-lane Mile of Bit Surface Treated Road		0 2	0 2	0 2	50	0	0	50
	Premix Leveling	416	Tons Premix	Per 2-lane Mile of Bit. Surface Treated Road		10 0	10 0	10 0	50	0	0	50
	Spot Surface Replacement	417	Tons Premix	Per 2-lane Mile of Bit. Surface Road	1 0	2.0	2 0	2 0	50	20	15	15
Concrete Surface Maint	Patching Surface	421	C. Y. Concrete	Per 2-lane Mile of Conc. Surface Road	5.0	5.0	5 0	5.0	30	50	20	0
	Premix Patching	422	Tons Premix	Per 2-lane Mile of Conc Surface Road	0.5	1.0	1 0	1.0	30	50	20	0
	Patching Base	423	C. Y. Material	Per 2-lane Mile of Conc Surface Road	5.0	10.0	10.0	10 0	30	50	20	0
	Crack Repair	424	Gallons Filler	Per 2- lane Mile of Conc Surface Road	5 0	10 0	10 0	10.0	0	50	50	0
	Joint Repair	425	100 Lin Ft Joint	Per 2-lane Mile of Conc Surface Road	8 0	8.0	8 0	8 0	0	50	50	0
Gravel or Shell Surf. Maint.	Patching Surface	431	C Y. Aggregate	Per 2-lane Mile of Gravel or Shell Surface Road		5.0	5 0	5 0	5	45	30	20
	Reshaping Surface	432	Miles	Per 2-lane Mile of Gravel or Shell Surface Road		12 0	12.0	12.0	15	25	35	25
	Restoring Surface	433	C. Y. Aggregate	Per 2-lane Mile of Gravel or Shell Surface Road		20 0	20 0	20 0	5	45	30	20

Figure 10. Performance standards for annual maintenance work quantities; perliminary values only effective date May 1968.

LOUISIANA DEPT OF HIGHWAYS —— MAINTENANCE STANDARD	INDEX NO M-1 FUNCTION NO 411 EFFECTIVE DATE 3/1/68
SURFACE TREATMENT PATCHING	

DESCRIPTION

Patching bituminous roadway surface with one or more applications of hot asphalt and aggregate.

PURPOSE

To seal small areas and prevent surface deterioration from cracking or raveling.

PROCEDURES

1. Broom area to be patched.
2. Adjust width of spray bar and shoot asphalt in a rectangular area at least six inches beyond deteriorated area. Small area patches will be shot with hand hose.
3. Spread aggregate uniformly over the asphalt, using the choke board where necessary.
4. Roll the patch, overlapping each pass, until the entire patch has been rolled
5. If more than one application is used, only the last application need be squared up.

Figure 11. Work procedure—premix patching.

DISTRIBUTION OF 680 MAN-HOURS NAWT FOR MEN
ASSIGNED TO PREMIX PATCHING WITH HOT MIX (412)

Items	Total Minutes	Percent of NAWT	Performance (Average Per Hour)
At Worksite			
A Cyclic work items			
1. Remove old pavement	787	1.9	
2. Tack hole	461	1 1	
3. Spread hot mix	7,588	18.6	217 square yards 6.5 tons
4. Roll patch	510	.1.3	
5 Move ahead to new work area	1,343	3.3	
B. Supporting work items	3,684	9.0	
C. Delays - wait on cyclic work items	4,848	11.9	
D. Delays - other	2,306	5.6	
Total Worksite	21,527	52.7	0.6 tons
Other			
E. Travel to, from, or between worksites	14,895	36.5	
F. Supporting work items	2,139	5.3	
G. Delays	466	1.1	
H. Non-supporting work items	1,750	4.4	
Total Other	19,250	47.3	
Grand Total	40,777	100.0	0.3 tons
Productive time (A/B/E/F)	31,407	77.0	

Figure 12. Accomplishment study data summary.

	FUNCTION	FUNC. CODE	WORK QUANTITY MEASUREMENT (Q)	AVERAGE RATE MAN HOURS/Q	AVERAGE UNIT COST $/Q	COST DISTRIBUTION - PERCENT			
						LABOR	EQUIP.	MATERIAL	CONTR. SERV.
Bituminous Surface Maint.	Surface Treatment Patching	411	C Y Aggregate	2.0	$ 13 50	39	17	44	
	Premix Patching	412	Tons Premix	3 0	17 10	39	13	48	
	Patching Base	413	C Y Material	2.0	8.70	45	38	17	
	Crack Repair	414	Gallons Filler	0 5	1.70	53	42	5	
	Seal Coat	415	Miles Sealed	52 0	800 00	11	5	84	
	Premix Leveling	416	Tons Premix	1.3	11 20	21	10	69	
	Spot Surface Replacement	417	Tons Premix	2.8	16.40	34	20	46	
Concrete Surface Maint	Patching Surface	421	C Y. Concrete	6 0	34 60	29	15	56	
	Premix Patching	422	Tons Premix	3 0	17.10	39	13	48	
	Patching Base	423	C Y Material	2 0	8.70	45	38	17	
	Crack Repair	424	Gallons Filler	0 5	1 70	53	42	5	
	Joint Repair	425	100 Lin. Ft Joint	1 4	3.70	76	20	4	
Gravel or Shell Surf. Maint.	Patching Surface	431	C Y. Aggregate	1.2	8.85	27	22	51	
	Reshaping Surface	432	Miles	1 6	7.20	45	55	--	
	Restoring Surface	433	C Y Aggregate	0 6	6 50	18	12	70	

Figure 13. Performance standards for maintenance unit costs and productivity; preliminary values only effective date May 1968.

Activity	Amount Done In 1967	1966-1967 Rate Differential	Man-Hour Savings 1/	1966-1967 Unit Cost Differential	Dollar Savings 2/
Surface Treatment Patching	3,356 Cu. Yds.	-0.3	- 1,007	-$ 3.10	-$10,404
Premix Patching	1,921 Tons	2.1	3,951	3 16	6,089
Concrete Patching	370 Cu. Yds.	16.5	6,105	41.22	15,251
Premix Patching - Concrete	5 Tons	6.0	30	18.91	95
Patching Non-Paved Surface	401 Cu. Yds.	0.6	241	2.98	1,195
Reshaping Non-Paved Surface	815 Miles	0.3	245	0.36	293
Patching Non-Paved Shoulders	4,196 Cu. Yds	0.3	1,259	1.10	4,616
Reshaping Non-Paved Shoulders	618 Miles	-0.2	- 124	- 2.25	- 1,391
Mowing	12,075 Acres	0.3	3,623	0.81	9,781
Litter Cleaning	224 Loads	-1.1	- 246		- 455
Total	--	--	14,077	--	$25,070

1/ Man-Hour Savings -- Amount Done in 1967 (1966 Rate Minus 1967 Rate)

2/ Dollar Savings -- Amount Done in 1967 (1966 Unit Cost Minus 1967 Unit Cost)

Figure 14. Benefits from method improvements.

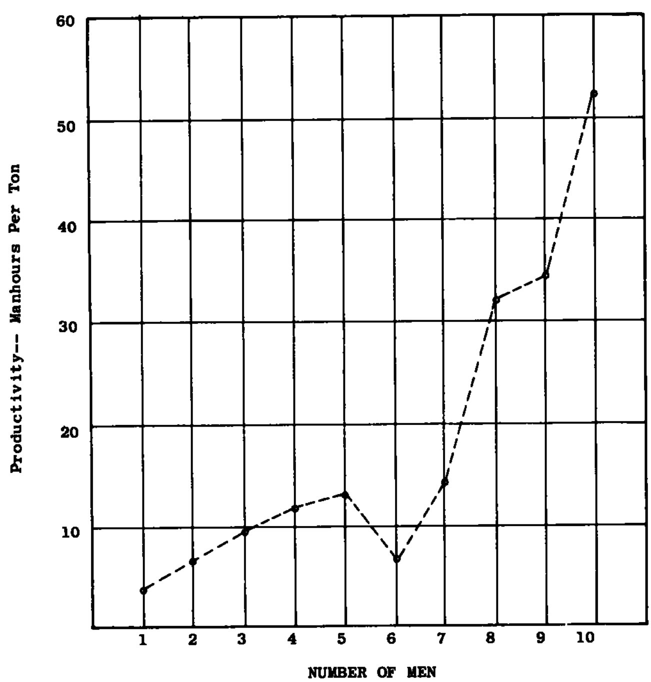

Figure 15. Productivity for cold-mix patching related to crew size.

Haul Distance	Number Of Trucks	Quantity (Cubic Yards)	Accomplishment (Man-Hours Per Cubic Yard)
0 - 5 Miles	1	45	0.4
6 - 10	2	56	0.5
11 - 15	2	34	0.8
11 - 15	3	51	0.6
16 and up	3	42	0.8

Figure 16. Number of haul trucks for various distances.

Activity	Quantity	Labor Hours	Total Cost
Bituminous Surface			
Surface Treatment Patching	1,114 Cu. Yds.	2,228	$ 15,039
Premix Patching	1,223 Tons	3,669	20,913
Patching Base	1,477 Cu. Yds.	2,954	12,850
Crack Repair	398 Gallons	199	676
Seal Coat	55 Miles	2,860	44,000
Premix Leveling	2,785 Tons	3,621	31,192
Spot Surface Replacement	716 Tons	2,005	11,742
Concrete Surface			
Patching Surface	102 Cu. Yds.	612	3,529
Premix Patching	20 Tons	60	342
Patching Base	203 Cu Yds.	406	1,766
Crack Repair	203 Gallons	101	345
Joint Repair	162 100 Lin.Ft.	227	599
Non-Paved Surface			
Patching Surface	135 Cu. Yds.	162	1,195
Reshaping Surface	322 Miles	515	2,318
Restoring Surface	536 Cu. Yds.	322	3,484
Shoulders			
Patching Non-Paved Shoulders	600 Cu. Yds.	720	$ 3,540
Reshaping Non-Paved Shoulders	773 Miles	1,160	5,256
Restoring Non-Paved Shoulders	1,132 Cu. Yds.	792	4,188
Paved Shoulder Maintenance	--	245	2,102
Roadside and Drainage			
Clean and Repair Drainage Structures	3,271 Man-Hours	3,271	7,523
Clean and Reshape Ditches	4 Miles	960	3,424
Machining Ditches	81 Miles	648	2,916
Mowing	14,243 Acres	14,243	45,578
Litter Cleaning Roadside	263 Loads	5,260	12,019
Servicing Litter Barrels	2,080 Barrels	1,248	3,016
Total	--	48,488	$239,552
Total less Seal Coat and Premix Leveling 1/		42,007	
Allowance for Leave (17%)		17,136	
Miscellaneous (18%)		18,144	
Betterments and Construction		23,513	
Total Available		100,800	

1/ Special maintenance items to be done by districtwide forces.

Figure 17. Annual program for Natchitoches Parish, fiscal 1969.

	Quarter							
	1st		2nd.		3rd.		4th	
Activity	Quantity	Labor Hours	Quantity	Labor Hours	Quantity	Labor Hours	Quantity	Labor Hours
Surface Treatment Patching	334 C Y.	668	223 C.Y	446	111 C Y	222	446 C Y	892
Premix Patching	612 Tons	1,835	245 Tons	734	183 Tons	550	183 Tons	550
Patching Base	517 C Y.	1,034	74 C.Y.	148	443 C.Y.	886	443 C Y	886
Crack Repair	--	--	199 Gal.	100	199 Gal.	99	--	--
Seal Coat	27 Mi.	1,430	--	--	--	--	28 Mi.	1,430
Premix Leveling	1,393 Tons	1,810	--	--	--	--	1,392 Tons	1,811
Spot Surface Replacement	358 Tons	1,002	143 Tons	401	107 Tons	301	108 Tons	301

Figure 18. Quantity breakdown of quarterly plan for bituminous surface maintenance Natchitoches Parish, fiscal 1969.

ROAD INSPECTION AND MAINTENANCE INVENTORY

Date ________ Sheet ____ of ____

Parish ________ Start Point ________ at ________ miles

Route Number ________ Heading N S E W

Control Section ________ End Point ________ at ________ miles

Mileage											
Miles From Start	1	2	3	4	5	6	7	8	9	10	Notes
Function/Surf Type											
411 - Surf Treat Patch											
412 - Premix Patching											
413 - Patching Base											
414 - Crack Repair											
417 - Surface Replace											
421 - Patching Surface											
422 - Premix Patching											
423 - Patching Base											
424 - Crack Repair											
425 - Joint Repair											
431 - Patching Surface											
441 - Patch NP Shoulder											
Edge Rutting											
442 Reshape Shoulder											
Cut & Haul											
461 - Erosion Control											
462 - Drainage Struct											
463 - Clean Ditches											
464 - Machining Ditches											
471 - Brush Cutting											
Other Work & Remarks											
Major Work											
Seal Coat											
Levelling											
Overlay											
Restore Shoulders											

CONDITION	Surface	Shoulders	Roadside	Traffic Serv	Overall
RATING	E G F P	E G F P	E G F P	E G F P	E G F P

Inspected by ________ and ________

Control Section ________

Figure 19. Work inspection form.

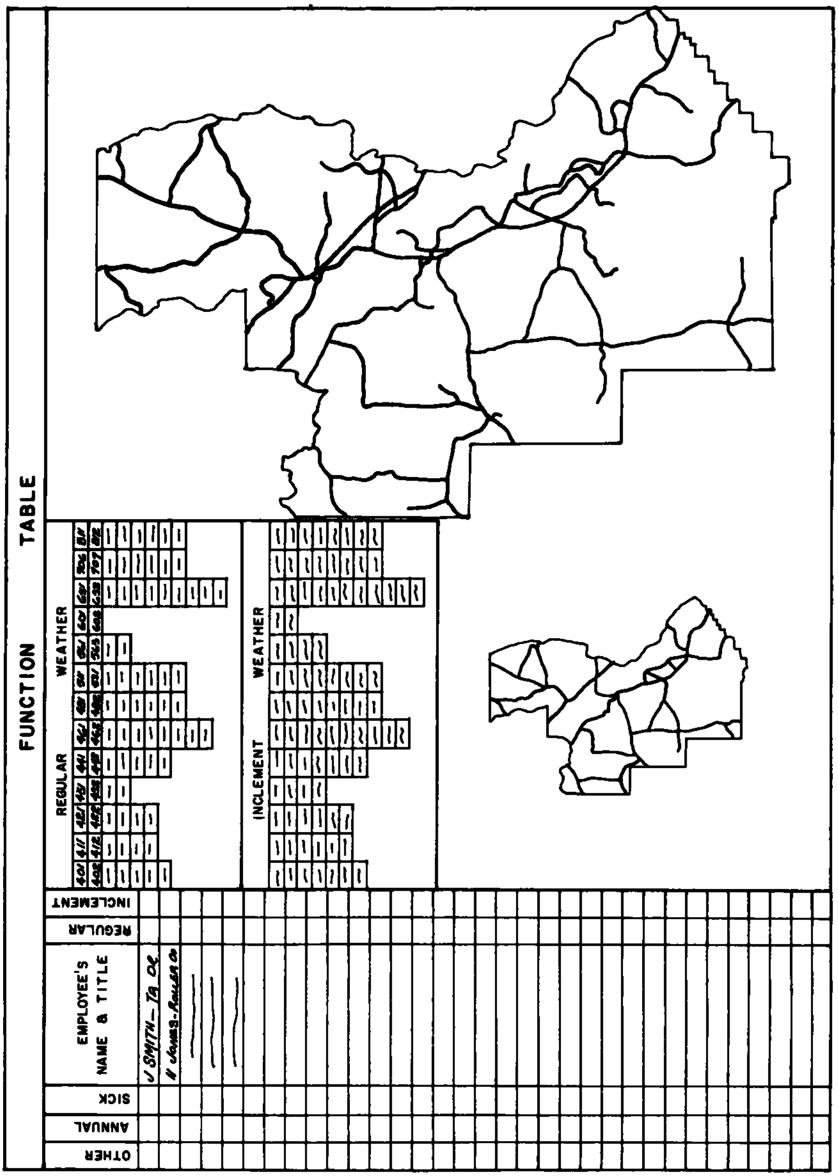

Figure 20. Work scheduling board.

Quantity Summary		Fiscal Year 1968		Actual Accomplishment Posted Thru 10/ 3/67						Quarter 1 ② 3 4	
Function No.	Description	"A" System		"B" System		"C" System		Man-Hours		Productivity	
		Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual	Planned	Actual
411	C.Y. Surface Treatment Patching	525	110	750	0	745	472	4,040	1,789	2.0	3.1
412	Tons Premix Patching (Bit)										
413	C.Y. Patching Base (Bit.)										
414	Gal Crack Repair (Bit.)										
421	C.Y. Patching Surface										
422	Tons Premix Patching (Conc.)										
423	C.Y. Patching Base (Conc.)										
424	Gal. Crack Repair (Conc.)										
425	100' of Joint Joint Repair (Conc.)										
431	C Y. Patching Surface (Gravel)										
432	Road Miles Reshape Surface (Gravel)										
441	C.Y. Patch Non-Paved Sh.										
442	Sh.Mi. Reshape Non-Paved Sh										
463	Ditch Clean & Reshape Ditches Mi.										
470	Acres Mowing										
473	Loads Litter Cleaning Roadside										

Figure 21. Parish work control board.

Quarter 1 (2) 3 4						District 08				Period Ending 10/31/67				
							PRODUCTIVITY							
Function No.	Description	Q. Planned	Q. Actual	M/H Planned	M/H Actual	Planned Accomplishment	Avoyelles	Grant	Rapides	Natchitoches	Sabine	Vernon	Winn	District Average
411	Surface Treatment Patching C.Y.	9,800	8,000	19,600	28,000	2.0	3.3	5.0	4.8	3.1	3.4	3.5	6.0	3.5
412	Premix Patching Tons													
413	Patching Base C.Y.													
414	Crack Repair Gal.													
421	Patching Surface C.Y.													
422	Premix Patching Tons													
423	Patching Base C.Y.													
424	Crack Repair Gal.													
425	Joint Repair 100' of Joint													
431	Patching Surface C.Y.													
432	Reshape Surface Rd. Mi.													
441	Patching Non-Paved Shoulders C.Y.													
442	Reshape Non-Paved Shoulders Sh. Mi.													
463	Clean & Reshape Ditches Ditch Mi.													
470	Mowing Acres													
473	Litter Cleaning Roadside Loads													

Figure 22. District work control board.

Employment Category	Persons in Force	Percent of Force
SUPERVISOR GROUP		
Headquarters Administration	28	
Statewide Gang Foremen	15	
District Administrators	76	
Resident Maintenance Engineers	4	
Maintenance Superintendents II	21	
Districtwide Gang Foremen	186	
Maintenance Superintendents I	59	
Parish Gang Foremen	210	
Bridge, Ferry and Tunnel Foremen	37	
Subtotal	636	13
POTENTIAL SUPERVISOR GROUP		
Equipment Operators III	240	
Equipment Operators II	119	
Equipment Operators I	1,228	
Equipment Inspectors and Mechanics	52	
Bridge, Ferry and Tunnel Operators	23	
Subtotal	1,662	34
NON-SUPERVISOR GROUP		
Equipment Operators II	531	
Equipment Operators I	98	
Carpenters	8	
Painters	61	
Electricians	13	
Equipment Maintainers	176	
Aides and Inspectors	2	
Laborers, Bridgemen and Trades Helpers	128	
Bridge, Ferry and Tunnel Operators	309	
Subtotal	2,326	48
CLERICAL GROUP		
Clerks	228	5
TOTAL	4,852	100

Figure 23. Distribution of maintenance personnel force.

THE NATIONAL ACADEMY OF SCIENCES is a private, honorary organization of more than 700 scientists and engineers elected on the basis of outstanding contributions to knowledge. Established by a Congressional Act of Incorporation signed by Abraham Lincoln on March 3, 1863, and supported by private and public funds, the Academy works to further science and its use for the general welfare by bringing together the most qualified individuals to deal with scientific and technological problems of broad significance.

Under the terms of its Congressional charter, the Academy is also called upon to act as an official—yet independent—adviser to the Federal Government in any matter of science and technology. This provision accounts for the close ties that have always existed between the Academy and the Government, although the Academy is not a governmental agency and its activities are not limited to those on behalf of the Government.

The NATIONAL ACADEMY OF ENGINEERING was established on December 5, 1964. On that date the Council of the National Academy of Sciences, under the authority of its Act of Incorporation, adopted Articles of Organization bringing the National Academy of Engineering into being, independent and autonomous in its organization and the election of its members, and closely coordinated with the National Academy of Sciences in its advisory activities. The two Academies join in the furtherance of science and engineering and share the responsibility of advising the Federal Government, upon request, on any subject of science or technology.

The NATIONAL RESEARCH COUNCIL was organized as an agency of the National Academy of Sciences in 1916, at the request of President Wilson, to enable the broad community of U.S. scientists and engineers to associate their efforts with the limited membership of the Academy in service to science and the nation. Its members, who receive their appointments from the President of the National Academy of Sciences, are drawn from academic, industrial and government organizations throughout the country. The National Research Council serves both Academies in the discharge of their responsibilities.

Supported by private and public contributions, grants, and contracts, and voluntary contributions of time and effort by several thousand of the nation's leading scientists and engineers, the Academies and their Research Council thus work to serve the national interest, to foster the sound development of science and engineering, and to promote their effective application for the benefit of society.

The DIVISION OF ENGINEERING is one of the eight major Divisions into which the National Research Council is organized for the conduct of its work. Its membership includes representatives of the nation's leading technical societies as well as a number of members-at-large. Its Chairman is appointed by the Council of the Academy of Sciences upon nomination by the Council of the Academy of Engineering.

The HIGHWAY RESEARCH BOARD, an agency of the Division of Engineering, was established November 11, 1920, as a cooperative organization of the highway technologists of America operating under the auspices of the National Research Council and with the support of the several highway departments, the Bureau of Public Roads, and many other organizations interested in the development of highway transportation. The purposes of the Board are to encourage research and to provide a national clearinghouse and correlation service for research activities and information on highway administration and technology.

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