HIGHWAY RESEARCH BOARD

Special Report 65

IOWA STATE HIGHWAY MAINTENANCE STUDY

Time Utilization, Productivity, Methods, and Management

1959 - 1960

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Special Report 65

IOWA STATE HIGHWAY MAINTENANCE STUDY

A Report to the
Iowa State Highway Commission and the
U.S. Bureau of Public Roads, Cosponsors,
from
Their Special Study Group

National Academy of Sciences —
National Research Council
Washington, D.C.
1961

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Foreword

This report closes the first phase of the study of State highway maintenance operations in Iowa. The second phase, already underway, is one of applying the results to a positive program to improve maintenance operations on the highway systems. Great opportunity is afforded in this respect. Many of the findings reported will be subject to further study to determine how the results already derived can best be utilized to bring about the desired profitable improvements in Iowa. The profits of the further study may be expected to be reduced cost, increased quality, and improved service to the motoring public.

Improvements in the maintenance of highways is an evolutionary process, even though specific changes can be quickly made, because one improvement will lead to another, and one activity is often related to another activity, to some type of equipment, or to a personnel situation. It is through fully coordinated attack by both administrative and supervisory management on all facets of maintenance problems that the kind of progress that is desired and achievable will result. Continuous evaluation is needed in each individual area of maintenance represented by the findings presented in this report, but care is necessary to keep the whole maintenance operation in balance. Concentrating on only one or two problem areas will yield individual improvements, but such improvements would be only a fraction of the total that can be achieved if the operations are viewed as a whole.

In issuing this publication through the Highway Research Board, it is the hope of the Iowa Highway Commission and the Bureau of Public Roads that it will be of service to all highway organizations that have responsibility for highway maintenance. It is believed that all State highway departments could profit by this introspective approach to their maintenance operations, and perhaps to other aspects of highway management as well.

To the individuals responsible for the actual execution of this research project, the Iowa Highway Commission and the Bureau of Public Roads extend their appreciation and thanks for pioneering in a new phase of highway research and for demonstrating the real prospects of achieving substantial results in highway economy. Especially is this type of work important in view of the heavy fiscal requirements of the present highway construction programs and the ensuing increased maintenance responsibilities.

E. H. Holmes
Assistant Commissioner for Research
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Chief Engineer
Iowa State Highway Commission

Preface

This study of maintenance operations on State highways in Iowa was undertaken to provide facts which could be used by management in exercising control over this activity and improving the economy of operations. The assignment required an intensive study and the use of research techniques.

A special study group was formed from within the Iowa State Highway Commission and the Bureau of Public Roads, the cosponsors, to carry out the assignment. This report was prepared by the study group. The findings are the product of the research effort, and the conclusions and recommendations are those of the study group rather than those of the cosponsors.

Attention has been given to operating methods, productivity, and time utilization as involved in (1) maintaining the structural or physical highway in itself, (2) rendering of certain services, such as snow removal and detour upkeep, and (3) the elements of management through which items (1) and (2) are accomplished. Not all of the information collected is reported. Many facts considered to be of secondary importance at this time are omitted. Thus, this report, although providing extensive coverage, would require substantial expansion to present a total picture of all operations of State highway maintenance in Iowa.

The research data clearly show the complexity and far-reaching extent of highway maintenance. It is evident that maintenance operations of a highway department must be treated as a unity, and that an effective program requires that directives, procedures, and decisions be viewed not as isolated actions but as elements to be fitted into their proper places in the total program.

In this respect, the whole maintenance operation may be likened to the characteristics of an inflated balloon. Applying pressure against one spot at a time makes a visible indentation. The consequence, however, of this indentation is to produce distortions elsewhere that are almost imperceptible. Thus, the visible gain at the point of pressure may be offset by failure to control the interlocking and dependent relationships elsewhere. Only a grasp which encompasses all aspects of maintenance operations simultaneously can effectively control the whole and hence the cost and quality.

The findings, conclusions, and recommendations reported herein form a solid foundation for a course of action to be followed by management in deriving the most favorable benefits from this study. The specific action in many cases will require additional study to determine the most effective means of improving the operations along the general lines indicated by this study. This report is in effect the "launching mechanism" for improving the economy of operations. "Continuous refueling" through additional study or research is required to achieve the continuing improvement which is needed.

It is hoped that this study in Iowa will stimulate enlarged and more widespread attention upon highway maintenance operations throughout the country.

M. J. Kilpatrick and R. L. Murdock
for the Study Group

Participants in the Study

This study was under the direction of Morgan J. Kilpatrick, Chief, Construction Economy Branch, Highway Needs and Economy Division, Office of Research, Bureau of Public Roads. For the Bureau of Public Roads, Clinton H. Burnes, Chief, Highway Needs Branch, was generally responsible for the management phase; William N. Records, Highway Research Engineer, and James M. Montgomery, Management Analyst, supervised the collection, summarization and analysis of data; and Jerry L. Lowder, Highway Research Engineer, was resident engineer and provided technical direction for the field work.

For the Iowa State Highway Commission, Division of Planning, Randall L. Murdock, Highway Engineer, was the resident engineer. He provided liaison with maintenance personnel and directed the field work. His assistant was William G. Mortenson.

Following is a list of State and Bureau personnel who were assigned to the study for a month or more during the period from May 1959 to May 1961. Most of the State personnel worked on the study for at least 12 months. Many of the Public Roads personnel, particularly engineers in training, were assigned for less than 6 months.

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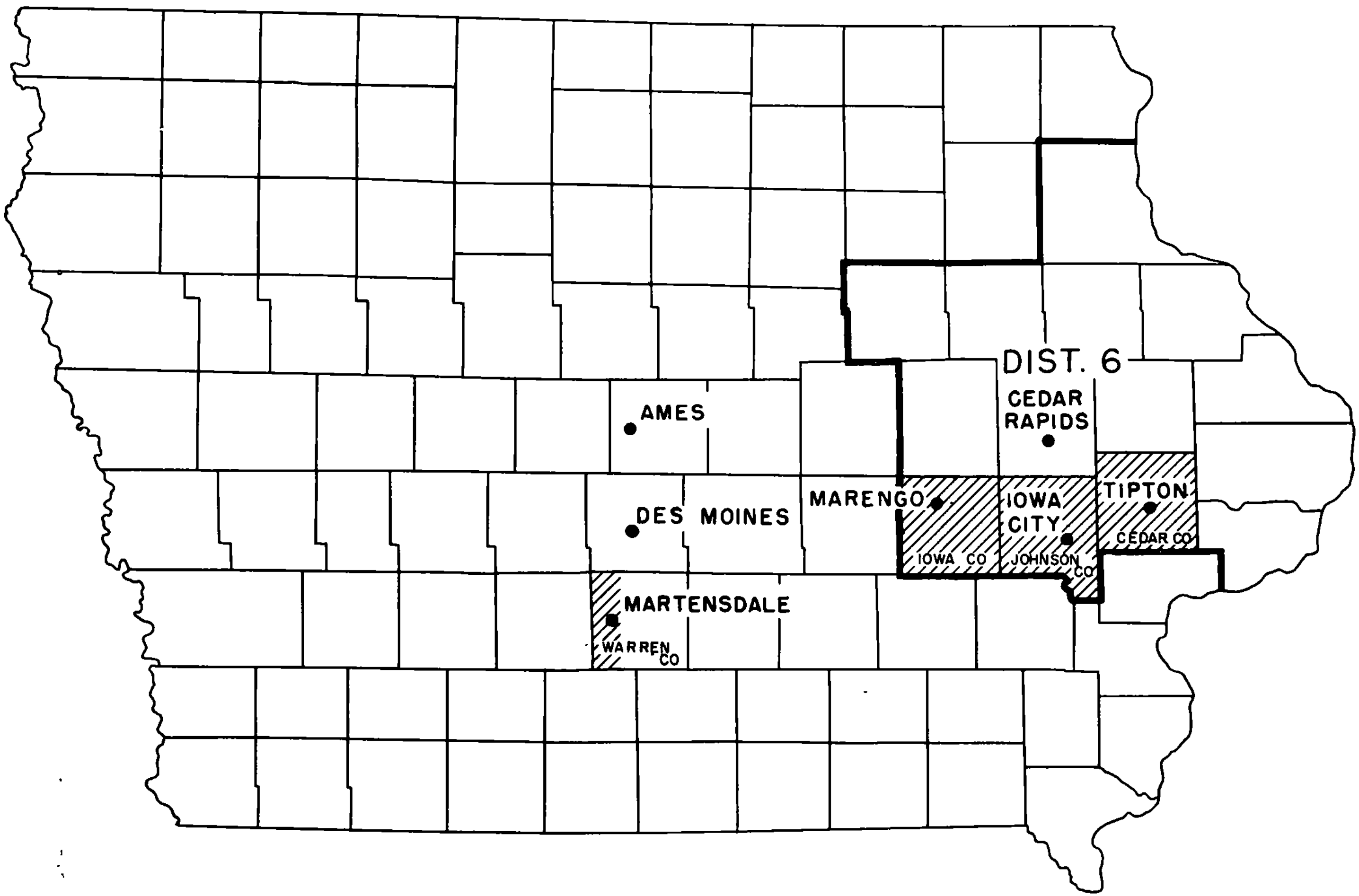
Contents



IOWA

SHADED SECTION SHOWS CONTROL STUDY AREA

IOWA STATE HIGHWAY MAINTENANCE STUDY

Section A

INTRODUCTION

This report contains results of a one-year study (August 1959 to August 1960) of maintenance operations on State primary and Interstate highways in Iowa. As its general objective, this study undertook (1) to develop, analyze, and report basic information about maintenance methods and procedures, manpower, utilization, equipment production rates, and organization of work and crews, and (2) to present recommendations concerning any aspect of maintaining the State primary road system including interstate routes.

Research techniques were used in the systematic gathering of information on field operations. Literally, millions of figures were recorded and analyzed. Some of the findings suggest a possible need for making additional appraisals and interpretations of available data to facilitate a goal of high efficiency and economy in highway maintenance work. Even more research of a similar nature, but on a smaller scale, may be required to satisfactorily achieve and keep the desired level of efficiency.

This report contains 7 sections, A through G. Findings are presented in Section E followed by Discussions and Conclusions in Section F, and finally the Recommendations in Section G.

PURPOSE OF THE STUDY

When this study was organized, eight specific objectives were set forth. A listing of these follows:

1. To develop basic data on the types and total extent of maintenance (man-hours and equipment hours) required for primary highways in a selected study area during a one-year period.
2. To develop basic data concerning time utilization and production rates for various maintenance operations.
3. To relate factors such as terrain, roadway design, crew size, and type of equipment to work accomplished.
4. To develop work performance units that can be used in management control and budget allocation.
5. To develop basic data relating to organization, policies and management actions involved in carrying out maintenance operations.
6. To examine certain other specialized aspects of maintenance, such as safety.
7. To analyze the basic data obtained from studies and prepare reports.

8. To recommend improvements in the maintenance organization, procedures, methods of performing operations, and, if applicable, highway design practices.

The criterion followed in establishing a concept for and later in carrying out this study was: How could maintenance operations be performed in a better manner, either qualitatively or quantitatively? Thus, it was intended to isolate facts and performances which could lead to improvements in maintenance operations. In consequence, the entire report emphasizes the imperfections and only token recognition has been given to the many meritorious things which are done by the maintenance organization and its employees.

BACKGROUND

While research has found great favor in construction, design, and traffic engineering, generally speaking, it has been neglected in the maintenance field. That the Iowa Highway Commission turned to research in an effort to improve its maintenance operation is a notable step.

The Commission's growing concern over increased expenditures for highway maintenance and increased services provided, as well as the forthcoming maintenance to be generated by new interstate mileage, underlies much of the present interest in methods and practices followed in performing maintenance work. Maintenance, with its diversified activities extending throughout the State, presents a local and Statewide challenge in the art of labor and equipment management and the possibility of a new horizon to the organization which can make substantial improvements in methods and practices.

A joint cooperative arrangement was worked out early in 1959 between the Iowa State Highway Commission and the Bureau of Public Roads for a full year study of maintenance operations. The Bureau of Public Roads agreed to assume technical direction of the study, furnish some of the personnel, and supervise preparation of the final report. The State, in general, agreed to furnish liaison, supervisory, and field personnel, office space, equipment, supplies, and needed services.

In addition to this summary report there are two supplements. Supplement I, which is available for general distribution, includes summarized study data, discussions concerning methods and practices followed in performing maintenance work, and data on maintenance workloads. This supplement could be of use only to those who may be planning to undertake similar studies or to make extended analyses of maintenance operations. Supplement II is largely statistical detail and could be of interest only to those concerned with specific operations performed under similar working conditions. For this reason, Supplement II will not be useful to most of the report readers and has not been reproduced for general distribution.

Section B

SCOPE AND PLAN OF STUDY

Provision was made to concentrate 50 percent of the study effort in three representative counties, as the control area. The counties chosen for this area were Iowa, Johnson, and Cedar, which are in District 6. Another 25 percent of the study was scheduled for other counties in District 6, and the remaining 25 percent was allocated to other areas of the State. After the study had been underway for six months, the area of concentrated coverage was extended to include the 25 miles of interstate Route 35 in Warren County. Field work was begun early in May 1959, with an inventory of measurable maintenance workloads in the three-county control area. This was followed in June and July by training the personnel and establishing procedures. Detailed field data were collected for the 52-week period from August 16, 1959, through August 13, 1960. Table 1 presents some comparative statistics for the three counties in the control area and the Statewide county average.

TABLE 1

COMPARISON BETWEEN CONTROL AREA COUNTIES AND STATEWIDE COUNTY AVERAGE OF VARIOUS ITEMS RELATED TO MAINTENANCE

Item	Control area counties			Control area	State-wide
	Cedar	Iowa	Johnson	County average	County average
State primary highways (7/1/59)					
Concrete (miles)	34.0	14.7	72.3	40.4	56.5
Brick (miles)	0.9	0.8	0.4	0.7	0.8
Bituminous overlay (miles)	17.9	42.8	15.6	25.4	16.2
Bituminous concrete (miles)	20.8	21.2	-	14.0	10.8
Bituminous surface treatments (miles)	0.7	0.8	13.5	5.0	7.5
Gravel (miles)	8.8	8.2	7.3	8.1	7.6
Total (miles)	83.1	88.5	109.1	93.6	99.4
Miles per maintenance employee	5.9	7.4	7.3	7.0	7.0
Average age of pavement surfaces	13	6	12	10	18
Average maintenance expenditure per mile (1959-60 FY)	$1,619	$1,127	$1,265	$1,326	$1,374
Average daily traffic (1/1/60 estimate)	2,140	1,840	2,800	2,300	1,823
Area - square miles	585	584	620	596	565
Population (1960 census)	17,791	16,396	53,663	29,283	27,854

The terrain found in various parts of Iowa is largely dependent upon past glacial action. Geologists have identified seven glacial till sheets or areas, each with its own typical terrain. The three-county control area and the interstate route selected for study were located within the Kansan area which covers the southern half of the State. Terrain in this area is characterized by rolling to hilly topography with some level areas on divides or in river valleys. This topography has developed primarily by erosion of the original glacial till plain.

Soils in the Kansan area are predominately clays classified as A-6 or A-7-6. However, there are some areas with a loess layer or pockets of gumbo till and granular materials. The principal source of road-building aggregate in the Kansan area is limestone quarries.

The three-county control area was located in the U.S. Weather Bureau's east-central district. Records indicate that precipitation and temperature in this district were as follows:

	Long-term average	August 1959 - August 1960
Annual mean temperature	49° F	48° F
Annual precipitation	33 in.	43 in.
Annual snowfall	30 in.	55 in.

The interstate route selected for study was in the Weather Bureau's south-central district. The records showed that temperature and precipitation were:

	Long-term average	1960
Annual mean temperature	51° F	49° F
Annual precipitation	32 in.	39 in.
Annual snowfall	28 in.	-

CHARACTER OF MAINTENANCE OPERATIONS

Purpose

Highway maintenance operations encompass work performed for the purpose of (1) preserving the capital investment in the facility, and (2) providing services to the public. The extent of services provided has been determined by policy of the State Highway Commission and the Maintenance Department in response to public demand, as well as by local practice.

Scope

Maintenance operations on the primary and interstate highways in Iowa constitute a major undertaking. There are 9,842 miles of primary and

Figure 1. Scenes of maintenance operations which preserve the capital investment in highway facilities.

Figure 2. Scenes of maintenance operations which provide service to the public.

interstate highways in the 99 counties. The county with the least miles has 47 while the county with the most miles has over 210. Maintenance operations use a force of 1,396 men, including 111 foremen, and 1,952 pieces of self-propelled equipment. They are stationed at 186 garages. Self-propelled equipment plus other types used for maintaining State highways had a value of approximately $3 million on July 1, 1960.

<u>Conditions</u>

Maintenance operations constitute a perpetual task. Large geographical areas are involved. There are seasonal variations in the workload and the peak of activity is usually reached during periods of severe winter weather. Maintenance includes an endless variety of work, partly due to topography, vegetation, and traffic, and partly due to conditions which have evolved from the quest for the most economical highway facility. To these variable conditions must be added the weather elements which influence timing and methods used for specific operations.

<u>Responsibilities</u>

While as stated previously the purpose of highway maintenance operations is twofold, the maintenance forces often have another responsibility; namely, acting as a service organization to departments within the Highway Commission. The magnitude of these latter services is indicated in Tables 2 and 3 by the time expended by maintenance forces for service and repair of non-maintenance vehicles, maintenance of detours off the existing primary system, care of traffic weighing stations, and miscellaneous work resulting from construction contracts.

From the beginning of highway maintenance, its heritage has included taking care of problems unknowingly or neglectfully perpetrated by design and construction engineers. Correcting these problems in future construction, unfortunately, does not provide a cure for the past. Some of these problems end up as perpetual obligations such as the necessity to clean sediment from drainage structures at regular intervals. Others such as erosion and shoulder repair may require special attention for a period of several years after construction.

The bulk of work done by maintenance forces is in connection with the primary responsibility for routine work which preserves investments or provides the public with a desired service. This work includes a host of operations: patching many types of roadway surfaces; keeping drainage structures and ditch lines free of obstruction; controlling vegetation; controlling snow and ice; erecting or replacing traffic signs; marking pavements; and picking up litter.

Many routine processes are used in performing maintenance work. Under the conditions encountered, however, only a small portion of the work is characterized by uniformity. Controlling snow and ice, for example, is routine in the sense that it is carried out every winter, but it is rarely accomplished under identical circumstances. The variables are numerous and often difficult to comprehend and measure or to predict with accuracy.

To see that these responsibilities and obligations are performed properly, the State Highway Commission depends, in the end, on its frontline supervisor, the maintenance foreman. He receives aid and guidance, of course, from superiors at the maintenance residency and the district offices and from those in the Central Office. Nevertheless, the foreman with his day-to-day contact plays a key part in the success achieved in maintaining the highways.

Figure 3 is an organization chart for maintenance operations in the Iowa Highway Commission. As used in this report, the term Central Office refers to the Iowa Highway Commission headquarters offices in Ames, Iowa, and the term Maintenance Department refers to the Maintenance Engineer and his staff who are located in the headquarters offices at Ames.

STUDY ORGANIZATION AND PROCEDURE

Organization

To accomplish the objectives of the one-year study, five groups of study personnel were employed. One group was assigned to each of the three counties in the control area, one to the interstate route selected for study, and the remaining group operated throughout the State. Several specialists also participated on a part-time basis. All field work was under the technical direction of the Bureau of Public Roads which had a full-time resident engineer assigned to the study. A State engineer was likewise assigned full time to the study. He provided liaison with the Maintenance Department and assisted with the responsibilities of the study. The Bureau of Public Roads assigned staff employees and engineers in training to the study for periods of 1 to 6 months. Usually there were 8 to 10 on the job. The State provided 14 men and a stenographer for the duration of the study. A study headquarters office was established at Cedar Rapids near the District 6 office. Field offices were initially established at State maintenance garages in Marengo, Iowa City, and Tipton. Later, another was set up at the Martensdale garage for the study on interstate Route 35.

Procedure

The study program included five broad phases:

1. Comprehensive studies were made to develop basic data relating to the types and total extent of maintenance performed on the primary road system during a one-year period in the three-county control area and on a segment of the interstate system during a six-month period. For this phase, daily records for each man and equipment unit working in the study area were kept. Road sections were subdivided to facilitate identification of worksites. The records showed the specific maintenance operation (functional type of work) performed, general location of each worksite, accomplishment, total time required for the operation, and non-operational delays of over 30 minutes. These records provided substantially more information regarding time distributions and work locations than could be developed by current maintenance reporting procedures. Time was accumulated in 140 different types of operation accounts. However, by the time most of the analysis work had been finished, operations found to be insignificant were combined and the original 140 operation accounts were reduced to 56.

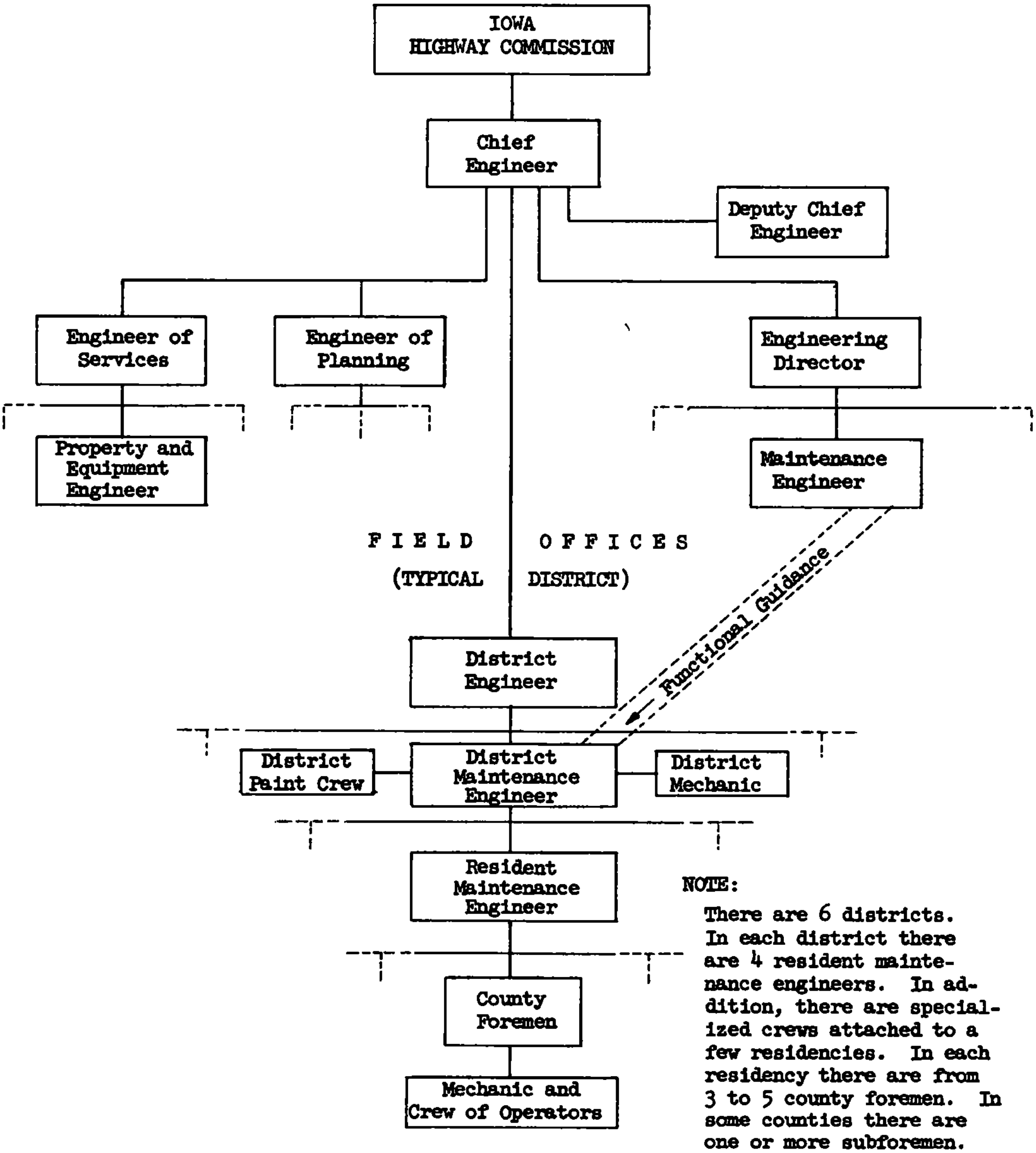


Figure 3. Organization for maintenance operations

2. Production studies were made to develop detailed data relating to specific maintenance operations throughout the State. This type of study was conducted on crew labor and individual units of equipment. Observers employed stopwatches to obtain a complete record of delays and working time associated with each individual operation throughout an entire day. A record was also kept of work accomplished, travel distance, materials consumed, and other items considered desirable. Over 60 different operations were covered by this type of study. Some operations were studied as many as 40 times.

3. Field and office reviews of management functions were carried out. The State's organizational structure was reviewed to determine positioning and lines of authority. Examination was made of staffing patterns and maintenance policies and controls. A questionnaire was developed to help determine individual concept of responsibility and authority. Resident maintenance engineers throughout the State kept a record of their daily activities one week out of every month for a period of six months. At various times, observers conducted time studies on foremen for a period of one day to one week to show where they went and what they did. Several such studies were also made of resident maintenance engineers. Extensive personal interviews were conducted with individuals from each level in maintenance operations from the maintenance engineer down to and including county mechanics.

4. Field and office investigations were made of certain special aspects or problem areas. These include erosion control, drainage problems, safety practices, foreman's span of control, and the State accounting practices from a use standpoint.

5. An office analysis of study data and the preparation of reports were the final steps.

Cooperation

Maintenance employees in the Central Office and in the field contributed freely of their time whenever it was needed in the conduct of this study.

Section C

ORGANIZATION FOR MAINTENANCE OPERATIONS IN IOWA

ORGANIZATION

Responsibility and authority for maintenance operations until in recent years were highly centralized. However, according to the existing organization chart (shown on page 9), this responsibility is now lodged with six district engineers who are accountable directly to the chief engineer. There are six district maintenance engineers to whom 24 resident maintenance engineers are accountable.

The maintenance engineer reports to and advises the engineering director and furnishes functional or technical guidance to the districts. The maintenance engineer is responsible for preparing maintenance standards; for coordinating maintenance activities among the districts; and for providing assistance on technical and management problems. He is also responsible for control of maintenance operations in accordance with established policy to the extent delegated to him by the engineering director.

Accomplishment of actual road and bridge maintenance functions within the 24 residencies is the responsibility of resident maintenance engineers. Each resident maintenance engineer supervises from three to five foremen, at least one for each county, who are responsible for day-to-day supervision of routine maintenance. In some counties subforemen are also used.

POLICIES

The Iowa State Highway Commission is under the general direction of a 5-member commission. The five Commissioners are appointed by the Governor and confirmed by 2/3 of the Senate for 4-year staggered terms. Not more than three of the five can be from one political party. According to statute, the highway commission is responsible to the people of Iowa to "devise and adopt standard plans of highway construction and maintenance ... furnish information and instruction to, answer inquiries of, and advise with, highway officers on matters of highway construction and maintenance ...." The law does not provide for appointment of any other highway officials. Consequently, the appointment of all highway personnel falls within the purview of the Commissioners. The Commissioners have full authority over the State's highway activities and accordingly can make operating decisions, but do not.

EXPENDITURES

Expenditures for maintenance of State primary and interstate highways during each of the past 6 years are as follows:

Fiscal year	Maintenance expenditure ($ mil)
1954-55	10.3
1955-56	10.2
1956-57	10.5
1957-58	10.6
1958-59	11.4
1959-60	1/ 13.5

1/ Increase over prior years reflects heavy snowfall, severe winter damage, and added institutional roads.

FUNCTIONS

The Maintenance Department is responsible for administering a Statewide program of road and bridge maintenance, including surface, snow and ice control, structures, roadside and drainage, shoulder and approaches, and traffic service. This responsibility involves the following functions:

(a) Obtaining uniform maintenance operations.
(b) Recommending to the Engineering Director the necessity for establishing or revising maintenance policies and standards.
(c) Preparing budget proposals.
(d) Developing a maintenance manual and keeping it current.
(e) Coordinating maintenance functions in the various districts.
(f) Making suggestions for specifications for materials.
(g) Applying access control rules and regulations.
(h) Preparing regulations and specifications.
(i) Providing opportunity for field offices to make recommendations and giving them a realistic review.

PERSONNEL

Personnel of the Iowa State Highway Commission as a group have a reputation for competency - many present and former leaders have Nationwide respect. This speaks well for the Commission as a group and implies in general that capability and interest are at a high level.

From 1946 to 1960, maintenance employees (less engineers) increased from 1,209 to 1,396 or 15 percent. Of this total, mechanics have shown the largest percentage increase, 30 percent, while foremen have increased the least, 10 percent. Most of the increase in mechanics has occurred since this study began. The total force of 1,396 employees is divided into the following classifications:

Classification	Number
Foremen	111
Operators	1,139
Mechanics	135
Laborers	11
Total	1,396

Except for foremen, mechanics, and a few laborers, all other non-professional maintenance employees are classified as operators. Three classifications are in use. Officially, they are described as Road Equipment Operators, (REO) I, II, and III.

Since 1946, the lowest level operator (REO I) has had his monthly salary range increased from $155-190 to $265-325 ($370 with three longevity steps). Foremen's salaries have increased from a range of $200-300 in 1946 to $340-400 in 1960 ($460 with three longevity steps). These salary ranges represent about a 70 percent rise (not including longevity increases) except for the high range of foremen's salaries which have increased only 33 percent. On the basis of wages per hour, the increases are more dramatic because the normal workweek is now 40 hours, whereas in 1946 it was 54 hours.

A typical county force consists of a foreman, a mechanic, and an average of 11 operators. However, not all county forces have a mechanic.

Section D

SUMMARY DISTRIBUTIONS OF THREE-COUNTY CONTROL AREA TIME

Comprehensive records were maintained for all labor and equipment utilized in the three-county control area during the one-year study period. In general, time was classified by operation according to the system outlined in the current AASHO Manual of Uniform Highway Accounting Procedures. However, a number of special overhead operation accounts were used and all non-operational major delays were specifically identified. Thus, the study classification of time is not the same as found in Iowa accounting records. Tables 2 and 3 present summarizations of labor and equipment time, respectively, charged to major groups of overhead operations, direct operations, and major delays.

The following special definitions are for terms which have been used in this and subsequent sections of this report:

Overhead operations - undistributed are major operations of a general nature which could not be logically allocated to specific direct operations.

Overhead operations - distributed are operations of a general nature which could be logically allocated to specific direct operations. They have been distributed in tables shown in Supplement I.

Direct operations - existing system are specific operations performed at worksites on the existing primary system (including daily preparations at a garage, yard, stockpile, or parking area).

Direct operations - new construction are specific operations performed at worksites on current construction projects or at worksites on construction-caused detours located off the existing primary system (including daily preparations at a garage, yard, stockpile, or parking area).

Total available working time (TAWT) is equal to scheduled working time for men or equipment plus any overtime actually worked. Paid leave and holiday time was excluded.

Net available working time (NAWT) is equal to total available working time minus non-operational major delays.

Non-operational major delays are individual periods of idleness which last for 30 or more minutes and which are caused by factors having no direct relationship to an operation.

Operational major delays are individual periods of idleness which last for 30 or more minutes and which are caused by factors having a direct relationship to an operation. They are part of NAWT.

Minor delays are individual periods of idleness which last for less than 30 minutes. They may be either operational or non-operational and are part of NAWT.

Productive time is the time during which men or equipment are engaged in actual work. It is equal to NAWT minus all delays.

Service and repair equipment (item 1(b), Tables 2 and 3) is that operation which covers activities of mechanics, operators, and the equipment which they use in performing major service or repair work on all types of equipment. Most equipment units charged to this operation were used for transporting men who performed the service or repair work, i.e., the mechanic's pickup. By definition, men or equipment engaged in service or repair for individual periods which lasted less than 30 minutes were not charged to this operation but were considered to be in minor delay status. Equipment being serviced or repaired and men or equipment waiting on service or repair of equipment were considered to be in major or minor delay status.

Class A Equipment consists of trucks, motorgraders, draglines, pickups, cars, tractors, loaders, mudjack machines, air compressors, and some other types of motorized or non-motorized equipment. Most, but not all, are self-propelled. For study purposes, separate records were kept for each unit of Class A equipment.

Class B equipment consists of trailers, truck beds, snowplows, blades, rollers, distributors, kettles, brooms, spreaders, and many other minor units. Some of these are motorized but none are self-propelled. For study purposes, separate records were kept for all Class B equipment not normally attached to a unit of Class A equipment. Towed units of Class B equipment were not considered to be attached to Class A units. Class B equipment normally attached to a unit of Class A equipment while in use (such as snowplows) was considered to be part of the Class A unit for study purposes.

Service and repair major non-operational delays (item V(a), in Table 3 - not shown separately in Table 2) are those delays where equipment units were being serviced and repaired for individual periods lasting 30 or more minutes or where men and equipment units were waiting on service or repair of equipment. Units of Class A equipment were charged with a major delay for service and repair whenever their attached Class B equipment was being worked on for 30 or more minutes. If the Class B equipment was detached, units of Class A equipment were charged with a major delay only if they sat idle and waited on completion of the service or repair. Time for installation of minor attachments like buckets and snowplows was not considered to be a delay, but installation of major attachments such as truck beds or snow plow frames were.

Data presented in Table 2 show that direct operations, items III and IV, total 55 percent. It should be recognized, however, that overhead operations - distributed, item II, relates directly to the several types of work included under direct operations. Accordingly, the sum of items II, III, and IV which is 70 percent may be a more realistic measure of effort expended at worksites. More than one-half of this effort was expended on service functions such as plowing snow, mowing, or detour maintenance. These items are not separately identified. However, analysis shows that if time spent on service functions were separately classified, the remainder, representing maintenance of the structural components of the existing highways, would total 23 percent (30 percent including distributed overhead).

The data in Table 3 show the utilization of equipment by type. As might be expected, light duty trucks had almost as many hours of NAWT as all other equipment types combined. The ratio of NAWT to TAWT varied considerably from type to type, with light duty trucks, draglines and pickups having the most intensive use. The ratio of non-operational service and repair delay time to NAWT varied as follows:

Type of equipment	Hours of NAWT per hour of service and repair delay
Light duty trucks	8.3
Heavy duty trucks	4.3
Motorgraders	5.6
Draglines	5.5
Pickups	17.0
Tractors and loaders	6.6
All other	16.4

TABLE 2

LABOR TIME DISTRIBUTION IN 3-COUNTY CONTROL AREA

Item No.	Description	Hours		Percent	
I	Overhead operations - undistributed:				
	(a) Supervise maintenance activities	5,554		7	
	(b) Service and repair equipment 1/	14,153		16	
	(c) Clean, repair or improve garage facilities	2,777		3	
			22,484		26
II	Overhead operations - distributed 2/:				
	(a) Travel	6,471		7	
	(b) Stockpile materials	3,802		4	
	(c) Other	3,288		4	
			13,561		15
III	Direct operations - existing system:				
	(a) Routine surface	6,883		8	
	(b) Special surface	6,278		7	
	(c) Shoulder and approach	2,717		3	
	(d) Roadside and drainage	7,936		9	
	(e) Snow and ice	15,624		18 3/	
	(f) Traffic service	3,063		4	
	(g) Other	1,379		2	
			43,880		51
IV	Direct operations - new construction:				
	(a) Detour	1,651		2	
	(b) Miscellaneous work resulting from construction contracts	1,507		2	
			3,158		4
	Net available working time (NAWT)		83,083		96
V	Major non-operational delays		3,142		4
	Total available working time (TAWT) 4/		86,225		100

1/ Includes 1,117 hours of time charged to non-maintenance equipment.

2/ This time has been distributed to direct operations in subsequent labor tables.

3/ From 1/3 to 1/2 more effort than normal was estimated to have been expended on snow and ice during the period of study.

4/ Paid leave amounted to an additional 8,411 hours or 9.8 percent of TAWT.

TABLE 3

EQUIPMENT TIME DISTRIBUTION IN 3-COUNTY CONTROL AREA

Time in hours

Item No.	Description	Light duty trucks	Heavy duty trucks	Motorgraders	Draglines	Pickups	Tractors and loaders	All other
I	Overhead operations - undistributed:							
	a. Supervise maintenance activities	33	-	-	-	2,148	-	-
	b. Service and repair equipment	189	10	3	6	1,105	64	-
	c. Clean, repair or improve garage facilities	294	22	17	2	84	107	173
		516	32	20	8	3,337	171	173
II	Overhead operations - distributed 1/							
	a. Travel	2,332	212	431	36	537	245	310
	b Stockpile materials	2,109	134	7	140	173	261	15
	c. Other	973	59	165	41	1,431	88	382
		5,414	405	603	217	2,141	594	707
III	Direct operations - existing system.							
	a. Routine surface	2,957	245	949	8	130	376	708
	b. Special surface	3,536	529	345	43	115	649	1,523
	c. Shoulder and approach	1,236	173	273	5	8	205	111
	d. Roadside and drainage	2,018	60	49	333	439	4,833	238
	e. Snow and ice	6,891	1,828	1,548	-	110	263	-
	f. Traffic service	802	20	21	13	785	48	218
	g. Other	709	14	40	-	110	15	17
		18,149	2,869	3,225	402	1,697	6,389	2,815
IV	Direct operations - new construction							
	a Detour	624	33	325	21	139	71	4
	b. Miscellaneous work resulting from construction contracts	389	52	543	7	152	77	7
		1,013	85	868	28	291	148	11
	Net available working time (NAWT)	25,092	3,391	4,716	655	7,466	7,302	3,706
V	Major non-operational delays:							
	a. Service and repair	3,032	797	843	120	439	1,099	226
	b. Standby - awaiting repair	605	438	266	11	144	1,442	150
	c. Standby - no work	12,488	9,464	6,214	601	9,514	28,403	36,076
	d. Other	764	83	138	44	414	638	145
		16,889	10,782	7,461	776	10,511	31,582	36,597
	Total available working time (TAWT)	41,981	14,173	12,177	1,431	17,977	38,884	40,303

1/ This time has been distributed to direct operations in subsequent tables.

Section E

FINDINGS

Analysis of comprehensive studies in the control area and production studies Statewide produced most of the findings which are subsequently itemized under various types of maintenance operations. Following the findings on maintenance operations are the group of findings produced by means of recognized management study techniques. During the management phase of the study, production study results, questionnaires, and personal interviews were the principal tools used. The findings and observations are listed under appropriate headings.

Some of the findings, as could be expected, are relatively more important than others, especially in terms of their impact on the total maintenance operation. However, no attempt is made to rank the individual findings, not only because of the questionable value of such a ranking, but also because to do so would involve a long and costly process.

The first group of findings are presented under the heading of Erect and Remove Snow Fences, the first of 28 similar listings. Supporting data and additional details about the operations and the findings will be found in Supplement I.

1. Erect and Remove Snow Fences

(a) Erection of all snow fence in the three-county control area was accomplished at an average rate of 0.9 minute labor NAWT per linear foot. Removal was carried out at the rate of 0.6 minute labor NAWT per foot. Production studies made throughout the State show that, on the average, erection was accomplished in 0.85 minute labor NAWT per linear foot.

(b) Several types of power fence post drivers were studied. Some differences in production rates were noted. Based on labor NAWT for cyclic work items at the worksite, the range of average performance during that portion of the day when posts were being driven varied from a low of 0.49 minute per post to a high of 1.03 minutes. The average time per post was 0.63 minute.

(c) Two men are required for loading and unloading snow fence rolls. There were often three men assigned to this job. These three men usually traveled together between loading and unloading sites, and travel time of men, other than the driver, was found to be a critical factor in obtaining effective labor utilization.

(d) Contacts with land owners for purposes of obtaining approval to erect snow fences accounted for more than two percent of labor NAWT time spent on erecting snow fence. Both foremen and operators were involved.

(e) Removal of snow fence was generally a well-coordinated and efficient operation. It could have been improved slightly if all work had been done by two-man crews.

(f) Snow fence was not raised after it had drifted full.

(g) Snow fence erection can be logically divided into three steps. They are: (1) hauling and driving posts, (2) hauling and distributing fence, and (3) erecting fence. Step 1 can best be accomplished by a crew consisting of two men, one truck, and a powered post driver. Steps 2 and 3 should be combined at each worksite and executed by a crew of two men and one truck for maximum economy. However, it is recognized that adverse conditions may make it necessary to perform steps 2 and 3 separately. If so, a crew of two men and two trucks will increase productivity during step 2.

(h) With the frequent coverage of the mileage by snow plows under existing operating plans, the accumulation of snow at any one point does not, as a rule, exceed the capacity of small plows to handle the drifts.

(i) In bad storms, such as the three experienced during the winter of 1959-60, the snow fence in place did not sufficiently retard the buildup of snow to keep some roads from becoming drifted full.

2. Sand (or Cinder) Roadway Surfaces

(a) It was estimated that abrasives (sand or cinders) were used at the average rate of 9.5 cu yd per mile of 2-lane road in the control area during the winter of 1959-60. Calcium chloride and/or rock salt were mixed with all abrasives used.

(b) There was considerable variation in the rate of abrasive application. The averages found on production studies were 0.085 cu yd or 235 lb/1000 sq yd of surface.

(c) The average observed production was 14,300 sq yd of surface sanded per hour of labor NAWT.

(d) The amount of calcium chloride and rock salt mixed with abrasives varied from load to load in the control area. In some cases, abrasives were used just as they came from stockpiles and thus contained about one-half sack of chloride per cubic yard or a ratio of 1:50 based on volume. In most cases, additional chloride or rock salt was added at the time trucks were loaded. The ratio of chloride and rock salt to abrasives was 1:10 in many loads and a few were observed where the ratio was 1:2. It was estimated that the average ratio in the control area was 1:20. Some of the variations observed were due to fluctuating temperatures and changing road conditions; others were due to experimentation by foremen and operators.

(e) Only rarely were abrasives spread in continuous coverage over the entire length of a road section; normal practice was to cover icy locations with particular attention given to hills, curves, intersections, railroad crossings, and bridges.

(f) Hand spreading of abrasives was almost nil. It amounted to one percent of labor NAWT charged to sand surfaces.

(g) It required approximately 10 minutes to load a truck with abrasives by means of a front-end loader.

(h) Trucks with spreader beds assigned to sanding surfaces had one or two operators aboard. Production studies indicate that the number of sanding runs with one operator was about equal to the number made with two operators. Trucks with end-dump beds assigned to sanding surfaces required two operators.

3. Salt Roadway Surfaces

(a) Salt was used at the rate of 6.3 tons per mile of 2-lane road on roads designated for salting in the control area during the winter of 1959-60.

(b) The average observed application rate for salt was 425 lb per mile of 2-lane road but the rate for individual runs varied between 370 and 515 lb per mile of 2-lane road. (These rates were computed on the basis that salt weighed 1,890 lb per cu yd.)

(c) The observed average production rate for salting was 6.5 miles of 2-lane road per hour of labor NAWT.

(d) Salt trucks were actually spreading salt 51 percent of NAWT as shown by production studies of salting operations.

(e) Travel speeds during salt runs with spreader trucks averaged 20.4 m.p.h. The average for an entire run ranged from 19 to 22 m.p.h.

(f) The 5 to $6\frac{1}{2}$ cu yd beds used on salt spreader trucks had sufficient capacity for a run of 22 to 28 miles at the observed average rate of application.

(g) Although no studies were made to determine the width of pavement covered with salt during a spreading operation, it was noted that some salt bounced off the pavement and onto the shoulders, particularly at speeds of about 25 m.p.h.

(h) The foremen were handicapped in arriving at some decisions regarding salting operations due to a lack of adequate weather indicators, weather forecasts, and fast communications.

(i) Salting did not decrease the total amount of effort put into snow and ice removal on roads in the control area. That is, the average effort for salted and non-salted roads was about the same. However, salted roads, which are usually the heavily traveled roads, were generally in a good condition at an earlier hour.

(j) It required about 10 minutes to load a truck with salt by means of a front-end loader.

4. Remove Snow and Ice from Roadway Surfaces and Shoulders

(a) It was observed that roads were generally kept in good condition.

(b) Snow and ice control vehicles were used during snow storm periods for approximately 40 minutes per day per mile of road. This time element appeared to hold true regardless of the quantity of snow or the rate of snowfall.

(c) No generally significant difference was found in the amount of equipment time used for snow and ice control on various roads in the study counties. However, a few short spurs with low traffic volumes received less effort than the other road sections.

(d) Plowing speeds of 15 m.p.h. were attained consistently by trucks but the range of speeds went as high as 32 m.p.h. A plowing speed of 17 to 20 m.p.h. was most frequently observed. Truck speeds while ice blading averaged about 6 m.p.h.

(e) The amount of operator labor time required to keep a snow and ice control vehicle on the road for one hour was 1.47 hours, 1.50 hours, and 2.00 hours in the three control area counties. On the interstate study the time was 1.95 hours. Data obtained from Commission records suggest that a value as high as 3.00 hours may prevail in several heavily populated counties and a value slightly lower than 1.47 is experienced in some rural counties.

(f) Some foremen permitted their men to engage in snow plowing work for continuous periods exceeding 16 hours. A special study about hours of continuous duty was made by a consultant. His report proposed that 12 hours of continuous duty should be followed by an 8-hour rest and that 16 hours should be followed by a 12-hour rest. Sixteen hours was thought to be near the maximum number that should be permitted.

(g) The practice of assigning two men to each piece of plowing equipment out on the road was largely adhered to in one county but was seldom followed in the other two.

(h) The number of operational trucks required for snow removal depends on three factors: Average interval between coverage, average road speed, and a time use ratio (see Table 4). The first factor can be established by a management decision. The latter two factors reflect management practices and existing conditions in a given area.

TABLE 4

NUMBER OF OPERATIONAL TRUCKS FOR SNOW REMOVAL ON 200 LANE-MILES OF HIGHWAY AT SELECTED INTERVALS OF COVERAGE

Variable factors		Number of operational trucks when interval between coverage is -						
Average road speed	Time ratio 1/	5 hr	4 hr	3 hr	2½ hr	2 hr	1½ hr	1 hr
Slow - 15 m.p.h.	Poor	6	7	9	11	14	18	27
	Fair	5	6	7	9	11	15	22
	Good	4	5	6	7	9	12	18
Average - 20 m.p.h.	Poor	4	5	7	8	10	14	20
	Fair	3	4	5	7	8	11	16
	Good	3	4	5	6	7	9	14
Fast - 25 m.p.h.	Poor	4	4	6	7	8	11	16
	Fair	3	4	5	6	7	9	14
	Good	2	3	4	5	6	8	11

1/ The ratio of on-the-road time of trucks to time in use. A ratio of 1 to 2 is poor, 1 to 1.65 is fair, and 1 to 1.35 is good.

Basic formula - $\frac{\text{Lane-miles x time ratio}}{\text{speed (m.p.h.) x trucks}} = \text{Frequency of passage or coverage interval in hours}$

(i) The number of men required to be available for snow removal work depends on four factors: Maximum number of hours men are allowed to work, total number of coverages in a 24-hour period, average road speed, and a time use ratio (see Table 5). The first two factors can be established by management decisions. The latter two factors reflect management practices and existing conditions in a given area.

TABLE 5

NUMBER OF AVAILABLE PERSONNEL 1/ FOR SNOW REMOVAL ON 200 LANE-MILES OF HIGHWAY 2/

Variable factors		Number of personnel needed when the total number of coverages in 24-hour period is -							
Average road speed	Time ratio 3/	5	6	7	8	9	10	12	16
Slow - 15 m.p.h.	Poor	10	12	14	15	17	19	23	30
	Fair	9	11	12	14	16	17	21	28
	Good	8	10	11	13	14	16	19	25
	Attainable	7	9	10	11	13	14	17	22
Average - 20 m.p.h.	Poor	8	9	10	12	13	14	17	23
	Fair	7	8	9	11	12	13	16	21
	Good	6	7	9	10	11	12	14	19
	Attainable	5	6	8	9	10	11	13	17
Fast - 25 m.p.h.	Poor	6	7	8	9	11	12	14	18
	Fair	6	7	8	9	10	11	13	17
	Good	5	6	7	8	9	10	11	15
	Attainable	5	5	6	7	8	9	10	13

1/ Foremen and mechanics excluded.
2/ Based on a maximum of 13 hours per man in a 24-hour period.
3/ The ratio of on-the-road time of trucks to labor time charged to this work. A ratio of 1 to 1.85 is poor, 1 to 1.65 is fair, 1 to 1.50 is good, and 1 to 1.35 is attainable.

(j) Trucks returned to the garages for refueling, repair, service, communications, or other reasons at frequent intervals. Often the trip to the garage involved relatively long travel that was essentially non-productive. The magnitude of this travel could not always be measured because the trucks traveled with their plows down and it was, therefore, counted as working time for study purposes even though little was accomplished. A check of 136 runs studied reveals that equipment units averaged about 2.5 hours on the road between visits to the garages.

(k) In the three-county control area the plowing of shoulders and the opening up of additional storage space was usually done during daylight hours after snow had stopped falling.

(l) Truck underbody blades were hardly ever used for plowing loose snow but were frequently used for removing packed snow and ice.

(m) No consistent relationship was found between plowing speeds and depth of snow.

(n) Measurements taken during one snow storm show that heavy work with Vee plows and wings result in the consumption of fuel at the maximum rate of 10 gallon per working hour. Accordingly, a heavy-duty truck with a 50-gallon tank could carry sufficient fuel to assure continuous operation for at least five hours. Light-duty trucks were found to use about six gallons per working hour when performing heavy work.

(o) Measurements of snowfall rates during the three big storms of 1959-60 indicate that not more than 1-inch per hour of new snow fell during the height of any storm. The more common rate of fall during heavy snows was found to be near one-half inch per hour.

(p) The amount of ballast carried by plowing trucks varied substantially from established recommendations.

(q) A heavily ballasted light duty truck, equipped with a one-way plow and chains, removed four inches of new fallen snow from the road in one pass without difficulty.

(r) There were eight Vee plows on hand in one of the control counties. Not more than four of these were used simultaneously during any of the storms which occurred during the winter of 1959-60.

(s) Rotary snow plows were not available in the control area on a continuous basis. They were stationed at points from 20 to 100 miles away and brought in to the control area only when needed.

(t) The work crews studied did not pull large drifts onto the pavement with wing plows and then blow the snow away with rotary plows. The personnel use only a limited number of techniques to cope with the variety of problems in snow and ice control.

(u) When the direction of travel during plowing is such that the wind is blowing from the right side of the truck, there is a tendency for snow to blow back over the plow and thus obscure the operator's vision. Truck speeds are reduced by 6 to 10 m.p.h. when this blow-back occurs. This condition is usually worst when the wind is from the right and parallel to the plow moldboard. When the wind blows at right angles and toward the plow moldboard, it has less effect on vision and speed. Wind blowing from the left does not usually affect the operator's vision and truck speed.

(v) Standard equipment windshield wipers on trucks used for snow removal did not keep windshields clear of snow and ice during all weather or plowing conditions.

(w) A night duty man was employed in one county during winter months. This man did a minor amount of productive work during his shift. The extent to which this practice was followed in other than the study counties was not determined but is not believed to be widespread.

5. <u>Mow Roadsides</u>

(a) Approximately 75 percent of the shoulder and right-of-way areas beyond the pavement edge were mowed. The mowed portion in the three-county control area averaged 8.3 acres per mile. Some right-of-way sections beyond the shoulder were mowed twice during one season. For that portion of the interstate system set up as a control area, the mowed area could not be determined accurately but averaged at least 30 acres per mile.

(b) Tractor sickle bar mowers of 5- and 6-foot lengths mowed 1.08 acres per hour of worksite time when the terrain was relatively smooth and dry. In rough, rocky, or wet terrain, they mowed 0.66 acre per hour of worksite time.

(c) Tractor rotary mowers with 5-foot blades, which were used primarily on the shoulders, averaged mowing 3.72 swath-miles per hour of worksite time or the equivalent of 2.28 acres. The shoulders were mowed from 1 to 4 times per year with main routes receiving the greatest number of mowings.

(d) A new 15-foot sectional tractor rotary mower acquired by the Commission late in 1960 was studied for two days. The limited measurements obtained during these two days indicate that it can mow 3 to 6 acres of right-of-way per hour of worksite time where the right-of-way is relatively wide and free from obstructions.

(e) When more than two tractor mowers worked in close proximity, the effect was to reduce the average accomplishment of each mower. This reduction was more pronounced in smooth and dry terrain than in rough, rocky, or wet terrain.

(f) Mowing in a long continuous line, in contrast to short stretches with frequent turnarounds, was found to result in increased productivity.

(g) For each hour of tractor mower worksite time recorded during production studies, it was found that 1.3 hours of labor NAWT were expended at the worksite, in travel, and in preparatory operations.

(h) Obstacles, such as railroad rail right-of-way markers and concrete reference posts were troublesome because they could not be identified easily in growing vegetation. Where tall secondary markers had been erected adjacent to the reference post or marker, this problem did not exist.

(i) Wet spots in the right-of-way were the source of delays. Tractors became stuck an average of 1.6 times per day.

(j) Hand mowing was a relatively inefficient operation. There was a substantial amount of time spent in travel (over 20 percent). The men were actually cutting weeds or grass only 36 percent of NAWT spent on this operation and it took 257 minutes NAWT to cut 100 sq yd of grass and weeds.

(k) Hand-operated rotary power mowers have a limited usefulness for highway work. However, they have a much higher production rate than hand work where conditions are suitable for their use. It took 77 minutes NAWT to cut 100 sq yd of grass and weeds, with hand-operated rotary power mowers.

(l) Two- or three-man crews were normally used for hand mowing. Most of this work could be accomplished by one-man crews with a slight gain in production per man-hour.

6. Patch Roadway Surfaces with Aggregate, Bituminous Cold Mix and Bituminous Hot Mix

(a) Average size of patch using various materials was observed to be:

Aggregate	16.0 sq yd
Cold mix	0.9 sq yd
Hot mix	2.4 sq yd

(b) Most of the cold mix patching operations studied were performed by two- or three-man crews including flagmen on some three-man crews. Major differences in production rates were observed between different size crews and between different crews of the same size. An important factor relating to these differences in production rates is the percentage of the crew time used for traveling to the worksite and between worksites. For small scale operations, which are those involving one truck load or less material per day, the two-man crews produce up to 20 percent more per man-hour than three-man crews under comparable conditions.

(c) It was apparent that crew members sometimes were assigned and worked on the basis of one man for each function without regard to the physical needs of the job underway. For example, there might be one man to clean holes, one to apply a tack coat, one to shovel in the mix, and another to rake and shape the patch. Such a crew did not ordinarily perform two or more of these steps simultaneously and the men spent considerable time waiting on each other.

(d) Most of the patching operations studied involved less than a full day's work by the crews. Sometimes the crews returned to the garage early because they ran out of materials.

(e) A few studies were conducted while crews performed extensive patching with aggregate on badly deteriorated roads. It was evident there was a lack of balance between men and equipment. Waits on hauling materials averaged about 20 percent of the labor NAWT. More trucks were definitely needed.

(f) A noticeable lack of uniformity was observed in the methods used for placing bituminous patches. Some holes were cleaned and primed prior to filling while others were not. Some patches were compacted with the truck wheels or with a roller while others were not compacted at all.

(g) Less than full loads of bituminous cold mixes were frequently hauled to the worksite by patching crews. The average load was 1.75 cu yd or about 2.6 tons. More material could have been used in half of the cases studied.

(h) Calcium chloride was used for almost all spot patching with aggregates on gravel and low type bituminous surfaces. It was carried to the worksites in bags and sparingly sprinkled by hand on the top of patches.

(i) Where small portable mixers were used to mix hot patching materials at the site there was an obvious lack of continuous quality control. A similar observation was made on cold mix preparation.

(j) Delays due to start late, excess lunch time, quit early, and personal reasons appeared to be higher for crews patching than for those engaged in most other direct maintenance operations.

7. Seal Bituminous and Concrete Pavements

(a) Production rates for sealing averaged 47 sq yd per hour of labor NAWT with a range of 10 to 86 sq yd per hour.

(b) It was frequently observed on sealing work that there was a lack of balance between labor, number of equipment units, and the type of equipment for the amount of work completed. This resulted in extensive amounts of lost time due to delays. The men spent 13 percent of NAWT waiting on other men to perform work such as hauling materials.

(c) Many crews spent 10 percent of NAWT waiting on heating bituminous materials. Some foremen had one man come to work early and start heating the oil thereby eliminating a delay at the garage and reducing this type of delay to about 5 percent of labor NAWT for the day.

(d) It was a common observation that specified proportions of bitumen and aggregate were not obtained in seal coat work. This is indicated by the range of values shown below:

Bitumen - from 0.15 to 0.50 gal per sq yd
Aggregate - from 18 to 61 lb per sq yd

The quantity of aggregate per 0.10 gal of bitumen varied between 5 and 27 pounds. On only one-third of the operations studied did the rate fall between 8 and 12 pounds of aggregate per 0.10 gal of bitumen.

(e) There was often insufficient rolling on sealed areas: average figures from production studies show that the crews spent 3.66 min per 100 sq yd. The sealed areas were rolled 0 to 5 times depending upon equipment used and job conditions.

(f) Sealing was used in some situations for which it was not suited except as a temporary expedient. Areas with base failures were often sealed repeatedly in hopes of averting breakup of the pavement. Many of these areas broke up eventually.

(g) A one-day sealing job was undertaken to determine if it was possible to increase production by preplanning the work. Production study data were used as a basis for determining labor requirements, equipment requirements, and a work sequence for each man and equipment unit. No changes were made in the method of doing work or the type of equipment used. This job was carried out successfully with the wholehearted cooperation of maintenance personnel in one of the three study counties. The results were:

Total production	12,780 sq yd
Production rate	130 sq yd/man-hour of NAWT
Bitumen application	0.24 gal/sq yd
Aggregate application	26 lb/sq yd

The complete job was judged to be equal to or better than average quality.

(h) It was observed that crews in one county were engaged in so-called emergency sealing operations on a 4.0-mile section of road during 15 days out of a 10-week period. They sealed 13,300 sq yd and expended 538 hours of labor NAWT. This particular road was being used regularly for heavy hauling by a paving contractor engaged in resurfacing another road. The maintenance forces had an overall average production rate for the 15 days of 25 sq yd per man hour. This rate falls within the range cited in item "a" but is substantially less than the 130 sq yd per man-hour for the planned operation reported in item "g".

8. Mudjack Concrete Pavement

(a) Crews mixed and pumped 0.06 cu yd dry materials (soil, lime, cement) per hour of labor NAWT. During the time material was actually being mixed and pumped, the mudjack machine averaged 2.2 cu yd of dry materials per hour.

(b) Mudjacking crews were consistently too large and had too much equipment for the amount of work completed. Most of the crews had 7 men and 6 or 7 units of equipment. Approximately 20 percent of labor NAWT was lost while men were idle or waiting for some other man to perform work. Five men could perform the work at almost the same rate as the 7-man crew. However, additional truck drivers would be required if more than 10 cu yd of soil and lime were used during the day.

(c) Little control of materials was observed in mudjacking work. It was apparent that the crews lacked technical knowledge on this subject.

(d) Studies of mudjacking work encompassed operations directed by a district man, part time by the county foreman, or by an operator. Insufficient data were obtained for an evaluation of the merits of the crew being directed by a district man or by a county foreman.

(e) Delays recorded during studies of this work indicated that most of those performing the job lacked sufficient familiarity with the equipment and the operation to efficiently organize and carry out the assignment.

9. Patch Concrete Pavement with Concrete

(a) As with other types of patching operations, observations of patching concrete pavement with concrete also indicated a lack of balance between labor, number of equipment units and the type of equipment. Only one production study of this work was made because only a small amount of this work was done in District 6. The crew spent 80.9 percent of their time at the worksite. Productive work amounted to 25.2 percent of the NAWT charged to the operation.

10. Blade Gravel Surfaces

(a) Blading of gravel surfaces was principally done by motorgraders. Heavy-duty trucks with underbody blades were rarely used. In the control area the time charged for this operation, before overhead distribution, was:

Motorgraders	888 hours
Heavy-duty trucks with underbody blade ...	37 hours

(b) Rates determined from production studies were as follows:

Motorgraders	30.63 min NAWT/pass mile
	5.34 min NAWT/1000 sq yd covered
Heavy trucks	25.66 min NAWT/pass mile
	4.17 min NAWT/1000 sq yd covered

(c) Production studies of motorgraders and heavy duty trucks with underbody blades used for blading gravel surfaces show blading speeds of 3.7 m.p.h. and 6.8 m.p.h., respectively, on the work performed by these units. Travel speeds of these units between the garage and the worksite averaged 14 m.p.h. and 28 m.p.h., respectively.

(d) Each pass averaged about 10 feet wide and areas were covered an average of 1.2 times.

(e) The operation was generally relatively efficient. The fact that one-man crews were almost always used, kept waits and other delays to a minimum.

11. Patch Shoulders and Approaches with Soil, Aggregate, and Bituminous Cold Mix

(a) Edge-rut patching with bituminous cold mix was frequently done as a small scale operation. The rate of application was about 30 lb per foot of edge.

(b) Most bituminous cold mix used for patching edge ruts was unloaded and spread by hand. The average productive time to shovel one cu yd into place was 27 minutes. It was then normally compacted with truck wheels.

(c) Most of the aggregate used for patching edge ruts was spread by truck spreader beds and then finished by hand. In some cases a drag spreader was used. It was then usually compacted with truck wheels. No rollers were used.

(d) The number of trucks used for soil or aggregate patching on shoulders was seldom in balance with the number of men assigned to the crew.

(e) Motorgraders were little used for shoulder and approach maintenance in the control area. Only 273 hours of time was charged during the one-year period, or about one-half hour NAWT per mile of shoulder maintained.

(f) A survey of 32 miles of road showed that almost all distressed areas, other than edge ruts, were located at mail box turnouts, field entrances, driveways, and intersecting roads.

(g) Shoulder elevations at the outer edge were above the pavement edge in many areas where field studies were made. This reverse slope concentrated water along the edge of the pavement which in turn resulted in eroded shoulders.

(h) The repair and leveling of turnouts, approaches and intersections was usually accomplished by hauling in more aggregate.

(i) Only rarely were edge ruts completely filled by patching. While usually only enough work was done to eliminate the most serious road hazards, this represented a gain and an improvement over the prior condition even though the improvement may not have been a final solution.

(j) There was no uniform policy or regular schedule followed for the maintaining of turnouts and approaches. Work was usually done only after a complaint was received.

(k) Almost all aggregate used for shoulder patching was hauled direct from a quarry, where one was available within reasonable haul range. Soil was obtained from roadside borrow pits.

12. Clean Unpaved Drainage Ditches

(a) A 3/8-cu yd dragline was the principal equipment unit used for ditch cleaning. Practically no hand work was observed. The dragline was actually loading material about 50 percent of its worksite NAWT.

(b) Waits and delays of all types characterized ditch cleaning operations where studies were made. The study data show that waits and delays accounted for 45 percent of the crew's labor NAWT.

(c) Often there was little planning of the operation, particularly with respect to identifying work locations. This lack of planning ultimately resulted in the crew losing from 2 to 5 percent of NAWT while trying to decide on work locations.

(d) The number of trucks used was not always in balance with the capacity of the dragline. Sometimes there were too many, sometimes not enough.

A rule of thumb developed from study data for matching trucks to a 3/8-cu yd dragline follows:

Haul plus return, miles	No. of trucks required
0.1 - 1.2	2
1.2 - 4.0	3
4.0 - 8.0	4
8.0 - 12.0	5

(e) No particular problems were encountered with disposal of material excavated. No case was observed where it had to be hauled more than 1.7 miles (haul plus return was 3.5 miles).

(f) Crews did not make any measurements of gradient to insure that the proper drainage had been obtained. All flow-line grades were established by eye.

(g) Ditches were usually left in a rough condition which might subsequently be difficult to mow.

(h) Some problem areas were observed which have required or will require repeated cleaning over a long period.

13. Clean, Erect, Replace or Repair Signs and Guideposts

(a) Sign and guidepost installations in the three-county control area were inventoried. There was a considerable difference in the number of such installations between rural and urban road sections.

	Average number per mile	
Installation	Rural road sections	Urban road sections
Signs	11	52
Sign posts	9	43
Guidepost	10	2

(b) Sign cleaning was done throughout the entire year. It was apparent that some foremen did not give this operation a high priority. Therefore, it was not always done when needed.

(c) Sign work consistently involved extensive travel time. Crews frequently worked only part of the day before returning to the garage or switching to another operation. Crews averaged 4.1 hours on this operation during each assignment and traveled 33 percent of this time.

(d) There were a limited number of studies during which power augers were used to dig post holes. The power auger decreased the amount of digging time required by one-third. However, in all cases, the crews included extra men to handle the power equipment so that there was a substantial increase in labor NAWT required to install posts with the power auger.

(e) There were rarely less than two or more than three men assigned to crews performing sign work. Practically all of this work could be accomplished by a one-man crew more efficiently due to reduction of time lost in travel and delays. Further, one man could wash 60 percent as many signs per day as a two-man crew and could erect, replace, or repair 70 to 85 percent as many signs and posts per day as a two-man crew.

14. Stockpile Materials

(a) Stockpiling of materials accounted for four percent of labor NAWT in the control area. Salt and abrasives were the two principal items involved.

(b) Salt storage sheds now in use are so designed that commercial hauling units cannot unload directly into stockpiles. The delivery vehicles were usually unloaded by a process involving considerable hand work. Salt required 15 minutes of labor NAWT per ton unloaded.

(c) Unloading and stockpiling of salt in the control area was found to require almost three-fourths as many labor NAWT hours as did the operation of spreading salt on the road. The figures are:

Stockpiling	546 hours
Spreading	764 hours

(d) Cinders were obtained by two garages on the basis of when available. That is, another maintenance organization had first call. Often, State trucks made trips to the source without knowing if they would be able to get a load. This resulted in considerable lost time.

(e) Procurement of some abrasives for snow and ice control with State forces appears to involve more costs for excavation, hauling, and stockpiling, than is economically justifiable. Further, a substantial share was done during the month of October and thus interfered with other important operations.

(f) Bituminous cold mix was stockpiled only in extremely small quantities. Normal practice was to obtain it from a commercial plant or to mix it at the garage just prior to use. Possibly, this practice was due to the "perishable" nature of the mixes used.

(g) The average loading time for bituminous cold mix was 2.62 min per cu yd when loaded by means of a front-end loader.

(h) The average loading time for aggregate was:

State front-end loader at stockpile ...	1.67 min/cu yd
Private front-end loader at quarry	0.46 min/cu yd

Private loaders used at quarries were always larger than State equipment.

(i) Trucks hauling from quarries averaged about four minutes per load waiting for the private loader to arrive at stockpiles, waiting on other trucks loading and waiting to weigh. Waits at State stockpiles averaged about two minutes per load.

(j) Travel to a stockpile or other source to obtain aggregates was frequently a controlling factor in crew productivity.

15. Service and Repair Equipment (Shoptime)

(a) An analysis of labor time expended on service and repair equipment revealed a large variation in total effort between counties in the control area that could not be related to workload. However, the variation in total effort generally paralleled the amount of operator time that the mechanic was permitted to use at his discretion.

(b) An examination of property and equipment cost records on trucks used in the control area revealed that in one year the internal reimbursable labor cost for service and repair performed by the county forces ranged from about one cent per mile to almost three cents. The period covered by the cost records did not match exactly the one-year study period; but the costs cited were in general agreement with the findings noted in item "a" above.

(c) Production studies of the service and repair operation show that county maintenance mechanics accounted for 37 percent of all labor. They accounted for about half of the productive effort expended on repairs and about a sixth of the effort on servicing work.

(d) The average time taken to perform the most common servicing items on trucks was determined from production studies. These times follow:

Service Item	Labor NAWT per Truck (Min)
Lubricate 1/	60
Clean air filter	11
Change oil	19
Change oil filter	20

1/ Includes the cleanup and routine checking

(e) Four to five hours of daily equipment servicing time now done by operators could be accomplished during nonscheduled working hours in those counties having as many as 10 operators.

(f) An examination of selected study data and State's records indicates that service and repair labor time for class B equipment during a one-year period was approximately 70 percent of that used for class A equipment. Further, this time was noted to be highly seasonal and reached a peak during the winter months. During that period it was 120 percent of the labor time used for class A equipment.

(g) Service and repair provided for non-maintenance vehicles by maintenance personnel during the one-year study accounted for an average of 372 hours total labor time per county in the three control counties. Overtime work has been required to handle the volume of repair service requested where district offices were located and in counties where extensive construction activities were underway.

(h) A comprehensive examination of the Property and Equipment central repair shop operation and facilities in Ames was made as an independent study. The report reveals considerable difference in relative efficiency achieved by several sections within the shop. On an overall basis the employees were found to be 65 percent productive. It was concluded from the available data that an aggressive improvement program could raise the employees' performance to 74 percent of the maximum which could be achieved if all effort was totally productive.

16. Crew Size

(a) The studies showed that crew sizes for various operations differed widely from day to day and county to county. Rarely were less than two men assigned to a job. Generally speaking, crews used for simple or small operations were too large and crews used for big or complex operations were too small.

(b) Only rarely, were men from different counties pooled for performing operations that obviously called for larger crews than could be formed within the county where the work was being done.

17. Statewide Expenditure Records

(a) Basic expenditure data presently available are not fully utilized by management in developing facts usable as guides to decisions.

(b) Materials purchased under contract are charged out to road section and type of work upon delivery to counties. This procedure of estimating the distribution of charges, although a practical method, results in an unknown error in cost records.

(c) Most equipment supplies are carried in inventory and charged out when used. Some of these items are minor.

(d) A statistical comparison was made of the values appearing on the Commission's time sheets and those recorded by the study group. The results indicated that a good agreement exists in the total working time reported but that a significant difference exists in the time allocated to specific cost categories.

(e) Maintenance expense records for salaries during the fiscal year 1959-60 show that in 94 counties the expenditure rate was between $400 and $900 per 2-lane mile of road. In one county the rate was less than $400 while in 4 counties the rate exceeded $900. An expenditure rate per 2-lane mile of road was also determined for the remaining maintenance expenses charged to each county but with contract amounts omitted; this is called other expenses. The number of 2-lane miles of road per operator was likewise computed in each county. County average salary expenditures per 2-lane mile were arrayed in ascending order. This array was divided into 20 groups (there were 5 counties in each group except one which had 4 counties) and group averages computed. Using the same 20 groups of counties, averages were likewise computed for other expenses and 2-lane miles of road per operator. The group averages are shown in Figure 4.

Figure 4 shows four important facts (1) staffing is not uniform on the basis of 2-lane miles of road, (2) other expenses, which generally may be described as equipment and materials expense, are reasonably constant at around $550 per 2-lane mile of road but diminish as salaries expense drops below $550, (3) the axiomatic inverse relationship between salaries expense per 2-lane mile of road and the 2-lane miles of road per operator is apparent, and (4) in the first 8 groups of low expense counties, the expenditures for salaries are approximately equal to the expenses for other items. Also, the increasing divergence between the curve for salaries and the curve for other expense as salaries expense increases is significant.

Further search and analysis of selected maintenance expenditure records, which unfortunately were not exactly the same as used for preparing Figure 4, revealed a relationship between maintenance expenditures per 2-lane mile of road for direct charges, which essentially includes all charges except overhead, and the number of operators per foreman. This is shown in Figure 5.

As shown in Figure 5, other expenses per 2-lane mile of road were found to be reasonably constant regardless of the number of men per foreman. Accordingly, the upward trend of direct charges must be accounted for by increased salaries expense. Thus, salaries expense per 2-lane mile of road tends to be proportional to the number of men per foreman.

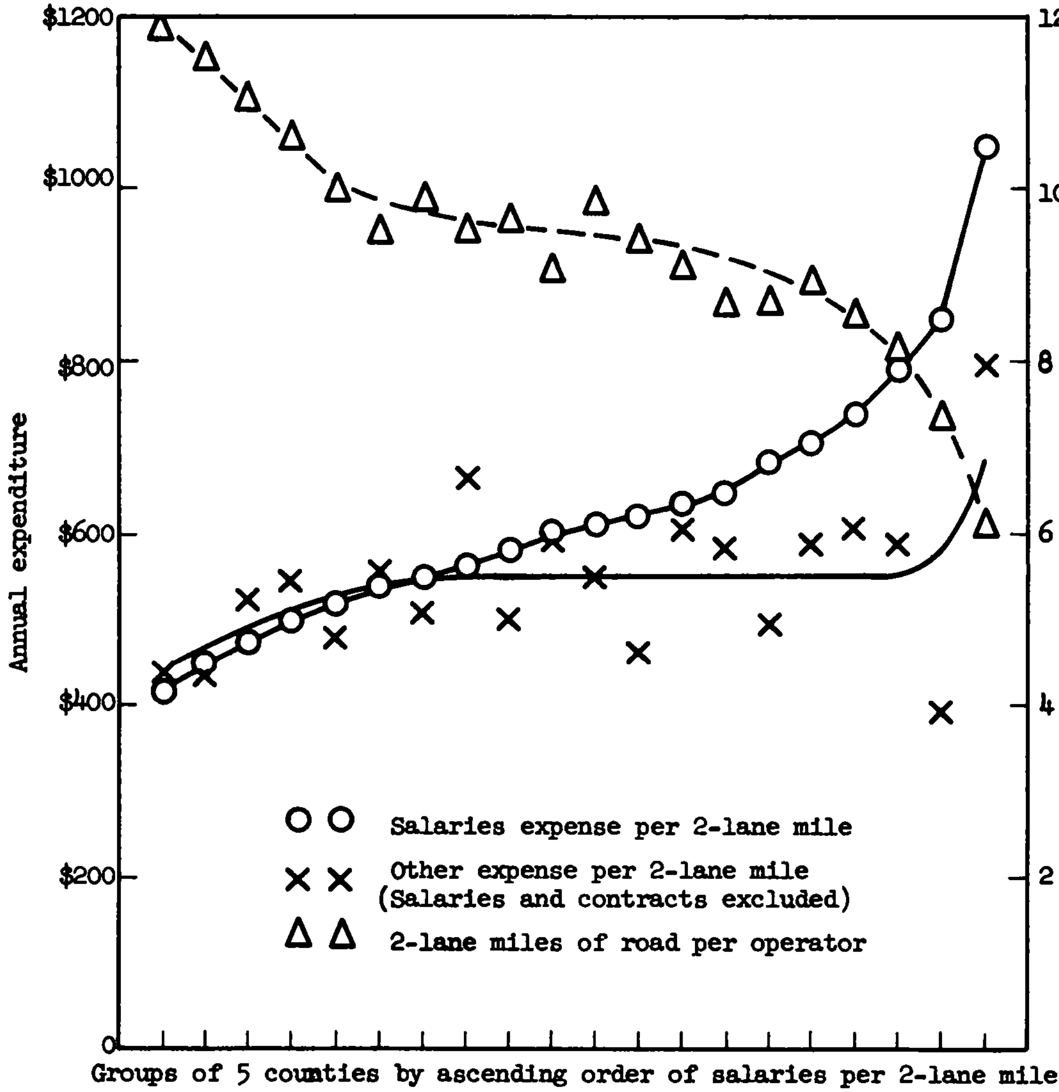


Figure 4. Comparison of selected maintenance expenditures and average miles of road per operator by 5 county groups

Figure 4 implies: (1) if salary expense in a county exceeds other expenses (as previously defined) then too many operators are employed for the quantity of work accomplished, which in turn suggests weak supervision and poor manpower utilization; and (2) less than ten 2-lane miles of road per operator is wasteful of manpower, but again, as suggested elsewhere in the report, this may be a consequence of weak supervision. Figure 5 shows that adding operators to a county crew does not increase the quantity of work accomplished when measured in terms of other expenses which are generally for materials and equipment. This again implies that lack of supervision is a factor.

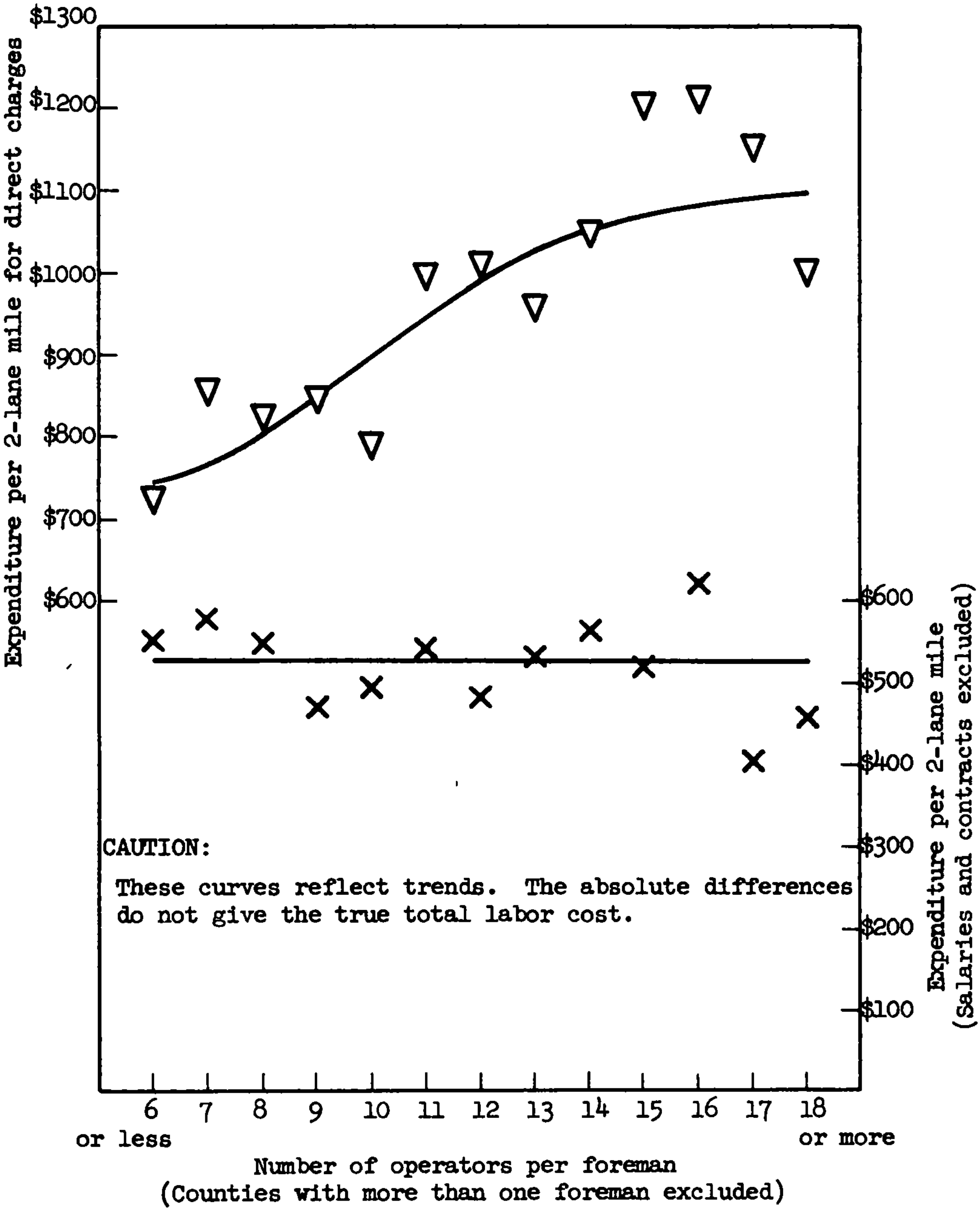


Figure 5. Trend of annual expenditures for various size crews

18. Garage and Yard Facilities

(a) Garages, stockpiles and other facilities are not always located strategically with respect to the area served. Lost time due to additional travel was substantial.

(b) Some of the excessive time required to load materials at garage yards or outlying yards was considered to be partly attributable to insufficient space.

(c) Many garages did not have adequate space for the dead storage of seasonal use equipment and some types of supplies. Often a shed at an outlying yard was used for the overflow.

(d) The lack of loading ramps resulted in lost time.

(e) Almost all materials were stored at ground level. This practice caused increased loading time and effort for those materials loaded or unloaded by hand.

(f) There was a noticeable lack of adequate lighting of garage yards during the nighttime period when snow storm plowing operations were studied.

(g) Heating in a number of garages is inadequate to provide proper cold weather working conditions.

(h) It was observed that water used in maintenance operations was normally obtained at the county garage. High capacity outlets were not available. On the average, over one hour was required per 1,000 gallons loaded into equipment tanks.

(i) Garage and yard maintenance accounted for over three percent of all labor NAWT in the control area. This operation included a wide variety of work such as reshaping a stockpile, repairing garage doors, removing a loading dock, erecting a sign, cutting weeds, washing windows, cleaning walls, sweeping floors and disposal of trash.

(j) Delays due to such items as excess lunch time, quit early, idle or personal reasons were over 16 percent of labor NAWT charged to garage and yard maintenance. This was much higher than recorded for most other operations.

19. Utilization of Supervisory Personnel

(a) Job guides for each type of supervisory position in maintenance, which adequately describe procedure, function, responsibilities, authority, and relationships do not exist.

(b) An accounting of the foremen's time, regardless of the activity or operation being performed, reveals that it was distributed as shown in Table 6.

TABLE 6

DISTRIBUTION OF FOREMAN'S TIME

"A" - By Location

Location	Percent (Rounded)
At county garage	50
In transit	35
At worksites	15
Total	100

"B" - By Operation

Operation	Percent (Rounded)
Supervise maintenance activities 1/	75
Patrol roads	15
Other	10
Total	100

1/ Includes all supervisory functions of the foreman plus related work and delays.

(c) From a review of (1) various field operations supervised by the foreman, (2) public contacts, (3) equipment used, and (4) demands by superiors, it was estimated that an individual foreman has some or all of the responsibility for over 100 kinds of work or services. Even if there were no more than 75 kinds of work performed in a single year it means that the foreman has slightly more than one percent or 20 hours per year of his time, when averaged, to devote to each kind of work.

(d) In the three-county control area the foremen supervised 9, 12, and 13 operators, respectively. Over the entire State the number of operators and laborers per county varied from a low of four men to a high of 43; however, some of the counties had subforemen. Based on the number of operators and laborers per foreman of both grades, the range between counties over the entire State was from a low of four men to a high of 25.

A special study and a report thereon was made by a consultant on the subject of the Foreman's Span of Control. This report finds that a good foreman can effectively supervise up to 12 men, possibly 15, but in some cases the correct number might be as low as eight. The midpoint is 10 men and when a mechanic is subtracted from the total the remainder is nine which would be the operators.

State records show that 48 counties have 10 to 25 operators per foreman and another eight counties have nine operators.

(e) Some foremen lack proper training to do their jobs effectively.

(f) District traveling mechanics have such extensive duties and responsibilities that they cannot effectively carry them out in a reasonable workweek.

(g) There is an extra workload for some resident maintenance engineers solely because their offices are located in the same city as district offices. They are often responsible for administrative work generated by district crews, district equipment, and construction department equipment.

(h) The following distribution of time is based on a sample of all 24 resident maintenance engineers. The sample taken was one week of each month during a six-month period.

1. Not considering vacation, holiday or sick leave, the average work-week for resident maintenance engineers is more than 45 hours.

2. Resident maintenance engineers in highly populated urban divisions spend more time in the office than the Statewide average.

3. The time spent in the office varies from one-fourth to more than two-thirds of the total working time. The average is one-half.

4. Paperwork accounts for 30 to 63 percent of the time. The average resident maintenance engineer spends about 45 percent of his time on paper-work.

5. Although, on the average, access control duties consume eight percent of his time, or slightly less than four hours per week, several engineers spend double this amount and occasionally spend as much as 16 hours per week.

6. During any given week, four or five resident maintenance engineers over the entire State have not been in contact with any foreman other than by telephone or mail.

(i) Resident maintenance engineers serving large urban areas have more problems, more responsibilities, and a larger total workload than those serving rural areas.

(j) The Maintenance Department Central office staff is too small to effectively provide (1) adequate functional guidance for field offices, (2) adequate control to insure that desired policies and procedures are followed by field personnel, and (3) personal contact in the field.

(k) Maintenance residency office stenographers are overloaded with work even though they are provided with part-time help. There is need for full-time assistance in some residencies.

20. Operating Procedures

(a) Maintenance operations inherit many problems from design and construction. Some problems are unwittingly perpetrated. Others are known before the completion of projects but deliberately turned over to maintenance for solution. The principal areas in which these problems occur are: Low type bituminous surfaces; shoulders and approaches; drainage structures; erosion control; and pavement settlement at fills and bridge approaches, and traffic safety features.

(b) Once project plans are approved, potential maintenance problems which come to the attention of construction personnel are not always eliminated. There is some reluctance on the part of the field construction engineers to request changes under present procedures.

(c) Maintenance has been given considerable responsibility in connection with construction projects. Principally, this responsibility involves taking care of major detours for the State primary system which are not located on the system. However, maintenance also installs project signs, keeps projects open for local resident travel during the winter, corrects deficiencies or completes some work needed to pass Federal-aid inspections, and provides services for construction field personnel. Reimbursement for this work does not cover the full cost. Thus, maintenance forces expend a considerable sum each year for work which furthers construction activities.

(d) There is no generally accepted procedure for coordinating construction and maintenance activities at the field level. Construction Department personnel are not kept adequately informed of maintenance problems. No uniform practice exists for maintenance representation during plan-in-hand construction project inspections.

(e) Maintenance personnel at various levels are not familiar enough with each others problems.

(f) Requests of and orders to resident maintenance engineers, other than of a routine nature, often come directly from the Central Office. This practice creates a situation whereby the resident maintenance engineers are responsible to more than one person.

21. Management Control

(a) Currently available manuals do not provide up-to-date and adequate instructions regarding policies and procedures for foremen and resident maintenance engineers. Recently appointed foremen and resident maintenance engineers are particularly handicapped.

(b) There is a lack of uniformity in the way maintenance is conducted from county to county and from residency to residency, and perhaps from district to district.

(c) Many supervisory personnel do not have a clear concept of their job, its functions, its responsibilities, and its relationships; conceptual skill is lacking.

(d) The Central Office is not always adequately informed of field problems.

(e) Functional guidance (technical, policy, and procedural) from the Central Office to field offices is inadequate.

(f) The Central Office staff does not spend enough time on field inspections nor do they visit the resident maintenance engineers as frequently as the resident maintenance engineers think is desirable.

(g) Maintenance residency and district offices have no responsibilities for preparing the maintenance budget.

(h) Weather and other factors which bring about unforeseeable change in maintenance expenditures do not ordinarily affect the entire State simultaneously, and thus will not materially unbalance a realistic Statewide budget, except for major disasters brought about by floods, excessive snowfall, or prolonged severe cold.

(i) District-wide meetings of field supervisors and mechanics were usually held twice each year for critique and instruction. Central Office personnel prepared the agenda and largely conducted the meetings. The time allowed for discussion of common problems by field personnel was not always sufficient to overcome the reluctance by field supervisors to speak out.

(j) Maintenance residency office stenographers met occasionally in conjunction with the district supervisors meeting. Central Office personnel conducted sessions which largely consisted of instructions regarding paperwork. The time allowed for other subjects or the discussion of common problems by the stenographers was not always sufficient.

(k) Meetings of foremen at the maintenance residency level were held infrequently and thus did not afford an adequate opportunity for the discussion of supervisory and other timely problems.

(l) The volume of paperwork in most maintenance residency offices is very heavy. There are over 300 forms in use. Equipment accounting, for example, is time-consuming.

22. Planning and Programs

(a) Overall, it is apparent that the amount of advance planning for maintenance operations, on a long and short term basis, is inadequate for the value of the capital investment in place and the expenditures made for services provided.

(b) There is little uniformity at the present time in the manner in which many operations are conducted. In fact, in some areas no one can determine what the policy is because so many orders and instructions have been given; some as part of old policy manuals, some verbally, and others simply as memoranda without any attempt to cross-reference policy manuals.

23. Personnel

(a) Many maintenance personnel feel that they are "second class citizens" within the Highway Commission. At one time, prestige was apparently higher.

(b) Interviews indicate resident maintenance engineers feel that promotional opportunities are inadequate. They believe that maintenance engineers are rarely promoted to jobs in other departments, but that engineers from other departments are promoted to higher level maintenance jobs.

(c) Well-qualified employees are seldom hired at more than the minimum rate in each grade.

(d) Employees classified as stenographers in maintenance residency offices need a new title to reflect more accurately the duties and responsibilities of their job.

(e) Foremen, as a group, do not have an adequate technical background, nor do they receive adequate technical guidance from resident maintenance engineers.

(f) Resident maintenance engineers have an adequate engineering background but lack sufficient training in the technical aspects of maintenance

(g) Job guides containing adequate descriptions of procedures, functions, responsibilities, authority, and relationships for each type of supervisory position in maintenance do not exist.

24. Procurement - Equipment, Materials, and Supplies

(a) There was a widespread use of field purchase orders to obtain materials for immediate routine use.

(b) County crews spent a significant amount of time transporting supplies from the Central Office to local garages.

(c) Some units of equipment were idle relatively long periods of time waiting for delivery of parts, batteries, and tires purchased through the Central Office.

(d) The extent of emergency purchasing of equipment parts varies widely from area to area. In many cases, spare units were cannibalized as a temporary expedient in lieu of making emergency purchases.

(e) Interviews with supervisory personnel show that they believe some equipment units have not been replaced soon enough in recent years. An investigation of equipment rosters shows that some major units are 10 or more years old while many minor units are 20 years or more old.

(f) There is an ineffective channel of communications whereby field supervisors and operating personnel can make recommendations regarding the type, size, and performance characteristics of equipment they need.

(g) Specifications used for the purchase of roadway equipment are seldom based on operating requirements or the conditions which will be encountered in use.

(h) The Central Office does not make factual studies on performance of equipment.

(i) Substantial quantities of materials which are purchased locally by field purchase orders are not regularly tested for compliance with specifications. Materials processed by county crews are seldom tested.

25. Office Facilities

(a) Some foremen do not have real office space; others have limited space.

(b) Space in many maintenance residency offices is insufficient for files, papers, and efficient operation.

(c) Many maintenance residency offices do not provide an atmosphere which is conducive to efficient work or the conduct of business.

(d) It was apparent that lack of air conditioning in some resident maintenance engineers' offices decreased efficiency in handling paper work.

26. Access Control

(a) Of 437 access permits granted by the State during 1960, resident maintenance engineers averaged processing 18 each. The range was from 5 to 47 per maintenance residency. By district the range was from 23 to 127. Approximately 150 applications were rejected.

(b) The volume of access permits granted, increased by more than five percent from 1959 to 1960 (415 to 437).

(c) District and residency offices have little authority or responsibility for access control permits. With authority extended to them, many obvious cases could be turned down without sending the access permit to the Access Control Committee at the Central Office.

(d) Resident maintenance engineers estimate that more than half the time spent with the public on access control never results in formal application for a permit. The number of applications submitted is not a true measure of the workload.

(e) Studies show that some resident maintenance engineers average more than eight hours per week on access control the year round. On the average, all engineers are spending four hours per week.

(f) Two experienced engineers in the Central Office work full time on access control. They are unable to carry the entire workload.

(g) Rules and regulations for access control are being changed. These changes are expected to reduce the amount of work involved.

27. Future Replacements for Personnel (Supervisory)

(a) As of February 1, 1960, 32 foremen were 60 years of age or over. Another 29 were 55 to 60 years of age. Thus, over half the foremen must be replaced in the next 10 years. As of May 1, 1961, the situation had changed somewhat. This is indicated by the following listing:

Age	Number of Foremen
60 and over	19
55 to 60	31
50 to 55	34
45 to 50	10
40 to 45	8
Under 40	6
Total	108

(b) Of the 24 resident maintenance engineers, five are 55 or more years of age.

(c) All six district maintenance engineers are over 50 years of age. Four are over 60 years of age.

(d) Nine maintenance residency office stenographers are over 55 years of age.

(e) The State Maintenance Engineer is nearing retirement age.

28. Safety

(a) Safety practices of crews in the control area were inspected and evaluated by the Bureau of Public Roads Safety Officer. His report is reproduced in Supplement II.

(b) The flagging of traffic was done irregularly. Usually, the larger the crew, the greater the amount of time spent flagging. Some small (two-man) crews did practically none, regardless of the traffic volume.

(c) Goggles were not always worn when a bench grinder was used even though a pair hung nearby and workmen were given orders to use them.

(d) Portable electric hand tools were not generally grounded when being used.

Section F

DISCUSSIONS AND CONCLUSIONS

Highway maintenance operations performed throughout many States have been studied from time to time as part of a much smaller scale research program. The facts developed by these earlier studies indicate broadly that many of the findings and observations made during the Iowa study are applicable throughout the country even though the numerical values and relative importance of each may vary. The conclusions, likewise, are not unique to Iowa, but the Iowa Highway Commission is unique insofar as it has brought these findings and conclusions into focus so that they can be studied for ways to make improvements.

Part of an important message has been disclosed by each of the findings and observations reported. Some of the findings do not indicate either weakness or strength in the maintenance organization or its operations. The others fail to tell the complete story, but their combined weight produces significant conclusions.

The collective pattern of the findings in Section E unmistakably shows a need for improving the degree and quality of supervision and management practiced in maintaining primary and interstate highways in Iowa. How this situation developed has not been a germane issue to the study. Rather, and as pointed out earlier, the primary concern has been to determine where maintenance operations could be upgraded in terms of lower unit cost, increased quantity, or higher quality.

While most findings are symptoms of varying degrees of weakness in supervision and management, they also reveal other problems, some of which are more basic than supervision. These problems are like colors in a visible spectrum: they blend together and the overlapping of causes becomes inevitable. But regardless of this overlapping, categorization has been used to simplify the following discussion and the subsequent recommendations.

1. Production rates, time utilization, and total accomplishment attained by the same crew on succeeding days and by different crews on the same day show marked variation. The findings are prima facie evidence

that an improvement in production rates, time utilization and total accomplishment can be achieved. Improved supervision with all of its ramifications will help on many operations. Different equipment may be required on certain types of work. Standards for work accomplishment would tend to encourage economical use of time.

2. Work methods employed are frequently characterized by lack of planning, conceptual ability and control. This lack, in part, can be traced to poor communications; ineffectual lines of authority; lack of standards; insufficiently trained resident maintenance engineers, foremen, and operators; improper or insufficient equipment; and the large volume of "so-called" emergency work. A small section of specialists devoted exclusively and constantly to the study of organizational structure and work methods would yield substantial benefits to the maintenance program.

3. Foremen have unequal workloads. Seven foremen, for example, have over 150 miles of road while five have less than 60. Their varying capabilities, no doubt, account for part of this inequality. A foreman or subforeman may have as many as 25 operators and laborers reporting to him while his contemporary in another part of the State may have only five or six. Certainly 25 operators are far too many for one man to supervise. Such a spread in responsibility indicates, among other things, a pressing need for additional foremen. The existing standard for staffing county garages to account for differences in workload is understandable but inadequate. It overlooks supervisory requirements. Before a better standard can be adopted, the physical volume of work as well as supervisory capabilities will have to be measured.

4. Arbitrary designation of the county as a unit for supervisory control by the foreman tends to perpetrate an unrealistic situation with respect to workloads. The elimination of county boundaries does not appear to present any major problems from an accounting or administrative standpoint and it could lead to greater uniformity in the supervisory workload at the foremen's level. Staffing to equalize the workload in the various counties rests on more than simply increasing the size of a county crew.

The idea of tailoring a geographical area and its roads to fit the capabilities of an optimum size crew has considerable merit. While admittedly it is a conjecturable approach, the problems involved in trying out the idea in 8 or 10 counties are not exceptionally difficult.

5. Deficiencies which occur in those foremen who lack technical knowledge about problems they are expected to control can be overcome by training and by use of maintenance residency crews. There is strong indication that for major maintenance operations, crews operating under the direction of a maintenance residency or senior foreman would be able to do a more efficient and more economical job than the existing county crews.

6. Foremen are not fully qualified in several counties because of inadequate training in basic and modern techniques, increased responsibilities, and an inability of the resident maintenance engineer to devote adequate time to providing the necessary leadership. The fact that foremen are often unwilling or have insufficient time for discussion of common problems at district maintenance meetings is a contributory factor.

7. Formal leadership below the foremen level should exist in every county, even if it is only parttime. Most foremen need subforemen and/or lead operators to effectively supervise their men. Since, on an overall basis, the total number of maintenance personnel about matches the total requirement, the additional foremen and subforemen may be available within the organization.

8. There is little evidence of the kind of planning that involves visualization of future needs and the development of an orderly scheme of action. Good planning for maintenance takes into consideration any trouble spots that are likely to develop whether they concern money, men, materials, equipment, or road surfaces. More attention to advance planning by all levels will produce measurable benefits in terms of improved manpower and equipment resources utilization, and consequently, lower costs. Adequate and current manuals of instructions and policies for foremen and resident maintenance engineers are necessary planning tools. Men recently appointed to these positions do not have enough guidelines under which to operate. This lack of guidelines imposes a hardship.

9. Advance planning for most major maintenance operations performed between March 15 and November 15 is feasible. Many of these operations recur month after month or year after year. Others occur at irregular intervals but can be predicted in advance. Centerline painting is a good example of a well-planned operation at the present time.

10. Daily work planning is also important. There is an apparent lack of understanding by the foremen and other supervisors of the costs generated and production losses per man incurred by the addition of extra men to a work crew and through failure to have a work plan. Excess manpower is particularly critical when the type of work calls for extensive travel or the physical requirements of the work are not evaluated realistically. Substantial savings can be realized here without sacrificing quality. Assignments of less than a full day's work for the crew are often made. Adverse weather conditions sometimes make this practice necessary but not to the extent revealed by the studies.

11. The following maxims are applicable to a decision regarding the number of men, in excess of one, who are sent to perform any operation:

(a) Add another man only when the physical requirements of a step or a task in the operation cannot be handled in any other way.

(b) Add another man if he can produce at an equal rate and he does not cause a reduction in the proportionate amount of time during the day that the crew spends on productive tasks.

(c) If the additional man causes a reduction in the amount of time that the enlarged crew spends on productive tasks, he must increase the overall rate of production enough to compensate for this loss.

(d) Add another man if the operation must be completed within the shortest possible time and insufficient equipment is available to permit the use of another small crew.

12. Failure to achieve favorable balance between labor and equipment occurs most frequently with those operations where hauling to the worksite is involved or where several different steps or tasks are followed in order to complete the job. In general terms, the problem of crew size and, to a lesser degree, the balance between labor and equipment, can be described as too many for small jobs and not enough for big jobs. Increases in the time crews spend at worksites, decreases in the amount of time used for travel and preparatory work, increases in the amount of worksite time used for actual productive work, and better balance between labor and equipment can be achieved by improved planning, supervision, and leadership. Significant gains can be achieved in each of the aforementioned items.

13. Daily and longer term work planning will not always be an easy task. Consideration needs to be given to many factors. Those persons

concerned need a good background knowledge of work planning, work methods, and workloads in order to do an effective job. There is no real substitute for formal training and experience when dealing with this subject. Work planning calls for:

(a) Determining the workload (total amount of work to be done).
(b) Selecting an efficient method for performing the operation.
(c) Determining the requirements for men, equipment, and materials.
(d) Realistically determining the time required to do the work using the selected method, crew size and equipment.
(e) Evaluating probable weather conditions and their effect on the operation.
(f) Scheduling the operation so it will not conflict with other important work.
(g) Making arrangements for special equipment, help from other crews, and necessary materials.

Workload is defined as the amount of work to be accomplished in carrying out maintenance operations on any given number of road sections during any period of time. There is a real need for the development of simple and reasonably accurate means for measuring the workload of specific operations and total workloads, and to express them in easy-to-use units, such as specific quantities for ultimate conversion to man-hours. This study has made advancement toward this goal.

14. Workloads which are wholly or partially dictated by policy, or local practices may call for an expenditure of manpower from which commensurate benefits are not obtained. For example, there is a great difference in cost between adequately mowing the right-of-way and in "manicuring" the right-of-way. A reappraisal of policy in several areas plus the delegation of some authority will relieve the exigency of some operations. There is need, for example, of a clearly defined policy on snow and ice control. One basis for establishing a policy would be setting an objective depth for the maximum allowable accumulation of new-fallen snow on the road. This depth would form a basis in turn for more realistic and uniform staffing of field garages. It would aid, also, in determining the proper number of plowing units. The following discussion relates to problems involved in establishing a snow removal policy:

(a) A county force should be adequate in number and properly equipped to cope with most but not all snowstorms. Perhaps this might be for all storms except those which occur at an average of 10-year intervals. On whatever basis selected, the men will probably encounter a maximum rate of snowfall of about 1 inch per hour over a relatively short span of time. The remaining time during storm conditions will most likely produce lower rates of snowfall, which are generally about one-half inch per hour as indicated by the study measurements. Wind-driven snow, of course, can accumulate at almost any rate and is an unsatisfactory basis on which to staff for snow removal work although an allowance could be made for this purpose.
(b) Since a process has not yet been devised whereby instantaneous removal of snow can be accomplished, the consequence is an inevitable accumulation of some snow on the pavement in addition to wind-driven snow at some places. The key problem in staffing for snow removal,

therefore, resolves itself to a decision of how much of this inevitable accumulation will be permitted at any given time or place. Uniform staffing is dependent on the number of trips per day and hence on the allowable depth of this accumulation. A maximum allowable accumulation of 2 to $2\frac{1}{2}$ inches of new snow is a practical depth which will not seriously interfere with the movement of traffic and would ensure a reasonable amount of manpower for year-round operations. On this basis, a total of seven trips or coverages over every lane-mile of road in 24 hours will handle all but the most severe storm conditions. Here, proper spacing of trips is essential in order to render the desired level of service. Many light storms would require less than seven trips per day. It should be noted, however, that a plan which provides for eight trips average per day generally means adding an average of one more operator in each county. Table 5 on page 23 in the section on Findings provides some basic information on this matter. Other data regarding mileages and personnel are available from published reports of the Iowa Highway Commission. By using an average of seven trips per day and allowing for one operator on the vehicle as a basis for staffing, 153 operators in excess of these computed needs are now employed by the Commission. This overage is reduced to 64 if staffing is based on eight trips per day. However, if provision is made for two operators riding together then approximately 500 additional operators are needed for seven trip coverage. These computed needs do not include an allowance for illness or other leave.

(c) Economical and continuous snow removal, whether 6 or 16 trips per day, requires day and night operation, preferably by separate crews. Some foremen split their crews after a storm has been underway for several hours, but others continue to work a full crew for extended periods of time and then stop work altogether. The greatest utilization of equipment, and hence the greatest efficiency in snow removal work, can be obtained by splitting the crews early. This is readily accomplished by sending home one-third to one-half of the crew when snow starts to fall or there are good prospects that it will start in the immediate future. In other words, by keeping only two-thirds, or less, of the crew on duty during the regular shift under such snow conditions, it is possible to provide for continuous operations without excessive hours of continuous duty. The often-used concept of keeping the entire crew out on the roads even when the rate of snowfall is insignificant (considered to be less than 1/4-inch per hour) or the total accumulation is small can rarely be justified on the basis of service rendered.

(d) With a procedure whereby crews are divided early, there will always be the possibility that an employee sent home for rest during regular working hours with the expectation of returning to duty at a later hour could be deprived of an opportunity to earn certain pay due to sudden ceasing of storm conditions. Should this occur, the employee so concerned should not be penalized because of this error in judgment on the part of the foreman, and he should be put to work for the proper number of hours performing duties which need to be done in the shop after a storm and paid accordingly. Such a guarantee would not cost any more than keeping the employee on duty during regular hours.

(e) Limiting the hours of continuous duty to 13 will assure that each individual does not reach a state of fatigue which endangers not only himself but also his co-workers and the traveling public. This limitation does not call for more men; rather it will require more thought to be given to the availability and assignment of personnel. Allowing up to 16 hours of continuous duty under extenuating circumstances might be desirable if approved by the resident maintenance engineer.

(f) Since no tangible economic benefit could be observed from the practice of having more than one operator in a plowing vehicle on most occasions, it follows that the practice of using two operators reflects concern about safety or of there being too many operators on duty for necessary operations (winging shoulders with a heavy duty truck normally requires two operators). Where coverages are made at night and only one vehicle is involved throughout the county, the benefits from two men in a truck are somewhat more obvious. Here the use of radio communications may eliminate altogether the desirability of using an extra operator in the truck. Rightfully, however, the policy governing the number of men on snow removal equipment, must give proper consideration to the safety of the public and to the maintenance employees.

(g) Plowing operations observed to be in progress when visibility was less than 50 feet appear to involve hazards which are incompatible with possible benefits. The willingness of operators to continue working under such restrictions is commendable but warrants careful consideration from a safety standpoint. Even 100-foot visibility may be too dangerous for safe operations.

(h) Findings show that trips are made to the garage every $2\frac{1}{2}$ hours on the average during snow plowing operations. More often than not, the trucks needed fuel. Additionally, an opportunity was then available for direct communications between the operators and the foreman or mechanic; however worthwhile, this practice tended to promote lengthy rest periods which were not always timely. This takes valuable time especially during the several critical hours of a storm when snow is falling at the peak rate of one inch per hour. The effect of these frequent trips to the garage is to increase the requirement for operators and trucks to keep any desired level of coverage. Some or complete relief from this situation could be obtained by installing larger fuel tanks and by specifying larger tanks in future purchases. On-the-road rest periods would also be helpful in some instances.

15. Policy regarding shift hours should be flexible. Irregular shift hours for several operations other than snow removal offer possible advantages for achieving greater crew productivity. Two such operations are routine servicing of equipment and advance preparations for a day's work.

16. The resident maintenance engineer is a key man in maintenance operations. His responsibility is to ensure that: maintenance operations are conducted in accordance with policy, operations are being conducted economically, the level of maintenance meets standards as set by the Commission, and equipment and personnel are being used efficiently. In addition, he is responsible for public relations in the field, access permit applications, utility and overweight and oversize permits, and a wide variety of equipment and personnel reports. Some of these activities are only indirectly related to maintenance and often consume valuable time. Nevertheless, it would seem that the resident maintenance engineer is the logical person to handle the responsibility.

17. The study data show that the average resident maintenance engineer consistently works well over 40 hours per week in an effort to take care of his many responsibilities. Too much of his time is spent worrying about daily accountability for supplies, equipment, and payroll which are not engineering problems. In effect, he is not the key man in maintenance operations that he could be. It can be concluded that he has insufficient time to do a fully adequate job. For one thing, he doesn't get out into the counties often enough. Thus, he tends to lose contact

with his foremen, and their work suffers for lack of leadership. Relief from this situation of being overworked could be obtained from several sources; namely, providing additional assistance, reducing the size of residencies, providing formal training in work planning and work methods, and providing foremen who have greater skills in work management. Possibly a paper work control manual could be developed, apart from the policy manual, to assist residency offices.

18. Some design and construction practices and policies have created serious problems for the maintenance forces. Such items as post-construction erosion control, seeding backfilling of washes, and the like interpose situations which maintenance forces are not properly equipped or trained to handle economically.

19. A continuing and formal policy is needed whereby deficient design or construction provisions adversely affecting maintenance are reported to the Central Office. In this way it should be possible to make proper corrections on newly planned work. There is wanting coordination between construction and maintenance in field operations. This is now a responsibility of the district. Part of the need to achieve better coordination is due to a lack of understanding and appreciation of maintenance problems by construction personnel. Lack of communications also is a factor. More frequent interchange of construction and maintenance people could alleviate the situation. In this connection, it would be helpful if each man appointed to a resident construction engineer's position had at least a year of maintenance experience.

20. Effective coordination at all levels is virtually impossible without adequate planning, policy and some standardization.

21. Field garages, at times, do have excess capacity for equipment service and repair but they are usually overloaded. Mechanics, too, are usually overloaded. Requests for service and repair of non-maintenance motor vehicles often exceed the spare capacity and aggravate the overload situation, especially with respect to the mechanic. Timing is a part of the problem and requests are not coordinated with the available capacity. The result is that operators are then used to assist the mechanic in the service and repair work on non-maintenance vehicles. Even where garage capacity is not overloaded, operators are often used for service and repair work on both maintenance and non-maintenance equipment. This practice results in postponing or disrupting regular maintenance work. Continuation of the practice raises a question regarding the economy and philosophy involved - does this work on non-maintenance equipment justify the retention or addition of more operators than can be used advantageously on maintenance work? The real need is for enough mechanics so that operators do only routine servicing or emergency work.

22. Certain materials and supplies procurement practices followed by the Iowa State Highway Commission are questioned as to their real economy. It appears that substantial indirect labor and equipment charges are overlooked in determining the best method of procurement. Long delays and tieup of a major piece of equipment while waiting for parts are not uncommon. In many cases, replacement items can be purchased as cheaply by field personnel as by the Central Office. Trucks continually going back and forth to the Central Office at Ames to pick up small items are wasteful of manpower and equipment.

23. Capital outlay for the purpose of improving facilities at county garages and at resident maintenance engineer offices would increase loyalty and the esprit de corps as well as promote greater efficiency. There is need, however, for research along economic lines to determine the

amount of capital investment that can be made for each hour of labor time saved. It is probably safe to say that an expenditure of $20, and possibly as much as $40, for any investment item can be justified for each hour of labor time saved per year. The opportunities are numerous. Data presented in this report or otherwise available to the State provide a source of information which can be used in supporting or rejecting selected capital expenditures in plant and garage equipment.

24. Salt storage facilities, for example, should be located, designed, and built on the basis of an economic evaluation rather than first cost. In this connection, there is probable justification for providing some overhead storage and the installation of mechanical elevators, particularly in heavily populated areas where timing becomes extremely significant.

25. Certain equipment procured for maintenance is sometimes inefficient for the work it must do. In some instances, such as mowing, the number of units obtained does not match the workload. Many maintenance operations would be more efficient if crews had the proper equipment in adequate numbers, such as larger distributors or more small units. A program of equipment research and development would provide answers to many problems.

26. At the present time, there are many different makes and models of the same purpose equipment assigned to each county. There would be definite advantages if each type of equipment at a given garage were limited to one make and, possibly, one model. For example, all of the light duty trucks in one county might be 1959 Fords while those in an adjoining county were all 1960 Chevrolets. This would enable mechanics to do service and repair work in a much more efficient manner and would greatly simplify spare parts stocking. It is recognized that complete uniformity is not practicable. However, it is feasible to attain more uniformity than now exists.

27. It was observed that dump trucks were used extensively for transporting men and minor amounts of materials to worksites. These units were driven at relatively slow speeds (average about 33 m.p.h.). Since travel time is an important factor in labor productivity, it would be desirable to increase average travel speeds. Pickup trucks would provide lower cost transportation and more versatility for some of the operations where dump trucks are now used.

28. Many units of self-propelled equipment lose a considerable amount of time while traveling to worksites or between worksites. An investigation disclosed, that, except for trucks, they were not equipped with special high speed travel gears. An investment of up to several hundred dollars for this feature can often be justified, particularly for units such as motorgraders.

29. Sickle bar mowers of 5- and 6-foot lengths have long been standard equipment for mowing. On many right-of-way areas they wastefully extend mowing time and thus increase mowing costs. Daily production in these areas could be increased 200 to 600 percent by using larger mowers.

30. Operator comfort, fatigue, and safety are important factors in the procurement of all equipment. Operators will produce at a significantly higher rate when they are working under favorable conditions. Mowing tractors, for example, would be much easier to operate if they had better stability, easier steering and a shock-absorbing seat.

31. Day-to-day communications at the county level are a problem. Crews must locate a telephone or travel to the garage when they need help or instructions. Even then, they are not always able to contact the

foreman since he must spend part of his time away from the garage. The foreman also encounters difficulties in contacting his crews to check on their work or change assignments. A considerable amount of time is lost in delays or extra travel. The use of two-way radio could largely solve this problem. It would mean that the foreman and his men could contact each other at almost any time or place. Resident maintenance engineers also would be able to communicate easily with the foreman. Even if they were not equipped with radios, they could call the county garage and have a message relayed. There is little doubt that many emergencies could be reduced to routine situations by the use of two-way radio. Accidents involving maintenance personnel or the traveling public could be reported promptly and assistance obtained.

32. Great effort is being made to improve the quality of reports, simplify them and cut down on their volume; however, further effort is needed in this direction. The volume of paperwork in some offices is nearly overwhelming. Equipment accounting, for example, is very time consuming, but an essential activity.

33. According to the organization chart, the Iowa State Highway Commission has decentralized much authority and responsibility to field offices. Under this concept, the various departments in the Central Office provide functional guidance (with some Central Office controls) to their counterparts in the districts, rather than direct supervision. However, this practice is not always followed. In many cases, the district engineer and the district maintenance engineer are bypassed and instructions to resident maintenance engineers come directly from the Central Office. At times, instructions or requests to resident maintenance engineers come from a department other than maintenance without even informing the State maintenance engineer. In such a situation a field employee does not know what his authority and responsibility are and to whom he is accountable. In effect, the resident maintenance engineer has a number of bosses.

34. District offices should supervise the residencies. This is part of the chain of command. Resident maintenance engineers receive orders and non-routine requests entirely too often from the Central Office. This form of circumvention is an outgrowth of (a) failure to insist that lines of authority and responsibility be followed, (b) faulty communication practices, (c) inadequate supervision and control, and (d) insufficient supervisory and management personnel. A similar situation exists in connection with letters from field offices to the Central Office.

In an emergency it should be possible to break the chain of command, but there is no valid excuse for breaking the chain as a matter of routine. Delay caused by going through channels is a problem of faulty communication practices, workload, and inadequate supervision and control. Unless authority to act is delegated to the lowest level possible, decentralization has not been effected. Field offices need the power of decision.

Section G

RECOMMENDATIONS

Observations made during the course of the study and analysis of the data collected indicate that when the following 19 recommendations are put into practice there will be material improvement in maintenance operations. Some of these recommendations can be put into effect immediately, others will take longer because of their interdependency or the necessity to develop long range plans.

1. Provide Training for Foremen

Foremen should be helped immediately by providing to them active counsel and guidance in the art and science of work methods and work planning. This training should include, among many other subjects, such topics as (a) selecting the proper size crew needed to perform daily operations; (b) assigning the proper number of equipment units to each crew; (c) organizing the work in such a way that crews are given a full day's work; (d) technical items; and (e) supervision. The findings presented in this report, plus other data which are available, provide the necessary reference materials for this program. Outside assistance is desirable.

A formal plan of training needs to be started which will produce 75 new and thoroughly trained foremen within a five-year period. This plan will provide 25 competent replacements for those foremen soon to retire, an undetermined number for interstate work, and between 30 and 45 critically needed men to assume subforemen responsibilities. Some of the 30 to 45 subforemen could provide the supervision needed for major maintenance operations performed on a residency basis. By continuing a formal training plan, future requirements for replacement foremen and periodic refresher courses in supervisory techniques could be provided.

2. Provide Training for Resident Maintenance Engineers

Each resident maintenance engineer should be provided formal training in planning and work methods. He is the engineering representative of maintenance in the field and should be in a position, both by training and experience, to provide leadership, assistance, and technical guidance to his foremen. In most cases, except as a result of many years' experience he is not prepared to do this. Replacement and new assistant residence maintenance engineers should undergo extensive field training in actual maintenance operations from the ground up, observing crews, their work methods and equipment. In addition, they should receive construction experience and spend time in the Central Office. The problem could be approached on the basis of rotational assignments, and the use of assistant resident maintenance engineers where needed. Regardless of the method to be used, resident maintenance engineers need more basic training in maintenance methods and formal training in planning, work methods, and in supervision.

3. Training Should Be the Full-Time Responsibility of a Staff Officer

Training along formal lines recommended in items 1 and 2 is a major responsibility that calls for high caliber direction. To this end, training should be directed by a qualified individual who devotes his entire time to this activity.

4. Realistic Staffing Needed at the County Level

As rapidly as foremen can be trained and assigned, every effort should be made to reduce to 10 the number of operators, laborers, and mechanics reporting to one foreman or subforemen, and to reduce the number of operators and laborers in a county to not more than one operator for each 22 lane-miles of road. The attainment at some future date of a ratio of one operator for each 26 lane-miles of road does not appear to be unrealistic. In Polk County and in other heavily populated urban areas there may be a need for further research to establish satisfactory ratios.

Should the idea of fitting a workload to an optimum size operating unit be given further consideration, it is recommended (a) the unit consist of one foreman, one mechanic, and eight operators, (b) the area contain approximately 180 lane-miles of road adjusted for those road sections where cities perform the maintenance under contract, and (c) the equipment fleet contain six snow plowing trucks, three pickup trucks, and other supporting equipment. One standby plowing truck or a motorgrader should be provided also. After gaining experience with this setup, it should be possible to reduce the number of operators or increase the number of lane-miles of road for each operating unit.

5. Operations Requiring a Large Size or Specialized Crew Need to Be Directed by a Residency Foreman, Responsible Directly to the Resident Maintenance Engineer

One of the steps toward achieving greater efficiency in field operations would be the use of residency supervised crews for major maintenance jobs. The residency could have a senior foreman and possibly one or more subforeman specialists trained in work methods. They would be supplemented by subforemen and/or operators from the county crews. Some variation in the makeup of residency responsibility would doubtlessly be necessary because of varying workloads.

6. More Planning Is Needed in Maintenance Operations

Planning for maintenance needs critical attention from the Central Office down to and including the foremen. Planning envisioned here involves in a broad sense: (a) establishing realistic goals; (b) developing policies to help reach these goals; (c) finding the technical means to achieve the objective; (d) organizing for efficient flow of work; (e) establishing procedures and standards to insure efficient operation; (f) assignment of individuals with concurrent responsibility, authority, and accountability; and (g) the measurement of results.

7. An Organization and Methods Group Should Be Established

A small organization and methods group, staffed with qualified specialists, with a mandate to operate on a broad scale and make objective analysis of problems and propose solutions to management should be set up. Since many of the problems involve several departments in the commission, the group could best function on a commission-wide basis even though the initial effort would be in connection with maintenance problems.

8. Policy and Procedure Manuals for Foremen and Resident Maintenance Engineers Should Be Rewritten and Kept Up-To-Date

When policy and procedure manuals are brought up-to-date, someone on the Central Office staff should be given both the time and responsibility to see that they are kept current.

9. A Policy with Decisiveness Is Needed for Realistic Snow Removal Operations and Staffing

A Policy on snow removal is needed which gives consideration to the following items: (a) Maximum depth of new-fallen snow which will be permitted to accumulate on the pavement; (b) limitation on hours of continuous duty and provisions for minimum rest periods; (c) a guarantee of work for men sent home with the expectation of returning to duty at night and then later finding that snow removal was not required; (d) limitation on the number of operators per vehicle for plowing, sanding, salting, or patrol operations (an exception could be made for that coverage during night hours when only one truck is manned); (e) a visibility limit for suspending routine plowing operations; and (f) on-the-road purchases of fuel and supplies.

10. Experimentation with Night-Hour Servicing of Equipment and Preparing for the Next Day's Work Should Be Adopted

Night-hour servicing of equipment can effectively increase the amount of time that operators spend away from the garage and at the worksite. Experimentation should be carried out to determine the minimum size of the operating unit for which it is economical to provide a man who works a regular 8-hour night shift. Such experimental work should include the element of advance preparation or loading of materials and supplies for the next day's work.

11. The Position of Resident Maintenance Engineer Should Be Strengthened

The resident maintenance engineer in many cases should have help to relieve him of a large volume of paperwork so that he can devote his time to leadership, planning, instruction, and inspection. In addition, he should be given the time and the opportunity to check construction design plans in order to recommend changes that will eliminate unnecessary maintenance problems.

All resident maintenance engineers receive a great deal of assistance from their stenographers who are generally overworked. Because of familiarity with paperwork and recordkeeping, experienced stenographers do much to relieve the burden on the resident maintenance engineer. However, many engineers seriously need a type of help stenographers are unable to perform, such as help with access control work, planning, and inspection.

Resident maintenance engineers needing the most help are generally in urban areas. Their problems are multiplied by the number and complexity of access permits, more public contacts, and, in general, a less capable class of personnel because of higher wages in business and industry. Since there is an unequal workload among the various divisions, some engineers need a smaller residency or an assistant resident maintenance engineer; others can make use of a full-time relatively high-grade engineering aid; several may need both; and a number need no additional help.

12. Additional Mechanics Are Needed

A mechanics helper or another mechanic should be provided for each group of six trucks in each county, pickups excluded. This need is also related to snow removal, as well as other operations. Table 4 on page 22 in the section on Findings shows that between six and seven operating trucks are required for snow removal work on each 200 lane-miles of road when based on 2 to $2\frac{1}{2}$-hour intervals between coverage. This number is equal to 28.6 to $33.\bar{3}$ lane-miles of road per truck. By using 30 lane-miles of road per truck and six trucks per mechanic as the two bases, it was determined that 47 additional mechanics or helpers are needed in the field garages. These additional mechanics will not be in sufficient number to provide extensive services for non-maintenance vehicles.

13. Repair and Service Provided for Non-Maintenance Vehicles in Maintenance Garages Should Be Re-examined at Many Locations

Wherever the repair and service of non-maintenance equipment requires overtime work on an extended basis, the services rendered and the overtime work should be curtailed or discontinued in the interest of increasing the mechanic's efficiency during his regular work shift. Wherever the field garage facilities are adequate only for care of maintenance equipment, the providing of any service other than emergency service to non-maintenance vehicles should be discontinued. If a decision is made to continue providing service to non-maintenance vehicles, then some garage facilities need to be expanded and/or extra mechanics hired.

14. Procurement Policies Need Revamping

Recognition should be given to the fact that Central Office procurement of all items does not necessarily result in the lowest total cost. Further study is needed in this area. Also, an economic analysis is needed of local procurement practices for obtaining abrasives for snow and ice control.

15. Facilities Plan Needed

A long-range plan for modernizing garage and storage facilities should be prepared and integrated with existing plans for interstate garage facilities. This involves, again, the problem of workloads and geographical areas. It involves, also, the adequacy of existing garages in terms of their physical dimensions, their locations, and the economy of alternate solutions.

16. Equipment Should Be Improved

(a) Standard 4-wheel drive rubber-tired loaders, which are more efficient for handling materials, should be provided. Some garages need loaders with buckets of 1- to $1\frac{1}{2}$-cu yd capacity for handling the volume of materials required for their operations.

(b) Mowing equipment with greater capacity is needed, particularly for interstate work. Units capable of cutting 10- and 15-foot swaths should be purchased until each residency has one 15-foot unit and most counties have one 10-foot unit. For interstate mowing, even more of these large units are needed.

(c) An effort should be made to procure mowing equipment which has better stability, better flotation, better steering, and more rugged construction. Basically, what is needed is a "highway mowing machine" instead of the present farm-type units.

(d) Purchase specifications for some types of equipment should include requirements relating to performance under actual operating conditions.

(e) Arrangements should be made to obtain the views of foremen and operators regarding the type, size, performance and other characteristics of equipment procured for their use. Conducting objective studies in this field would overcome personal preferences and opinions.

(f) A limited number of tire sizes should be designated as standard for maintenance equipment and specified for new equipment.

(g) Heavy duty components should be specified for all truck electrical systems. A limited number of battery sizes should be designated as standard and specified for new units.

(h) Tractors, loaders, and motorgraders should be equipped with high speed travel gears.

(i) Trucks used for hauling or snow removal operations should be equipped with larger fuel tanks or auxiliary fuel tanks. A total capacity of 50 gallons would be adequate for most units.

(j) Snow plows should be designed or modified for maximum interchangeability. One arrangement would be to have a group of plows for medium duty trucks and another group for heavy duty trucks and motorgraders. Studies indicate that the average county never needs or uses more than four Vee plows at any one time; thus, with interchangeability it should be possible to eliminate a number of Vee plows throughout the State.

(k) Every garage should have at least one truck equipped with a winch operated by power takeoff.

(l) Trucks used for day-to-day maintenance operations should be equipped with a standard rack for hand tools (shovels, pick, crowbar, axe).

(m) Each garage should be provided with one or more pickups to use for general transportation and light hauling in addition to those now provided for the foreman and the mechanic.

(n) Some field garages have need for a self-propelled hand-guided mower.

17. Installation of Two-Way Radio Should Be Accomplished

Two-way radio offers great promise as a tool for more efficient and effective maintenance operations.

18. Central Office Staff Needs to Be Enlarged

The Central Office staff should be in a position to: (a) furnish effective functional guidance of maintenance operations; (b) spot or unravel knotty problems in field offices; and (c) make recommendations regarding policy. At the present time the staff is not adequate to handle the volume of work that must be done.

While it is recommended that more personnel be added to the Central Office staff, care should be taken that it doesn't grow out of proportion to the work it should be doing. The function of the Central Office is to help the field offices get the job done, not to do the job itself.

19. Authority and Responsibility Should Be Firmly Established for and Adhered to by Each Supervisor in the Chain of Command

Authority and responsibility need to be clearly spelled out to and thoroughly understood by each supervisor, and lines of communication, both formal and informal, need to be firmly established and followed before any other change or recommendation concerning management can be really effective.

It is basic to good management that each supervisor know his function, his responsibilities and commensurate authority, and his relationship to personnel in the commission as well as to the public. The study clearly showed that individuals at the same level hold diverse opinions concerning their responsibility and authority. To correct this situation, job guides should be prepared for each type of position in the chain of command in the maintenance organization, including that of the district engineer.

THE NATIONAL ACADEMY OF SCIENCES—NATIONAL RESEARCH COUNCIL is a private, nonprofit organization of scientists, dedicated to the furtherance of science and to its use for the general welfare. The ACADEMY itself was established in 1863 under a congressional charter signed by President Lincoln. Empowered to provide for all activities appropriate to academies of science, it was also required by its charter to act as an adviser to the federal government in scientific matters. 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.

The NATIONAL RESEARCH COUNCIL was established by the ACADEMY in 1916, at the request of President Wilson, to enable scientists generally to associate their efforts with those of the limited membership of the ACADEMY in service to the nation, to society, and to science at home and abroad. Members of the NATIONAL RESEARCH COUNCIL receive their appointments from the president of the ACADEMY. They include representatives nominated by the major scientific and technical societies, representatives of the federal government, and a number of members at large. In addition, several thousand scientists and engineers take part in the activities of the research council through membership on its various boards and committees.

Receiving funds from both public and private sources, by contribution, grant, or contract, the ACADEMY and its RESEARCH COUNCIL thus work to stimulate research and its applications, to survey the broad possibilities of science, to promote effective utilization of the scientific and technical resources of the country, to serve the government, and to further the general interests of science.

The HIGHWAY RESEARCH BOARD was organized November 11, 1920, as an agency of the Division of Engineering and Industrial Research, one of the eight functional divisions of the NATIONAL RESEARCH COUNCIL. The BOARD is a cooperative organization of the highway technologists of America operating under the auspices of the ACADEMY-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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