HIGHWAY RESEARCH BOARD

Special Report 65

Supplement I

IOWA STATE HIGHWAY MAINTENANCE STUDY

Time Utilization, Productivity, Methods,
and Management
1959 - 1960

National Academy of Sciences—
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HIGHWAY RESEARCH BOARD

Special Report 65

Supplement I

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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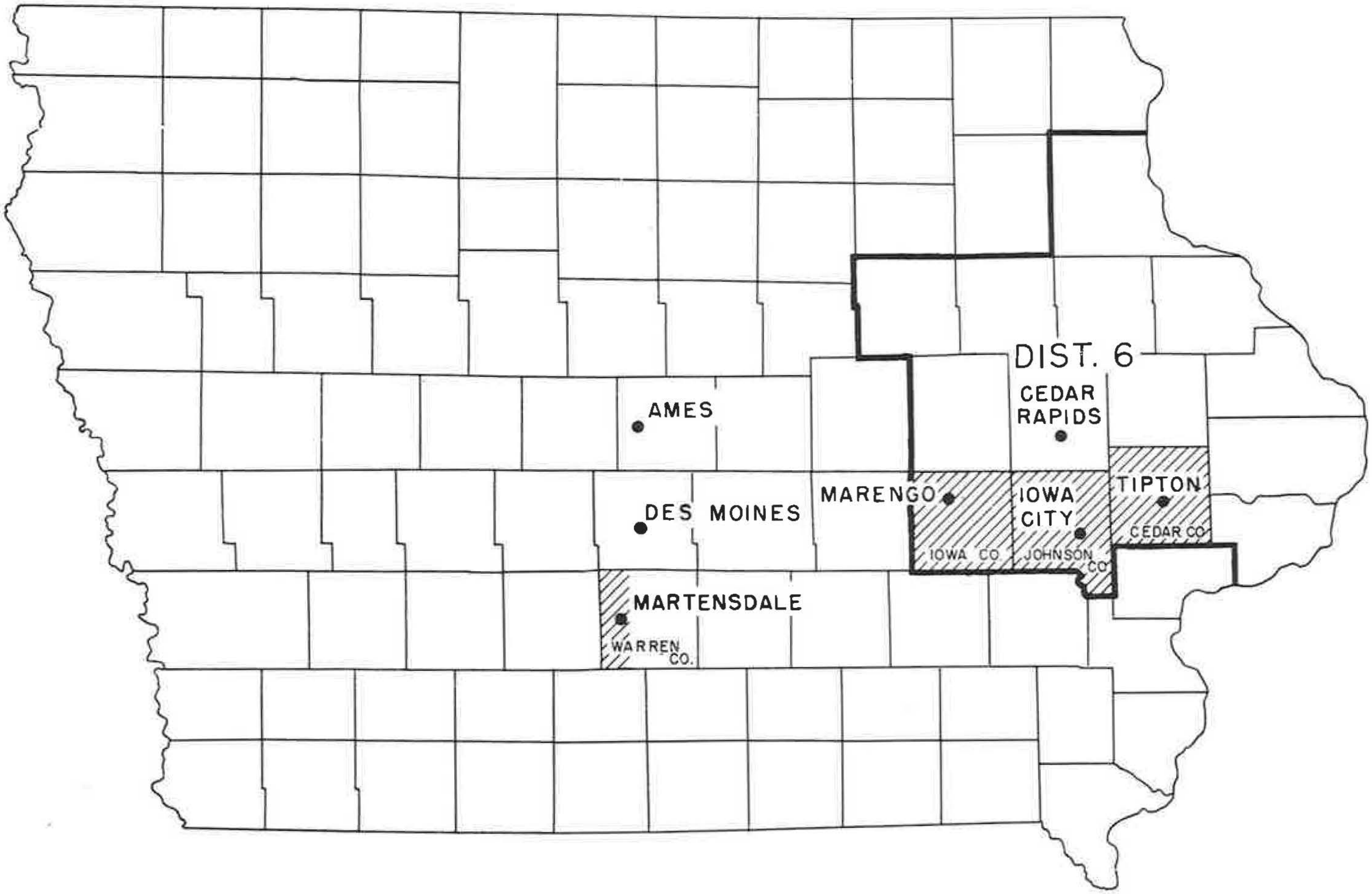

IOWA

SHADED SECTION SHOWS CONTROL STUDY AREA

Special Report 65, the basic report to which this volume is a supplement, is available at $1.20 per copy from

Highway Research Board
2101 Constitution Avenue
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IOWA STATE HIGHWAY MAINTENANCE STUDY

SUPPLEMENT I

Section A

INTRODUCTION

> The Iowa State Highway Maintenance Study Report, Highway Research Board Special Report No. 65, contains the principal findings, conclusions, and recommendations developed during a one-year study of maintenance operations on State primary and interstate highways in Iowa, as well as descriptive background material. Supplement I presents a large portion of the numerical data from which was drawn many of the facts included in Special Report No. 65. Many parts of the supplement are naturally linked with the findings, conclusions, and recommendations in Special Report No. 65; and since some material is not repeated, the reader is urged to use both volumes concurrently.

Supplement I includes data on workloads, an accounting of labor and equipment time by type of work, labor time charges per mile of road by selected groups of roads in the three-county control area and similar data on a section of Interstate 35 in Warren County. Results from the many production studies made throughout the State are shown in summary form along with discussions of methods and procedures followed in performing various maintenance operations. Special reports on selected subjects and a sample illustration of a mathematical approach to rating the principal criteria for solutions of some maintenance production problems are also included.

Interpretation and application of the findings are dependent upon many factors including such items as knowledge about local conditions, supervisor personalities, catastrophic situations, the physical plant, and others which do not lend themselves to precise numerical evaluation. The data contained herein do, however, point to the nature and magnitude of many elements which can affect productive effort on maintenance work and when interpreted in the light of conditions known to exist, will provide direction toward profitable adjustments and changes that can be made by management. It should be recognized, nevertheless, that the expense of some delays or certain inefficient procedures may be less than the cost of remedying the situation and hence a change is unwarranted unless external benefits can be derived. The plan of action which considers the whole of maintenance rather than an individual segment is most desirable.

Each of the 7 sections in this supplement contains a description of material presented therein and, where appropriate, of study techniques used in developing the data shown.

Special definitions for frequently used terms are reproduced below:

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.

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 were excluded.

Net available working time (NAWT) is equal to total available working time minus nonoperational major delays.

Nonoperational 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 nonoperational 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 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 no matter how short or long the period.

Service and repair major nonoperational delays 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 installing minor attachments like buckets and snowplows was not considered to be a delay, but installation of major attachments such as truck beds or snowplow frames was.

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.

Throughout this volume, road surfaces have been classified as one of six types. The following list shows the terminology used, State unit codes and a description for those types where variations may require interpretation.

Type	State unit code	Description
Portland cement concrete	10	
Brick	50	
Bituminous overlay	80	Bituminous concrete mat placed over an old portland cement concrete or brick surface
Bituminous plant mix	90	Bituminous concrete mat with gravel, crushed stone, or soil-cement base course
Bituminous treated	(30) (40)	Bituminous penetration mat with a gravel or crushed stone base course (some are stabilized)
Gravel	20	Gravel or crushed stone surface usually without any base course

Section B

COMPREHENSIVE STUDIES IN THE THREE-COUNTY CONTROL AREA

1. Background

Studies undertaken to develop basic data about the types and total extent of maintenance performed by State forces on the primary road system are called comprehensive studies. They were intended to provide an overall picture of maintenance on primary highways throughout Iowa. Current State records for labor, equipment, materials, and supplies were examined to see if they would provide data needed for the comprehensive studies. It was decided that the State records did not contain all of the information needed and did not show enough details. Therefore, the study group developed a special accounting system to obtain the needed data.

A group of direct operation accounts were set up to accumulate labor and equipment time. These operations were based on the list of functions shown in the 1958 AASHO Manual of Uniform Accounting Procedures. In addition, two groups of overhead operation accounts were used to accumulate labor and equipment time which could not be immediately allocated to any direct operation. The accounts in one group, called overhead operations - undistributed, covered work such as service and repair equipment and were not allocated to any operation. The other group, overhead operations - distributed, consisted of operations which were allocated to direct operations. Stockpiling aggregates is one of the operations in this latter group. Labor and equipment time was also classified according to where work was performed. State road sections were used to identify worksites. However, most of the State sections were divided into study subsections to provide a more detailed breakdown of worksite locations for certain direct operations. Overhead operations were classified only according to the county where they occurred.

Two-man study crews were assigned full time to each of three counties in a selected control area for a 52-week period. They observed activities of State maintenance forces, prepared daily time records for each employee and major equipment unit working in the control area, and obtained background information. The daily time records for men and equipment units showed the following information: total available working time (TAWT); nonoperational major delays (over 30 minutes); net available working time (NAWT) spent on each operation; and the location of worksites. In most cases, study crews were able to obtain the distribution of time to the nearest 10 minutes. Worksites were identified as being in a particular county, road section and, in many cases, a study subsection. Background data included records of materials used, work accomplished, mileage operated by individual trucks, and other similar information.

All study records were forwarded to a headquarters office where they were checked for accuracy and consistency. Most of the data were then transferred to punch cards for machine processing. During the 52-week study period, study crews recorded 86,225 hours of TAWT for labor and 166,926 hours of TAWT for major equipment units. Labor had an additional 8,411 hours of paid leave so study crews actually accounted for 94,636 hours. A check showed that this latter figure differed from State total labor payroll hours for the same period by less than 1 percent. No check was made on equipment time but it is believed that study records and State records in total agree within 1 or 2 percent.

2. Characteristics of the three-county control area

The control area for comprehensive studies nominally consisted of Cedar, Iowa, and Johnson Counties. However, it was actually defined as including only those roads normally maintained by State maintenance crews stationed in the three counties. Thus, detours over county roads, a road section in a State park, and a few road sections in adjoining counties were included in the control area because they were maintained by the three crews. Roads contracted to a city for maintenance (except certain specified traffic control items) and several road sections normally maintained by State crews stationed in other counties were excluded even though they were within the political boundaries of the three counties. During the one-year study period there were several changes in roads normally maintained by the three crews and thus in the limits of the control area. For example, during winter months the three crews were given responsibility for salting roads in other counties.

The control area was selected by the special study group staff after consultation with State personnel from the Central and District 6 Offices. Consideration was given to terrain, soil types, weather, traffic, road surface types, and suitability for study. The selected area was recognized as not being a perfect sample but was considered to be reasonably representative of conditions found throughout Iowa. It also met some practical limitations of study criteria. Each of the three counties in the selected control area had certain distinguishing characteristics. Each had all major types of roadway surfaces but in varying proportions. Average traffic varied considerably. Cedar and Iowa Counties included only small cities while Johnson County had small cities and a moderately large urban area. In Cedar County, the State maintenance crew operated out of two garages; in the other counties there was only one garage. Each county was located in a different maintenance residency which meant that there were some differences in policies and procedures. Crew sizes and equipment complements varied from county to county although they were related in a general way to variations in total workload. Table 1 presents, for selected items, a comparison between the three counties in the control area, an average county in the control area, and an average county in the State. It should be kept in mind that the three control area counties are actually defined as including only the roads normally maintained by the three State maintenance crews. Thus, figures shown here do not agree exactly with comparable data shown on Page 3 of Special Report No. 65 which are based on political boundaries. Table 2 shows the nominal fleet of "A" equipment used in the three-county control area.

TABLE 1
COMPARISON BETWEEN CHARACTERISTICS OF CONTROL AREA COUNTIES AND STATE AVERAGE COUNTY FOR SELECTED ITEMS

Item	Control area				State average county
	Cedar	Iowa	Johnson	Average county	
Roads maintained 8/17/59: (miles)					
Portland cement concrete - unit 10	33.3	14.9	69.6	39.3	56.5
Brick - unit 50	-	0.4	0.2	0.2	0.8
Bituminous overlay - unit 80	15.8	46.4	12.8	25.0	16.2
Bituminous concrete - unit 90	20.7	21.6	-	14.1	10.8
Bituminous treated - units 30 and 40	0.6	0.7	17.1	6.1	7.5
Gravel - unit 20	12.3	2.1	4.3	6.2	7.6
Total	82.7	86.1	104.0	90.9	99.4
Average age of surfaces (years)	13	6	12	11	18
Average daily traffic (1/1/60 estimate)	1,965	1,970	2,600	2,210	1,823
Average maintenance expenditure per mile (FY 1959-60)	$1,690	$980	$1,330	$1,370	$1,374
Mean temperature: (^{o}F)					
Average year	49	49	49	49	49
Study year August 1959-August 1960	48	48	48	48	49
Total precipitation: (inches)					
Average year	33	33	33	33	31
Study year August 1959-August 1960	43	43	43	43	38
Snowfall: (inches)					
Average year	30	30	30	30	27
Study year November 1959-March 1960	55	55	55	55	52
Predominating soil types	- A-6 to A-7-6 -				
State maintenance crew 8/17/59:					
All personnel	13	12	15	13	13
Trucks	7	8	9	8	7
Motorgraders	2	1	3	2	2
Tractors and front end loaders	6	6	7	6	7
Other equipment units	8	7	6	7	9
Number of state garages	2	1	1	1	2

TABLE 2

"A" EQUIPMENT ASSIGNED TO THE THREE-COUNTY CONTROL AREA AUGUST 17, 1959 1/

Equipment group	State number	Make and model	Year purchased	Auxiliary equipment 2/
Cedar County				
Light duty trucks	A 5732	Ford F600	1955	2.4 cu yd end dump bed Ⓐ Ⓑ
"	A 6278	Ford F600	1956	4.0 cu yd end dump bed Ⓐ Ⓑ
"	A 6782	I.H.C. A162	1958	3.0 cu yd end dump bed Ⓐ
"	A 7107	I.H.C. A162	1959	6.5 cu yd spreader bed Ⓐ
"	A 7402	Chevrolet 6403	1959	4.1 cu yd end dump bed Ⓐ Ⓑ
Medium and heavy duty trucks	A 5081	Ford F800	1953	3.0 cu yd end dump bed Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
"	A 6318	Ford F800	1956	4.8 cu yd spreader bed Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
Motorgraders	A 2824	Caterpillar 12	1945	Ⓑ Ⓒ Ⓓ
"	A 5074	Caterpillar 212	1953	Ⓑ Ⓒ Ⓓ
Pickups	A 5107	Chevrolet 3104	1953	
"	A 6232	Ford F100	1956	
"	A 6718	Ford F100	1957	
Tractors and frontend loaders	A 3719	Case VA-1	1949	6 ft sickle bar mower, 0.34 cu yd loader bucket
"	A 4753	Case D-1	1952	0.75 cu yd loader bucket
"	A 4923	I.H.C. FAA	1953	5 ft sickle bar mower
"	A 6106	John Deere 420U	1957	6 ft sickle bar mower
"	A 6580	John Deere 420T	1957	5 ft rotary mower
"	A 6926	Ford	1958	6 ft sickle bar mower, 0.29 cu yd loader bucket
Iowa County				
Light duty trucks	A 4579	I.H.C. L-162	1951	3.0 cu yd end dump bed, 3.2 cu yd spreader bed Ⓐ
"	A 5433	Ford F600	1954	3.9 cu yd end dump bed, 5.0 cu yd spreader bed Ⓐ Ⓑ
"	A 6002	Ford F600	1956	3.9 cu yd end dump bed Ⓐ Ⓑ
"	A 6217	Ford F600	1956	5.3 cu yd spreader bed Ⓐ
"	A 6711	Chevrolet 6403	1957	4.0 cu yd end dump bed Ⓐ
"	A 6801	Ford F600	1958	4.0 cu yd end dump bed Ⓐ
Medium and heavy duty trucks	A 4299	Ford F6	1951	2.0 cu yd end dump bed Ⓐ Ⓑ Ⓓ Ⓔ
"	A 6300	Ford F800	1956	3.0 cu yd end dump bed Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
Motorgrader	A 3230	Galion 102	1947	Ⓑ Ⓒ Ⓓ
Pickups	A 6787	Chevrolet 3104	1958	
"	A 7120	Studebaker 4E3	1959	
Tractors and frontend loaders	A 2050	McCormick-Deering	1939	
"	A 2319	Minneapolis-Moline VII	1949	0.75 cu yd loader bucket
"	A 2914	Ford 6H021	1946	6 ft sickle bar mower
"	A 3639	John Deere M-1	1946	6 ft sickle bar mower
"	A 4352	John Deere M-1	1951	6 ft sickle bar mower
"	A 6632	John Deere 420T	1957	5 ft rotary mower, 0.34 cu yd loader bucket
Johnson County				
Light duty trucks	A 5129	I.H.C. R162	1954	2.3 cu yd end dump bed, 3.8 cu yd spreader bed Ⓐ
"	A 5477	I.H.C. R162	1955	3.6 cu yd end dump bed Ⓐ
"	A 5498	I.H.C. R162	1955	3.1 cu yd end dump bed Ⓐ Ⓑ
"	A 6203	Chevrolet 6403	1956	3.5 cu yd end dump bed, 4.5 cu yd spreader bed Ⓐ Ⓑ
"	A 6326	I.H.C. S162	1956	3.4 cu yd end dump bed Ⓐ
"	A 6330	Ford F600	1957	2.8 cu yd end dump bed Ⓐ
"	A 6904	Chevrolet 6403	1958	4.4 cu yd end dump bed, 4.5 cu yd spreader bed Ⓐ Ⓑ
Medium and heavy duty trucks	A 1313	Oshkosh C-35	1934	2.4 cu yd end dump bed Ⓐ Ⓑ Ⓒ Ⓓ Ⓔ
"	A 5863	Ford F800	1956	5.3 cu yd spreader bed Ⓐ Ⓑ Ⓓ Ⓔ
Motorgraders	A 3552	American 800M	1948	Ⓓ
"	A 4179	Caterpillar 112	1950	Ⓐ Ⓑ Ⓓ
"	A 7127	Adams 440	1958	Ⓑ Ⓒ Ⓓ
Pickups	A 5501	Ford F100	1955	
"	A 6359	Ford F100	1956	
Tractors and frontend loaders	A 2836	Hough I-6	1946	0.69 cu yd loader bucket
"	A 4353	John Deere M-1	1951	6 ft sickle bar mower
"	A 4354	John Deere M-1	1951	6 ft sickle bar mower
"	A 4628	John Deere M-1	1952	6 ft sickle bar mower
"	A 5176	John Deere 40U	1954	6 ft sickle bar mower, 0.33 cu yd loader bucket
"	A 6949	John Deere 420T	1958	5 ft rotary mower
"	A 7276	I.H.C. 240		6 ft sickle bar mower
District and Division				
Light duty trucks	3/ A 4694	Chevrolet 3809	1952	Acid tanks and sprayer
"	3/ A 5490	I.H.C. 192	1955	Stake bed, hydraulic tailgate, pump
"	3/ A 5495	Ford F600	1955	Stake bed, paint tanks, paint sprayer, glass bead bin
Truck mounted draglines	4/ A 4530	Schield-Bantam T-35	1951	3/8 cu yd drag bucket
"	4/ A 5228	Schield-Bantam T-35	1954	3/8 cu yd drag bucket
"	4/ A 5229	Schield-Bantam T-35	1954	3/8 cu yd drag bucket
Pickups	3/ A 5090	Ford F100	1953	
"	3/ A 6157	Ford F100	1956	
Elevating grader	A 3296	Athey	1947	
Soil mixers	A 3024	Seaman	1947	
"	A 4009	Seaman	1950	
Mudjacks	A 4569	Koehring 502A	1951	
Self propelled rollers	A 5428	Ferguson 152	1954	
Air compressors	A 1234	Sullivan WK-60	1940	
"	A 3150	Le Roi G2A	1947	
"	A 7447	Smith 75-P	1959	

1/ See Page 3 for definition of "A" equipment.

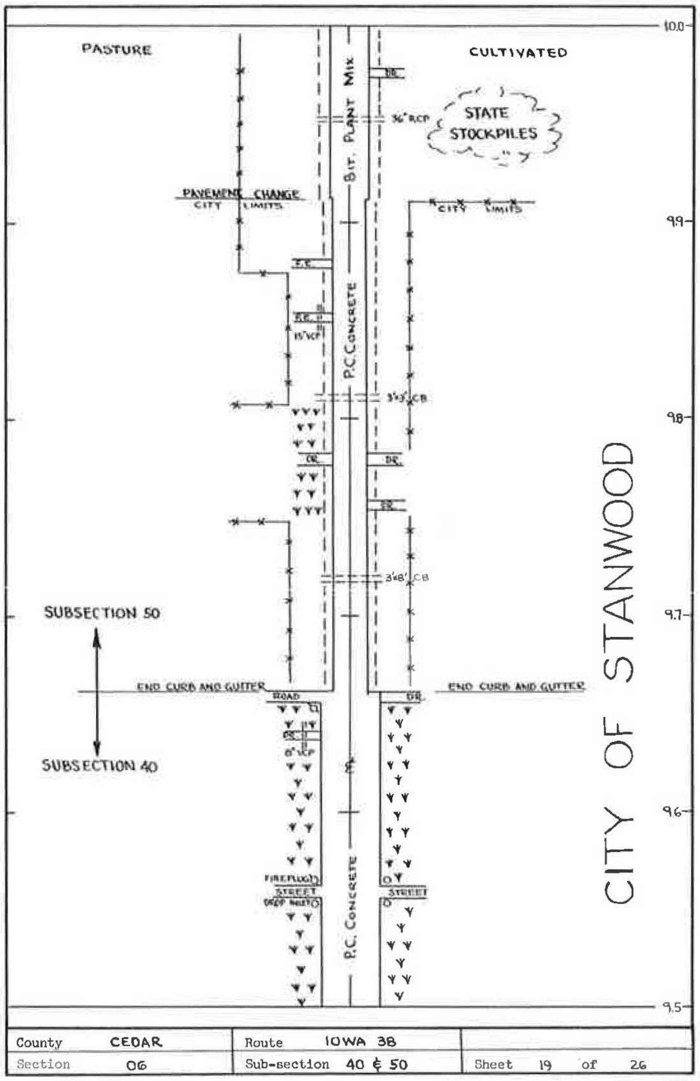
2/ Circled letters indicate following auxiliary equipment: Ⓐ One-way plow, Ⓑ Vee plow, Ⓒ Wing plow, Ⓓ Underbody blade, and Ⓔ Four-wheel drive.

3/ District paint crew.

4/ One used in each of three control area counties.

3. Inventory of workload in the three-county control area

Before starting comprehensive studies, the special study group made a detailed field inventory of all road sections in the three-county control area. The objective was to measure workload components for which State maintenance forces were normally responsible. In total, these components constituted the workload for each road section. Data obtained during the inventory were used to prepare strip maps which showed roadways, drainage structures, right-of-way lines, intersecting roads and some culture. A typical example is shown in Figure 1. Summaries were also prepared which listed quantities of the various workload components by State road section and study subsection. Table 3 shows these quantities for each section and county in the control area.



County CEDAR
Section 06
Route IOWA 38
Sub-section 40 ¢ 50
Sheet 19 of 26

Figure 1. Sample strip map prepared from field inventory data.

4. Distribution of labor and equipment time in the three-county control area by type of work

Data obtained during the comprehensive studies were summarized to show the distribution of labor and equipment time expended in the control area by type of work or delay. Table 4 presents the results of this summary for the entire three-county control area while Tables 5, 6, and 7 present results for each of the three counties. These tables show how much effort was expended in the three counties by State maintenance crews normally assigned there plus effort expended by other State crews such as the District 6 paint crew. Time spent by State crews working outside the control area or on city and county roads (reimbursable work) was excluded.

Each functional type of work is represented by an operation such as patch roadway surfaces with aggregate. These operations are listed under three main headings: Overhead operations - undistributed, Direct operations — maintenance of existing system, and Direct operations — new construction. The latter heading includes only work which was generated by construction or reconstruction projects on the primary or interstate road systems. The term detours indicates that traffic was being routed over existing county roads or city streets off the State system. Tables 4 to 7 also list nonoperational major delays by type.

As previously indicated, the special study accounting system included a group of operation accounts under the heading overhead operations — distributed. The labor and equipment time charged to these accounts was allocated to all direct operations before preparing the summary on which these tables are based.

Figure 2. State garage typical of those in the three-county control area.

TABLE

INVENTORY OF WORKLOAD IN THREE-CO

County	Section No.	Length (Mi)	ADT (vpd)	ROADWAY SURFACE AREA								SHOULDERS AND APPROACHES		
				Portland cement concrete (Sq Yd)	Brick (Sq Yd)	Bitumi-nous overlay (Sq Yd)	Bitumi-nous concrete (Sq Yd)	Bitumi-nous surface treatment (Sq Yd)	Gravel (Sq Yd)	Bridge deck (Sq Yd)	Total (Sq Yd)	Shoulder area 1/ (Sq Yd)	Inter-secting roads 2/	Drives or entrances 3/
Cedar	01	11.37	825	17,180	-	-	149,380	-	-	3,765	170,325	117,560	38	106
	03	11.40	4,320	12,725	-	148,245	-	-	-	80	161,050	153,745	28	55
	04	12.70	3,770	136,765	-	47,460	-	-	-	450	184,675	123,245	35	58
	05	13.75	720	-	-	13,990	93,180	-	132,825	510	240,505	61,915	37	80
	06	13.17	1,965	89,420	-	21,335	43,380	-	-	110	154,245	73,960	40	97
	07	14.10	1,270	165,185	-	1,865	-	-	-	575	167,625	96,110	38	121
	Detour	6.16	300	-	-	-	-	7,125	83,855	135	91,115	2,715	13	62
	County total	82.65	1,965	421,275	-	232,895	285,940	7,125	216,680	5,625	1,169,540	629,250	229	579
Iowa	01	12.30	2,830	49,175	-	125,210	-	-	-	1,750	176,135	106,500	26	91
	02	13.02	3,985	1,430	-	177,540	-	-	-	235	179,205	90,190	23	122
	03	2.68	510	13,345	-	-	-	-	20,485	650	34,480	7,600	5	18
	04	22.38	1,275	87,700	4,580	145,270	-	-	-	1,455	239,005	206,475	69	142
	05	10.28	2,310	-	-	107,175	-	-	-	2,800	109,975	69,905	21	60
	06	0.62	450	-	-	-	-	7,030	-	-	7,030	3,435	6	9
	07	13.77	1,255	3,090	-	4,185	175,570	-	-	4,390	187,235	71,825	42	110
	08	9.55	1,180	24,800	-	-	88,630	1,555	10,250	3,325	128,560	48,745	28	150
	09	1.54	375	-	-	-	18,185	-	-	3,645	21,830	6,985	-	7
	County total	86.14	1,970	179,540	4,580	559,380	282,385	8,585	30,735	18,250	1,083,455	611,660	220	709
Johnson	01	15.22	1,720	193,860	-	-	-	-	-	1,235	195,095	176,575	29	156
	02	8.65	1,150	1,695	-	-	-	119,950	-	105	121,750	22,285	16	103
	03	12.73	3,095	70,680	-	109,255	-	-	-	105	180,040	118,005	24	117
	04	4.23	10,820	84,370	3,470	-	-	-	-	1,195	89,035	67,795	13	44
	05	10.27	3,600	149,680	-	29,025	-	-	-	1,990	180,695	110,360	25	58
	06	6.09	550	-	-	-	-	85,285	-	2,115	87,400	25,285	7	44
	07	1.23	885	17,670	-	-	-	-	-	135	17,805	6,170	12	16
	08	0.79	635	6,145	-	2,295	-	-	-	-	8,440	4,820	5	6
	09	11.00	2,670	117,305	-	-	-	-	-	630	117,935	101,905	18	130
	10	13.27	3,815	154,485	-	39,160	-	-	-	1,365	195,010	157,230	20	78
	11	13.75	1,690	160,420	-	-	-	-	-	1,270	161,690	131,920	39	131
	12	4.85	550	-	-	-	-	27,530	37,800	1,130	66,460	6,240	17	37
	13	0.57	1,235	-	-	-	-	8,775	-	-	8,775	4,180	3	5
	State Park	1.34	400	-	-	-	-	-	44,385	-	44,385	-	-	8
	County total	103.99	2,600	956,310	3,470	179,735	-	241,540	82,185	11,275	1,474,515	932,770	228	933

1/ All shoulders were basically soil and sod although some had received applications of aggregate and/or bituminous mixes. Gravel surfaced roads were assumed to have no shoulders.
2/ Maintained in whole or part by city and county forces.
3/ Does not include mailbox turnouts. Maintained in part by owners.
4/ Area between edges of shoulders and right-of-way lines.
5/ Area which maintenance crews normally mowed including shoulders but excluding steep slopes, marshy areas, etc.
6/ Does not include reflectors.
7/ Both cable and beam types.
8/ Some road sections were partially maintained by city or county forces under contract. However, the State crew was responsible for maintenance of signs and sign posts. There were 388 signs and 304 sign posts on 8.08 miles of contracted roads in Johnson County.

3
UNTY CONTROL AREA (8-17-59)

ROW area 4/ (Acres)	Mowed area 5/ (Acres)	ROADWAY AND APPROACH DRAINAGE STRUCTURES					Signs 6/	POSTS					Guard-rail 7/ (Lin Ft)	Snow fence — winter 1959-60 (Lin Ft)
		Bridges and bridge culverts	Box culverts and cattle passes	Pipes	Drop inlets	Spill-ways		Sign	Guide	Guard-rail	Other	Total		
123.3	119.3	7	30	86	30	-	165	138	8	-	61	207	-	704
85.9	84.8	2	14	74	5	-	133	118	134	-	90	342	-	15,137
166.1	150.8	3	15	56	17	-	171	151	79	-	23	253	-	6,001
120.9	118.8	2	33	84	12	-	163	144	123	-	1	268	-	9,606
89.6	87.6	2	41	79	22	12	226	179	177	110	55	521	1,100	18,534
121.1	118.9	4	50	76	-	116	148	128	193	-	43	364	-	7,536
28.5	13.4	1	7	50	-	-	103	79	8	-	61	148	-	-
735.4	693.6	21	190	505	86	128	1,109	937	722	110	334	2,103	1,100	57,518
112.4	111.3	3	29	65	2	-	166	148	129	26	89	392	260	-
82.0	73.0	1	53	68	1	-	234	200	112	-	154	466	-	2,988
19.6	17.7	1	5	16	2	-	28	22	17	-	2	41	-	-
143.8	139.2	6	76	127	7	150	289	232	248	-	199	679	-	22,637
100.8	93.7	6	33	44	3	64	162	144	129	-	219	492	-	8,406
2.1	2.0	-	3	10	-	-	32	25	2	-	5	32	-	488
127.6	126.3	6	40	71	-	-	240	222	50	-	120	392	-	4,437
84.1	76.8	5	16	115	2	-	225	199	27	-	85	311	-	2,043
30.1	30.1	1	-	6	-	-	15	12	2	-	11	25	-	-
702.5	670.1	29	255	522	17	214	1,391	1,204	716	26	884	2,830	260	40,999
177.5	153.0	5	27	149	1	21	100	98	44	-	-	142	-	2,903
31.7	27.1	1	10	108	2	-	99	87	38	-	-	125	-	12,881
96.5	87.7	2	39	110	4	-	197	184	70	8	37	299	80	6,742
26.4	25.2	1	7	40	23	-	146	132	9	66	-	207	858	-
144.5	141.6	3	15	78	13	1	94	88	20	-	21	129	-	2,100
74.3	71.9	2	10	29	-	-	56	52	23	-	-	75	-	-
4.5	2.2	1	1	6	14	6	41	30	114	21	-	165	200	252
2.6	1.8	-	1	10	-	2	12	11	-	-	-	11	-	-
82.6	52.3	4	25	87	1	40	118	109	169	-	-	278	-	4,605
182.8	155.7	1	28	105	1	-	114	99	39	1,117	22	1,277	14,521	-
145.3	128.1	6	36	113	7	106	148	134	216	1,327	-	1,677	13,270	2,224
43.0	39.6	3	5	23	-	-	63	54	188	451	-	693	5,863	861
4.4	1.7	-	2	9	2	-	22	17	-	-	-	17	-	-
-	-	-	-	3	-	-	25	22	79	-	-	101	-	-
1,016.1	887.9	29	206	870	68	176	8/ 1,235	8/ 1,117	1,009	2,990	80	5,196	34,792	32,568

TABLE 4

LABOR AND EQUIPMENT TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Operation	Labor time (Hours)	Percent of TAWT	EQUIPMENT TIME IN HOURS						
			Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors & front-end loaders	All others
I Overhead operations — undistributed:									
A. Supervise maintenance activities	5,554	6.5	33	-	-	-	2,148		
B. Service and repair equipment:									
1. Service or repair maintenance equipment	13,036	15.1	162	10	3	6	1,001	63	-
2. Service or repair non-maintenance equipment	1,117	1.3	27	-	-	-	104	1	-
	14,153	16.4	189	10	3	6	1,105	64	-
C. Clean, repair or improve garage facilities	2,777	3.2	294	22	17	2	84	107	173
Subtotal	22,484	26.1	516	32	20	8	3,337	171	173
II Direct operations - maintenance of existing system:									
A. Routine surface:									
1. Patch roadway surfaces with aggregate	2,612	3.0	1,300	120	349	22	80	175	53
2. Patch roadway surfaces with bituminous cold mix	4,297	5.0	1,898	73	154	3	176	148	213
3. Patch roadway surfaces with bituminous hot mix	1,176	1.4	560	97	2	1	38	136	554
4. Blade gravel surfaces	864	1.0	48	40	683	-	12	5	3
5. Fill joints and cracks in roadway surfaces	216	0.2	88	-	-	-	3	2	35
6. Apply dust palliatives to gravel surfaces	142	0.2	61	8	-	-	5	4	25
7. Clean or drain roadway surfaces	198	0.2	75	7	5	-	25	2	-
	9,505	11.0	4,030	345	1,193	26	339	472	883
B. Special surface:									
1. Mudjack concrete pavements	1,091	1.3	576	108	46	1	28	111	232
2. Rebuild gravel surfaces	965	1.1	764	130	20	1	20	1	4
3. Seal bituminous and concrete pavements	3,481	4.0	1,868	192	23	15	71	213	898
4. Resurface with bituminous mixes	1,520	1.8	697	107	234	1	30	282	549
5. Plane or roll bituminous pavements	255	0.3	54	24	80	-	34	36	37
6. Rebuild aggregate base courses	633	0.7	332	58	36	49	88	97	81
	7,945	9.2	4,291	619	439	67	271	740	1,801
C. Shoulder and approach:									
1. Patch shoulders and approaches with soil	614	0.7	338	21	99	1	10	9	58
2. Patch shoulders and approaches with aggregate	1,451	1.7	727	30	24	11	24	67	37
3. Patch shoulders and approaches with bituminous cold mix	1,170	1.4	446	118	45	1	21	83	137
4. Reseed or resod shoulders and approaches	102	0.1	43	-	-	-	1	22	6
5. Blade or reshape shoulders and approaches	379	0.4	38	35	191	1	8	67	-
	3,716	4.3	1,592	204	359	14	64	248	238
D. Roadside and drainage:									
1. Repair cut and fill slopes	363	0.4	179	17	15	15	21	22	3
2. Repair or replace pipes and tiles	273	0.3	138	7	3	19	31	4	8
3. Clean pipes, tiles and box culverts	358	0.4	139	-	23	31	34	39	-
4. Clean or repair unpaved drainage ditches	1,605	1.9	637	21	15	290	310	23	5
5. Clean paved flumes, gutters and drop inlets	163	0.2	54	1	-	-	13	5	-
6. Repair stone riprap	217	0.3	96	4	-	-	10	34	30
7. Remove trees from roadsides	145	0.2	62	-	-	2	7	-	-
8. Mow roadsides with tractors (including shoulders)	5,162	6.0	734	21	4	5	232	4,681	15
9. Mow roadsides with hand tools (including shoulders)	612	0.7	305	8	-	-	26	23	2
10. Spray weeds on roadsides	613	0.7	212	-	-	-	54	96	218
	9,511	11.1	2,556	79	60	362	738	4,927	281
E. Snow and ice:									
1. Remove snow from roadway surfaces and shoulders	11,187	13.0	4,843	1,541	1,472	61	679	148	-
2. Remove snow from bridges	246	0.3	92	15	16	-	25	2	-
3. Erect snow fences	2,504	2.9	1,050	3	2	3	64	3	-
4. Remove snow fences	1,599	1.8	582	2	8	2	90	50	-
5. Sand roadway surfaces	2,377	2.7	1,362	81	3	55	107	182	-
6. Salt roadway surfaces	1,363	1.6	545	97	103	1	56	91	-
7. Remove ice from roadway surfaces and shoulders	928	1.1	371	230	4	1	55	11	-
8. Remove snow and ice from drainage ditches	238	0.3	89	1	-	-	38	1	-
9. Put out and remove cinder barrels	150	0.2	71	-	-	-	6	2	-
	20,592	23.9	9,005	1,970	1,608	123	1,120	490	
F. Traffic service:									

1. Paint centerlines and edgelines	1,393	1.6	169	21	8	1	602	1	200
2. Paint bridge endwalls, medians and miscellaneous pavement markings	461	0.5	118	-	3	1	77	23	47
3. Erect, replace, repair or paint signs and guideposts	1,509	1.8	549	2	1	2	293	16	25
4. Clean signs and reflectors	405	0.5	167	2	-	-	76	4	4
5. Remove or paint guardrails	106	0.1	35	-	5	-	16	3	-
6. Miscellaneous work at weigh stations and roadside parks	198	0.2	86	1	13	14	7	16	1
	4,072	4.7	1,124	26	30	18	1,071	63	277
G. Other:									
1. Clean or repair bridges	181	0.2	67	-	-	-	13	1	22
2. Remove litter from right-of-way	498	0.6	203	3	-	-	16	-	1
3. Miscellaneous work resulting from disasters	204	0.2	96	13	-	1	17	3	1
4. Miscellaneous work resulting from maintenance contracts	674	0.8	410	-	41	-	93	14	2
	1,557	1.8	776	16	41	1	139	18	26
Subtotal	56,898	66.0	23,374	3,259	3,730	611	3,742	6,958	3,506
III Direct operations - new construction:									
A. Detour:									
1. Patch roadway surfaces with aggregate	404	0.5	257	13	-	1	26	14	2
2. Patch roadway surfaces with bituminous cold mix	186	0.2	96	1	9	-	2	15	5
3. Blade gravel surfaces	377	0.4	4	2	349	-	5	1	2
4. Clean or drain roadway surfaces	16	-	7	-	-	-	1	-	-
5. Rebuild gravel surfaces	202	0.3	94	7	7	-	15	23	1
6. Rebuild aggregate base courses	168	0.2	80	7	-	23	8	5	-
7. Repair cut and fill slopes	10	-	5	-	-	-	-	1	-
8. Mow roadsides with tractor (including shoulders)	19	-	-	-	-	-	-	17	-
9. Remove snow from roadway surfaces and shoulders	93	0.1	36	5	15	1	6	1	-
10. Remove snow from bridges	2	-	1	-	-	-	-	-	-
11. Erect snow fences	9	-	3	-	-	-	-	-	-
12. Remove snow fences	1	-	1	-	-	-	-	-	-
13. Sand roadway surfaces	33	0.1	15	1	-	1	2	3	-
14. Remove ice from roadway surfaces and shoulders	10	-	-	5	-	-	1	-	-
15. Erect, replace, repair or paint signs and guideposts	248	0.3	106	-	-	-	40	-	1
16. Clean signs and reflectors	9	-	-	-	-	-	8	-	-
17. Miscellaneous work resulting from detours	261	0.3	49	-	6	-	80	4	3
	2,048	2.4	754	41	386	26	194	84	14
B. Miscellaneous work resulting from construction contracts	1,653	1.9	448	59	580	10	193	89	13
Subtotal	3,701	4.3	1,202	100	966	36	387	173	27
NAWT (I + II + III)	(83,083)	(96.4)	(25,092)	(3,391)	(4,716)	(655)	(7,466)	(7,302)	(3,706)
IV Major non-operational delays:									
A. Service and repair:									
1. Service (fuel, oil, grease, wash, etc.)	12	-	929	207	243	20	164	210	25
2. Repair engines and power trains	130	0.2	905	212	271	71	124	210	131
3. Repair chasses and bodies	17	-	146	14	39	10	30	44	-
4. Repair tires	6	-	41	4	40	-	17	126	2
5. Repair hoists and attachments	26	-	480	245	120	4	-	312	2
6. All other repair	73	0.1	531	115	130	15	104	197	66
	264	0.3	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. Change attachments or make other modifications	-	-	274	18	63	1	4	53	47
E. Weather	532	0.6	157	14	18	32	63	530	84
F. Instructions or inspections	298	0.4	51	7	8	3	14	3	1
G. Personnel:									
1. Start late, quit early, or excess lunchtime	155	0.2	19	6	5	4	24	2	1
2. Idle	901	1.0	15	2	4	-	5	3	-
3. Personal	211	0.3	25	-	1	-	205	1	2
	1,267	1.5	59	8	10	4	234	6	3
H. All other	781	0.8	223	36	39	4	99	46	10
Subtotal	3,142	3.6	16,689	10,782	7,461	776	10,511	31,582	36,597
TAWT (I + II + III + IV)	(86,225)	(100.0)	(41,981)	(14,173)	(12,177)	(1,431)	(17,977)	(38,884)	(40,303)

TABLE 5

LABOR AND EQUIPMENT TIME IN CEDAR COUNTY (INCLUDING DISTRIBUTED OVERHEAD)

Operation	Labor time (Hours)	Percent of TAWT	EQUIPMENT TIME IN HOURS						
			Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and front-end loaders	All other
I Overhead operations — undistributed:									
A. Supervise maintenance activities	2,182	7.5	25	-	-	-	816	-	-
B. Service and repair equipment:									
1. Service or repair maintenance equipment	4,442	15.2	73	5	1	-	417	19	-
2. Service or repair non-maintenance equipment	472	1.6	23	-	-	-	49	1	-
	4,914	16.8	96	5	1	-	466	20	-
C. Clean, repair or improve garage facilities	868	3.0	224	17	9	-	59	53	173
Subtotal	7,964	27.3	345	22	10	-	1,341	73	173
II Direct operations — maintenance of existing system:									
A. Routine surface:									
1. Patch roadway surfaces with aggregate	861	2.9	465	106	1	2	40	60	4
2. Patch roadway surfaces with bituminous cold mix	1,717	5.9	737	53	5	-	106	34	11
3. Patch roadway surfaces with bituminous hot mix	79	0.3	27	2	-	-	9	-	-
4. Blade gravel surfaces	401	1.4	-	1	372	-	6	1	1
5. Fill joints and cracks in roadway surfaces	38	0.1	14	-	-	-	-	1	-
6. Clean or drain roadway surfaces	111	0.4	44	2	-	-	18	-	-
	3,207	11.0	1,287	164	378	2	179	96	16
B. Special surface:									
1. Seal bituminous and concrete pavements	1,119	3.8	602	3	1	3	26	98	284
2. Resurface with bituminous mixes	495	1.7	186	47	94	-	9	107	207
3. Plane or roll bituminous pavements	54	0.2	4	24	-	-	1	6	6
4. Rebuild aggregate base courses	113	0.4	50	3	5	18	25	19	11
	1,781	6.1	842	77	100	21	61	230	508
C. Shoulder and approach:									
1. Patch shoulders and approaches with soil	6	-	2	-	-	-	-	-	-
2. Patch shoulders and approaches with aggregate	333	1.1	154	6	-	1	5	25	1
3. Patch shoulders and approaches with bituminous cold mix	160	0.6	71	4	-	-	6	2	4
4. Blade or reshape shoulders and approaches	16	0.1	-	3	9	-	1	1	-
	515	1.8	227	13	9	1	12	28	5
D. Roadside and drainage:									
1. Repair cut and fill slopes	15	0.1	7	-	-	-	-	-	-
2. Repair or replace pipes and tiles	95	0.3	46	-	-	-	9	2	8
3. Clean pipes, tiles and box culverts	57	0.2	25	-	-	-	1	1	-
4. Clean or repair unpaved drainage ditches	46	0.2	17	8	3	6	1	-	-
5. Clean paved flumes, gutters and drop inlets	151	0.5	48	1	-	-	13	5	-
6. Mow roadsides with tractors (including shoulders)	2,156	7.4	291	17	1	2	101	1,997	5
7. Mow roadsides with hand tools (including shoulders)	298	1.0	154	8	-	-	19	23	1
8. Spray weeds on roadsides	276	0.9	130	-	-	-	4	1	112
	3,094	10.6	718	34	4	8	148	2,029	126
E. Snow and ice:									
1. Remove snow from roadway surfaces and shoulders	3,941	13.5	1,481	408	326	18	248	52	-
2. Remove snow from bridges	92	0.3	42	-	-	-	14	2	-
3. Erect snow fences	1,025	3.5	414	1	1	1	30	2	-
4. Remove snow fences	598	2.1	221	-	7	-	31	1	-
5. Sand roadway surfaces	847	2.9	348	70	-	29	36	96	-
6. Salt roadway surfaces	405	1.4	175	6	-	-	20	33	-
7. Remove ice from roadway surfaces and shoulders	205	0.7	18	97	-	-	13	-	-
8. Remove snow and ice from drainage ditches	130	0.5	54	-	-	-	16	-	-
	7,243	24.9	2,753	582	334	48	408	186	
F. Traffic service:									
1. Paint centerlines and edgelines	485	1.6	89	-	-	-	202	1	68
2. Paint bridge endwalls, medians and miscellaneous pavement markings	123	0.4	42	-	-	-	28	-	-
3. Erect, replace, repair or paint signs and guideposts	514	1.8	151	-	-	-	179	1	2

4. Clean signs and reflectors	83		0.3		14		2		-		-		34		-		-	
5. Remove or paint guardrails	29		0.1		8		-		-		-		14		-		-	
6. Miscellaneous work at weigh stations and roadside parks	110		0.4		49		1		-		-		6		10		1	
		1,344		4.6		353		3		-		-		463		12		71
G. Other:																		
1. Clean or repair bridges	2		-		-		-		-		-		-		1		-	
2. Remove litter from right-of-way	166		0.6		67		3		-		-		6		-		-	
3. Miscellaneous work resulting from disasters	7		-		-		-		-		-		-		-		-	
4. Miscellaneous work resulting from maintenance contracts	425		1.5		248		-		-		-		65		14		1	
		600		2.1		315		3		-		-		71		15		1
Subtotal		17,784		61.1		6,495		876		825		80		1,342		2,596		727
III Direct operations — new construction:																		
A. Detour:																		
1. Patch roadway surfaces with aggregate	404		1.4		257		13		-		1		26		14		2	
2. Patch roadway surfaces with bituminous cold mix	12		0.1		8		-		-		-		-		-		-	
3. Blade gravel surfaces	377		1.3		4		2		349		-		5		1		2	
4. Clean or drain roadway surfaces	16		0.1		7		-		-		-		1		-		-	
5. Rebuild gravel surfaces	202		0.7		94		7		7		-		15		23		1	
6. Repair cut and fill slopes	10		0.1		5		-		-		-		-		1		-	
7. Remove snow from roadway surfaces and shoulders	93		0.3		36		5		15		1		6		1		-	
8. Remove snow from bridges	2		-		1		-		-		-		-		-		-	
9. Erect snow fences	9		-		3		-		-		-		-		-		-	
10. Remove snow fences	1		-		1		1		-		-		-		-		-	
11. Sand roadway surfaces	33		0.1		15		5		-		1		2		3		-	
12. Remove ice from roadway surfaces and shoulders	10		-		-		-		-		-		1		-		-	
13. Erect, replace, repair or paint signs and guideposts	4		-		-		-		-		-		4		-		-	
14. Clean signs and reflectors	9		-		-		-		-		-		8		-		-	
15. Miscellaneous work resulting from detours	114		0.4		20		-		5		-		49		4		3	
		1,296		4.5		451		33		376		3		117		47		8
B. Miscellaneous work resulting from construction contracts		939		3.2		297		24		167		8		154		23		11
Subtotal		2,235		7.7		748		57		543		11		271		70		19
NAWT (I + II + III)	(27,983)		(96.1)		(7,588)		(955)		(1,378)		(91)		(2,954)		(2,739)		(919)	
IV Major non-operational delays:																		
A. Service and repair:																		
1. Service (fuel, oil, grease, wash, etc.)	4		-		250		50		68		1		44		84		8	
2. Repair engines and power trains	82		0.3		250		120		32		-		73		105		41	
3. Repair chasses and bodies	16		0.1		19		7		4		-		2		1		-	
4. Repair tires	3		-		4		2		14		-		5		59		-	
5. Repair hoists and attachments	21		0.1		136		75		13		-		-		91		1	
6. All other repair	34		0.1		128		23		11		-		48		86		21	
		160		0.6		787		277		142		1		172		426		71
B. Standby — awaiting repair		-		-		311		262		23		-		43		309		97
C. Standby — no work		-		-		3,429		3,145		2,113		1		3,213		8,593		17,019
D. Change attachments or make other modifications		-		-		86		9		19		-		-		28		-
E. Weather		341		1.2		83		6		2		-		29		181		21
F. Instructions or inspections		68		0.2		11		3		1		-		9		-		1
G. Personnel:																		
1. Start late, quit early, or excess lunchtime	93		0.3		9		2		-		1		8		2		-	
2. Idle	243		0.8		11		2		3		-		5		1		-	
3. Personal	53		0.2		19		-		-		-		103		1		-	
		389		1.3		39		4		3		1		116		4		-
H. All other		182		0.6		33		7		2		3		22		14		1
Subtotal		1,140		3.9		4,779		3,713		2,305		6		3,604		9,555		17,210
TAWT (I + II + III + IV)	(29,123)		(100.0)		(12,367)		(4,668)		(3,683)		(97)		(6,558)		(12,294)		(18,129)	

TABLE 6
LABOR AND EQUIPMENT TIME IN IOWA COUNTY (INCLUDING DISTRIBUTED OVERHEAD)

Operation	Labor time (Hours)		Percent of TAWT		EQUIPMENT TIME IN HOURS													
					Light duty trucks		Medium and heavy duty trucks		Motor-graders		Drag-lines		Pickups		Tractors and front-end loaders		All others	
I Overhead operations - undistributed:																		
A. Supervise maintenance activities		1,396		5.7		2		-		-		-		456		-		-
B. Service and repair equipment:																		
1. Service or repair maintenance equipment	3,080		12.7		24		3		-		1		285		11		-	
2. Service or repair non-maintenance equipment	140		0.6		1		-		-		-		20		-		-	
		3,220		13.3		25		3		-		1		305		11		-
C. Clean, repair or improve garage facilities		698		2.9		37		4		1		2		11		26		-
Subtotal		5,314		21.9		64		7		1		3		772		37		-
II Direct operations - maintenance of existing system:																		
A. Routine surface:																		
1. Patch roadway surfaces with aggregate	270		1.1		210		13		7		1		5		1		1	
2. Patch roadway surfaces with bituminous cold mix	485		2.0		263		1		2		-		14		12		83	
3. Patch roadway surfaces with bituminous hot mix	1,097		4.5		533		95		2		1		29		136		554	
4. Blade gravel surfaces	177		0.7		3		39		94		-		3		4		1	
5. Fill joints and cracks in roadway surfaces	1		-		1		-		-		-		-		-		-	
6. Clean or drain roadway surfaces	53		0.2		22		5		-		-		1		2		-	
		2,083		8.5		1,032		153		105		2		52		155		639
B. Special surface:																		
1. Mudjack concrete pavements	788		3.2		407		108		45		1		23		109		178	
2. Rebuild gravel surfaces	965		4.0		764		130		20		1		20		1		4	
3. Seal bituminous and concrete pavements	700		2.9		451		58		20		2		15		52		193	
4. Resurface with bituminous mixes	267		1.1		138		9		20		-		11		23		59	
5. Plane or roll bituminous pavements	65		0.3		12		-		30		-		16		-		-	
6. Rebuild aggregate base courses	520		2.1		282		55		31		31		63		78		70	
		3,305		13.6		2,054		360		166		35		148		263		504
C. Shoulder and approach:																		
1. Patch shoulders and approaches with soil	19		0.1		9		-		-		-		-		2		-	
2. Patch shoulders and approaches with aggregate	327		1.3		212		-		2		1		6		13		21	
3. Patch shoulders and approaches with bituminous cold mix	93		0.4		41		-		11		-		3		9		19	
4. Blade or reshape shoulders and approaches	137		0.6		7		32		22		1		4		54		-	
		576		2.4		269		32		35		2		13		78		40
D. Roadside and drainage:																		
1. Repair cut and fill slopes	171		0.7		85		17		-		15		18		4		3	
2. Repair or replace pipes and tiles	91		0.4		35		7		3		12		14		1		-	
3. Clean pipes, tiles and box culverts	44		0.2		18		-		-		6		2		-		-	
4. Clean or repair unpaved drainage ditches	1,129		4.6		446		12		4		220		248		20		4	
5. Clean paved flumes, gutters and drop inlets	8		-		3		-		-		-		-		-		-	
6. Repair stone riprap	217		0.9		96		4		-		-		10		34		30	
7. Remove trees from roadsides	56		0.2		25		-		-		2		3		-		-	
8. Mow roadsides with tractors (including shoulders)	1,410		5.8		306		2		2		1		55		1,286		6	
9. Mow roadsides with hand tools (including shoulders)	314		1.3		151		-		-		-		7		-		1	
10. Spray weeds on roadsides	180		0.8		44		-		-		-		29		51		52	
		3,620		14.9		1,209		42		9		256		386		1,396		96
E. Snow and ice:																		
1. Remove snow from roadway surfaces and shoulders	3,466		14.3		1,704		506		424		15		241		55		-	
2. Remove snow from bridges	154		0.6		50		15		16		-		11		-		-	
3. Erect snow fences	860		3.5		362		1		1		1		25		1		-	

4. Remove snow fences	509		2.1		208		1		1		1		12		17		-	
5. Sand roadway surfaces	1,061		4.4		752		9		1		14		48		48		-	
6. Salt roadway surfaces	267		1.1		113		18		-		-		12		9		-	
7. Remove ice from roadway surfaces and shoulders	238		1.0		135		30		4		-		18		7		-	
8. Remove snow and ice from drainage ditches	19		0.1		9		1		-		-		-		1		-	
9. Put out and remove cinder barrels	28		0.1		14		-		-		-		1		1		-	
		6,602		27.2		3,347		581		447		31		368		139		-
F. Traffic Service:																		
1. Paint centerlines and edgelines	429		1.8		35		20		-		-		175		-		66	
2. Paint bridge endwalls, medians and misc pvt markings	21		0.1		8		-		-		1		-		-		-	
3. Erect, replace, repair or paint signs and guideposts	389		1.6		187		1		1		1		31		1		22	
4. Clean signs and reflectors	225		0.9		118		-		-		-		20		-		1	
		1,064		4.4		348		21		1		2		226		1		89
G. Other:																		
1. Clean or repair bridges	150		0.6		54		-		-		-		13		-		22	
2. Remove litter from right-of-way	192		0.8		87		-		-		-		4		-		1	
3. Miscellaneous work resulting from disasters	182		0.8		94		13		-		1		5		3		1	
4. Miscellaneous work resulting from maintenance contracts	201		0.8		161		-		22		-		5		-		1	
		725		3.0		396		13		22		1		27		3		25
Subtotal		17,975		74.0		8,655		1,202		785		329		1,220		2,035		1,393
III Direct operations - new construction:																		
A. Detour — miscellaneous work		5		-		2		-		1		-		-		-		-
B. Miscellaneous work resulting from construction contracts		603		2.4		104		35		413		2		29		60		2
Subtotal		608		2.4		106		35		414		2		29		60		2
NAWT (I + II + III)	(23,897)		(98.3)		(8,825)		(1,244)		(1,200)		(334)		(2,021)		(2,132)		(1,395)	
IV Major non-operational delays:																		
A. Service and repair:																		
1. Service (fuel, oil, grease, wash, etc.)	2		-		183		26		79		3		32		90		7	
2. Repair engines and power trains	17		0.1		167		20		115		8		18		63		10	
3. Repair chasses and bodies	-		-		10		3		-		-		4		2		-	
4. Repair tires	2		-		13		-		13		-		7		17		-	
5. Repair hoists and attachments	4		-		134		36		45		3		-		83		-	
6. All other repair	18		0.1		126		41		53		5		10		55		25	
		43		0.2		633		126		305		19		71		310		42
B. Standby — awaiting repair		-		-		35		21		204		-		13		365		-
C. Standby — no work		-		-		3,398		2,916		886		54		3,014		10,516		11,068
D. Change attachments or make other modifications		-		-		146		7		20		1		4		25		16
E. Weather		61		0.3		42		8		10		32		10		76		34
F. Instructions or inspections		26		0.1		8		-		1		1		2		1		-
G. Personnel:																		
1. Start late, quit early, or excess lunchtime	14		0.1		3		1		1		3		5		-		-	
2. Idle	20		0.1		2		-		-		-		-		2		-	
3. Personal	35		0.1		2		-		-		-		69		-	-	-	
		69		0.3		7		1		1		3		74		2		-
H. All other		206		0.8		83		15		22		1		25		6		6
Subtotal		405		1.7		4,352		3,094		1,449		111		3,213		11,301		11,166
TAWT (I + II + III + IV)	(24,302)		(100.0)		(13,177)		(4,338)		(2,649)		(445)		(5,234)		(13,433)		(12,561)	

TABLE 7

LABOR AND EQUIPMENT TIME IN JOHNSON COUNTY (INCLUDING DISTRIBUTED OVERHEAD)

Operation	Labor time (Hours)		Percent of TAWT		EQUIPMENT TIME IN HOURS													
					Light duty trucks		Medium and heavy duty trucks		Motor-graders		Drag-lines		Pickups		Tractors and front-end loaders		All other	
I Overhead operations — undistributed:																		
A. Supervise maintenance activities		1,976		6.0		6		-		-		-		876		-		-
B. Service and repair equipment:																		
1. Service or repair maintenance equipment	5,514		16.8		65		2		2		5		299		33		-	
2. Service or repair non-maintenance equipment	505		1.5		3		-		-		-		35		-		-	
		6,019		18.3		68		2		2		5		334		33		-
C. Clean, repair or improve garage facilities		1,211		3.7		33		1		7		-		14		28		-
Subtotal		9,206		28.0		107		3		9		5		1,224		61		-
II Direct operations – maintenance of existing system:																		
A. Routine surface:																		
1. Patch roadway surfaces with aggregate	1,481		4.5		625		1		341		19		35		114		48	
2. Patch roadway surfaces with bituminous cold mix	2,095		6.4		898		19		147		3		56		102		119	
3. Blade gravel surfaces	286		0.9		45		-		217		-		3		-		1	
4. Fill joints and cracks in roadway surfaces	177		0.6		73		-		-		-		3		1		35	
5. Apply dust palliatives to gravel surfaces	142		0.4		61		8		-		-		5		4		25	
6. Clean or drain roadway surfaces	34		0.1		9		-		5		-		6		-		-	
		4,215		12.9		1,711		28		710		22		108		221		228
B. Special surface:																		
1. Mudjack concrete pavements	303		0.9		169		-		1		-		5		2		54	
2. Seal bituminous and concrete pavements	1,662		5.1		815		131		2		10		30		63		421	
3. Resurface with bituminous mixes	758		2.3		373		51		120		1		10		152		283	
4. Plane or roll bituminous pavements	136		0.4		38		-		50		-		17		30		31	
		2,859		8.7		1,395		182		173		11		62		247		789
C. Shoulder and approach:																		
1. Patch shoulders and approaches with soil	589		1.8		327		21		99		1		10		7		58	
2. Patch shoulders and approaches with aggregate	791		2.4		361		24		22		9		13		29		15	
3. Patch shoulders and approaches with bituminous cold mix	917		2.8		334		114		34		1		12		72		114	
4. Reseed or resod shoulders and approaches	102		0.3		43		-		-		-		1		22		6	
5. Blade or reshape shoulders and approaches	226		0.7		31		-		160		-		3		12		-	
		2,625		8.0		1,096		159		315		11		39		142		193
D. Roadside and drainage:																		
1. Repair cut and fill slopes	177		0.5		87		-		15		-		3		18		-	
2. Repair or replace pipes and tiles	87		0.3		57		-		-		7		8		1		-	
3. Clean pipes, tiles and box culverts	257		0.8		96		-		23		25		31		38		-	
4. Clean or repair unpaved drainage ditches	430		1.3		174		1		8		64		61		3		1	
5. Clean paved flumes, gutters and drop inlets	4		-		3		-		-		-		-		-		-	
6. Remove trees from roadsides	89		0.3		37		-		-		-		4		-		-	
7. Mow roadsides with tractors (including shoulders)	1,596		4.8		137		2		1		2		76		1,398		4	
8. Spray weeds on roadsides	157		0.5		38		-		-		-		21		44		54	
		2,797		8.5		629		3		47		98		204		1,502		59
E. Snow and ice:																		
1. Remove snow from roadway surfaces and shoulders	3,780		11.5		1,658		627		722		28		190		41		-	
2. Erect snow fences	619		1.9		274		1		-		1		9		-		-	
3. Remove snow fences	492		1.5		153		1		-		1		47		32		-	
4. Sand roadway surfaces	469		1.4		262		2		2		12		23		38		-	
5. Salt roadway surfaces	691		2.1		257		73		103		1		24		49		-	

6. Remove ice from roadway surfaces and shoulders	485		1.5		218		103		-		1		24		4		-	
7. Remove snow and ice from drainage ditches	89		0.3		26		-		-		-		22		-		-	
8. Put out and remove cinder barrels	122		0.4		57		-		-		-		5		1		-	
		6,747		20.6		2,905		807		827		44		344		165		-
F. Traffic Service:																		
1. Paint centerlines and edgelines	479		1.5		45		1		8		1		225		-		66	
2. Paint bridge endwalls, medians and miscellaneous pavement markings	317		1.0		68		-		3		-		49		23		47	
3. Erect, replace, repair or paint signs and guideposts	606		1.8		211		1		-		1		83		14		1	
4. Clean signs and reflectors	97		0.3		35		-		-		-		22		4		3	
5. Remove or paint guardrails	77		0.2		27		-		5		-		2		3		-	
6. Miscellaneous work at weigh stations and roadside parks	88		0.3		37		-		13		14		1		6		-	
		1,664		5.1		423		2		29		16		382		50		117
G. Other:																		
1. Clean or repair bridges	29		0.1		13		-		-		-		-		-		-	
2. Remove litter from right-of-way	140		0.4		49		-		-		-		6		-		-	
3. Miscellaneous work resulting from disasters	15		0.1		2		-		-		-		12		-		-	
4. Miscellaneous work resulting from maintenance contracts	48		0.1		1		-		19		-		23		-		-	
		232		0.7		65		-		19		-		41		-		-
Subtotal		21,139		64.5		8,224		1,181		2,120		202		1,180		2,327		1,386
III Direct operations — new construction:																		
A. Detour:																		
1. Patch roadway surfaces with bituminous cold mix	174		0.5		88		1		9		-		2		15		5	
2. Rebuild aggregate base courses	168		0.5		80		7		-		23		8		5		-	
3. Mow roadsides with tractor (including shoulders)	19		0.1		-		-		-		-		-		17		-	
4. Erect, replace, repair or paint signs and guideposts	244		0.8		106		-		-		-		36		-		1	
5. Miscellaneous work resulting from detours	142		0.4		27		-		-		-		31		-		-	
		747		2.3		301		8		9		23		77		37		6
B. Miscellaneous work resulting from construction contracts		111		0.3		47		-		-		-		10		6		-
Subtotal		858		2.6		348		8		9		23		87		43		6
NAWT (I + II + III)	(31,203)		(95.1)		(8,679)		(1,192)		(2,138)		(230)		(2,491)		(2,431)		(1,392)	
IV Major non-operational delays:																		
A. Service and repair:																		
1. Service (fuel, oil, grease, wash, etc.)	6		-		496		131		96		16		88		36		10	
2. Repair engines and power trains	31		0.1		488		72		124		63		33		42		80	
3. Repair chasses and bodies	1		-		117		4		35		10		24		41		-	
4. Repair tires	1		-		24		2		13		-		5		50		2	
5. Repair hoists and attachments	1		-		210		134		62		1		-		138		1	
6. All other repair	21		0.1		277		51		66		10		46		56		20	
		61		0.2		1,612		394		396		100		196		363		113
B. Standby - awaiting repair		-		-		259		155		39		11		88		768		53
C. Standby - no work		-		-		5,661		3,403		3,215		546		3,287		9,294		7,989
D. Change attachments or make other modifications		-		-		42		2		24		-		-		-		31
E. Weather		130		0.4		32		-		6		-		24		273		29
F. Instructions or inspections		204		0.6		32		4		6		2		3		2		-
G. Personnel:																		
1. Start late, quit early, or excess lunchtime	48		0.1		7		3		4		-		11		-		1	
2. Idle	638		2.0		2		-		1		-		-		-		-	
3. Personal	123		0.4		4		-		1		-		33		-		2	
		809		2.5		13		3		6		-		44		-		3
H. All other		393		1.2		107		14		15		-		52		26		3
Subtotal		1,597		4.9		7,758		3,975		3,707		659		3,694		10,726		8,221
TAWT (I + II + III + IV)	(32,800)		(100.0)		(16,437)		(5,167)		(5,845)		(889)		(6,185)		(13,157)		(9,613)	

5. Distribution of labor and equipment time in the three-county control area by selected road subsections

As previously indicated, labor and equipment time was classified according to location of worksite during comprehensive studies. For direct operations, worksites were identified by county, State road sections, and for certain kinds of work, by study subsections. Overhead operation worksites were identified only by county. The labor and equipment time for distributed overhead and direct operations which had not been charged originally to study subsections was allocated to these subsections. Next, study subsections were classified according to rural or urban location, principal surface type, period of most recent surface construction, or reconstruction, and average daily traffic (ADT) Subsections which were not reasonably homogeneous or which had special factors influencing maintenance were excluded at this point. Most of the exclusions were for the following reasons: (1) principal surface type accounted for less than 90 percent of a subsection's surface area; (2) subsection was a detour over county roads; (3) maintenance of most items in subsection was contracted; and (4) subsection was maintained by State crews for less than a full year during the study period.

Similar subsections were grouped according to one or more classification factors. The data for each group were averaged to determine labor and equipment time expended per mile for each operation. Table 8 shows the basis of classification for each group, total length of subsections in the group and average workload per mile as found during the field inventory. Note that there is a wide variation in the number of miles of road included in each group. Also, classification factors do not take into account all of the variables affecting maintenance. This would indicate that differences between subsection groups for average labor and equipment time per mile should be evaluated carefully and perhaps considered as trends rather than actual differences which might be applied over the entire State primary system.

Table 9 provides a summary of labor time charged to major groups of direct operations for each road subsection group while Tables 10 to 46 show a more detailed breakdown of labor and equipment time for each road subsection group. The time shown includes allocations of distributed overhead as indicated above but does not include any part of undistributed overhead operations.

If the reader should desire to make an allocation of undistributed overhead operation charges to other accounts, it can be accomplished by several means. One way would be to use labor time as a base. This can be readily done by using the following rate table which indicates the amount of labor or equipment time that would need to be added to the respective labor and equipment groups in Tables 10 to 46 for each hour of labor time per mile shown in these tables.

Labor	0.371 hour/mile
Light duty trucks	0.009 hour/mile
Medium and heavy duty trucks	Negligible
Motorgraders	"
Draglines	"
Pickups	0.055 hour/mile
Tractors and front-end loaders ..	0.003 hour/mile
All other	0.003 hour/mile

TABLE 8

INVENTORY OF WORKLOAD FOR SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (8-17-59)

— Quantities per mile —

Road sub-section group	Loca-tion	Principal surface type	Period con-structed 1/	ADT	Length of group (Mile)	Roadway surface area 2/ (Sq Yd)	Shoulders and approaches			ROW area 6/ (Acre)	Mowed area 7/ (Acre)	Roadway and approach drainage structures					Signs 8/	Posts					Guard-rail (Lin Ft) 9/	Snow-fence (Lin Ft)
							Shoulder area 3/ (Sq Yd)	Inter-secting roads 4/	Drives or en-trances 5/			Bridge or bridge culverts	Box cul-verts	Pipes	Drop inlets	Spill-ways		Sign	Guide	Guard-rail	Other	Total		
1	Rural	Portland cement concrete	1926-45	Under 1000	0.87	11,355	7,090	1	17	5.2	2.5	-	1	7	1	7	26	18	131	24	-	173	230	290
2	"	"	"	1000-3000	52.01	11,180	8,325	2	87	8.4	7.4	0.2	3	6	1	6	8	7	15	28	2	52	276	841
3	"	"	1946-59	Under 1000	3.13	17,925	13,915	2	12	18.4	18.1	0.6	1	14	-	-	10	7	2	4	-	13	36	-
4	"	"	"	1000-3000	16.16	12,905	11,220	2	10	12.1	10.5	0.3	2	10	1	1	7	6	3	-	-	9	-	286
5	"	"	"	3000-5000	10/ 22.80	14,515	11,370	2	5	15.0	13.5	0.1	2	6	1	1	9	8	3	-	-	11	-	19
6	"	Bituminous overlay	"	1000-3000	23.45	10,635	8,555	2	7	8.0	7.5	0.5	3	6	1	6	13	11	13	-	17	41	-	733
7	"	"	"	3000-5000	37.50	11,845	6,980	2	9	5.3	5.0	0.1	3	7	1	-	14	14	8	-	9	31	2	653
8	"	Bituminous plant mix	"	Under 1000	22.82	13,695	9,705	2	7	13.2	13.0	0.4	2	6	1	-	9	8	4	-	5	17	-	32
9	"	"	"	1000-3000	17.93	13,750	5,385	2	9	9.5	9.2	0.3	3	6	-	-	14	14	4	-	10	28	-	265
10	"	Bituminous treated	1926-45	1000-3000	8.45	14,045	2,610	2	12	3.7	3.2	-	1	13	1	-	11	10	4	-	-	14	-	1,508
11	"	"	1946-59	Under 1000	6.09	14,350	4,155	1	7	12.2	11.8	0.3	2	5	-	-	9	9	6	-	-	15	-	-
12	"	Gravel	1926-45	Under 1000	9.65	20,535	-	1	8	4.4	4.1	0.1	3	6	1	-	9	8	14	-	-	22	-	969
13	Urban	Portland cement concrete	"	1000-3000	2.30	16,866	1,605	20	5	1.7	1.7	1.7	1	6	18	3	62	52	5	-	-	57	-	31
14	"	"	"	3000-5000	0.61	11,215	9,610	7	13	-	-	1.6	3	10	-	-	34	33	3	-	-	36	-	-
15	"	"	"	Over 5000	1.84	15,300	3,460	11	10	0.5	0.5	-	1	7	8	-	35	24	2	-	-	26	-	365
16	"	"	1946-59	Under 1000	0.12	14,415	-	17	-	-	-	-	-	8	17	-	42	33	-	-	-	33	-	-
17	"	"	"	1000-3000	0.50	12,680	-	10	36	-	-	-	4	34	4	-	24	24	4	-	6	34	-	-
18	"	"	"	Over 5000	11/ 6.78	14,225	9,570	3	7	7.7	7.5	0.3	1	5	3	-	18	26	2	10	-	38	76	-
19	"	Bituminous overlay	"	1000-3000	0.64	10,565	4,815	17	2	3.1	3.1	-	3	3	-	-	63	45	5	-	6	56	-	-
20	"	"	"	3000-5000	1.11	20,315	110	18	17	0.2	0.2	-	4	14	12	-	74	67	2	-	2	71	-	-
21	"	Bituminous plant mix	"	Under 1000	0.40	23,225	-	5	5	1.8	1.8	-	-	3	20	-	8	8	-	-	-	8	-	590
22	"	"	"	1000-3000	0.91	8,980	780	12	53	0.7	0.7	1.1	-	37	-	-	68	56	5	-	8	69	-	-
23	"	Bituminous treated	1926-45	Under 1000	0.62	11,340	5,550	10	15	3.4	3.2	-	5	16	-	-	52	40	3	-	8	51	-	787
24	"	"	1946-59	1000-3000	1.09	16,385	3,835	10	7	5.5	1.6	-	4	9	2	-	42	35	-	-	-	35	-	-
25	All rural				10/ 220.95	12,880	7,925	2	8	9.3	8.5	0.3	3	7	1	2	11	10	9	7	5	31	67	536
26	All urban				11/ 16.92	18,575	8,015	9	11	6.1	5.7	0.5	2	11	7	1	42	35	2	4	1	42	51	87
27	All portland concrete surfaces				10/ 11/ 107.12	13,350	9,780	2	8	10.5	9.4	0.3	2	7	1	3	11	10	9	14	1	34	145	465
28	All bituminous overlay surfaces				62.70	11,525	7,425	2	8	6.2	5.8	0.3	3	6	1	2	15	14	10	-	12	36	1	665
29	All bituminous plant mix surfaces				42.06	13,710	7,580	2	9	11.3	11.0	0.4	2	7	1	-	13	11	4	-	7	22	-	136
30	All bituminous treated surfaces				16.34	14,215	3,380	2	10	7.0	6.3	0.1	2	10	1	-	14	12	4	-	-	16	-	818
31	All gravel surfaces				9.65	20,535	-	1	8	4.4	4.1	0.1	3	6	1	-	9	8	14	-	-	22	-	969
32	All constructed 1926-45				76.44	12,965	6,295	3	9	6.8	6.0	0.3	3	7	1	4	12	10	14	19	1	44	191	882
33	All constructed 1946-59				10/ 11/ 161.43	13,435	8,710	2	8	10.1	9.4	0.3	2	7	1	1	13	12	6	1	6	25	7	325
34	All under 1000 ADT				43.70	15,615	6,865	2	8	11.1	10.7	0.3	2	7	1	1	10	9	9	1	2	21	7	253
35	All 1000-3000 ADT				123.53	12,020	7,660	2	9	8.4	7.5	0.3	3	7	1	4	12	11	10	12	5	38	116	673
36	All 3000-5000 ADT				10/ 62.02	12,960	8,490	2	8	8.7	7.9	0.1	2	7	1	1	15	13	6	-	5	24	1	401
37	All over 5000 ADT				11/ 8.62	21,915	13,285	5	8	10.2	10.0	0.3	1	8	6	-	30	26	1	8	-	35	100	78

1/ Period during which most recent surface construction or reconstruction took place.

2/ Bridge decks and small areas (less than 10 percent) of different surface types have been combined with principal surface type.

3/ All shoulders were basically soil and sod although some had received applications of aggregate and bituminous mixes. Gravel surfaced roads were assumed to have no shoulders.

4/ Maintained in whole or part by city and county forces.

5/ Does not include mailbox turnouts. Maintained in part by owner.

6/ Area between outside edges of shoulders and right-of-way lines.

7/ Area which maintenance crews normally mowed including shoulders but excluding steep slopes, marshy areas, etc.

8/ Does not include reflectors.

9/ Both cable and beam types.

10/ Includes 0.85 mile of 3-lane surface.

11/ Includes 4.52 miles of 4-lane surface.

TABLE 9

SUMMARY OF LABOR TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

— Time in hours per mile —

Road sub-section group	Loca-tion	Principal surface type	Period con-structed 1/	ADT	Routine surface	Special surface	Shoulder and approach	Roadside and drainage	Snow and ice	Traffic service	Other	Total
1	Rural	Portland cement concrete	1926-45	Under 1000	62.4	-	19.3	18.4	108.7	54.5	-	263.3
2	"	"	"	1000-3000	21.2	0.1	12.0	37.8	96.6	13.8	7.1	188.6
3	"	"	1946-59	Under 1000	0.9	25.0	17.7	18.9	59.4	14.4	85.1	221.4
4	"	"	"	1000-3000	3.3	3.9	27.6	15.9	60.3	9.8	3.8	124.6
5	"	"	"	3000-5000	0.8	-	28.7	46.7	59.8	11.6	1.1	148.7
6	"	Bituminous overlay	"	1000-3000	51.0	6.9	5.2	39.2	85.5	9.8	4.7	202.3
7	"	"	"	3000-5000	5.1	0.2	14.9	44.0	82.4	18.2	6.1	170.9
8	"	Bituminous plant mix	"	Under 1000	31.7	75.8	2.4	31.1	66.2	14.0	1.0	222.2
9	"	"	"	1000-3000	2.7	11.1	2.0	38.5	65.2	9.0	2.6	131.1
10	"	Bituminous treated	1926-45	1000-3000	301.4	221.0	4.3	4.6	110.3	10.2	1.4	653.2
11	"	"	1946-59	Under 1000	40.3	100.6	9.4	6.6	31.8	5.5	5.6	199.8
12	"	Gravel	1926-45	Under 1000	131.5	99.7	0.3	11.9	74.3	0.8	33.9	352.4
13	Urban	Portland cement concrete	"	1000-3000	12.8	-	8.2	7.6	72.1	21.6	-	122.3
14	"	"	"	3000-5000	46.7	-	22.5	32.9	53.6	31.9	5.9	193.5
15	"	"	"	Over 5000	173.1	-	8.6	33.3	72.4	14.7	56.9	359.0
16	"	"	1946-59	Under 1000	-	-	-	-	115.8	9.2	-	125.0
17	"	"	"	1000-3000	-	102.2	18.8	8.8	51.8	11.0	10.4	203.0
18	"	"	"	Over 5000	15.1	-	50.0	84.2	78.7	40.9	7.2	276.1
19	"	Bituminous overlay	"	1000-3000	41.9	-	-	5.0	55.9	17.3	-	120.1
20	"	"	"	3000-5000	28.4	29.8	9.6	-	53.3	21.9	-	143.0
21	"	Bituminous plant mix	"	Under 1000	-	-	-	41.0	75.0	21.1	-	137.1
22	"	"	"	1000-3000	6.4	12.8	4.5	6.6	54.4	22.7	5.7	113.1
23	"	Bituminous treated	1926-45	Under 1000	232.7	808.6	37.3	64.1	53.7	20.3	106.6	1,323.3
24	"	"	1946-59	1000-3000	48.0	50.5	3.7	4.2	34.9	2.0	-	143.3
25	All rural				33.8	25.8	12.0	34.0	78.2	12.4	6.8	203.0
26	All urban				43.8	38.6	25.9	43.9	68.0	27.1	13.7	261.0
27	All portland cement concrete surfaces				16.0	1.9	20.5	37.6	79.8	14.9	8.3	179.0
28	All bituminous overlay surfaces				23.1	3.2	10.9	41.0	82.8	15.0	5.3	181.3
29	All bituminous plant mix surfaces				18.5	46.1	2.3	33.7	65.4	12.0	1.8	179.8
30	All bituminous treated surfaces				184.6	187.1	7.4	7.6	73.7	8.2	6.9	475.5
31	All gravel surfaces				131.5	99.7	0.3	11.9	74.3	0.8	33.9	352.4
32	All constructed 1926-45				72.1	43.9	9.9	32.7	93.5	12.6	11.6	276.3
33	All constructed 1946-59				16.7	18.7	14.5	35.6	69.7	14.0	5.2	174.4
34	All under 1000 ADT				55.7	88.9	4.8	22.7	63.5	10.9	16.4	262.9
35	All 1000-3000 ADT				41.0	19.6	10.6	31.6	84.7	11.7	4.9	204.1
36	All 3000-5000 ADT				4.4	0.7	19.8	43.9	73.0	16.0	4.1	161.9
37	All over 5000 ADT				48.9	-	41.1	73.3	77.3	35.3	17.7	293.6

1/ Period during which most recent surface construction or reconstruction took place.

TABLE 10

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 1: Location – Rural; Surface – Portland cement concrete; Period constructed – 1926-45;
Average daily traffic – Under 1000

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	62.4	25.9	.2	1.8	-	7.0	.6	2.0
Subtotal	62.4	25.9	.2	1.8	-	7.0	.6	2.0
B. Special surface:	-	-	-	-	-	-	-	-
C. Shoulder and approach								
1. Patch shoulders and approaches with aggregate	19.3	6.8	-	-	-	.2	-	-
Subtotal	19.3	6.8	-	-	-	.2	-	-
D. Roadside and drainage:								
1. Mow roadsides with tractor (including shoulders)	15.4	1.4	-	-	-	.2	14.6	.1
2. Spray weeds on roadsides	3.0	-	-	-	-	2.3	1.0	1.2
Subtotal	18.4	1.4	-	-	-	2.5	15.6	1.3
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	42.8	28.4	1.8	8.4	.3	2.1	.5	-
2. Erect snow fences	8.4	3.3	-	-	-	.1	-	-
3. Remove snow fences	19.3	6.6	-	-	-	.2	1.2	-
4. Sand roadway surfaces	2.2	1.5	-	-	-	-	.1	-
5. Salt roadway surfaces	7.6	3.7	-	.7	-	.2	.5	-
6. Remove ice from roadway surfaces and shoulders	3.3	2.3	-	-	-	.1	-	-
7. Remove snow and ice from drainage ditches	2.8	1.2	-	-	-	.2	-	-
8. Put out and remove cinder barrels	22.3	11.7	-	-	-	.2	-	-
Subtotal	108.7	58.7	1.8	9.1	.3	3.1	2.3	-
F. Traffic Service:								
1. Paint centerlines and edgelines on pavements	2.4	-	-	-	-	.8	-	1.0
2. Paint bridge endwalls, medians, and miscellaneous pavement markings	13.3	5.6	-	-	-	.1	-	-
3. Erect, replace, repair, or paint signs or guideposts	3.8	1.5	-	-	-	1.4	-	-
4. Clean signs and reflectors	2.2	.2	-	-	-	.7	-	-
5. Remove or paint guardrails	32.8	8.2	-	5.8	-	.3	-	-
Subtotal	54.5	15.5	-	5.8	-	3.3	-	1.0
Total	263.3	108.3	2.0	16.7	.3	16.1	18.5	4.3

TABLE 11

BOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 2: Location -- Rural; Surface – Portland cement concrete; Period constructed – 1926-45;
Average daily traffic – 1000-3000
– Time in hours per mile –

Direct operations	Labor	light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	16.2	6.9	.1	.1	-	.9	.2	.4
2. Fill joints and cracks in roadway surfaces	3.7	1.5	-	-	-	.1	-	.7
3. Clean or drain roadway surfaces	1.3	.3	-	.1	-	.3	-	-
Subtotal	21.2	8.7	.3	.2	-	1.3	.2	1.1
B. Special surface:								
1. Plane or roll bituminous pavements	.1	-	-	-	-	-	-	-
Subtotal	.1	-	-	-	-	-	-	-
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	.6	.4	-	.1	-	-	-	.1
2. Patch shoulders and approaches with aggregate	5.8	2.8	-	.3	.1	.1	.2	.2
3. Patch shoulders and approaches with bituminous cold mix	4.6	1.9	.3	.1	-	.1	.1	.4
4. Blade or reshape shoulders and approaches	1.0	-	.1	.7	-	-	.1	-
Subtotal	12.0	5.1	.4	1.2	.1	.2	.4	.7
D. Roadside and drainage:								
1. Repair cut and fill slopes	.5	.2	-	-	.1	.1	-	-
2. Repair or replace pipes and tiles	.9	.5	-	-	-	-	-	-
3. Clean pipes, tiles, and box culverts	1.6	.8	-	-	.1	.1	-	-
4. Clean or repair unpaved drainage ditches	4.0	1.6	-	-	.4	.5	-	-
5. Mow roadsides with tractor (including shoulders)	24.4	2.7	-	-	-	1.7	22.7	.1
6. Mow roadsides with hand tools (including shoulders)	2.9	1.3	-	-	-	.1	-	-
7. Spray weeds on roadsides	3.5	1.3	-	-	-	.2	.5	1.3
Subtotal	37.8	8.4	-	-	.6	2.7	23.2	1.4
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	46.8	19.3	8.3	2.1	.2	2.8	.6	-
2. Remove snow from bridges	.5	.2	-	-	-	.2	-	-
3. Erect snow fences	16.3	6.6	-	-	-	.5		
4. Remove snow fences	10.1	3.6	-	-	-	.5	.3	-
5. Sand roadway surfaces	10.7	5.4	.4	-	.3	.5	1.0	-
6. Salt roadway surfaces	5.3	2.1	.3	.1	-	.2	.4	-
7. Remove ice from roadway surfaces and shoulders	3.4	1.1	1.3	-	-	.2	-	-
8. Remove snow and ice from drainage ditches	2.2	1.0	-	-	-	.2	-	-
9. Cut out and remove cinder barrels	1.3	.6	-	-	-	.1	-	-
Subtotal	96.6	39.9	10.3	2.2	.5	5.2	2.3	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	4.8	.9	-	.1	-	2.1	-	.6
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.8	.7	-	-	-	.1	.1	.1
3. Erect, replace, repair or paint signs and guideposts	5.2	1.8	-	-	-	1.2	-	-
4. Clean signs and reflectors	.6	.3	-	-	-	.1	-	-
5. Remove or paint guardrails	1.4	.5	-	-	-	.2	.1	-
Subtotal	13.8	4.2	-	.1	-	3.7	.2	.7
G. Other:								
1. Clean or repair bridges	.5	.2	-	-	-	-	-	-
2. Remove litter from right-of-way	2.7	1.1	-	-	-	.2	-	-
3. Miscellaneous work resulting from maintenance contracts	3.9	2.9	-	-	-	.7	-	-
Subtotal	7.1	4.2	-	-	-	.9	-	-
Total	188.6	70.5	11.0	3.7	1.2	14.0	26.3	3.9

TABLE 12

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 3: Location — Rural; Surface — Portland cement concrete; Period constructed — 1946-59;
Average daily traffic — Under 1000

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	.9	.5	-	-	-	-	-	-
Subtotal	.9	.5	-	-	-	-	-	-
B. Special surface:								
1. Mudjack concrete pavements	25.0	12.2	2.8	.1	-	.5	3.4	5.4
Subtotal	25.0	12.2	2.8	.1	-	.5	3.4	5.4
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	14.2	6.4	-	-	.1	.2	1.2	.1
2. Blade or reshape shoulders and approaches	3.5	-	-	3.1	-	-	-	-
Subtotal	17.7	6.4	-	3.1	.1	.2	1.2	.1
D. Roadside and drainage:								
1. Clean pipes, tiles and box culverts	.9	.2	-	-	-	-	-	-
2. Mow roadsides with tractor (including shoulders)	7.4	2.1	-	-	-	.2	6.6	-
3. Spray weeds on roadsides	10.6	5.0	-	-	-	.2	.1	4.3
Subtotal	18.9	7.3	-	-	-	.4	6.7	4.3
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	45.5	8.7	4.2	24.8	.1	3.3	1.3	-
2. Remove snow from bridges	3.9	1.4	.2	-	-	.3	-	-
3. Sand roadway surfaces	4.9	2.0	.5	-	.2	.2	.3	-
4. Salt roadway surfaces	.2	.1	-	-	-	-	-	-
5. Remove ice from roadway surfaces and shoulders	4.9	.3	.6	-	-	.4	.1	-
Subtotal	59.4	12.5	5.5	24.8	.3	4.2	1.7	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	2.8	.2	.1	-	-	1.6	-	.2
2. Erect, replace, repair or paint signs and guideposts	11.5	3.5	-	-	-	4.0	-	-
3. Clean signs and reflectors	.1	-	-	-	-	-	-	-
Subtotal	14.4	3.7	.1	-	-	5.6	-	.2
G. Other:								
1. Miscellaneous work resulting from construction contracts	85.1	27.5	.1	1.9	.1	28.5	.2	.2
Subtotal	85.1	27.5	.1	1.9	.1	28.5	.2	.2
Total	221.4	70.1	8.5	29.9	.5	39.4	13.2	10.2

TABLE 13

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 4: Location - Rural; Surface - Portland cement concrete; Period constructed - 1946-59;
Average daily traffic — 1000-3000

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	.1	-	-	-	-	-	-	-
2. Patch roadway surfaces with bituminous cold mix	2.9	1.2	-	.1	-	.1	.2	.2
3. Clean or drain roadway surfaces	.3	.1	-	-	-	.1	-	-
Subtotal	3.3	1.3	-	.1	-	.2	.2	.2
B. Special surface:								
1. Mudjack concrete pavements	3.9	2.1	-	-	-	.1	.1	.8
Subtotal	3.9	2.1	-	-	-	.1	.1	.8
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	13.4	7.3	-	2.3	-	.3	.4	1.0
2. Patch shoulders and approaches with aggregate	10.8	5.8	-	-	.1	.2	.4	-
3. Patch shoulders and approaches with bituminous cold mix	2.0	.7	-	.1	-	-	.1	.2
4. Blade or reshape shoulders and approaches	1.4	-	-	1.4	-	-	-	-
Subtotal	27.6	13.8	-	3.8	.1	.5	.9	1.2
D. Roadside and drainage:								
1. Clean pipes, tiles, and box culverts	1.3	.6	-	-	-	-	-	-
2. Clean or repair unpaved drainage ditches	4.6	2.3	-	-	.9	.6	.1	-
3. Mow roadsides with tractor (including shoulders)	9.5	1.2	-	-	-	.1	8.2	-
4. Mow roadsides with hand tools (including shoulders)	.1	-	-	-	-	-	-	-
5. Spray weeds on roadsides	.4	.1	-	-	-	-	-	.2
Subtotal	15.9	4.2	-	-	.9	.7	8.3	.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	37.4	17.4	2.1	10.9	.4	2.2	.6	-
2. Erect snow fences	4.7	2.0	-	-	-	.1	-	-
3. Remove snow fences	3.7	1.2	-	-	-	.4	.2	-
4. Sand roadway surfaces	7.2	5.3	-	-	.2	.3	.6	-
5. Salt roadway surfaces	.3	.3	-	1.2	-	-	-	-
6. Remove ice from roadway surfaces and shoulders	5.1	2.6	1.0	-	.3	.1	-	-
7. Remove snow and ice from drainage ditches	.4	.4	-	-	-	-	-	-
8. Put out and remove cinder barrels	1.5	.7	-	-	-	.1	-	-
Subtotal	60.3	29.9	3.1	12.1	.9	3.2	1.4	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavement	5.5	.2	-	-	-	3.0	-	1.0
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.4	.5	-	-	-	-	.2	.2
3. Erect, replace, repair or paint signs and guideposts	1.7	.6	-	-	-	.2	-	-
4. Clean signs and reflectors	1.2	.3	-	-	-	.2	.1	.1
Subtotal	9.8	1.6	-	-	-	3.4	.3	1.3
G. Other:								
1. Remove litter from right-of-way	3.8	1.6	-	-	-	.1	-	-
Subtotal	3.8	1.6	-	-	-	.1	-	-
Total	124.6	54.5	3.1	16.0	1.9	8.2	11.2	3.7

TABLE 14

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA
(INCLUDING DISTRIBUTED OVERHEAD)

Group 5: Location — Rural; Surface — Portland cement concrete; Period constructed — 1946-59;
Average daily traffic — 3000-5000
— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	.6	.3	-	-	-	-	-	-
2. Clean or drain roadway surfaces	.2	.1	-	-	-	-	-	-
Subtotal	.8	.4	-	-	-	-	-	-
B. Special surface	-	-	-	-	-	-	-	-
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	11.7	6.4	.9	1.9	-	.2	-	1.1
2. Patch shoulders and approaches with aggregate	5.4	2.4	.3	-	.1	.1	.1	-
3. Patch shoulders and approaches with bituminous cold mix	9.5	2.5	1.5	.3	-	.1	1.5	1.1
4. Reseed or resod shoulders and approaches	.6	.2	-	-	-	-	.1	-
5. Blade or reshape shoulders and approaches	1.5	.2	-	1.3	-	-	-	-
Subtotal	28.7	11.7	2.7	3.5	.1	.4	1.7	2.2
D. Roadside and drainage:								
1. Repair cut and fill slopes	3.1	2.1	-	-	-	.1	-	-
2. Repair or replace pipes and tiles	1.4	.5	-	-	.2	.3	-	-
3. Clean pipes, tiles and box culverts	.7	.2	-	-	-	.1	-	-
4. Clean or repair unpaved drainage ditches	.4	.1	-	-	.1	-	-	-
5. Remove trees from roadsides	.8	.3	-	-	-	.1	-	-
6. Mow roadsides with tractor (including shoulders)	37.8	8.0	-	-	.1	1.3	35.7	.1
7. Mow roadsides with hand tools (including shoulders)	1.1	.4	-	-	-	-	.7	-
8. Spray weeds on roadsides	1.4	.5	-	-	-	-	.1	.6
Subtotal	46.7	12.1	-	-	.4	1.9	36.5	.7
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders:	41.9	14.7	8.9	6.3	.2	2.4	.4	-
2. Remove snow from bridges	.5	.4	-	-	-	-	-	-
3. Erect snow fences	.4	.2	-	-	-	-	-	-
4. Remove snow fences	.2	.1	-	-	-	-	-	-
5. Sand roadway surfaces	2.2	1.2	-	-	.1	.1	.2	-
6. Salt roadway surfaces	10.4	3.6	1.3	.8	-	.5	.8	-
7. Remove ice from roadway surfaces and shoulders	4.1	1.5	1.1	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	.1	-	-	-	-	-	-	-
Subtotal	59.8	21.7	11.3	7.1	.3	3.2	1.5	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	4.8	.1	-	-	-	2.6	-	.7
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.6	.3	-	-	-	.6	-	.1
3. Erect, replace, repair or paint signs and guideposts	4.5	1.6	-	-	-	1.1	-	-
4. Clean signs and reflectors	.7	.2	-	-	-	.3	-	-
Subtotal	11.6	2.2	-	-	-	4.6	-	.8
G. Other:								
1. Remove litter from right-of-way	1.1	.5	-	-	-	-	-	-
Subtotal	1.1	.5	-	-	-	-	-	-
Total	148.7	48.6	14.0	10.6	.8	10.1	39.7	3.7

TABLE 15

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA
(INCLUDING DISTRIBUTED OVERHEAD)

Group 6: Location - Rural; Surface - Bituminous overlay; Period constructed - 1946-59;
Average daily traffic - 1000-3000

- Time in hours per mile -

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	5.8	2.9	-	-	-	.1	-	1.6
2. Patch roadway surfaces with bituminous hot mix	45.1	21.6	4.1	.1	.1	1.1	5.8	22.5
3. Fill joints and cracks in roadway surfaces	.1	-	-	-	-	-	-	-
Subtotal	51.0	24.5	4.1	.1	.1	1.2	5.8	24.1
B. Special surface:								
1. Mudjack concrete pavements	4.1	2.3	.4	-	-	.1	.3	.8
2. Plane or roll bituminous pavements	2.8	.5	-	1.3	-	.7	-	-
Subtotal	6.9	2.8	.4	1.3	-	.8	.3	.8
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	3.2	2.7	-	-	-	.1	-	-
2. Blade or reshape shoulders and approaches	2.0	-	.4	.4	-	-	.9	-
Subtotal	5.2	2.7	.4	.4	-	.1	.9	-
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.6	.8	.1	-	.1	.2	-	.1
2. Clean pipes, tiles, and box culverts	1.3	.5	-	-	.2	-	-	-
3. Clean or repair unpaved drainage ditches	12.4	5.6	-	-	2.7	2.7	-	-
4. Repair stone riprap	.2	.1	-	-	-	-	-	-
5. Mow roadsides with tractor (including shoulders)	15.7	3.4	-	-	-	.9	15.5	.1
6. Mow roadsides with hand tools (including shoulders)	4.8	2.5	-	-	-	.1	-	-
7. Spray weeds on roadsides	3.2	.6	-	-	-	.6	1.0	1.0
Subtotal	39.2	13.5	.1	-	3.0	4.5	16.5	1.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	42.0	19.2	8.8	1.9	.2	3.0	.3	-
2. Remove snow from bridges	1.4	.6	.1	-	-	.1	-	-
3. Erect snow fences	13.6	5.7	-	-	-	.4	-	-
4. Remove snow fences	8.2	3.3	-	-	-	.2	.4	-
5. Sand roadway surfaces	14.0	10.0	.2	-	.2	.6	.6	-
6. Salt roadway surfaces	3.4	.4	.8	-	-	.2	.2	-
7. Remove ice from roadway surfaces and shoulders	2.3	1.3	.4	-	-	.2	.1	-
8. Put out and remove cinder barrels	.6	.3	-	-	-	-	-	-
Subtotal	85.5	40.8	10.3	1.9	.4	4.7	1.6	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavement	5.3	.5	.3	-	-	2.1	-	.8
2. Paint bridge endwalls, medians and miscellaneous pavement markings	.1	.1	-	-	-	-	-	-
3. Erect, replace, repair or paint signs and guideposts	3.0	1.3	-	-	-	.1	-	-
4. Clean signs and reflectors	1.4	.8	-	-	-	-	-	-
Subtotal	9.8	2.7	.3	-	-	2.2	-	.8
G. Other:								
1. Clean or repair bridges	2.7	1.1	-	-	-	-	-	.5
2. Remove litter from right-of-way	2.0	1.0	-	-	-	-	-	-
Subtotal	4.7	2.1	-	-	-	-	-	.5
Total	202.3	89.1	15.6	3.7	3.5	13.5	25.1	27.4

TABLE 16

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 7: Location – Rural; Surface – Bituminous overlay; Period constructed – 1946-59;
Average daily traffic – 3000-5000

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	4.2	1.9	.1	-	-	.1	-	.1
2. Patch roadway surfaces with bituminous hot mix	.3	.2	-	-	-	.1	-	.1
3. Fill joints and cracks in roadway surfaces	.1	-	-	-	-	-	-	-
4. Clean or drain roadway surfaces	.5	.2	.1	-	-	.1	-	-
Subtotal	5.1	2.3	.2	-	-	.3	-	.2
B. Special surface:								
1. Seal bituminous pavements	.2	.2	-	-	-	-	-	.1
Subtotal	.2	.2	-	-	-	-	-	.1
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	.7	.3	-	-	-	-	.1	-
2. Patch shoulders and approaches with aggregates	7.4	3.8	.1	.1	.1	.1	.5	.6
3. Patch shoulders and approaches with bituminous cold mix	5.6	2.4	.5	.5	-	.1	.3	.7
4. Blade or reshape shoulders and approaches	1.2	-	.3	.4	-	-	.4	-
Subtotal	14.9	6.5	.9	1.0	.1	.2	1.3	1.3
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.6	.8	.2	-	.1	.1	.1	-
2. Repair or replace pipes and tiles	2.0	.8	.2	.1	.2	.3	-	-
3. Clean pipes, tiles and box culverts	.3	.1	-	-	-	-	-	-
4. Clean or repair unpaved drainage ditches	10.9	4.3	.2	-	1.7	2.2	-	-
5. Clean paved flumes, gutters and drop inlets	.4	.2	-	-	-	-	-	-
6. Repair stone riprap	.7	.3	-	-	-	.1	.2	-
7. Mow roadsides with tractor (including shoulders)	22.5	2.5	-	-	-	.8	19.9	.1
8. Mow roadsides with hand tools (including shoulders)	3.5	1.8	-	-	-	.1	.2	-
9. Spray weeds on roadsides	2.1	.5	-	-	-	.4	.4	.7
Subtotal	44.0	11.3	.6	.1	2.0	4.0	20.8	.8
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	43.8	21.0	4.3	6.5	.2	2.7	.7	-
2. Remove snow from bridges	1.3	.4	.1	.1	-	.1	-	-
3. Erect snow fences	12.3	5.1	-	-	-	.3	-	-
4. Remove snow fences	7.6	2.9	-	-	-	.4	.1	-
5. Sand roadway surfaces	5.1	3.2	.1	-	.1	.2	.3	-
6. Salt roadway surfaces	8.7	4.3	.1	.5	-	.4	.5	-
7. Remove ice from roadway surfaces and shoulders	3.1	1.7	.4	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	.3	.1	-	-	-	-	-	-
9. Put out and remove cinder barrels	.2	.1	-	-	-	-	-	-
Subtotal	82.4	38.8	5.0	7.1	.3	4.3	1.7	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.5	.3	.2	-	-	2.5	-	.8
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.7	.5	-	-	-	.3	.1	.1
3. Erect, replace, repair and paint signs and guideposts	7.3	2.9	-	-	-	1.5	-	.2
4. Clean signs and reflectors	3.6	1.4	-	-	-	.7	-	-
5. Remove or paint guardrails	.1	-	-	-	-	-	-	-
Subtotal	18.2	5.1	.2	-	-	5.0	.1	1.1
G. Other:								
1. Clean or repair bridges	.7	.2	-	-	-	.1	-	-
2. Remove litter from right-of-way	2.0	.8	-	-	-	-	-	-
3. Miscellaneous work resulting from maintenance contracts	3.1	1.8	-	-	-	.2	-	-
4. Miscellaneous work resulting from construction contracts	.3	.2	-	-	-	.1	-	-
Subtotal	6.1	3.0	-	-	-	.4	-	-
Total	170.9	67.2	6.9	8.2	2.4	14.2	23.9	3.5

TABLE 17

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA
(INCLUDING DISTRIBUTED OVERHEAD)

Group 8: Location — Rural; Surface — Bituminous plant mix; Period constructed — 1946-59;
Average daily traffic — Under 1000

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	12.5	4.1	3.8	-	-	.3	.4	.1
2. Patch roadway surfaces with bituminous cold mix	16.7	6.7	.6	.2	-	1.6	.9	.2
3. Patch roadway surfaces with bituminous hot mix	2.3	.9	.1	-	-	.2	-	-
4. Clean or drain roadway surfaces	.2	.1	-	-	-	-	-	-
Subtotal	31.7	11.8	4.5	.2	-	2.1	1.3	.3
B. Special surface:								
1. Seal bituminous pavements	47.6	25.7	.1	-	.1	1.1	4.2	12.0
2. Resurface with bituminous mixes	20.9	7.8	2.0	4.1	-	.4	4.7	9.0
3. Plane or roll bituminous pavements	2.3	.1	1.0	-	-	-	.3	.3
4. Rebuild aggregate base courses	5.0	2.2	.1	.2	.8	1.1	.8	.5
Subtotal	75.8	35.8	3.2	4.3	.9	2.6	10.0	21.8
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	2.0	1.1	-	-	-	-	.2	-
2. Patch shoulders and approaches with bituminous cold mix	.3	.1	-	-	-	-	-	-
3. Blade or reshape shoulders and approaches	.1	-	-	-	-	-	.1	-
Subtotal	2.4	1.2	-	-	-	-	.3	-
D. Roadside and drainage:								
1. Repair cut and fill slopes	.3	.1	-	-	-	-	-	-
2. Repair or replace pipes and tiles	2.0	.9	-	-	-	.4	-	.4
3. Clean pipes, tiles and box culverts	.3	.1	-	-	-	-	-	-
4. Clean or repair unpaved drainage ditches	1.3	.6	-	.2	.3	.2	-	-
5. Mow roadsides with tractor (including shoulders)	21.4	1.9	.7	-	-	.7	18.9	.1
6. Mow roadsides with hand tools (including shoulders)	3.2	1.6	.4	-	-	.2	-	-
7. Spray weeds on roadsides	2.6	1.2	-	-	-	-	.1	1.1
Subtotal	31.1	6.4	1.1	.2	.3	1.5	19.0	1.6
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	44.1	16.7	4.9	3.7	.3	2.8	.8	-
2. Remove snow from bridges	.6	.3	-	-	-	-	.1	-
3. Erect snow fences	.6	.2	-	-	-	-	-	-
4. Remove snow fences	.3	.1	-	-	-	-	-	-
5. Sand roadway surfaces	14.2	5.8	1.6	-	.4	.6	1.6	-
6. Salt roadway surfaces	.9	.4	-	-	-	.1	-	-
7. Remove ice from roadway surfaces and shoulders	4.7	.6	1.8	-	-	.3	-	-
8. Remove snow and ice from drainage ditches	.4	.2	-	-	-	-	-	-
9. Put out and remove cinder barrels	.4	.2	-	-	-	-	-	-
Subtotal	66.2	24.5	8.3	3.7	.7	3.8	2.5	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	7.1	2.1	-	-	-	2.6	-	1.3
2. Paint bridges, endwalls, medians and miscellaneous pavement markings	1.1	.5	-	-	-	.2	-	-
3. Erect, replace, repair or paint signs and guideposts	5.4	2.0	-	-	-	1.5	-	.3
4. Clean signs and reflectors	.4	.1	-	-	-	.1	-	-
Subtotal	14.0	4.7	-	-	-	4.4	-	1.6
G. Other:								
1. Clean or repair bridges	.5	.2	-	-	-	-	-	.1
2. Remove litter from right-of-way	.5	.2	-	-	-	-	-	-
Subtotal	1.0	.4	-	-	-	-	-	.1
Total	222.2	84.8	17.1	8.4	1.9	14.4	33.1	25.4

TABLE 18

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 9: Location — Rural; Surface — Bituminous plant mix; Period constructed — 1946-59;
Average daily traffic — 1000-3000

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	1.1	.6	-	-	-	-	-	.3
2. Patch roadway surfaces with bituminous hot mix	1.6	1.1	-	-	-	-	-	1.1
Subtotal	2.7	1.7	-	-	-	-	-	1.4
B. Special surface:								
1. Seal bituminous pavements	11.1	6.3	1.8	-	-	.2	.7	2.5
Subtotal	11.1	6.3	1.8	-	-	.2	.7	2.5
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	1.0	.7	-	-	-	-	.1	-
2. Patch shoulders and approaches with bituminous cold mix	.9	.7	-	-	-	-	.1	.5
3. Blade or reshape shoulders and approaches	.1	-	.1	-	-	-	-	-
Subtotal	2.0	1.4	.1	-	-	-	.2	.5
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.3	.5	.2	-	.3	.3	-	-
2. Repair or replace pipes and tiles	.9	.3	-	-	.2	.2	-	-
3. Clean or repair unpaved drainage ditches	5.9	2.7	-	-	.5	.8	-	-
4. Repair stone riprap	9.6	4.4	.2	-	-	.3	1.6	1.7
5. Remove trees from roadsides	.9	.4	-	-	.1	.1	-	-
6. Mow roadsides with tractor (including shoulders)	14.8	4.0	-	-	-	.3	13.1	.1
7. Mow roadsides with hand tools (including shoulders)	2.6	1.2	-	-	-	-	-	-
8. Spray weeds on roadsides	2.5	1.0	-	-	-	.1	.7	.7
Subtotal	38.5	14.5	.4	-	1.1	2.1	15.4	2.5
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	33.4	19.9	2.7	3.2	.2	2.3	.6	-
2. Remove snow from bridges	3.4	1.1	.3	.6	-	.2	-	-
3. Erect snow fences	5.0	2.3	-	-	-	.1	-	-
4. Remove snow fences	3.1	1.1	-	-	-	.2	-	-
5. Sand roadway surfaces	17.7	12.7	.1	-	.2	.8	.8	-
6. Salt roadway surfaces	.1	.1	-	-	-	-	-	-
7. Remove ice from roadway surfaces and shoulders	2.5	1.4	.3	.2	-	.2	.1	-
Subtotal	65.2	38.6	3.4	4.0	.4	3.8	1.5	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.6	.5	.3	-	-	2.1	-	.9
2. Erect, replace, repair or paint signs and guideposts	1.8	1.3	-	-	-	.3	-	-
3. Clean signs and reflectors	1.6	1.1	-	-	-	-	-	-
Subtotal	9.0	2.9	.3	-	-	2.4	-	.9
G. Other:								
1. Clean or repair bridges	1.2	.4	-	-	-	-	-	.3
2. Remove litter from right-of-way	1.4	.7	-	-	-	-	-	-
Subtotal	2.6	1.1	-	-	-	-	-	.3
Total	131.1	66.5	6.0	4.0	1.5	8.5	17.8	8.1

TABLE 19

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 10: Location - Rural; Surface — Bituminous Treated; Period constructed — 1926-45
Average daily traffic - 1000-3000

— Time in hours per mile —

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	144.1	56.0	.2	37.4	2.0	3.8	13.2	5.6
2. Patch roadway surfaces with bituminous cold mix	157.3	65.9	2.0	13.4	.2	2.1	9.6	10.8
Subtotal	301.4	121.9	2.2	50.8	2.2	5.9	22.8	16.4
B. Special surface:								
1. Seal bituminous pavements	127.5	57.8	13.6	.1	.8	2.5	2.7	33.3
2. Resurface with bituminous mixes	88.8	43.7	6.0	14.0	.1	1.2	17.9	33.1
3. Plane or roll bituminous pavements	4.7	.1	-	2.9	-	.1	1.6	1.6
Subtotal	221.0	101.6	19.6	17.0	.9	3.8	22.2	68.0
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	.9	.6	-	-	-	-	-	-
2. Patch shoulders and approaches with bituminous cold mix	3.4	1.9	-	.1	-	.1	.1	.4
Subtotal	4.3	2.5	-	.1	-	.1	.1	.4
D. Roadside and drainage:								
1. Clean pipes, tiles and box culverts	.7	.3	-	-	-	-	-	-
2. Mow roadsides with tractor (including shoulders)	.9	-	-	-	-	-	.7	-
3. Spray weeds on roadsides	3.0	.9	-	-	-	-	1.2	1.2
Subtotal	4.6	1.2	-	-	-	-	1.9	1.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	46.7	24.0	1.0	9.9	.4	2.2	.6	-
2. Erect snow fences	22.5	10.1	-	-	.1	.3	-	-
3. Remove snow fences	19.0	5.8	-	-	-	3.1	1.3	-
4. Sand roadway surfaces	16.2	7.8	.1	.1	.4	.7	1.3	-
5. Salt roadway surfaces	1.9	.7	-	.6	-	.1	.1	-
6. Remove ice from roadway surfaces and shoulders	4.0	2.8	-	-	-	.2	-	-
Subtotal	110.3	51.2	1.1	10.6	.9	6.6	3.3	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	7.2	2.0	-	-	-	1.7	-	.2
2. Erect, replace, repair and paint signs and guideposts	2.9	.8	-	-	-	.8	-	-
3. Clean signs and reflectors	.1	-	-	-	-	-	-	-
Subtotal	10.2	2.8	-	-	-	2.5	-	.2
G. Other:								
1. Remove litter from right-of-way	1.4	.5	-	-	-	-	-	-
Subtotal	1.4	.5	-	-	-	-	-	-
Total	653.2	281.7	22.9	78.5	4.0	18.9	50.3	86.2

TABLE 20

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 11: Location — Rural; Surface — Bituminous treated; Period constructed — 1946-59;
Average daily traffic — Under 1000

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-Lines	Pickups	Tractors and frontend loaders	All other
A. Routine surface:								
1. Patch roadway surfaces with aggregate	15.9	8.1	-	1.2	.1	.2	.1	-
2. Patch roadway surfaces with bituminous cold mix	24.4	10.4	.1	1.5	-	.3	.7	1.0
Subtotal	40.3	18.5	.1	2.7	.1	.5	.8	1.0
B. Special surface:								
1. Seal bituminous pavements	86.1	48.6	2.5	.1	.5	1.3	6.4	20.4
2. Plane or roll bituminous pavements	14.5	4.7	-	3.5	-	2.7	2.8	2.8
Subtotal	100.6	53.3	2.5	3.6	.5	4.0	9.2	23.2
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	2.8	.9	-	-	-	-	-	-
2. Patch shoulders and approaches with bituminous cold mix	5.8	2.6	.1	.2	-	.1	.1	.6
3. Blade or reshape shoulders and approaches	.8	-	-	.8	-	-	-	-
Subtotal	9.4	3.5	.1	1.0	-	.1	.1	.6
D. Roadside and drainage:								
1. Mow roadsides with tractor (including shoulders)	5.4	.1	-	-	-	.1	4.4	-
2. Spray weeds on roadsides	1.2	.1	-	-	-	1.0	.3	.4
Subtotal	6.6	.2	-	-	-	1.1	4.7	.4
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	21.6	11.3	3.3	1.4	.2	1.0	.3	-
2. Sand roadway surfaces	3.0	1.2	-	-	.1	.1	.2	-
3. Salt roadway surfaces	3.0	1.4	-	.9	-	.1	.2	-
4. Remove ice from roadway surfaces and shoulders	4.2	1.5	.5	-	-	.2	-	-
Subtotal	31.8	15.4	3.8	2.3	.3	1.4	.7	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	1.5	-	-	-	-	.3	-	.3
2. Paint bridges, endwalls, medians and miscellaneous pavement markings	2.5	.9	-	-	-	-	.4	.4
3. Erect, replace, repair or paint signs and guideposts	1.2	.5	-	-	-	.1	-	-
4. Clean signs and reflectors	.3	.1	-	-	-	-	-	-
Subtotal	5.5	1.5	-	-	-	.4	.4	.7
G. Other:								
1. Remove litter from right-of-way	3.8	1.2	-	-	-	.1	-	-
2. Miscellaneous work resulting from construction contracts	1.8	1.0	-	-	-	-	.6	-
Subtotal	5.6	2.2	-	-	-	.1	.6	-
Total	199.8	94.6	6.5	9.6	.9	7.6	16.5	25.9

TABLE 21

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 12: Location – Rural; Surface – Gravel; Period constructed – 1926-45

Average daily traffic – Under 1000

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	76.0	52.3	3.2	.1	.2	3.8	5.5	.3
2. Blade gravel surfaces	53.9	1.0	2.8	45.9	-	.8	.5	.1
3. Clean or drain roadway surfaces	1.6	.9	-	-	-	.2	-	-
Subtotal	131.5	54.2	6.0	46.0	.2	4.8	6.0	.4
B. Special surface:								
1. Rebuild gravel surfaces	99.7	77.6	13.5	1.9	.1	2.1	.1	.4
Subtotal	99.7	77.6	13.5	1.9	.1	2.1	.1	.4
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	.2	.1	-	-	-	-	-	-
2. Blade or reshape shoulders and approaches	.1	-	-	.1	-	-	-	-
Subtotal	.3	.1	-	.1	-	-	-	-
D. Roadside and drainage:								
1. Repair cut and fill slopes	.8	.4	-	-	-	-	.1	-
2. Clean and repair unpaved drainage ditches	7.2	3.3	-	-	1.5	1.6	-	-
3. Mow roadsides with tractor (including shoulders)	2.4	1.0	-	-	-	-	1.8	-
4. Mow roadsides with hand tools (including shoulders)	.3	.3	-	-	-	-	-	-
5. Spray weeds on roadsides	1.2	.6	-	-	-	-	-	.5
Subtotal	11.9	5.6	-	-	1.5	1.6	1.9	.5
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	28.2	5.8	2.5	14.4	.1	2.0	.8	-
2. Remove snow from bridges	1.4	.6	-	-	-	.1	-	-
3. Erect snow fences	25.8	11.7	-	-	-	.7	.1	-
4. Remove snow fences	15.9	5.4	-	.6	-	.7	-	-
5. Sand roadway surfaces	3.0	1.1	.4	-	.1	.1	.2	-
Subtotal	74.3	24.6	2.9	15.0	.2	3.6	1.1	-
F. Traffic service:								
1. Erect, replace, repair or paint signs and guideposts	.6	.1	-	-	-	.2	-	-
2. Clean signs and reflectors	.2	.1	-	-	-	.1	-	-
Subtotal	.8	.2	-	-	-	.3	-	-
G. Other:								
1. Miscellaneous work resulting from maintenance contracts	9.0	4.2	-	3.1	-	1.3	-	-
2. Miscellaneous work resulting from construction contracts	24.9	5.7	2.5	9.2	-	1.5	.3	.9
Subtotal	33.9	9.9	2.5	12.3	-	2.8	.3	.9
Total	352.4	172.2	24.9	75.3	2.0	15.2	9.4	2.2

TABLE 22

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 13: Location — Urban; Surface — Portland cement concrete; Period constructed — 1926-45;

Average daily traffic — 1000-3000

— Time in hours per mile —

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	12.3	5.7	-	.3	-	.1	.1	.4
2. Clean or drain roadway surfaces	.5	.4	-	-	-	-	-	-
Subtotal	12.8	6.1	-	.3	-	.1	.1	.4
B. Special surface	-	-	-	-	-	-	-	-
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	4.4	1.5	-	-	.1	.1	-	.1
2. Patch shoulders and approaches with bituminous cold mix	3.0	1.4	-	.1	-	-	-	.3
3. Blade or reshape shoulders and approaches	.8	-	-	.7	-	-	-	-
Subtotal	8.2	2.9	-	.8	.1	.1	-	.4
D. Roadside and drainage:								
1. Clean pipes, tiles, and box culverts	2.3	1.0	-	-	-	-	-	-
2. Mow roadsides with tractor (including shoulders)	4.9	.7	-	-	-	.1	4.7	-
3. Mow roadsides with hand tools (including shoulders)	.4	.4	-	-	-	-	-	-
Subtotal	7.6	2.1	-	-	-	.1	4.7	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	41.7	18.4	5.8	2.5	.3	2.4	.5	-
2. Remove snow from bridges	4.6	1.5	-	-	-	1.4	-	-
3. Erect snow fences	1.0	.4	-	-	-	-	-	-
4. Remove snow fences	.5	.2	-	-	-	-	-	-
5. Sand roadway surfaces	10.0	3.9	1.1	-	.3	.4	1.3	-
6. Salt roadway surfaces	4.0	1.5	.3	.2	-	.2	.3	-
7. Remove ice from roadway surfaces and shoulders	3.7	1.0	1.2	-	-	.2	-	-
8. Remove snow and ice from drainage ditches	6.6	2.3	-	-	-	.9	-	-
Subtotal	72.1	29.2	8.4	2.7	.6	5.5	2.1	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavement	5.9	1.6	-	.1	-	2.4	-	.8
2. Erect, replace, repair or paint signs and guideposts	12.3	3.0	-	-	-	3.4	-	-
3. Clean signs and reflectors	3.4	.7	-	-	-	1.1	-	-
Subtotal	21.6	5.3	-	.1	-	6.9	-	.8
Total	122.3	45.6	8.4	3.9	.7	12.7	6.9	1.6

TABLE 23

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 14: Location - Urban; Surface - Portland cement concrete; Period constructed - 1926-45;
Average daily traffic - 3000-5000
- Time in hours per mile -

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	46.7	22.1	.2	1.3	-	5.1	2.0	1.5
Subtotal	46.7	22.1	.2	1.3	-	5.1	2.0	1.5
B. Special surface	-	-	-	-	-	-	-	-
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	18.9	8.4	-	-	-	.3	2.1	-
2. Blade or reshape shoulders and approaches	3.6	-	-	1.3	-	-	2.3	-
Subtotal	22.5	8.4	-	1.3	-	.3	4.4	-
D. Roadside and drainage:								
1. Clean or repair unpaved drainage ditches	6.9	-	-	-	3.2	-	-	-
2. Mow roadsides with tractor (including shoulders)	23.5	.2	-	-	-	.3	18.2	-
3. Spray weeds on roadsides	2.5	-	-	-	-	-	1.0	1.0
Subtotal	32.9	.2	-	-	3.2	.3	19.2	1.0
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	39.2	18.4	1.8	11.5	.3	2.1	.5	-
2. Sand roadway surfaces	8.4	5.4	-	-	.2	.3	.7	-
3. Salt roadway surfaces	.7	.3	-	1.2	-	-	.2	-
4. Remove ice from roadway surfaces and shoulders	5.3	2.8	1.0	-	-	.3	-	-
Subtotal	53.6	26.9	2.8	12.7	.5	2.7	1.4	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.7	.5	-	-	-	2.8	-	.8
2. Erect, replace, repair or paint signs and guideposts	20.8	7.9	-	-	-	2.5	-	-
3. Clean signs and reflectors	5.4	1.3	-	-	-	1.0	.5	.5
Subtotal	31.9	9.7	-	-	-	6.3	.5	1.3
G. Other								
1. Remove litter from right-of-way	5.9	1.6	-	-	-	-	-	-
Subtotal	5.9	1.6	-	-	-	-	-	-
Total	193.5	68.9	3.0	15.3	3.7	14.7	27.5	3.8

TABLE 24

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 15: Location — Urban; Surface — Portland cement concrete; Period constructed — 1926-45;
Average daily traffic - Over 5000

— Time in hours per mile —

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	142.2	64.1	3.3	.2	-	9.0	1.5	.4
2. Patch roadway surfaces with bituminous hot mix	14.4	4.4	-	-	-	2.2	-	-
3. Clean or drain roadway surfaces	16.5	6.5	-	-	-	-	-	-
Subtotal	173.1	75.0	3.3	.2	-	11.2	1.5	.4
B. Special surface	-	-	-	-	-	-	-	-
C. Shoulder and approach:								
1. Patch shoulders and approaches with bituminous cold mix	8.1	3.1	-	.3	-	.1	.2	.9
2. Blade or reshape shoulders and approaches	.5	-	-	.5	-	-	-	-
Subtotal	8.6	3.1	-	.8	-	.1	.2	.9
D. Roadside and drainage:								
1. Clean paved flumes, gutters and drop inlets	30.3	9.8	-	-	-	4.1	.1	-
2. Mow roadsides with tractor (including shoulders)	3.0	-	-	-	-	.1	2.8	-
Subtotal	33.3	9.8	-	-	-	4.2	2.9	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	36.1	16.0	5.6	2.2	.2	2.0	.3	-
2. Erect snow fences	8.1	3.4	-	-	-	.1	-	-
3. Remove snow fences	6.6	2.2	-	-	-	.2	.3	-
4. Sand roadway surfaces	2.9	1.3	.1	-	.1	.3	.2	-
5. Salt roadway surfaces	11.5	5.0	.3	-	-	.4	.9	-
6. Remove ice from roadway surfaces and shoulders	2.1	.9	.9	-	-	.1	-	-
7. Remove snow and ice from drainage ditches	3.2	.8	-	-	-	.1	-	-
8. Put out and remove cinder barrels	1.9	.8	-	-	-	.2	.1	-
Subtotal	72.4	30.4	6.9	2.2	.3	3.4	1.8	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavement	4.1	.6	-	-	-	2.1	-	.6
2. Erect, replace, repair and paint signs and guideposts	6.6	1.9	-	-	-	2.9	-	-
3. Clean signs and reflectors	4.0	1.1	-	-	-	1.6	-	-
Subtotal	14.7	3.6	-	-	-	6.6	-	.6
G. Other:								
1. Miscellaneous work resulting from maintenance contracts	56.9	30.4	-	-	-	9.4	7.0	.2
Subtotal	56.9	30.4	-	-	-	9.4	7.0	.2
Total	359.0	152.3	10.2	3.2	.3	34.9	13.4	2.1

TABLE 25

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 16: Location – Urban; Surface – Portland cement concrete; Period constructed – 1946-59;
Average daily traffic – Under 1000

– Time in hours per mile –

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface	-	-	-	-	-	-	-	-
B. Special surface	-	-	-	-	-	-	-	-
C. Shoulder and approach	-	-	-	-	-	-	-	-
D. Roadside and drainage	-	-	-	-	-	-	-	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	96.7	9.2	9.2	75.0	-	7.5	3.3	-
2. Sand roadway surfaces	2.5	1.7	-	-	-	-	-	-
3. Salt roadway surfaces	.8	-	-	-	-	-	-	-
4. Remove ice from roadway surfaces and shoulders	15.8	.8	2.5	-	-	.8	-	-
Subtotal	115.8	11.7	11.7	75.0	-	8.3	3.3	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	9.2	.8	.8	-	-	5.8	-	.8
Subtotal	9.2	.8	.8	-	-	5.8	-	.8
Total	125.0	12.5	12.5	75.0	-	14.1	3.3	.8

TABLE 26

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 17: Location — Urban; Surface — Portland cement concrete; Period constructed - 1946-59;
Average daily traffic — 1000-3000

— Time in hours per mile —

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface	-	-	-	-	-	-	-	-
B. Special surface:								
1. Mudjack concrete pavement	27.8	17.4	4.4	-	-	.6	3.6	4.8
2. Seal concrete pavements	74.4	42.6	12.6	-	-	1.4	4.8	24.2
Subtotal	102.2	60.0	17.0	-	-	2.0	8.4	29.0
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	18.8	16.8	-	-	-	.2	.2	-
Subtotal	18.8	16.8	-	-	-	.2	.2	-
D. Roadside and drainage:								
1. Clean pipes, tiles and box culverts	7.6	3.6	-	-	-	.2	-	-
2. Mow roadsides with hand tools (including shoulders)	1.2	.6	-	-	-	-	-	-
Subtotal	8.8	4.2	-	-	-	.2	-	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	35.0	20.6	3.4	1.4	.2	2.4	.6	-
2. Sand roadway surfaces	14.8	10.6	-	-	.2	.6	.6	-
3. Remove ice from roadway surfaces and shoulders	2.0	1.8	-	-	-	.2	-	-
Subtotal	51.8	33.0	3.4	1.4	.4	3.2	1.2	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	6.0	1.0	.2	-	-	1.8	-	1.2
2. Erect, replace, repair or paint signs and guideposts	3.2	-	-	-	-	2.2	-	-
3. Clean signs and reflectors	1.8	1.0	-	-	-	-	-	-
Subtotal	11.0	2.0	.2	-	-	4.0	-	1.2
G. Other:								
1. Remove litter from right-of-way	10.4	4.8	-	-	-	.2	-	-
Subtotal	10.4	4.8	-	-	-	.2	-	-
Total	203.0	120.8	20.6	1.4	.4	9.8	9.8	30.2

TABLE 27

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 18: Location -- Urban; Surface -- Portland cement concrete; Period constructed -- 1946-59;
Average daily traffic -- Over 5000

-- Time in hours per mile --

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All other
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	15.1	6.7	.1	.4	.1	2.3	.3	.9
Subtotal	15.1	6.7	.1	.4	.1	2.3	.3	.9
B. Special surface	-	-	-	-	-	-	-	-
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	10.6	6.0	-	1.9	-	.1	-	1.5
2. Patch shoulders and approaches with aggregate	14.8	6.7	.6	1.3	.1	.4	.4	.8
3. Patch shoulders and approaches with bituminous cold mix	8.7	3.9	1.3	.3	-	.1	.7	1.1
4. Reseed or resod shoulders and approaches	13.1	5.7	-	-	-	.1	3.0	.6
5. Blade or reshape shoulders and approaches	2.8	-	-	2.7	-	-	-	-
Subtotal	50.0	22.3	1.9	6.2	.1	.7	4.1	4.0
D. Roadside and drainage:								
1. Repair cut and fill slopes	15.0	5.4	-	2.3	-	.2	2.6	-
2. Clean pipes, tiles and box culverts	24.7	8.3	-	3.4	3.2	3.7	5.5	-
3. Clean or repair unpaved drainage ditches	8.1	3.2	-	1.2	1.2	1.5	.1	-
4. Clean paved flumes, gutters and drop inlets	.7	.4	-	-	-	-	-	-
5. Remove trees from roadsides	10.5	4.5	-	-	-	.1	-	-
6. Mow roadsides with tractor (including shoulders)	25.0	.7	-	-	-	.3	21.0	.1
7. Spray weeds on roadsides	.2	-	-	-	-	-	.1	.1
Subtotal	84.2	22.5	-	6.9	4.4	5.8	29.3	.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	52.1	27.2	3.0	13.7	.4	2.5	.6	-
2. Sand roadway surfaces	5.0	3.2	-	-	.1	.2	.4	-
3. Salt roadway surfaces	7.7	3.5	.1	2.2	-	.3	.5	-
4. Remove ice from roadway surfaces and shoulders	8.3	4.2	1.2	-	-	.4	.1	-
5. Remove snow and ice from drainage ditches	5.6	-	-	-	-	2.8	-	-
Subtotal	78.7	38.1	4.3	15.9	.5	6.2	1.6	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	7.4	.2	-	-	-	4.2	-	1.2
2. Paint bridge endwalls, medians and miscellaneous pavement markings	14.9	1.8	-	-	-	4.0	.4	2.8
3. Erect, replace, repair or paint signs and guideposts	14.5	5.9	-	-	-	2.9	-	-
4. Clean signs and reflectors	4.1	.9	-	-	-	1.4	.3	.2
Subtotal	40.9	8.8	-	-	-	12.5	.7	4.2
G. Other:								
1. Clean or repair bridges	.4	.2	-	-	-	-	-	-
2. Remove litter from right-of-way	3.5	.8	-	-	-	.5	-	-
3. Miscellaneous work resulting from maintenance contracts	.3	.1	-	-	-	.1	-	-
4. Miscellaneous work resulting from construction contracts	3.0	.6	-	-	-	.8	-	-
Subtotal	7.2	1.7	-	-	-	1.4	-	-
Total	276.1	100.1	6.3	29.4	5.1	28.9	36.0	9.3

TABLE 28

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 19: Location – Urban; Surface – Bituminous overlay; Period constructed – 1946-59;
Average daily traffic – 1000-3000

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	32.2	15.5	.2	.2	-	.6	-	12.0
2. Clean and drain roadway surfaces	9.7	4.8	-	-	-	-	-	-
Subtotal	41.9	20.3	.2	.2	-	.6	-	12.0
B. Special surface:	-	-	-	-	-	-	-	-
C. Shoulder and approach:	-	-	-	-	-	-	-	-
D. Roadside and drainage:								
1. Mow roadsides with tractor (including shoulders)	.6	-	-	-	-	-	.5	-
2. Mow roadsides with hand tools (including shoulders)	4.4	2.0	-	-	-	.2	-	-
Subtotal	5.0	2.0	-	-	-	.2	.5	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	39.5	15.8	10.0	.9	.2	2.8	.5	-
2. Sand roadway surfaces	13.4	9.7	.2	-	.2	.6	.6	-
3. Remove ice from roadway surfaces and shoulders	2.5	1.3	.6	-	-	.2	.2	-
4. Put out and remove cinder barrels	.5	.2	-	-	-	-	-	-
Subtotal	55.9	27.0	10.8	.9	.4	3.6	1.3	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	4.1	.2	.2	-	-	1.9	-	.6
2. Erect, replace, repair or paint signs and guideposts	8.0	3.8	-	-	-	.2	-	-
3. Clean signs and reflectors	5.2	2.8	-	-	-	.2	-	-
Subtotal	17.3	6.8	.2	-	-	2.3	-	.6
Total	120.1	56.1	11.2	1.1	.4	6.7	1.8	12.6

TABLE 29

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 20: Location - Urban; Surface - Bituminous overlay; Period constructed - 1946-59;
Average daily traffic - 3000-5000
- Time in hours per mile -

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All Others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	28.4	12.2	.7	-	-	2.3	-	-
Subtotal	28.4	12.2	.7	-	-	2.3	-	-
B. Special surface:								
1. Seal bituminous pavements	29.8	19.0	4.6	-	.2	1.4	-	10.0
Subtotal	29.8	19.0	4.6	-	.2	1.4	-	10.0
C. Shoulder and approach:								
1. Blade or reshape shoulders and approaches	9.6	.2	-	-	-	.2	7.2	-
Subtotal	9.6	.2	-	-	-	.2	7.2	-
D. Roadside and drainage:	-	-	-	-	-	-	-	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	34.9	16.0	2.8	5.7	.2	2.3	.6	-
2. Sand roadway surfaces	8.6	4.1	.7	-	.3	.4	.5	-
3. Salt roadway surfaces	3.8	2.0	-	-	-	.2	.1	-
4. Remove ice from roadway surfaces and shoulders	4.5	.8	1.8	-	-	.3	.1	-
5. Remove snow and ice from drainage ditches	1.4	.7	-	-	-	-	-	-
6. Put out and remove cinder barrels	.1	.1	-	-	-	-	-	-
Subtotal	53.3	23.7	5.3	5.7	.5	3.2	1.3	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.8	1.3	.1	-	-	2.1	-	1.3
2. Erect, replace, repair or paint signs and guideposts	4.7	-	-	-	-	3.2	-	-
3. Clean signs and reflectors	11.4	5.6	-	-	-	1.4	-	.1
Subtotal	21.9	6.9	.1	-	-	6.7	-	1.4
Total	143.0	62.0	10.7	5.7	.7	13.8	8.5	11.4

TABLE 30

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA
(INCLUDING DISTRIBUTED OVERHEAD)

Group 21: Location — Urban; Surface — Bituminous plant mix; Period constructed — 1946-59;
Average daily traffic — Under 1000

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:	-	-	-	-	-	-	-	-
B. Special surface:	-	-	-	-	-	-	-	-
C. Shoulder and approach:	-	-	-	-	-	-	-	-
D. Roadside and drainage:								
1. Clean paved flumes, gutters and drop inlets	41.0	19.5	-	-	-	-	-	-
Subtotal	41.0	19.5	-	-	-	-	-	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	35.0	12.3	4.8	1.3	.3	2.0	.5	-
2. Erect snow fences	10.8	4.0	-	-	-	.3	-	-
3. Remove snow fences	4.0	2.0	-	-	-	-	-	-
4. Sand roadway surfaces	13.3	4.0	2.3	-	.5	.5	2.0	-
5. Salt roadway surfaces	.3	-	-	-	-	.3	-	-
6. Remove ice from roadway surfaces and shoulders	3.3	.3	1.0	-	-	.3	-	-
7. Remove snow and ice from drainage ditches	8.3	2.5	-	-	-	1.5	-	-
Subtotal	75.0	25.1	8.1	1.3	.8	4.9	2.5	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	7.8	2.8	-	-	-	3.0	-	1.0
2. Erect, replace, repair or paint signs and guideposts	13.0	3.8	-	-	-	4.3	-	-
3. Clean signs and reflectors	.3	-	-	-	-	.3	-	-
Subtotal	21.1	6.6	-	-	-	7.6	-	1.0
Total	137.1	51.2	8.1	1.3	.8	12.5	2.5	1.0

TABLE 31

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 22: Location — Urban; Surface — Bituminous plant mix; Period constructed — 1946-59;
Average daily traffic — 1000-3000

— Time in hours per mile —

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	6.4	3.2	-	-	-	.1	-	2.3
Subtotal	6.4	3.2	-	-	-	.1	-	2.3
B. Special surface:								
1. Seal bituminous pavements	12.8	10.1	.4	-	-	.2	-	3.2
Subtotal	12.8	10.1	.4	-	-	.2	-	3.2
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	4.3	2.4	-	-	-	.1	-	-
2. Blade or reshape shoulders and approaches	.2	-	.2	-	-	-	-	-
Subtotal	4.5	2.4	.2	-	-	.1	-	-
D. Roadside and drainage:								
1. Repair stone riprap	6.2	3.1	-	-	-	.1	-	-
2. Mow roadsides with hand tools (including shoulders)	.4	.3	-	-	-	.2	-	.1
Subtotal	6.6	3.4	-	-	-	.3	-	.1
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	35.1	20.8	3.4	1.5	.2	2.4	.7	-
2. Remove snow from bridges	2.5	.8	.1	.9	-	.2	-	-
3. Sand roadway surfaces	14.7	10.6	.1	-	.2	.7	.7	-
4. Remove ice from roadway surfaces and shoulders	2.1	1.7	-	-	-	.1	.1	-
Subtotal	54.4	33.9	3.6	2.4	.4	3.4	1.5	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.9	.9	.3	-	-	1.9	-	1.1
2. Paint bridge endwalls, medians and miscellaneous pavement markings	6.6	3.1	-	-	-	.2	-	-
3. Erect, replace, repair or paint signs and guideposts	5.0	1.7	-	-	-	1.0	-	-
4. Clean signs and reflectors	5.2	2.9	-	-	-	.1	-	-
Subtotal	22.7	8.6	.3	-	-	3.2	-	1.1
G. Other:								
1. Remove litter from right-of-way	5.7	2.6	-	-	-	.1	-	-
Subtotal	5.7	2.6	-	-	-	.1	-	-
Total	113.1	64.2	4.5	2.4	.4	7.4	1.5	6.7

TABLE 32

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 23: Location — Urban; Surface — Bituminous treated; Period constructed — 1926-45;

Average daily traffic — Under 1000

— Time in hours per mile —

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	5.0	3.7	-	-	-	-	-	-
2. Patch roadway surfaces with bituminous cold mix	227.7	155.8	.7	1.1	.2	4.7	13.2	3.4
Subtotal	232.7	159.5	.7	1.1	.2	4.7	13.2	3.4
B. Special surface:								
1. Seal bituminous pavements	501.5	320.5	23.6	30.3	1.8	9.7	50.0	146.8
2. Resurface with bituminous mixes	307.1	166.1	-	31.8	-	6.0	36.3	63.2
Subtotal	808.6	486.6	23.6	62.1	1.8	15.7	86.3	210.0
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	7.3	3.9	-	-	-	.2	-	-
2. Patch shoulders and approaches with bituminous cold mix	12.7	4.4	-	-	-	-	-	-
3. Blade or reshape shoulders and approaches	17.3	6.3	3.9	5.2	-	.3	-	-
Subtotal	37.3	14.6	3.9	5.2	-	.5	-	-
D. Roadside and drainage:								
1. Clean or repair unpaved drainage ditches	63.1	19.8	4.8	1.9	-	1.2	20.7	.3
2. Mow roadsides with tractor (including shoulders)	1.0	-	-	-	-	-	.8	-
Subtotal	64.1	19.8	4.8	1.9	-	1.2	21.5	.3
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	38.2	21.0	6.6	-	-	2.7	.5	-
2. Erect snow fences	11.1	.2	-	-	-	.2	-	-
3. Remove snow fences	3.1	1.0	-	-	-	-	-	-
4. Remove ice from roadway surface and shoulders	1.3	1.5	-	-	-	-	-	-
Subtotal	53.7	23.7	6.6	-	-	2.9	.5	-
F. Traffic service:								
1. Erect, replace, repair or paint signs and guideposts	20.3	11.9	-	-	-	2.1	-	-
Subtotal	20.3	11.9	-	-	-	2.1	-	-
G. Other:								
1. Remove litter from right-of-way	3.2	.7	-	-	-	-	-	-
2. Miscellaneous work resulting from maintenance contracts	103.4	79.7	-	.2	-	2.4	-	.5
Subtotal	106.6	80.4	-	.2	-	2.4	-	.5
Total	1,323.3	796.5	39.6	70.5	2.0	29.5	121.5	214.2

TABLE 33

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 24: Location -- Urban; Surface -- Bituminous treated; Period constructed -- 1946-59;
Average daily traffic -- 1000-3000

- Time in hours per mile -

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	7.6	3.4	-	-	-	.2	-	-
2. Patch roadway surfaces with bituminous cold mix	40.4	19.1	.2	1.4	-	.5	.5	1.6
Subtotal	48.0	22.5	.2	1.4	-	.7	.5	1.6
B. Special surface:								
1. Seal bituminous pavements	44.2	23.0	-	-	.3	.6	.2	11.7
2. Plane or roll bituminous pavements	6.3	8.3	-	2.7	-	.1	-	-
Subtotal	50.5	31.3	-	2.7	.3	.7	.2	11.7
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	3.7	1.3	-	.1	-	-	-	.4
Subtotal	3.7	1.3	-	.1	-	-	-	.4
D. Roadside and drainage:								
1. Mow roadsides with tractor (including shoulders)	4.2	-	-	-	-	-	3.3	-
Subtotal	4.2	-	-	-	-	-	3.3	-
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	24.2	13.6	4.9	.8	-	1.2	.1	-
2. Sand roadway surfaces	9.2	4.0	-	-	.3	.4	.7	-
3. Salt roadway surfaces	.6	.3	.1	-	-	-	-	-
4. Remove ice from roadway surfaces and shoulders	.9	.8	.3	-	-	-	-	-
Subtotal	34.9	18.7	5.3	.8	.3	1.6	.8	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	.3	.1	-	-	-	-	-	-
2. Erect, replace, repair or paint signs and guideposts	1.7	.5	-	-	-	.9	-	-
Subtotal	2.0	.6	-	-	-	.9	-	-
Total	143.3	74.4	5.5	5.0	.6	3.9	4.8	13.7

TABLE 34

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 25: All rural

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	10.6	5.1	.5	1.5	.1	.4	.8	.2
2. Patch roadway surfaces with bituminous cold mix	14.2	6.1	.3	.6	-	.5	.5	.8
3. Patch roadway surfaces with bituminous hot mix	5.2	2.5	.4	-	-	.2	.6	2.5
4. Blade gravel surfaces	2.4	-	.1	2.0	-	-	-	-
5. Fill joints and cracks in roadway surfaces	.9	.4	-	-	-	-	-	.2
6. Clean or drain roadway surfaces	.5	.2	-	-	-	.1	-	-
Subtotal	33.8	14.3	1.3	4.1	.1	1.2	1.9	3.7
B. Special surface:								
1. Mudjack concrete pavements	1.1	.6	.1	-	-	-	.1	.2
2. Rebuild gravel surfaces	4.4	3.4	.6	.1	-	.1	-	-
3. Seal bituminous and concrete pavements	13.1	6.7	.8	-	.1	.3	.8	3.3
4. Resurface with bituminous mixes	5.6	2.5	.5	1.0	-	.1	1.2	2.2
5. Plane or roll bituminous pavements	1.1	.2	.1	.3	-	.2	.2	.2
6. Rebuild aggregate base courses	.5	.2	-	-	.1	.1	.1	.1
Subtotal	25.8	13.6	2.1	1.4	.2	.8	2.4	6.0
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	2.4	1.3	.1	.4	-	-	-	.2
2. Patch shoulders and approaches with aggregate	5.0	2.6	.1	.1	-	.1	.2	.2
3. Patch shoulders and approaches with bituminous cold mix	3.5	1.4	.3	.2	-	.1	.3	.4
4. Reseed or resod, shoulders and approaches	.1	-	-	-	-	-	-	-
5. Blade or reshape shoulders and approaches	1.0	-	.1	.6	-	-	.2	-
Subtotal	12.0	5.3	.6	1.3	-	.2	.7	.8
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.0	.5	.1	-	.1	.1	-	-
2. Repair or replace pipes and tiles	1.0	.4	-	-	.1	.1	-	-
3. Clean pipes, tiles and box culverts	.8	.3	-	-	.1	-	-	-
4. Clean or repair unpaved drainage ditches	5.4	2.3	-	-	.9	.9	-	-
5. Clean paved flumes, gutters and drop inlets	.1	-	-	-	-	-	-	-
6. Repair stone riprap	.9	.4	-	-	-	-	.2	.1
7. Remove trees from roadsides	.2	.1	-	-	-	-	-	-
8. Mow roadsides with tractor (including shoulders)	19.7	2.9	.1	-	-	.9	18.0	.1
9. Mow roadsides with hand tools (including shoulders)	2.4	1.2	-	-	-	.1	.1	-
10. Spray weeds on roadsides	2.5	.9	-	-	-	.2	.4	.9
Subtotal	34.0	9.0	.2	-	1.2	2.3	18.7	1.1
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	41.6	18.0	5.7	5.3	.2	2.6	.6	-
2. Remove snow from bridges	1.0	.4	.1	.1	-	.1	-	-
3. Erect snow fences	10.3	4.3	-	-	-	.3	-	-
4. Remove snow fences	6.6	2.4	-	-	-	.4	.2	-
5. Sand roadway surfaces	9.4	5.4	.4	-	.2	.4	.7	-
6. Salt roadway surfaces	4.5	1.8	.3	.4	-	.2	.3	-
7. Remove ice from roadway surfaces and shoulders	3.4	1.4	.8	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	.7	.3	-	-	-	.1	-	-
9. Put out and remove cinder barrels	.7	.3	-	-	-	-	-	-
Subtotal	78.2	34.3	7.3	5.8	.4	4.3	1.9	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.0	.7	.1	-	-	2.2	-	.7
2. Paint bridge endwalls, medians, and miscellaneous pavement markings	1.2	.4	-	-	-	.1	.1	.1
3. Erect, replace, repair or paint signs and guideposts	4.4	1.7	-	-	-	.9	-	.1
4. Clean signs and reflectors	1.3	.5	-	-	-	.2	-	-
5. Remove or paint guardrails	.5	.2	-	-	-	.1	-	-
Subtotal	12.4	3.5	.1	-	-	3.5	.1	.9
G. Other:								
1. Clean or repair bridges	.7	.2	-	-	-	-	-	.1
2. Remove litter from right-of-way	1.9	.8	-	-	-	.1	-	-
3. Miscellaneous work resulting from maintenance contracts	1.8	1.2	-	.1	-	.2	-	-
4. Miscellaneous work resulting from construction contracts 1/	2.4	.7	.1	.5	-	.5	-	.1
Subtotal	6.8	2.9	.1	.6	-	.8	-	.2
Total	203.0	82.9	11.7	13.2	1.9	13.1	25.7	12.7

1/ Some sections were wholly or partially under construction during part of the study period.

TABLE 35

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 26: All urban

– Time in hours per mile – 1/

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All other
A. Routine surface:								
1. Patch roadway surfaces with aggregate	.7	.4	-	-	-	-	-	-
2. Patch roadway surfaces with bituminous cold mix	39.3	19.7	.5	.4	.1	2.5	.9	1.3
3. Patch roadway surfaces with bituminous hot mix	1.6	.5	-	-	-	.2	-	-
4. Clean or drain roadway surfaces	2.2	.9	-	-	-	-	-	-
Subtotal	43.8	21.5	.5	.4	.1	2.7	.9	1.3
B. Special surface:								
1. Mudjack concrete pavements	.8	.5	.1	-	-	-	.1	.2
2. Seal bituminous and concrete pavements	26.1	16.3	1.6	1.1	.1	.5	2.0	7.7
3. Resurface with bituminous mixes	11.3	6.1	-	1.2	-	.2	1.3	2.3
4. Plane or roll bituminous pavements	.4	.5	-	.2	-	-	-	-
Subtotal	38.6	23.4	1.7	2.5	.1	.7	3.4	10.2
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	4.2	2.4	-	.8	-	.1	-	.6
2. Patch shoulders and approaches with aggregate	8.3	4.0	.2	.5	-	.2	.3	.3
3. Patch shoulders and approaches with bituminous cold mix	5.5	2.3	.5	.2	-	.1	.3	.6
4. Reseed or resod shoulders and approaches	5.2	2.3	-	-	-	.1	1.2	.3
5. Blade or reshape shoulders and approaches	2.7	.2	.2	1.5	-	.1	.6	-
Subtotal	25.9	11.2	.9	3.0	-	.6	2.4	1.8
D. Roadside and drainage:								
1. Repair cut and fill slopes	6.0	2.2	-	.9	-	.1	1.0	-
2. Clean pipes, tiles and box culverts	10.4	3.6	-	1.4	1.3	1.5	2.2	-
3. Clean or repair unpaved drainage ditches	5.8	2.0	.2	.5	.6	.6	.8	-
4. Clean paved flumes, gutters and drop inlets	4.5	1.7	-	-	-	.4	-	-
5. Repair stone riprap	.3	.2	-	-	-	-	-	-
6. Remove trees from roadsides	4.2	1.8	-	-	-	.1	-	-
7. Mow roadsides with tractors (including shoulders)	12.2	.4	-	-	-	.2	10.3	-
8. Mow roadsides with hand tools (including shoulders)	.3	.2	-	-	-	-	-	-
9. Spray weeds on roadsides	.2	-	-	-	-	-	.1	.1
Subtotal	43.9	12.1	.2	2.8	1.9	2.9	14.4	.1
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	43.0	21.2	4.2	7.6	.3	2.3	.5	-
2. Remove snow from bridges	.8	.2	-	.1	-	.2	-	-
3. Erect snow fences	1.7	.5	-	-	-	-	-	-
4. Remove snow fences	1.0	.3	-	-	-	-	-	-
5. Sand roadway surfaces	7.2	4.0	.3	-	.2	.3	.6	-
6. Salt roadway surfaces	5.2	2.3	.1	.9	-	.2	.4	-
7. Remove ice from roadway surfaces and shoulders	5.1	2.4	1.0	-	-	.3	.1	-
8. Remove snow and ice from drainage ditches	3.8	.5	-	-	-	1.3	-	-
9. Put out and remove cinder barrels	.2	.1	-	-	-	-	-	-
Subtotal	68.0	31.5	5.6	8.6	.5	4.6	1.6	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.7	.6	-	-	-	2.8	-	.9
2. Paint bridge endwalls, medians and miscellaneous pavement markings	6.3	.9	-	-	-	1.6	.1	1.1
3. Erect, replace, repair or paint signs and guideposts	11.1	4.0	-	-	-	2.6	-	-
4. Clean signs and reflectors	4.0	1.3	-	-	-	1.0	.1	.1
Subtotal	27.1	6.8	-	-	-	8.0	.2	2.1
G. Other:								
1. Clean or repair bridges	.1	.1	-	-	-	-	-	-
2. Remove litter from right-of-way	2.3	.7	-	-	-	.2	-	-
3. Miscellaneous work resulting from maintenance contracts	10.1	6.3	-	-	-	1.2	.8	.1
4. Miscellaneous work resulting from construction contracts	1.2	.2	-	-	-	.3	-	-
Subtotal	13.7	7.3	-	-	-	1.7	.8	.1
Total	261.0	113.8	8.9	17.3	2.6	21.2	23.7	15.6

1/ 26.7 percent of the mileage was four-lane highways.

TABLE 36

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 27: All portland cement concrete surfaces

— Time in hours per mile — 1/

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	.1	-	-	-	-	-	-	-
2. Patch roadway surfaces with bituminous cold mix	12.9	5.6	.2	.1	-	.8	.2	.3
3. Patch roadway surfaces with bituminous hot mix	.2	.1	-	-	-	-	-	-
4. Fill joints and cracks in roadway surfaces	1.8	.7	-	-	-	-	-	.3
5. Clean or drain roadway surfaces	1.0	.3	-	.1	-	.2	-	-
Subtotal	16.0	6.7	.2	.2	-	1.0	.2	.6
B. Special surfaces:								
1. Mudjack concrete pavements	1.5	.8	.1	-	-	-	.1	.3
2. Seal bituminous and concrete pavements	.3	.2	.1	-	-	-	-	.1
3. Plane or roll bituminous pavements	.1	-	-	-	-	-	-	-
Subtotal	1.9	1.0	.2	-	-	-	.1	.4
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	5.5	3.0	.2	.9	-	.1	.1	.5
2. Patch shoulders and approaches with aggregate	7.4	3.6	.1	.2	.1	.1	.3	.1
3. Patch shoulders and approaches with bituminous cold mix	5.3	1.9	.5	.2	-	.1	.5	.6
4. Reseed or resod shoulders and approaches	1.0	.4	-	-	-	-	.2	.1
5. Blade or reshape shoulders and approaches	1.3	.1	.1	1.1	-	-	.1	-
Subtotal	20.5	9.0	.9	2.4	.1	.3	1.2	1.3
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.8	.9	-	.1	-	.1	.2	-
2. Repair or replace pipes and tiles	.7	.3	-	-	.1	.1	-	-
3. Clean pipes, tiles and box culverts	2.8	1.1	-	.2	.2	.3	.4	-
4. Clean or repair unpaved drainage ditches	3.3	1.3	-	.1	.5	.4	-	-
5. Clean paved flumes, gutters and drop inlets	.6	.2	-	-	-	.1	-	-
6. Remove trees from roadsides	.8	.4	-	-	-	-	-	-
7. Mow roadsides with tractor (including shoulders)	23.5	3.3	-	-	-	1.1	21.8	.1
8. Mow roadsides with hand tools (including shoulders)	1.7	.7	-	-	-	.1	.1	-
9. Spray weeds on roadsides	2.4	.9	-	-	-	.1	.3	.9
Subtotal	37.6	9.1	-	.4	.8	2.3	22.8	1.0
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	44.3	18.2	6.8	5.9	.3	2.6	.5	-
2. Remove snow from bridges	.6	.2	-	-	-	.1	-	-
3. Erect snow fences	8.9	3.6	-	-	-	.3	-	-
4. Remove snow fences	5.8	2.1	-	-	-	.3	.2	-
5. Sand roadway surfaces	7.6	4.1	.3	-	.2	.4	.7	-
6. Salt roadway surfaces	5.7	2.2	.5	.5	-	.2	.4	-
7. Remove ice from roadway surfaces and shoulders	4.1	1.6	1.2	-	-	.2	-	-
8. Remove snow and ice from drainage ditches	1.7	.6	-	-	-	.3	-	-
9. Put out and remove cinder barrels	1.1	.5	-	-	-	.1	-	-
Subtotal	79.8	33.1	8.8	6.4	.5	4.5	1.8	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.0	.6	-	.1	-	2.5	-	.7
2. Paint bridge endwalls, medians and miscellaneous pavement markings	2.4	.6	-	-	-	.4	.1	.3
3. Erect, replace, repair or paint signs and guideposts	5.5	1.9	-	-	-	1.3	-	-
4. Clean signs and guideposts	1.1	.3	-	-	-	.3	.1	.1
5. Remove or paint guardrails	.9	.3	-	.1	-	.1	-	-
Subtotal	14.9	3.7	-	.2	-	4.6	.2	1.1
G. Other:								
1. Clean or repair bridges	.3	.1	-	-	-	-	-	-
2. Remove litter from right-of-way	2.4	1.0	-	-	-	.1	-	-
3. Miscellaneous work resulting from maintenance contracts	2.9	1.9	-	-	-	.5	.1	-
4. Miscellaneous work resulting from construction contracts 2/	2.7	.9	-	.1	-	.9	-	-
Subtotal	8.3	3.9	-	.1	-	1.5	.1	-
Total	179.0	66.5	10.1	9.7	1.4	14.2	26.4	4.4

1/ 4.2 percent of the mileage was 4-lane divided highway.
2/ Some sections were wholly or partially under construction during part of the study period.

TABLE 37

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 28: <u>All bituminous overlay surfaces</u>

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	5.5	2.6	.1	-	-	.1	-	.8
2. Patch roadway surfaces with bituminous hot mix	17.1	8.2	1.5	-	-	.4	2.2	8.5
3. Fill joints and cracks in roadway surfaces	.1	-	-	-	-	-	-	-
4. Clean or drain roadway surfaces	.4	.1	-	-	-	.1	-	-
Subtotal	23.1	10.9	1.6	-	-	.6	2.2	9.3
B. Special surface:								
1. Mudjack concrete pavements	1.5	.9	.2	-	-	-	.1	.3
2. Seal bituminous and concrete pavements	.7	.4	.1	-	-	-	-	.2
3. Plane or roll bituminous pavements	1.0	.2	-	.5	-	.3	-	-
Subtotal	3.2	1.5	.3	.5	-	.3	.1	.5
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	.4	.2	-	-	-	-	-	-
2. Patch shoulders and approaches with aggregate	5.6	3.3	.1	-	.1	.1	.3	.4
3. Patch shoulders and approaches with bituminous cold mix	3.3	1.4	.3	.3	-	.1	.2	.4
4. Blade or reshape shoulders and approaches	1.6	-	.4	.4	-	-	.7	-
Subtotal	10.9	4.9	.8	.7	.1	.2	1.2	.8
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.6	.7	.2	-	.1	.1	.1	.1
2. Repair or replace pipes and tiles	1.2	.5	.1	.1	.1	.2	-	-
3. Clean pipes, tiles and box culverts	.6	.3	-	-	.1	-	-	-
4. Clean or repair unpaved drainage ditches	11.1	4.6	.1	-	2.0	2.3	-	-
5. Clean paved flumes, gutters and drop inlets	.2	.1	-	-	-	-	-	-
6. Repair stone riprap	.5	.2	-	-	-	.1	.1	-
7. Mow roadsides with tractor (including shoulders)	19.4	2.7	-	-	-	.8	17.7	.1
8. Mow roadsides with hand tools (including shoulders)	3.9	2.1	-	-	-	.1	.1	-
9. Spray weeds on roadsides	2.5	.5	-	-	-	.5	.6	.8
Subtotal	41.0	11.7	.4	.1	2.3	4.1	18.6	1.0
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	42.9	20.2	6.0	4.7	.2	2.8	.5	-
2. Remove snow from bridges	1.3	.5	.1	.1	-	.1	-	-
3. Erect snow fences	12.5	5.2	-	-	-	.3	-	-
4. Remove snow fences	7.6	3.0	-	-	-	.3	.2	-
5. Sand roadway surfaces	8.6	5.8	.1	-	.2	.4	.4	-
6. Salt roadway surfaces	6.5	2.7	.3	.3	-	.3	.4	-
7. Remove ice from roadway surfaces and shoulders	2.8	1.5	.4	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	.2	.1	-	-	-	-	-	-
9. Put out and remove cinder barrels	.4	.2	-	-	-	-	-	-
Subtotal	82.8	39.2	6.9	5.1	.4	4.4	1.6	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.4	.4	.2	-	-	2.3	-	.8
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.0	.3	-	-	-	.1	.1	.1
3. Erect, replace, repair or paint signs and guideposts	5.6	2.3	-	-	-	1.0	-	.1
4. Clean signs and reflectors	2.9	1.3	-	-	-	.4	-	-
5. Remove or paint guardrails	.1	-	-	-	-	-	-	-
Subtotal	15.0	4.3	.2	-	-	3.8	.1	1.0
G. Other:								
1. Clean or repair bridges	1.4	.5	-	-	-	.1	-	.2
2. Remove litter	1.9	.9	-	-	-	-	-	-
3. Miscellaneous work resulting from maintenance contracts	1.8	1.1	-	-	-	.1	-	-
4. Miscellaneous work resulting from construction contracts 1/	.2	.1	-	-	-	.1	-	-
Subtotal	5.3	2.6	-	-	-	.3	-	.2
Total	181.3	75.1	10.2	6.4	2.8	13.7	23.8	12.8

1/ Some sections were partially under construction for short periods of time.

TABLE 38

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 29: <u>All bituminous plant mix surfaces</u>

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-Graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	6.8	2.2	2.1	-	-	.2	.2	-
2. Patch roadway surfaces with bituminous cold mix	9.7	4.0	.4	.1	-	.9	.5	.3
3. Patch roadway surfaces with bituminous hot mix	1.9	.9	.1	-	-	.1	-	.5
4. Clean or drain roadway surfaces	.1	-	-	-	-	-	-	-
Subtotal	18.5	7.1	2.6	.1	-	1.2	.7	.8
B. Special surface:								
1. Seal bituminous and concrete pavements	30.9	16.9	.8	-	.1	.7	2.6	7.6
2. Resurface with bituminous mixes	11.3	4.2	1.1	2.2	-	.2	2.5	4.9
3. Roll or plane bituminous pavements	1.2	.1	.6	-	-	-	.2	.1
4. Rebuild aggregate base courses	2.7	1.2	.1	.2	.5	.6	.5	.3
Subtotal	46.1	22.4	2.6	2.4	.6	1.5	5.8	12.9
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	1.6	.9	-	-	-	-	.2	-
2. Patch shoulders and approaches with bituminous cold mix	.6	.4	-	-	-	-	-	.2
3. Blade or reshape shoulders and approaches	.1	-	-	-	-	-	-	-
Subtotal	2.3	1.3	-	-	-	-	.2	.2
D. Roadside and drainage:								
1. Repair cut and fill slopes	.7	.3	.1	-	.1	.1	-	-
2. Repair or replace pipes and tiles	1.4	.6	-	-	.1	.3	-	.2
3. Clean pipes, tiles and box culverts	.2	.1	-	-	-	-	-	-
4. Clean or repair unpaved drainage ditches	3.2	1.4	-	.1	.4	.4	-	-
5. Clean paved flumes, gutters and drop inlets	.4	.2	-	-	-	-	-	-
6. Repair stone riprap	4.2	2.0	.1	-	-	.1	.7	.7
7. Remove trees from roadsides	.4	.2	-	-	-	.1	-	-
8. Mow roadsides with tractor (including shoulders)	17.9	2.7	.4	-	-	.5	15.8	.1
9. Mow roadsides with hand tools (including shoulders)	2.8	1.4	.2	-	-	.1	-	-
10. Spray weeds on roadsides	2.5	1.1	-	-	-	-	.3	.9
Subtotal	33.7	10.0	.8	.1	.6	1.6	16.8	1.9
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	39.2	18.1	3.9	3.4	.2	2.5	.7	-
2. Remove snow from bridges	1.8	.6	.1	.3	-	.1	-	-
3. Erect snow fences	2.5	1.1	-	-	-	.1	-	-
4. Remove snow fences	1.5	.6	-	-	-	.1	-	-
5. Sand roadway surfaces	15.7	8.8	.9	-	.3	.7	1.3	-
6. Salt roadway surfaces	.5	.2	-	-	-	.1	-	-
7. Remove ice from roadway surfaces and shoulders	3.7	.9	1.1	.1	-	.3	-	-
8. Remove snow and ice from drainage ditches	.3	.1	-	-	-	-	-	-
9. Put out and remove cinder barrels	.2	.1	-	-	-	-	-	-
Subtotal	65.4	30.5	6.0	3.8	.5	3.9	2.0	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	6.4	1.4	.1	-	-	2.4	-	1.1
2. Paint bridge endwalls, medians, and miscellaneous pavement markings	.7	.3	-	-	-	.1	-	-
3. Erect, replace, repair or paint signs and guideposts	3.9	1.7	-	-	-	1.0	-	.1
4. Clean signs and reflectors	1.0	.6	-	-	-	.1	-	-
Subtotal	12.0	4.0	.1	-	-	3.6	-	1.2
G. Other:								
1. Clean or repair bridges	.8	.3	-	-	-	-	-	.2
2. Remove litter from right-of-way	1.0	.5	-	-	-	-	-	-
Subtotal	1.8	.8	-	-	-	-	-	.2
Total	179.8	76.1	12.1	6.4	1.7	11.8	25.5	17.2

TABLE 39

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 30: <u>All bituminous treated surfaces</u>

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	81.9	32.6	.1	20.0	1.1	2.1	6.9	3.0
2. Patch roadway surfaces with bituminous cold mix	102.7	45.5	1.1	7.7	.1	1.4	5.8	6.2
Subtotal	184.6	78.1	1.2	27.7	1.2	3.5	12.7	9.2
B. Special surface:								
1. Seal bituminous and concrete pavements	120.7	62.0	8.9	1.3	.7	2.2	5.7	31.3
2. Resurface with bituminous mixes	58.1	29.1	3.1	8.5	.1	.9	10.7	19.7
3. Plane or roll bituminous pavements	8.3	2.3	-	3.0	-	1.1	1.9	1.9
Subtotal	187.1	93.4	12.0	12.8	.8	4.2	18.3	52.9
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	1.8	.8	-	-	-	-	-	-
2. Patch shoulders and approaches with bituminous cold mix	4.6	2.2	-	.1	-	.1	.1	.5
3. Blade or reshape shoulders and approaches	1.0	.2	.2	.5	-	-	-	-
Subtotal	7.4	3.2	.2	.6	-	.1	.1	.5
D. Roadside and drainage:								
1. Clean pipes, tiles and box culverts	.4	.1	-	-	-	-	-	-
2. Clean or repair unpaved drainage ditches	2.4	.8	.2	.1	-	-	.8	-
3. Mow roadsides with tractor (including shoulders)	2.8	-	-	-	-	-	2.3	-
4. Spray weeds on roadsides	2.0	.5	-	-	-	.4	.7	.8
Subtotal	7.6	1.4	.2	.1	-	.4	3.8	.8
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	35.5	18.5	2.3	5.7	.3	1.7	.4	-
2. Erect snow fences	12.1	5.3	-	-	-	.2	-	-
3. Remove snow fences	10.0	3.1	-	-	-	1.6	.7	-
4. Sand roadway surfaces	10.2	4.8	-	-	.3	.4	.8	-
5. Salt roadway surfaces	2.2	.9	-	.7	-	.1	.2	-
6. Remove ice from roadway surfaces and shoulders	3.7	2.2	.3	-	-	.2	-	-
Subtotal	73.7	34.8	2.6	6.4	.6	4.2	2.1	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	4.3	1.1	-	-	-	1.0	-	.2
2. Paint bridge endwalls, medians and miscellaneous pavement markings	.9	.3	-	-	-	-	.1	.2
3. Erect, replace, repair or paint signs and guideposts	2.9	1.1	-	-	-	.6	-	-
4. Clean signs and reflectors	.1	.1	-	-	-	-	-	-
Subtotal	8.2	2.6	-	-	-	1.6	.1	.4
G. Other:								
1. Remove litter from right-of-way	2.3	.7	-	-	-	-	-	-
2. Miscellaneous work resulting from maintenance contracts	3.9	3.0	-	-	-	.1	-	-
3. Miscellaneous work resulting from construction contracts 1/	.7	.4	-	-	-	-	.2	-
Subtotal	6.9	4.1	-	-	-	.1	.2	-
Total	475.5	217.6	16.2	47.6	2.6	14.1	37.3	63.8

1/ Some sections were partially under construction for short periods of time.

TABLE 40

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA
(INCLUDING DISTRIBUTED OVERHEAD)

Group 31: All gravel surfaces

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	76.0	52.3	3.2	.1	.2	3.8	5.5	.3
2. Blade gravel surfaces	53.9	1.0	2.8	45.9	-	.8	.5	.1
3. Clean or drain roadway surfaces	1.6	.9	-	-	-	.2	-	-
Subtotal	131.5	54.2	6.0	46.0	.2	4.8	6.0	.4
B. Special surface:								
1. Rebuild gravel surfaces	99.7	77.6	13.5	1.9	.1	2.1	.1	.4
Subtotal	99.7	77.6	13.5	1.9	.1	2.1	.1	.4
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	.2	.1	-	-	-	-	-	-
2. Blade or reshape shoulders and approaches	.1	-	-	.1	-	-	-	-
Subtotal	.3	.1	-	.1	-	-	-	-
D. Roadside and drainage:								
1. Repair cut and fill slopes	.8	.4	-	-	-	-	.1	-
2. Clean and repair unpaved drainage ditches	7.2	3.3	-	-	1.5	1.6	-	-
3. Mow roadsides with tractor (including shoulders)	2.4	1.0	-	-	-	-	1.8	-
4. Mow roadsides with hand tools (including shoulders)	.3	.3	-	-	-	-	-	-
5. Spray weeds on roadsides	1.2	.6	-	-	-	-	-	.5
Subtotal	11.9	5.6	-	-	1.5	1.6	1.9	.5
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	28.2	5.8	2.5	14.4	.1	2.0	.8	-
2. Remove snow from bridges	1.4	.6	-	-	-	.1	-	-
3. Erect snow fences	25.8	11.7	-	-	-	.7	.1	-
4. Remove snow fences	15.9	5.4	-	.6	-	.7	-	-
5. Sand roadway surfaces	3.0	1.1	.4	-	.1	.1	.2	-
Subtotal	74.3	24.6	2.9	15.0	.2	3.6	1.1	-
F. Traffic service:								
1. Erect, replace, repair or paint signs and guideposts	.6	.1	-	-	-	.2	-	-
2. Clean signs and reflectors	.2	.1	-	-	-	.1	-	-
Subtotal	.8	.2	-	-	-	.3	-	-
G. Other:								
1. Miscellaneous work resulting from maintenance contracts	9.0	4.2	-	3.1	-	1.3	-	-
2. Miscellaneous work resulting from construction contracts 1/	24.9	5.7	2.5	9.2	-	1.5	.3	.9
Subtotal	33.9	9.9	2.5	12.3	-	2.8	.3	.9
Total	352.4	172.2	24.9	75.3	2.0	15.2	9.4	2.2

1/ Some sections were wholly or partially under construction during part of the study period.

TABLE 41

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 32: All constructed 1926-45

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	25.7	12.9	.4	4.2	.3	.9	2.2	.7
2. Patch roadway surfaces with bituminous cold mix	35.3	15.5	.5	1.6	-	1.2	1.4	1.6
3. Patch roadway surfaces with bituminous hot mix	.3	.1	-	-	-	.1	-	-
4. Blade gravel surfaces	6.8	.1	.4	5.8	-	.1	.1	-
5. Fill joints and cracks in roadway surfaces	2.5	1.0	-	-	-	-	-	.5
6. Clean or drain roadway surfaces	1.5	.5	-	.1	-	.2	-	-
Subtotal	72.1	30.1	1.3	11.7	.3	2.5	3.7	2.8
B. Special surface:								
1. Rebuild gravel surfaces	12.6	9.8	1.7	.2	-	.3	-	-
2. Seal bituminous and concrete pavements	18.3	9.1	1.7	.3	.1	.4	.7	4.9
3. Resurface with bituminous mixes	12.4	6.2	.7	1.8	-	.2	2.3	4.2
4. Plane or roll bituminous pavements	.6	-	-	.3	-	-	.2	.2
Subtotal	43.9	25.1	4.1	2.6	.1	.9	3.2	9.3
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	.4	.3	-	.1	-	-	-	.1
2. Patch shoulders and approaches with aggregate	4.7	2.2	-	.2	-	.1	.2	.1
3. Patch shoulders and approaches with bituminous cold mix	3.9	1.6	.2	.1	-	-	.1	.3
4. Blade or reshape shoulders and approaches	.9	.1	.1	.5	-	-	.1	-
Subtotal	9.9	4.2	.3	.9	-	.1	.4	.5
D. Roadside and drainage:								
1. Repair cut and fill slopes	.4	.2	-	-	.1	.1	-	-
2. Repair or replace pipes and tiles	.6	.3	-	-	-	-	-	-
3. Clean pipes, tiles and box culverts	1.2	.6	-	-	.1	.1	-	-
4. Clean or repair unpaved drainage ditches	4.2	1.6	.1	-	.5	.5	.2	-
5. Clean paved flumes, gutters and drop inlets	.7	.2	-	-	-	.1	-	-
6. Mow roadsides with tractor (including shoulders)	17.6	2.0	-	-	-	1.1	16.3	.1
7. Mow roadsides with hand tools (including shoulders)	5.1	2.6	.1	-	-	.1	.3	-
8. Spray weeds on roadsides	2.9	1.1	-	-	-	.1	.5	1.1
Subtotal	32.7	8.6	.2	-	.7	2.1	17.3	1.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	43.9	18.2	6.5	4.7	.2	2.6	.6	-
2. Remove snow from bridges	.7	.2	-	-	-	.2	-	-
3. Erect snow fences	17.3	7.2	-	-	-	.5	-	-
4. Remove snow fences	11.4	4.0	-	.1	-	.8	.4	-
5. Sand roadway surfaces	9.9	4.9	.4	-	.3	.5	.9	-
6. Salt roadway surfaces	4.3	1.7	.2	.1	-	.1	.3	-
7. Remove ice from roadway surfaces and shoulders	3.0	1.2	1.0	-	-	.2	-	-
8. Remove snow and ice from drainage ditches	1.8	.8	-	-	-	.2	-	-
9. Put out and remove cinder barrels	1.2	.6	-	-	-	-	-	-
Subtotal	93.5	38.8	8.1	4.9	.5	5.1	2.2	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	4.4	.9	-	.1	-	1.8	-	.5
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.3	.5	-	-	-	.1	.1	.1
3. Erect, replace, repair or paint signs and guideposts	4.9	1.6	-	-	-	1.1	-	-
4. Clean signs and reflectors	.7	.3	-	-	-	.2	-	-
5. Remove or paint guardrails	1.3	.4	-	.1	-	.2	-	-
Subtotal	12.6	3.7	-	.2	-	3.4	.1	.6
G. Other:								
1. Clean or repair bridges	.3	.1	-	-	-	-	-	-
2. Remove litter from right-of-way	2.1	.8	-	-	-	.1	-	-
3. Miscellaneous work resulting from maintenance contracts	6.0	3.8	-	.4	-	.8	.2	-
4. Miscellaneous work resulting from construction contracts 1/	3.2	.7	.3	1.2	-	.2	-	.1
Subtotal	11.6	5.4	.3	1.6	-	1.1	.2	.1
Total	276.3	115.9	14.3	21.9	1.6	15.2	27.1	14.5

1/ Some sections were wholly or partially under construction during part of the study period.

TABLE 42

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 33: All constructed 1946-59

– Time in hours per mile – 1/

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	2.4	.9	.5	.1	-	.1	.1	-
2. Patch roadway surfaces with bituminous cold mix	6.9	3.0	.1	.1	-	.4	.2	.5
3. Patch roadway surfaces with bituminous hot mix	7.1	3.4	.6	-	-	.2	.8	3.4
4. Fill joints and cracks in roadway surfaces	.1	-	-	-	-	-	-	-
5. Clean or drain roadway surfaces	.2	.1	-	-	-	-	-	-
Subtotal	16.7	7.4	1.2	.2	-	.7	1.1	3.9
B. Special surface:								
1. Mudjack concrete pavements	1.6	.8	.1	-	-	-	.1	.3
2. Seal bituminous and concrete pavements	12.1	6.7	.4	-	.1	.2	.9	3.0
3. Resurface with bituminous mixes	3.0	1.1	.3	.6	-	.1	.7	1.3
4. Plane or roll bituminous pavements	1.3	.3	.2	.3	-	.2	.2	.1
5. Rebuild aggregate base courses	.7	.3	-	-	.1	.2	.1	.1
Subtotal	18.7	9.2	1.0	.9	.2	.7	2.0	4.8
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	3.6	2.0	.1	.6	-	.1	.1	.3
2. Patch shoulders and approaches with aggregate	5.5	2.9	.1	.1	-	.1	.3	.2
3. Patch shoulders and approaches with bituminous cold mix	3.6	1.3	.4	.2	-	.1	.3	.5
4. Reseed or resod shoulders and approaches	.6	.3	-	-	-	-	.1	-
5. Blade or reshape shoulders and approaches	1.2	-	.1	.7	-	-	.3	-
Subtotal	14.5	6.5	.7	1.6	-	.3	1.1	1.0
D. Roadside and drainage:								
1. Repair cut and fill slopes	1.9	.9	.1	.1	.1	.1	.1	-
2. Repair or replace pipes, and tiles	1.0	.4	.1	-	.1	.2	-	.1
3. Clean pipes, tiles and box culverts	1.6	.6	-	.1	.2	.2	.2	-
4. Clean or repair unpaved drainage ditches	6.0	2.6	.1	.1	1.1	1.1	-	-
5. Clean paved flumes, gutters and drop inlets	.2	.1	-	-	-	-	-	-
6. Repair stone riprap	1.3	.6	-	-	-	.1	.2	.2
7. Remove trees from roadsides	.6	.3	-	-	-	-	-	-
8. Mow roadsides with tractor (including shoulders)	19.9	3.1	.1	-	-	.7	18.0	.1
9. Mow roadsides with hand tools (including shoulders)	1.0	.5	-	-	-	.1	-	-
10. Spray weeds on roadsides	2.1	.7	-	-	-	.2	.4	.7
Subtotal	35.6	9.8	.4	.3	1.5	2.7	18.9	1.1
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	40.8	18.3	5.2	5.9	.2	2.5	.6	-
2. Remove snow from bridges	1.1	.4	.1	.1	-	.1	-	-
3. Erect snow fences	6.0	2.5	-	-	-	.1	-	-
4. Remove snow fences	3.7	1.4	-	-	-	.2	.1	-
5. Sand roadway surfaces	9.0	5.5	.3	-	.2	.4	.6	-
6. Salt roadway surfaces	4.6	1.9	.3	.5	-	.2	.3	-
7. Remove ice from roadway surfaces and shoulders	3.8	1.6	.8	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	.4	.1	-	-	-	.1	-	-
9. Put out and remove cinder barrels	.3	.2	-	-	-	-	-	-
Subtotal	69.7	31.9	6.7	6.5	.4	3.8	1.7	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.5	.6	.1	-	-	2.4	-	.9
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.7	.4	-	-	-	.3	.1	.2
3. Erect, replace, repair or paint signs and guideposts	4.9	1.9	-	-	-	1.0	-	.1
4. Clean signs and reflectors	1.8	.7	-	-	-	.3	-	-
5. Remove or paint guardrails	.1	-	-	-	-	-	-	-
Subtotal	14.0	3.6	.1	-	-	4.0	.1	1.2
G. Other:								
1. Clean or repair bridges	.8	.3	-	-	-	-	-	.1
2. Remove litter	1.8	.8	-	-	-	.1	-	-
3. Miscellaneous work resulting from maintenance contracts	.7	.4	-	-	-	.1	-	-
4. Miscellaneous work resulting from construction contracts 2/	1.9	.6	-	-	-	.6	-	-
Subtotal	5.2	2.1	-	-	-	.8	-	.1
Total	174.4	70.5	10.1	9.5	2.1	13.0	24.9	12.1

1/ 2.8 percent of the mileage was four lane highway.

2/ Some sections were partially under construction for short periods of time.

TABLE 43

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

Group 34: All under 1000 ADT

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	25.6	14.9	2.7	.2	.1	1.0	1.4	.1
2. Patch roadway surfaces with bituminous cold mix	16.6	7.7	.4	.4	-	1.1	.8	.3
3. Patch roadway surfaces with bituminous hot mix	1.2	.4	-	-	-	.1	-	-
4. Blade gravel surfaces	11.9	.2	.6	10.1	-	.2	.1	-
5. Clean or drain roadway surfaces	.4	.2	-	-	-	-	-	-
Subtotal	55.7	23.4	3.7	10.7	.1	2.4	2.3	.4
B. Special surface:								
1. Mudjack concrete pavements	1.8	.9	.2	-	-	-	.2	.4
2. Rebuild gravel surfaces	22.0	17.2	3.0	.4	-	.5	-	.1
3. Seal bituminous and concrete pavements	44.0	24.8	.8	.5	.2	.9	3.8	11.2
4. Resurface with bituminous mixes	15.3	6.4	1.1	2.6	-	.3	3.0	5.6
5. Plane or roll bituminous pavements	3.2	.7	.5	.5	-	.4	.5	.5
6. Rebuild aggregate base courses	2.6	1.1	-	.1	.4	.6	.4	.3
Subtotal	88.9	51.1	5.6	4.1	.6	2.7	7.9	18.1
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	3.0	1.4	-	-	-	-	.2	-
2. Patch shoulders and approaches with bituminous cold mix	1.1	.5	-	-	-	-	-	.1
3. Blade or reshape shoulders and approaches	.7	.1	.1	.4	-	-	-	-
Subtotal	4.8	2.0	.1	.4	-	-	.2	.1
D. Roadside and drainage:								
1. Repair cut and fill slopes	.3	.1	-	-	-	-	-	-
2. Repair or replace pipes and tiles	1.0	.5	-	-	-	.2	-	.2
3. Clean pipes, tiles and box culverts	.2	.1	-	-	-	-	-	-
4. Clean or repair unpaved drainage ditches	3.2	1.3	.1	.1	.5	.4	.3	-
5. Clean paved flumes, gutters and drop inlets	.4	.2	-	-	-	-	-	-
6. Mow roadsides with tractor (including shoulders)	13.3	1.4	.4	-	-	.4	11.6	-
7. Mow roadsides with hand tools (including shoulders)	1.7	.9	.2	-	-	.1	-	-
8. Spray weeds on roadsides	2.6	1.1	-	-	-	.2	.1	1.0
Subtotal	22.7	5.6	.7	.1	.5	1.3	12.0	1.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	37.5	13.2	4.0	7.5	.2	2.4	.8	-
2. Remove snow from bridges	.9	.4	-	-	-	.1	-	-
3. Erect snow fences	6.4	2.8	-	-	-	.2	-	-
4. Remove snow fences	4.1	1.4	-	.2	-	.2	-	-
5. Sand roadway surfaces	9.0	3.6	1.0	-	.3	.4	1.0	-
6. Salt roadway surfaces	1.1	.5	-	.1	-	.1	.1	-
7. Remove ice from roadway surfaces and shoulders	3.5	.6	1.1	-	-	.2	-	-
8. Remove snow and ice from drainage ditches	.3	.2	-	-	-	-	-	-
9. Put out and remove cinder barrels	.7	.3	-	-	-	-	-	-
Subtotal	63.5	23.0	6.1	7.8	.5	3.6	1.9	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	4.2	1.1	-	-	-	1.5	-	.8
2. Paint bridge endwalls, medians, and miscellaneous pavement markings	1.2	.5	-	-	-	.1	.1	.1
3. Erect, replace, repair or paint signs and guideposts	4.4	1.6	-	-	-	1.2	-	.1
4. Clean signs and reflectors	.4	.1	-	-	-	.1	-	-
5. Repair or paint guardrails	.7	.2	-	.1	-	-	-	-
Subtotal	10.9	3.5	-	.1	-	2.9	.1	1.0
G. Other:								
1. Clean or repair bridges	.3	.1	-	-	-	-	-	-
2. Remove litter from right-of-way	.8	.3	-	-	-	-	-	-
3. Miscellaneous work resulting from maintenance contracts	3.5	2.1	-	.7	-	.3	-	-
4. Miscellaneous work resulting from construction contracts 1/	11.8	3.4	.5	2.2	-	2.4	.2	.2
Subtotal	16.4	5.9	.5	2.9	-	2.7	.2	.2
Total	262.9	114.5	16.7	26.1	1.7	15.6	24.6	21.0

1/ Some sections were wholly or partially under construction during part of the study period.

TABLE 44

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA
(INCLUDING DISTRIBUTED OVERHEAD)

Group 35: All 1000-3000 ADT

– Time in hours per mile –

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with aggregate	10.0	3.9	-	2.6	.2	.3	.9	.4
2. Patch roadway surfaces with bituminous cold mix	20.1	8.6	.3	1.0	-	.6	.8	1.4
3. Patch roadway surfaces with bituminous hot mix	8.8	4.3	.8	-	-	.2	1.1	4.4
4. Fill joints and cracks in roadway surfaces	1.5	.6	-	-	-	-	-	.3
5. Clean or drain roadway surfaces	.6	.2	-	-	-	.1	-	-
Subtotal	41.0	17.6	1.1	3.6	.2	1.2	2.8	6.5
B. Special surface:								
1. Mudjack concrete pavements	1.4	.8	.1	-	-	-	.1	.3
2. Seal bituminous and concrete pavements	11.2	5.4	1.3	-	.1	.2	.3	2.9
3. Resurface with bituminous mixes	6.1	3.0	.4	1.0	-	.1	1.2	2.3
4. Plane or roll bituminous pavements	.9	.2	-	.5	-	.1	.1	.1
Subtotal	19.6	9.4	1.8	1.5	.1	.4	1.7	5.6
C. Shoulder and approach								
1. Patch shoulders and approaches with soil	2.0	1.1	-	.3	-	.1	.1	.2
2. Patch shoulders and approaches with aggregate	4.9	2.7	-	.1	-	.1	.2	.1
3. Patch shoulders and approaches with bituminous cold mix	2.7	1.1	.1	.1	-	-	.1	.3
4. Blade or reshape shoulders and approaches	1.0	-	.1	.6	-	-	.2	-
Subtotal	10.6	4.9	.2	1.1	-	.2	.6	.6
D. Roadside and drainage:								
1. Repair cut and fill slopes	.7	.3	.1	-	.1	.1	-	-
2. Repair or replace pipes and tiles	.5	.2	-	-	-	-	-	-
3. Clean pipes, tiles and box culverts	1.2	.6	-	-	.1	.1	-	-
4. Clean or repair unpaved drainage ditches	5.5	2.4	-	-	.9	.9	-	-
5. Repair stone riprap	1.5	.7	-	-	-	.1	.2	.2
6. Remove trees from roadsides	.1	.1	-	-	-	-	-	-
7. Mow roadsides with tractor (including shoulders)	16.9	2.5	-	-	-	.9	15.7	.1
8. Mow roadsides with hand tools (including shoulders)	2.5	1.2	-	-	-	.1	-	-
9. Spray weeds on roadsides	2.7	.9	-	-	-	.2	.6	.9
Subtotal	31.6	8.9	.1	-	1.1	2.4	16.5	1.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	42.3	19.4	6.2	3.9	.2	2.6	.5	-
2. Remove snow from bridges	1.1	.4	.1	.1	-	.2	-	-
3. Erect snow fences	12.4	5.2	-	-	-	.3	-	-
4. Remove snow fences	8.1	2.9	-	-	-	.5	.3	-
5. Sand roadway surfaces	12.3	7.5	.2	-	.3	.6	.9	-
6. Salt roadway surfaces	3.2	1.1	.3	.2	-	.1	.2	-
7. Remove ice from roadway surfaces and shoulders	3.3	1.5	.8	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	1.1	.5	-	-	-	.1	-	-
9. Put out and remove cinder barrels	.9	.4	-	-	-	.1	-	-
Subtotal	84.7	38.9	7.6	4.2	.5	4.7	2.0	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.2	.7	.1	.1	-	2.2	-	.7
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.0	.4	-	-	-	.1	.1	.1
3. Erect, replace, repair or paint signs and guideposts	3.8	1.4	-	-	-	.7	-	-
4. Clean signs and reflectors	1.1	.5	-	-	-	.1	-	-
5. Remove or paint guardrails	.6	.2	-	-	-	.1	-	-
Subtotal	11.7	3.2	.1	.1	-	3.2	.1	.8
G. Other:								
1. Clean or repair bridges	.9	.3	-	-	-	-	-	.2
2. Remove litter from right-of-way	2.4	1.0	-	-	-	.1	-	-
3. Miscellaneous work resulting from maintenance contracts	1.6	1.2	-	-	-	.3	-	-
Subtotal	4.9	2.5	-	-	-	.4	-	.2
Total	204.1	85.4	10.9	10.5	1.9	12.5	23.7	14.9

TABLE 45

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 36: All 3000-5000 ADT

— Time in hours per mile —

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	3.7	1.7	.1	-	-	.1	-	.1
2. Patch roadway surfaces with bituminous hot mix	.2	.1	-	-	-	-	-	.1
3. Fill joints and cracks in roadway surfaces	.1	-	-	-	-	-	-	-
4. Clean or drain roadway surfaces	.4	.1	-	-	-	-	-	-
Subtotal	4.4	1.9	.1	-	-	.1	-	.2
B. Special surface:								
1. Seal bituminous and concrete pavements	.7	.4	.1	-	-	-	-	.2
Subtotal	.7	.4	.1	-	-	-	-	.2
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	4.7	2.6	.3	.7	-	.1	-	.4
2. Patch shoulders and approaches with aggregate	6.6	3.3	.1	-	.1	.1	.4	.3
3. Patch shoulders and approaches with bituminous cold mix	6.8	2.4	.9	.4	-	.1	.8	.9
4. Reseed or resod shoulders and approaches	.2	.1	-	-	-	-	-	-
5. Blade or reshape shoulders and approaches	1.5	.1	.2	.8	-	-	.4	-
Subtotal	19.8	8.5	1.5	1.9	.1	.3	1.6	1.6
D. Roadside and drainage:								
1. Repair cut and fill slopes	2.1	1.2	.1	-	.1	.1	.1	-
2. Repair or replace pipes and tiles	1.7	.7	.1	.1	.2	.3	-	-
3. Clean pipes, tiles and box culverts	.4	.2	-	-	-	.1	-	-
4. Clean or repair unpaved drainage ditches	6.8	2.7	.1	-	1.1	1.3	-	-
5. Clean paved flumes, gutters and drop inlets	.2	.1	-	-	-	-	-	-
6. Repair stone riprap	.4	.2	-	-	-	.1	.1	-
7. Remove trees from roadsides	.3	.1	-	-	-	.1	-	-
8. Mow roadsides with tractor (including shoulders)	27.7	4.4	-	-	-	.9	25.3	.1
9. Mow roadsides with hand tools (including shoulders)	2.5	1.2	-	-	-	-	.4	-
10. Spray weeds on roadsides	1.8	.5	-	-	-	.3	.3	.7
Subtotal	43.9	11.3	.3	.1	1.4	3.2	26.2	.8
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	42.8	18.5	5.9	6.4	.2	2.6	.5	-
2. Remove snow from bridges	.9	.4	.1	.1	-	.1	-	-
3. Erect snow fences	7.6	3.1	-	-	-	.2	-	-
4. Remove snow fences	4.7	1.8	-	-	-	.2	.1	-
5. Sand roadway surfaces	4.1	2.5	.1	-	.1	.2	.3	-
6. Salt roadway surfaces	9.1	3.9	.5	.6	-	.4	.6	-
7. Remove ice from roadway surfaces and shoulders	3.5	1.6	.7	-	-	.2	.1	-
8. Remove snow and ice from drainage ditches	.2	.1	-	-	-	-	-	-
9. Put out and remove cinder barrels	.1	.1	-	-	-	-	-	-
Subtotal	73.0	32.0	7.3	7.1	.3	3.9	1.6	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	5.3	.2	.1	-	-	2.5	-	.8
2. Paint bridge endwalls, medians and miscellaneous pavement markings	1.6	.4	-	-	-	.4	-	.1
3. Erect, replace, repair or paint signs and guideposts	6.3	2.4	-	-	-	1.3	-	.1
4. Clean signs and reflectors	2.7	1.0	-	-	-	.6	-	-
5. Remove or paint guardrails	.1	-	-	-	-	-	-	-
Subtotal	16.0	4.0	.1	-	-	4.8	-	1.0
G. Other:								
1. Clean or repair bridges	.4	.1	-	-	-	.1	-	-
2. Remove litter from right-of-way	1.6	.7	-	-	-	-	-	-
3. Miscellaneous work resulting from maintenance contracts	1.9	1.1	-	-	-	.1	-	-
4. Miscellaneous work resulting from construction contracts 1/	.2	.1	-	-	-	-	-	-
Subtotal	4.1	2.0	-	-	-	.2	-	-
Total	161.9	60.1	9.4	9.1	1.8	12.5	29.4	3.8

1/ Some sections were partially under construction for short periods of time.

TABLE 46

LABOR AND EQUIPMENT TIME CHARGED TO DIRECT OPERATIONS ON SELECTED ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

(INCLUDING DISTRIBUTED OVERHEAD)

Group 37: All over 5000 ADT

— Time in hours per mile — 1/

Direct operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pick-ups	Tractors and frontend loaders	All others
A. Routine surface:								
1. Patch roadway surfaces with bituminous cold mix	42.3	19.0	.8	.4	.1	3.7	.6	.8
2. Patch roadway surfaces with bituminous hot mix	3.1	.9	-	-	-	.5	-	-
3. Clean or drain roadway surfaces	3.5	1.4	-	-	-	-	-	-
Subtotal	48.9	21.3	.8	.4	.1	4.2	.6	.8
C. Shoulder and approach:								
1. Patch shoulders and approaches with soil	8.4	4.7	-	1.5	-	.1	-	1.2
2. Patch shoulders and approaches with aggregate	11.6	5.3	.5	1.1	.1	.3	.3	.6
3. Patch shoulders and approaches with bit cold mix	8.5	3.7	1.0	.3	-	.1	.6	1.0
4. Reseed or resod shoulders and approaches	10.3	4.5	-	-	-	.1	2.4	.5
5. Blade or reshape shoulders and approaches	2.3	-	-	2.2	-	-	-	-
Subtotal	41.1	18.2	1.5	5.1	.1	.6	3.3	3.3
D. Roadside and drainage:								
1. Repair cut and fill slopes	11.8	4.3	-	1.8	-	.2	2.1	-
2. Clean pipes, tiles and box culverts	19.4	6.5	-	2.7	2.5	2.9	4.3	-
3. Clean or repair unpaved drainage ditches	6.4	2.5	-	.9	1.0	1.1	-	-
4. Clean paved flumes, gutters and drop inlets	7.0	2.4	-	-	-	.9	-	-
5. Remove trees from roadsides	8.2	3.6	-	-	-	.1	-	-
6. Mow roadsides with tractor (including shoulder)	20.3	.5	-	-	-	.3	17.1	.1
7. Spray weeds on roadsides	.2	-	-	-	-	-	.1	.1
Subtotal	73.3	19.8	-	5.4	3.5	5.5	23.6	.2
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	48.7	24.8	3.5	11.2	.4	2.4	.6	-
2. Erect snow fences	1.7	.7	-	-	-	-	-	-
3. Remove snow fences	1.4	.5	-	-	-	-	.1	-
4. Sand roadway surfaces	4.6	2.8	-	-	.1	.2	.4	-
5. Salt roadway surfaces	8.5	3.8	.2	1.7	-	.4	.6	-
6. Remove ice from roadway surfaces and shoulders	6.9	3.4	1.1	-	-	.4	.1	-
7. Remove snow and ice from drainage ditches	5.1	.2	-	-	-	2.2	-	-
8. Put out and remove cinder barrels	.4	.2	-	-	-	-	-	-
Subtotal	77.3	36.4	4.8	12.9	.5	5.6	1.8	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	6.7	.3	-	-	-	3.7	-	1.1
2. Paint bridge endwalls, medians & misc pvmt markings	11.7	1.4	-	-	-	3.2	.3	2.2
3. Erect, replace, repair or paint signs and guideposts	12.8	5.0	-	-	-	2.9	-	-
4. Clean signs and reflectors	4.1	.9	-	-	-	1.4	.2	.2
Subtotal	35.3	7.6	-	-	-	11.2	.5	3.5
G. Other:								
1. Clean or repair bridges	.3	.1	-	-	-	-	-	-
2. Remove litter from right-of-way	2.7	.7	-	-	-	.4	-	-
3. Misc work resulting from maintenance contracts	12.4	6.6	-	-	-	2.1	1.5	-
4. Misc work resulting from construction contracts 2/	2.3	.5	-	-	-	.6	-	-
Subtotal	17.7	7.9	-	-	-	3.1	1.5	-
Total	293.6	111.2	7.1	23.8	4.2	30.2	31.3	7.8

1/ 52.5 percent of the mileage was four-lane highway.
2/ Some sections were partially under construction for short periods of time.

6. Distribution of labor and equipment time in the three-county control area by month

Comprehensive study records were summarized to obtain the distribution of time by month for labor and five major types of equipment utilized in the three-county control area. All undistributed overhead and direct operations were grouped under major headings. The summaries are shown in Tables 47 to 52. It should be remembered that the data in these tables do not present a complete picture of operations in the control area since many types of equipment (draglines, distributors, rollers, compressors, etc.) are not included.

TABLE 47

LABOR TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

— Time in hours —

Operation group	Month												
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Year total
I Overhead operations — undistributed	1,315	1,930	2,000	2,043	2,185	2,115	2,530	2,537	1,337	1,790	1,425	1,277	22,484
Subtotal	1,315	1,930	2,000	2,043	2,185	2,115	2,530	2,537	1,337	1,790	1,425	1,277	22,484
II Direct operations — maintenance of existing system:													
A. Routine surface	913	167	235	134	509	595	547	863	1,567	1,520	1,053	1,402	9,505
B. Special surface	1,165	366	535	197	855	326	300	157	864	934	1,430	816	7,945
C. Shoulder and approach	370	1,334	543	63	453	48	12	82	273	358	72	108	3,716
D. Roadside and drainage	2,114	1,550	560	113	439	403	82	-	145	650	1,846	1,609	9,511
E. Snow and ice	33	38	1,534	3,783	1,560	3,167	4,375	4,600	1,467	35	-	-	20,592
F. Traffic service	336	317	145	203	393	110	108	183	608	790	432	447	4,072
G. Other	70	38	230	36	72	30	3	72	153	453	218	182	1,557
Subtotal	5,001	3,810	3,782	4,529	4,281	4,679	5,427	5,957	5,077	4,740	5,051	4,564	56,898
III Direct operations — new construction:													
A. Detour	76	43	116	70	421	78	65	206	103	182	353	335	2,048
B. Miscellaneous work resulting from construction contracts	39	85	77	85	326	216	177	75	257	90	100	126	1,653
Subtotal	115	128	193	155	747	294	242	281	360	272	453	461	3,701
NAWT (I + II + III)	(6,431)	(5,868)	(5,975)	(6,727)	(7,213)	(7,088)	(8,199)	(8,775)	(6,774)	(6,802)	(6,929)	(6,302)	(83,083)
IV Major non-operational delays	92	77	377	233	232	402	475	433	254	200	239	128	3,142
TAWT (I + II + III + IV)	(6,523)	(5,945)	(6,352)	(6,960)	(7,445)	(7,490)	(8,674)	(9,208)	(7,028)	(7,002)	(7,168)	(6,430)	(86,225)

TABLE 48

LIGHT DUTY TRUCK TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

— Time in hours —

Operation group	Month												
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Year total
I Overhead operations — undistributed	7	164	59	28	22	24	49	45	23	45	12	38	516
Subtotal	7	164	59	28	22	24	49	45	23	45	12	38	516
II Direct operations — maintenance of existing system:													
A. Routine surface	432	85	86	49	237	249	201	377	707	695	365	547	4,030
B. Special surface	494	189	262	104	508	220	233	117	493	534	768	369	4,291
C. Shoulder and approach	115	654	239	14	171	24	8	47	97	151	33	39	1,592
D. Roadside and drainage	486	377	150	97	165	142	36	-	54	223	444	382	2,556
E. Snow and ice	3	51	796	1,645	697	1,449	1,879	1,983	499	3	-	-	9,005
F. Traffic service	70	118	87	63	138	44	46	78	90	206	97	87	1,124
G. Other	73	19	127	10	23	12	-	38	53	212	117	92	776
Subtotal	1,673	1,493	1,747	1,982	1,939	2,140	2,403	2,640	1,993	2,024	1,824	1,516	23,374
III Direct operations — new construction:													
A. Detour	17	8	36	16	176	26	20	66	29	77	150	133	754
B. Miscellaneous work resulting from construction contracts	22	27	29	23	112	40	59	9	35	17	30	45	448
Subtotal	39	35	65	39	288	66	79	75	64	94	180	178	1,202
NAWT (I + II + III)	(1,719)	(1,692)	(1,871)	(2,049)	(2,249)	(2,230)	(2,531)	(2,760)	(2,080)	(2,163)	(2,016)	(1,732)	(25,092)
IV Major non-operational delays	1,445	1,255	1,367	1,274	1,316	1,586	1,759	1,677	1,327	1,177	1,363	1,343	16,889
TAWT (I + II + III + IV)	(3,164)	(2,947)	(3,238)	(3,323)	(3,565)	(3,816)	(4,290)	(4,437)	(3,407)	(3,340)	(3,379)	(3,075)	(41,981)

TABLE 49

HEAVY DUTY TRUCK TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

– Time in hours –

Operation group	Month												
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Year total
I Overhead operations – undistributed	-	14	-	1	1	3	1	5	2	1	3	1	32
Subtotal	-	14	-	1	1	3	1	5	2	1	3	1	32
II Direct operations – maintenance of existing system:													
A. Routine surface	17	-	8	12	27	6	12	11	26	28	33	165	345
B. Special surface	82	4	54	2	106	8	40	16	31	71	126	79	619
C. Shoulder and approach	59	73	36	2	8	-	-	4	8	3	-	11	204
D. Roadside and drainage	19	3	15	-	2	4	-	-	6	5	15	10	79
E. Snow and ice	-	-	11	219	103	331	659	647	-	-	-	-	1,970
F. Traffic service	16	-	-	-	4	2	-	-	1	1	1	1	26
G. Other	-	-	1	-	2	-	-	6	-	7	-	-	16
Subtotal	193	80	125	235	252	351	711	684	72	115	175	266	3,259
III Direct operations – new construction:													
A. Detour	1	-	1	3	12	2	-	2	1	4	7	8	41
B. Miscellaneous work resulting from construction contracts	-	1	1	1	19	9	3	8	14	1	1	1	59
Subtotal	1	1	2	4	31	11	3	10	15	5	8	9	100
NAWT (I + II + III)	(194)	(95)	(127)	(240)	(284)	(365)	(715)	(699)	(89)	(121)	(186)	(276)	(3,391)
IV Major non-operational delays	925	913	937	776	771	802	751	866	1,085	1,065	1,051	840	10,782
TAWT (I + II + III + IV)	(1,119)	(1,008)	(1,064)	(1,016)	(1,055)	(1,167)	(1,466)	(1,565)	(1,174)	(1,186)	(1,237)	(1,116)	(14,173)

TABLE 50

MOTORGRADER TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

— Time in hours —

Operation group	Month												
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Year total
I Overhead operations — undistributed	1	5	-	-	1	1	7	2	-	1	-	2	20
Subtotal	1	5	-	-	1	1	7	2	-	1	-	2	20
II Direct operations — maintenance of existing system:													
A. Routine surface	97	64	51	16	48	32	42	48	286	210	180	119	1,193
B. Special surface	155	37	7	2	19	4	7	2	14	32	79	81	439
C. Shoulder and approach	13	120	38	32	35	2	2	2	60	26	17	12	359
D. Roadside and drainage	4	18	3	-	28	-	-	-	-	2	2	3	60
E. Snow and ice	-	-	4	180	56	245	514	600	9	-	-	-	1,608
F. Traffic service	4	1	-	-	5	-	-	-	1	9	6	4	30
G. Other	-	-	-	-	-	-	-	-	-	-	-	41	41
Subtotal	273	240	103	230	191	283	565	652	370	279	284	260	3,730
III Direct operations — new construction:													
A. Detour	34	13	19	16	55	17	22	29	42	29	44	66	386
B. Miscellaneous work resulting from construction contracts	17	6	2	2	100	128	63	51	114	52	42	3	580
Subtotal	51	19	21	18	155	145	85	80	156	81	86	69	966
NAWT (I + II + III)	(325)	(264)	(124)	(248)	(347)	(429)	(657)	(734)	(526)	(361)	(370)	(331)	(4,716)
IV Major non-operational delays	747	739	933	767	690	679	508	506	408	379	475	630	7,461
TAWT (I + II + III + IV)	(1,072)	(1,003)	(1,057)	(1,015)	(1,037)	(1,108)	(1,165)	(1,240)	(934)	(740)	(845)	(961)	(12,177)

TABLE 51

PICKUP TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

— Time in hours —

Operation group	Month												
	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Year total
I Overhead operations — Undistributed	357	316	250	218	246	211	255	283	254	314	304	329	3,337
Subtotal	357	316	250	218	246	211	255	283	254	314	304	329	3,337
II Direct operations — maintenance of existing system:													
A. Routine surface	26	3	5	3	14	13	37	47	49	64	32	46	339
B. Special surface	45	7	5	5	21	7	6	3	29	63	50	30	271
C. Shoulder and approach	6	23	10	1	8	1	-	1	5	6	1	2	64
D. Roadside and drainage	149	81	15	-	48	84	3	-	15	58	206	79	738
E. Snow and ice	7	15	69	215	70	180	195	242	127	-	-	-	1,120
F. Traffic service	106	71	21	16	64	18	19	31	258	205	119	143	1,071
G. Other	-	1	13	3	4	3	-	11	14	29	42	19	139
Subtotal	339	201	138	243	229	306	260	335	497	425	450	319	3,742
III Direct operations - new construction:													
A. Detour	7	5	13	8	48	5	2	14	7	14	43	28	194
B. Miscellaneous work resulting from construction contracts	10	22	21	25	38	20	4	-	10	1	8	34	193
Subtotal	17	27	34	33	86	25	6	14	17	15	51	62	387
NAWT (I + II + III)	(713)	(544)	(422)	(494)	(561)	(542)	(521)	(632)	(768)	(754)	(805)	(710)	(7,466)
IV Major non-operational delays	755	731	891	794	884	1,033	1,162	1,246	854	783	744	634	10,511
TAWT (I + II + III + IV)	(1,468)	(1,275)	(1,313)	(1,288)	(1,445)	(1,575)	(1,683)	(1,878)	(1,622)	(1,537)	(1,549)	(1,344)	(17,977)

TABLE 52

TRACTOR AND FRONTEND LOADER TIME IN THREE-COUNTY CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

– Time in hours –

Operation group	Month												
	Aug.	Sept.	Oct.	Nov	Dec.	Jan.	Feb.	Mar.	April	May	June	July	Year total
I Overhead operations — undistributed	9	32	10	13	15	16	15	20	20	9	2	10	171
Subtotal	9	32	10	13	15	16	15	20	20	9	2	10	171
II Direct operations — maintenance of existing system:													
A. Routine surface	84	15	4	2	12	11	11	10	35	128	68	92	472
B. Special surface	239	43	14	2	19	5	16	7	78	110	107	100	740
C. Shoulder and approach	48	52	22	2	19	3	-	1	62	31	4	4	248
D. Roadside and drainage	1,386	1,104	265	7	43	7	1	-	12	184	830	1,088	4,927
E. Snow and ice	-	6	96	77	31	117	80	45	38	-	-	-	490
F. Traffic service	2	1	7	1	10	-	-	1	2	22	16	1	63
G. Other	-	1	-	-	-	1	-	1	1	1	13	-	18
Subtotal	1,759	1,222	408	91	134	144	108	65	228	476	1,038	1,285	6,958
III Direct operations - new construction:													
A. Detour	2	-	5	2	30	1	1	2	1	10	21	9	84
B. Miscellaneous work resulting from construction contracts	-	-	-	-	28	2	-	-	36	-	17	6	89
Subtotal	2	-	5	2	58	3	1	2	37	10	38	15	173
NAWT (I + II + III)	(1,770)	(1,254)	(423)	(106)	(207)	(163)	(124)	(87)	(285)	(495)	(1,078)	(1,310)	(7,302)
IV Major non-operational delays	1,662	1,912	2,907	2,764	2,881	2,634	2,688	3,067	2,991	3,131	2,790	2,155	31,582
TAWT (I + II + III + IV)	(3,432)	(3,166)	(3,330)	(2,870)	(3,088)	(2,797)	(2,812)	(3,154)	(3,276)	(3,626)	(3,868)	(3,465)	(38,884)

Section C

COMPREHENSIVE STUDIES IN THE INTERSTATE CONTROL AREA MARCH THROUGH AUGUST 1960

1. Background

Studies were also undertaken to develop basic data about the types and total extent of maintenance performed by State forces on the Interstate System in Iowa. **They** too are called comprehensive studies. The techniques used were the same as those used in the three-county control area which were described in Section B-1. One important modification was that limited data were obtained on the time spent on overhead operations or in major nonoperational delay status.

A two-man study crew was assigned full-time to the interstate control area for a six-month period. They observed activities of State maintenance forces, prepared daily time records for each employee and major equipment unit working in the control area, and obtained background information. The daily time records for men and equipment units showed total available working time (TAWT) spent in the control area; some major nonoperational delays (over 30 minutes); net available working time (NAWT) spent on each direct operation and some overhead operations; and the location of worksites. In most cases, study crews were able to obtain the distribution of time to the nearest 15 minutes. Worksites were identified as being in a particular county, State road section and, in many cases, a study subsection. Study crews also recorded materials used, work accomplished, and other supporting information.

All study records were forwarded to a headquarters office for checking and processing. Most of the data was then transferred to punch cards and summarized by machine methods. It was not feasible to check study records against State records since the interstate control area did not cover the entire area maintained by one State crew.

2. Characteristics of the interstate control area

The control area was located in Warren County. It was defined as including all interstate road sections in the county plus two short road sections, partially in Warren County and partially in Madison County, which were normally maintained in conjunction with interstate sections. State maintenance forces which maintained these sections were also responsible for other road sections in Warren County but these were excluded from the control area.

Since only a portion of Warren County was included in the control area, it is difficult to make any comparison with Statewide averages, Therefore, **Table** 53 presents data only for the control area.

TABLE 53

CHARACTERISTICS OF INTERSTATE CONTROL AREA

Item	Control area
Roads maintained 3/1/60 (miles)	
Interstate mainline portland cement concrete	23.1
Interstate ramps portland cement concrete	4.9
Primary bituminous concrete	5.8
Total	33.8
Average age of surfaces (years)	2
Average daily traffic on interstate mainline (1/1/60 estimate)	3,465
Mean temperature (^{O}F)	
Average year	51
1960	49
Total precipitation (inches)	
Average year	32
1960	39
Snowfall (inches)	
Average year	28
Predominating soil types	A-6 to A-7-6

3. Inventory of workload in the interstate control area

During the course of comprehensive studies, the special study group made a detailed inventory of road sections in the interstate control area. The objective was to measure workload components for which State maintenance crews were normally responsible. In total, these components constituted the workload for each road section. Data obtained during the inventory were used to prepare strip maps which showed roadways, ramps, drainage structures, overpasses, right-of-way lines, and other items. An example of similar strip maps was shown in Figure 1. Summaries were also prepared which listed quantities for various workload components by State road section and study subsections.

Study road subsections on the Interstate System were grouped according to whether they were on the mainline roadway or in interchange areas. Figure 3 indicates what was included in a typical interchange area subsection. After classification, average workload quantities per mile were computed for the two groups of subsections. Workload quantities per mile were not computed for study road subsections on the primary system. Table 54 presents workload quantities for all State road sections included in the interstate control area and average workload quantities per mile for the two groups of interstate subsections.

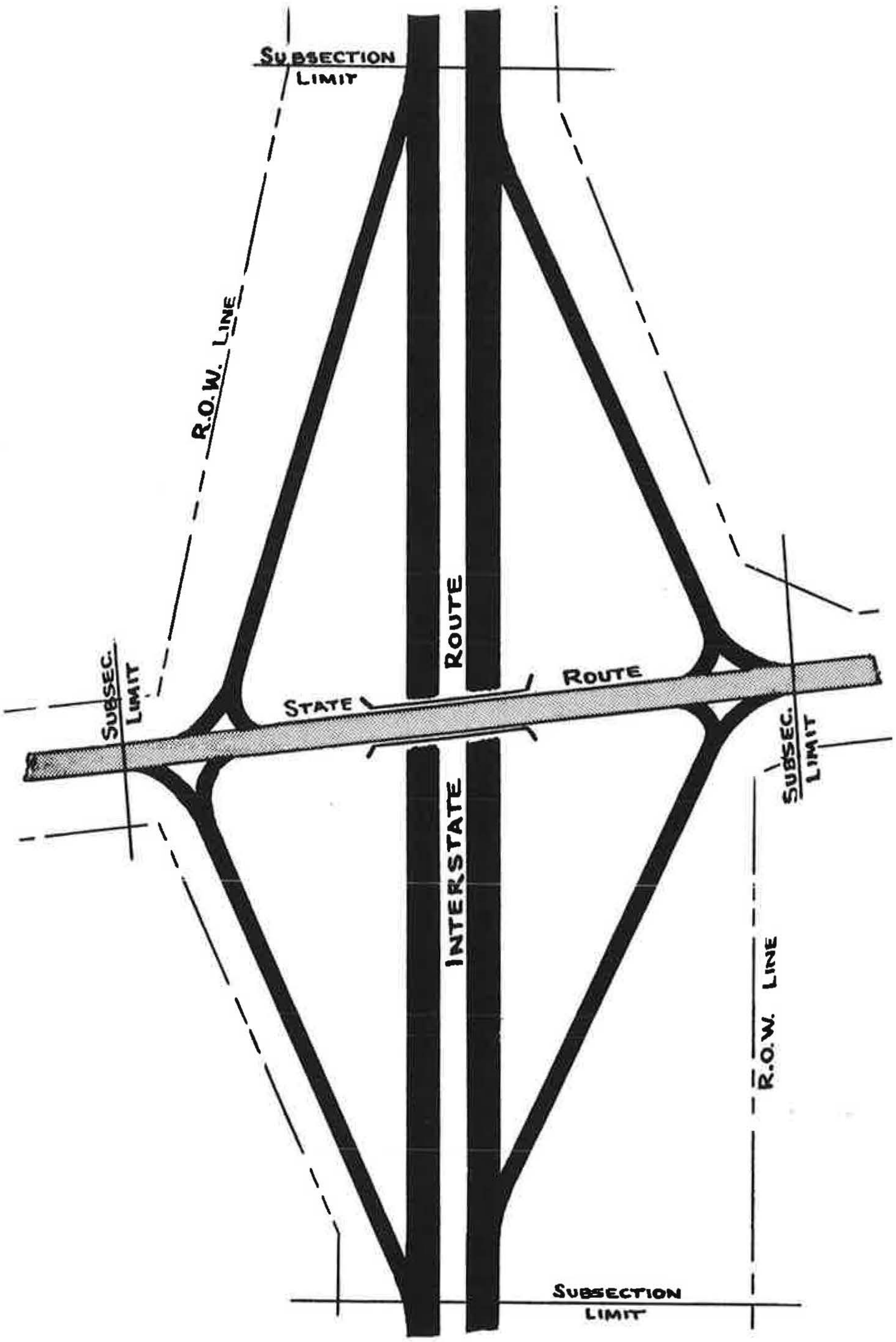


Figure 3. Sketch of an interchange area subsection.

4. Distribution of labor and equipment time in the interstate control area by type of work

Data obtained during comprehensive studies were summarized to show the distribution of labor and equipment time in the control area by type of work. This time represents effort expended by the State maintenance crew normally assigned there plus effort expended by other State crews such as the District 1 paint crew. Time spent by State crews working outside the control area was excluded.

Each functional type of work is represented by an operation such as remove snow from roadway surfaces and shoulders. These operations are listed under the heading direct operations - maintenance of existing system. As previously indicated, comprehensive studies in the interstate control area included only a limited coverage of overhead operations and major nonoperational delays. Therefore, the data for these categories cannot be presented as was done for the three-county control area in Tables 4 to 7. However, an allowance of time was made for work falling in the category overhead operations - distributed on the basis of comprehensive studies in the three-county control area. This overhead allowance was allocated to direct operations - maintenance of existing system before preparing the summary on which Table 55 is based.

5. Distribution of labor and equipment time in the interstate control area by selected road subsections

As previously indicated, labor and equipment time was classified according to location of worksites during comprehensive studies. Worksites for direct operations were identified by county, State road sections and, for certain kinds of work, by study subsections. Overhead operation worksites were identified only by county. The labor and equipment time for distributed overhead and direct operations which had not been charged originally to study subsections was allocated to these subsections. Next, study subsections were classified according to whether they were (1) interstate mainline, (2) interstate interchange areas, or (3) on the primary system. Study data for the first two groups were averaged to determine labor and equipment time expended per mile for each operation. The group of primary system subsections was excluded since this type of maintenance was covered by studies in the three-county control area.

Table 54 shows the total length of subsections and average workload per mile for the interstate mainline and interstate interchange area subsection groups. Tables 56 and 57 show average labor and equipment time in hours per mile for the two groups. Footnotes on Tables 54, 56, and 57 give factors which may be used to convert data from mainline miles to equivalent two-lane miles. The reader should keep in mind that data obtained from comprehensive studies in the interstate control area covers only a six-month period. Therefore, any comparisons with data from comprehensive studies in the three-county control area or any other source should be made with caution.

TABLE 54

INVENTORY OF WORKLOAD IN INTERSTATE CONTROL AREA (3/1/60)

Section Number	Length	ADT	Roadway surface area					Shoulders			Approaches		Right-of-way area 4/ (acres)	Estimated mowed area 5/ (acres)	Roadway and approach drainage structures				Signs 6/	Posts					Beam type guardrail (lin ft)
			Mainline portland cement concrete (sq yd)	Ramp portland cement concrete (sq yd)	Bituminous concrete (sq yd)	Bridge deck (sq yd)	Total (sq yd)	Bituminous concrete (sq yd)	Soil and sod 1/ (sq yd)	Total	Intersecting roads 2/	Drives or entrances 3/			Bridges and bridge culverts	Box culverts and cattle passes	Pipes	Drop inlets		Sign	Delineator	Guardrail	Other	Total	
13	1.47	775	-	-	22,800	-	22,800	-	11,720	11,720	9	9	15.6	14	-	-	12	-	14	14	-	-	11	25	-
14	4.35	660	-	-	57,040	-	57,040	-	38,570	38,570	17	45	47.0	39	-	5	45	-	24	24	-	-	32	56	-
41	7/ 12.80	3,465	363,620	45,670	-	9,430	418,720	231,500	20,730	252,230	-	-	927.9	440	13	20	137	73	168	261	751	76	-	1,088	473
42	7/ 10.28	5,195	287,180	34,330	-	6,130	327,640	108,210	16,070	124,280	-	-	449.5	335	9	10	122	63	92	130	600	40	-	770	225
Control area total	-	-	650,800	80,000	79,840	15,560	826,200	339,710	87,090	426,800	26	54	1440.0	828	22	35	315	136	298	429	1,351	116	43	1,939	698
— Quantities per mile —																									
All Interstate mainline subsections	8/ 21.09	4,240	28,250	-	-	580	28,830	18,480	80	18,560	-	-	58.7	30	1	1	9	5	5	9	53	5	-	67	31
All Interstate interchange area subsections	9/ 1.99	1,345	27,650	40,150	-	1,640	69,440	14,900	17,620	32,520	-	-	69.4	68	3	2	30	11	79	98	119	4	-	221	25

1/ These shoulders had received some applications of aggregate and/or bituminous mixes.
2/ Maintained in whole or part by city and county forces.
3/ Does not include mailbox turnouts. Maintained in part by owners.
4/ Area between outside edges of shoulders and right-of-way lines.
5/ Estimated area which maintenance crews normally mowed including sod shoulders.
6/ Does not include reflectors
7/ Mainline mileage only. Ramps and crossroads accounted for 3.42 miles in Section 41 and 2.53 miles in Section 42.
8/ All four lanes divided. The workload per two-lane equivalent mile would be one-half the figures shown.
9/ Based on mileages of mainline roadway in interchange areas. This mainline roadway was four lanes divided. Ramps totaled an additional 5.95 two-lane miles. The workload per two-lane equivalent mile for the entire interchange area would be one-fifth the figures shown.

TABLE 55

LABOR AND EQUIPMENT TIME IN INTERSTATE CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

— Time in hours —

Operation	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and front-end loaders	All other
II Direct operations — maintenance of existing system:								
A. Routine surface:								
1. Patch roadway surfaces with bituminous hot mix	296	144	-	-	-	4	1	129
B. Special surface:								
1. Mudjack concrete pavements	275	106	-	-	-	48	5	125
C. Shoulder and approach:								
1. Patch shoulders and approaches with aggregate	106	67	-	-	11	2	11	-
2. Patch shoulders and approaches with bituminous cold mix	3	-	-	-	-	1	-	-
3. Patch shoulders and approaches with bituminous hot mix	492	183	1	1	-	6	2	289
4. Blade or reshape shoulders and approaches	1	-	-	-	-	-	-	-
	602	250	1	2	11	9	13	289
D. Roadside and drainage:								
1. Repair cut and fill slope	2,410	1,346	45	178	302	317	248	13
2. Repair pipes	40	22	-	-	-	-	-	-
3. Clean or repair unpaved drainage ditches	717	385	1	29	135	116	29	1
4. Clean paved flumes, gutters and drop inlets	20	11	-	-	-	-	-	-
5. Plant trees on roadsides	119	45	-	-	-	1	-	-
6. Mow roadsides with tractor (including shoulders)	1,474	-	2	-	-	54	1,360	-
7. Mow roadsides by hand	6	-	-	-	-	6	-	-
8. Spray weeds on roadsides	463	165	1	-	-	5	-	153
9. Reseed or resod roadsides	724	428	1	1	-	13	89	1
	5,973	2,402	50	208	437	512	1,726	168
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	1,577	729	172	16	-	56	23	-
2. Remove snow from bridges	79	39	1	-	-	2	-	-
3. Remove snow fences	10	4	-	-	-	-	-	-
4. Sand roadway surfaces	3	3	-	-	-	-	-	-
5. Salt roadway surfaces	1	1	-	-	-	-	1	-
6. Remove ice from roadway surfaces and shoulders	49	20	6	-	-	1	-	-
	1,719	796	179	16	-	59	24	-
F. Traffic service:								
1. Paint centerlines and edgelines on pavements	98	19	3	-	-	27	-	18
2. Paint bridge endwalls, medians and miscellaneous pavement markings	68	-	-	-	-	14	-	17
3. Repair electrical signs and signals	11	5	-	-	-	-	5	-
4. Erect, replace, repair or paint signs and guideposts	133	58	-	-	2	8	25	-
5. Clean signs and reflectors	12	4	-	-	-	-	-	3
6. Miscellaneous work at roadside parks	23	8	4	-	-	4	4	-
	345	94	7	-	2	53	34	38
G. Other:								
1. Clean or repair bridges	200	79	-	-	-	5	-	-
2. Remove litter from right-of-way	2	-	-	-	-	1	-	-
	202	79	-	-	-	6	-	-
NAWT (direct operations - existing system)	(9,412)	(3,871)	(237)	(226)	(450)	(691)	(1,803)	(749)

TABLE 56

LABOR AND EQUIPMENT TIME CHARGED TO SELECT ROAD SUBSECTIONS IN INTERSTATE CONTROL AREA (INCLUDING DISTRIBUTED OVERHEAD)

ALL MAINLINE PORTLAND CEMENT CONCRETE SURFACES

Time in hours per mile 1/

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All other
B. Special surface:								
1. Mudjack concrete pavements	10.0	4.0	2/	-	-	1.8	0.2	5.0
Subtotal	10.0	4.0		-	-	1.8	0.2	5.0
C. Shoulder and approach:								
1. Patch shoulders with aggregate	0.5	0.1	-	-	-	-	-	-
2. Patch shoulders with bituminous cold mix	0.1	-	-	-	-	0.1	-	-
3. Patch shoulders with bituminous hot mix	23.3	8.7	2/	2/	-	0.3	0.1	13.6
Subtotal	23.9	8.8	2/	2/	-	0.4	0.1	13.6
D. Roadside and drainage:								
1. Repair cut and fill slopes	83.9	46.6	2.1	7.4	11.6	11.8	9.0	0.6
2. Repair or replace pipes and tiles	1.9	1.0	-	-	-	-	-	-
3. Clean or repair unpaved drainage ditches	33.6	18.3	0.1	1.2	6.4	5.5	1.4	2/
4. Clean paved flumes, gutters, and drop inlets	1.0	0.5	-	-	-	-	-	-
5. Plant trees on roadsides	5.6	2.1	-	-	-	0.1	2/	-
6. Mow roadsides with tractor	51.4	-	0.1	-	-	1.8	47.1	-
7. Spray weeds on roadsides	17.9	6.4	2/	-	-	0.2	-	6.0
8. Reseed or resod roadsides	30.6	18.1	2/	0.1	-	0.5	3.1	0.1
Subtotal	225.9	93.0	2.3	8.7	18.0	19.9	60.6	6.7
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	48.4	21.9	5.4	0.5	-	1.7	0.7	-
2. Remove snow from bridges	2.8	1.4	0.1	-	-	0.1	-	-
3. Remove ice from roadway surfaces and shoulders	1.7	0.8	0.2	-	-	2/	2/	-
Subtotal	52.9	24.1	5.7	0.5	-	1.8	0.7	-
F. Traffic service:								
1. Paint centerlines or edgelines on pavements	2.5	0.5	0.1	-	-	0.9	-	0.6
2. Paint bridge endwalls, medians, and miscellaneous pavement markings	0.6	-	-	-	-	0.1	-	0.2
3. Erect, replace, repair, or paint signs and guideposts	1.3	0.7	-	-	-	-	-	-
4. Clean signs and reflectors	0.1	2/	-	-	-	-	-	2/
5. Miscellaneous work at roadside parks	1.1	0.4	0.2	-	-	0.2	0.2	-
Subtotal	5.6	1.6	0.3	-	-	1.2	0.2	0.8
G. Other:								
1. Clean or repair bridges	9.4	3.7	-	-	-	0.2	-	-
2. Remove litter from right-of-way	0.1	-	-	-	-	2/	-	-
Subtotal	9.5	3.7	-	-	-	0.2	-	-
Total	327.8	135.2	8.3	9.2	18.0	25.3	61.8	26.1

1/ All mileage was four-lanes divided. Therefore, to obtain time in hours per two-lane equivalent mile, divide figures in this table by two.

2/ Less than 0.1 hour.

TABLE 57

LABOR AND EQUIPMENT TIME CHARGED TO SELECTED ROAD SUBSECTIONS IN INTERSTATE CONTROL AREA (INCLUDING DISTRICT OVERHEAD)

ALL INTERCHANGE AREA PORTLAND CEMENT CONCRETE SURFACES

Time in hours per mile 1/

Direct operations	Labor	Light duty trucks	Medium and heavy duty trucks	Motor-graders	Drag-lines	Pickups	Tractors and frontend loaders	All other
B. Special surface:								
1. Mudjack concrete pavements	31.8	11.0	-	-	-	4.4	0.4	9.5
Subtotal	31.8	11.0	-	-	-	4.4	0.4	9.5
C. Shoulder and approach:								
1. Patch shoulder with aggregate	48.5	32.0	-	-	5.4	1.1	5.5	-
2. Blade or reshape shoulders	0.4	-	-	0.7	-	-	-	-
Subtotal	48.9	32.0	-	0.7	5.4	1.1	5.5	-
D. Roadside and drainage:								
1. Repair cut and fill slopes	322.7	182.4	0.4	10.8	28.9	33.9	28.6	0.7
2. Clean or repair unpaved drainage ditches	3.7	-	-	1.8	-	-	-	-
3. Plant trees on roadsides	1.1	0.5	-	-	-	-	-	-
4. Mow roadsides with tractor (including shoulders)	109.2	-	-	-	-	3.9	104.7	-
5. Mow roadsides with hand tools	3.2	-	-	-	-	3.1	-	-
6. Reseed or resod roadsides	39.2	22.8	-	-	-	1.2	12.0	0.2
Subtotal	479.1	205.7	0.4	12.6	28.9	42.1	145.3	0.9
E. Snow and ice:								
1. Remove snow from roadway surfaces and shoulders	122.7	55.5	13.4	1.3	-	4.3	1.8	-
2. Remove snow from bridges	9.5	4.6	0.2	-	-	0.2	-	-
3. Sand roadway surfaces	1.5	1.3	-	-	-	-	-	-
4. Salt roadway surfaces	0.6	0.5	-	-	-	-	0.3	-
5. Remove ice from roadway surfaces and shoulders	4.3	1.9	0.5	-	-	0.1	-	-
Subtotal	138.6	63.8	14.1	1.3	-	4.6	2.1	-
F. Traffic service:								
1. Paint centerlines or edgelines on pavements	6.3	1.2	0.3	-	-	2.2	-	1.5
2. Paint bridge endwalls, medians, and miscellaneous pavement markings	27.8	-	-	-	-	6.1	-	6.7
3. Repair electrical signs and signals	5.4	2.7	-	-	-	-	2.6	-
4. Erect, replace, repair, or paint signs and guideposts	50.6	22.2	-	-	1.1	3.9	12.3	-
5. Clean signs and reflectors	1.7	0.6	-	-	-	-	-	0.4
Subtotal	91.8	26.7	0.3	-	1.1	12.2	14.9	8.6
Total	790.2	339.2	14.8	14.6	35.4	64.4	168.2	19.0

1/ Based on the mileage of mainline surfaces included in interchange areas. This mainline surface was four-lanes divided. In addition, interchange ramp surfaces accounted for considerable mileage. A two-lane equivalent of both mainline and ramp surfaces would be five times the length of mainline mileage in the interchange areas. Therefore, to obtain time in hours per two-lane equivalent mile, divide figures in this table by five.

Section D

PRODUCTION STUDIES OF MAINTENANCE OPERATIONS

1. Background

The special study group conducted production studies which provided detailed information on most of the operations performed by State maintenance crews. The general objective of these studies was to obtain basic data regarding time utilization, performance rates, work methods, and crew sizes under field conditions. Such data could not be obtained from the overall picture developed by comprehensive studies. According to the study plan there was a concentration of production studies in the three-county control area; however, a substantial number were conducted in other areas throughout Iowa. The approximate distribution of study effort was as follows:

50 percent in the three-county control area
25 percent in the remainder of District 6
25 percent in Districts 1-5

Table 58 shows the number of studies made according to major groups of operations and their general location.

TABLE 58
NUMBER AND LOCATION OF PRODUCTION STUDIES

Location	Major group of operation								
	Over-head	Routine surface	Special surface	Shoulder and approach	Roadside and drainage	Snow and ice	Traffic service	Other	Total
District 1	12	1	-	3	8	4	5	1	34
District 2	4	4	-	2	10	1	-	-	21
District 3	5	2	1	1	4	1	2	2	18
District 4	12	-	1	-	5	2	3	1	24
District 5	3	-	2	1	3	-	2	2	13
Three-county control area (Cedar, Iowa, and Johnson)	74	22	11	6	25	56	15	7	216
Remainder of District 6	25	12	5	12	24	12	8	3	101
Totals	135	41	20	25	79	76	35	16	427

A study crew ranging from 5 to 15 men carried out production studies. The following procedures were used:

1. A group of 1 to 8 men from the study crew traveled to a preselected State maintenance garage.
2. Study supervisors held a briefing session for State maintenance employees to explain the purpose of studies and the techniques which would be used by study crews. The maintenance employees were requested to follow normal practices and to work at a normal pace.
3. One or more operations which were to be performed that day were selected for study. No attempt was made to have State crews perform any particular operation.
4. Study personnel were assigned to observe the activities of maintenance employees and equipment units involved in the selected operations. Each study man recorded data on one or more maintenance employees plus the equipment units they normally operated.
5. Study men observed performance of the operation and timed each work item or delay encountered by their assigned men and equipment units. Stopwatches were used and any item or delay of two seconds (0.03 minute) or longer in duration was recorded.
6. Study men recorded accomplishment, equipment used, worksite conditions and general background data.
7. Most studies lasted for an entire day. However, when maintenance employees worked on more than one operation during a day, each operation was considered to be a separate study.
8. Study crews returned to their headquarters office to prepare study summaries. At a later date, data on all studies for each operation were combined and analyzed.

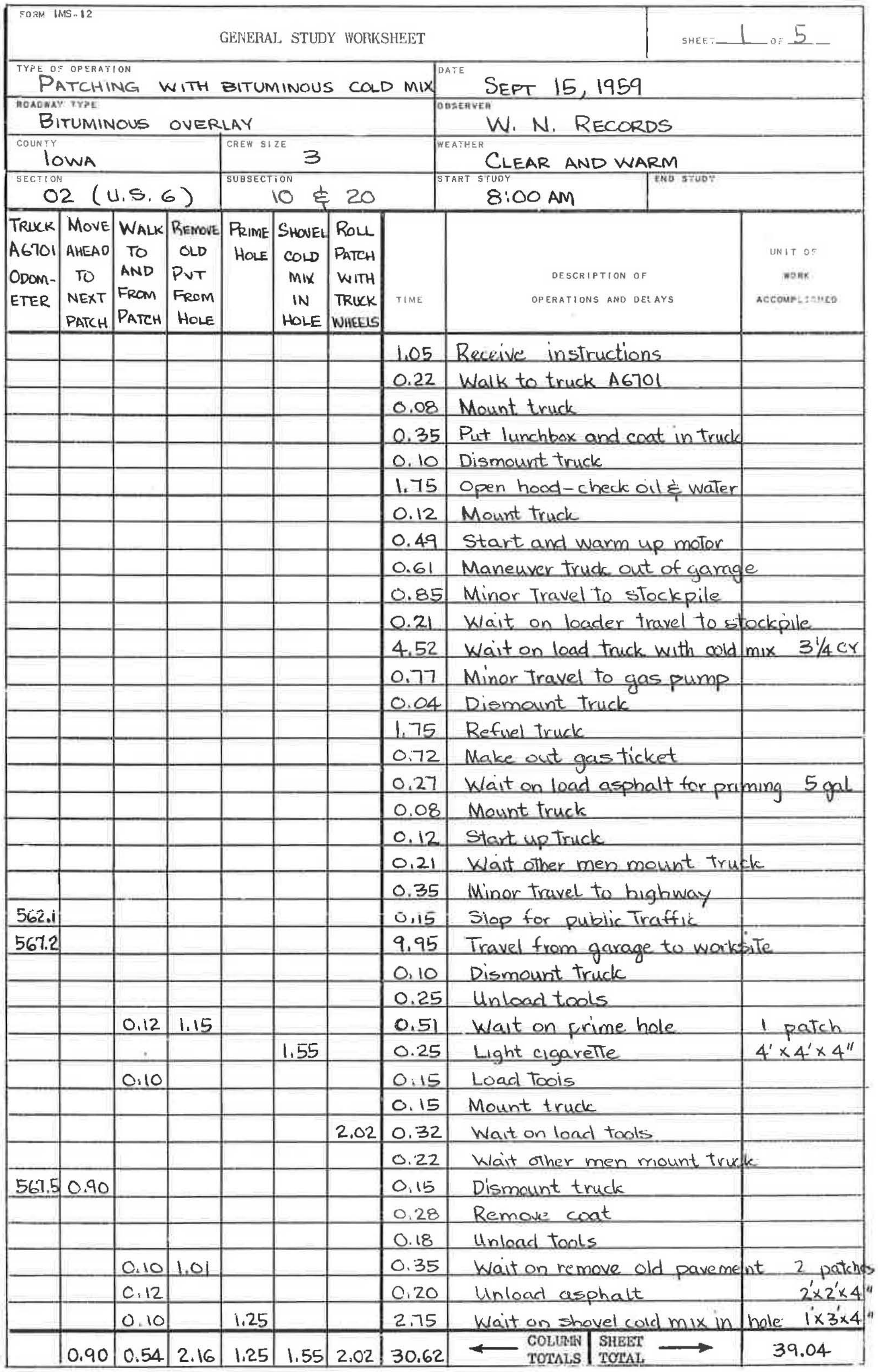
Figure 4 shows the type of data study personnel recorded on field sheets.

In this section the summarized production study data and the related narrative descriptions are grouped in the same major categories used for comprehensive study data; namely, undistributed overhead, distributed overhead, and direct operations. In total, 27 different operations are reported on and they are listed in Table 59.

Several of the operations in distributed overhead involved separate processes and were the subject of production studies even though the comprehensive control study time was eventually distributed to other operations. Thus, a complete picture of handling salt, for example, embraces not only the production study summary of the direct operation salt roadway surfaces, but also the production study summary of the overhead operation stockpile salt.

Travel was separately identified during comprehensive studies and during production studies. In the former case, travel was reallocated to other operations when the distributed overhead accounts were closed out. For production studies, travel was included as one of the time elements in study summaries, and therefore is not presented separately as are the other selected distributed overhead operations.

In the following narratives, table format has been standardized. In each case, the total number of man- or equipment- NAWT hours covered by studies is indicated. This total does not include any major nonoperational delay time.



FORM IMS-12

GENERAL STUDY WORKSHEET

SHEET 1 OF 5

TYPE OF OPERATION: PATCHING WITH BITUMINOUS COLD MIX
DATE: SEPT 15, 1959
ROADWAY TYPE: BITUMINOUS OVERLAY
OBSERVER: W. N. RECORDS
COUNTY: IOWA
CREW SIZE: 3
WEATHER: CLEAR AND WARM
SECTION: 02 (U.S. 6)
SUBSECTION: 10 & 20
START STUDY: 8:00 AM
END STUDY:

TRUCK A6701 ODOM-ETER	MOVE AHEAD TO NEXT PATCH	WALK TO AND FROM PATCH	REMOVE OLD PVT FROM HOLE	PRIME HOLE	SHOVEL COLD MIX IN HOLE	ROLL PATCH WITH TRUCK WHEELS	TIME	DESCRIPTION OF OPERATIONS AND DELAYS	UNIT OF WORK ACCOMPLISHED
							1.05	Receive instructions	
							0.22	Walk to truck A6701	
							0.08	Mount truck	
							0.35	Put lunchbox and coat in truck	
							0.10	Dismount truck	
							1.75	Open hood-check oil & water	
							0.12	Mount truck	
							0.49	Start and warm up motor	
							0.61	Maneuver truck out of garage	
							0.85	Minor Travel to stockpile	
							0.21	Wait on loader travel to stockpile	
							4.52	Wait on load truck with cold mix	3¼ CY
							0.77	Minor Travel to gas pump	
							0.04	Dismount truck	
							1.75	Refuel truck	
							0.72	Make out gas ticket	
							0.27	Wait on load asphalt for priming	5 gal
							0.08	Mount truck	
							0.12	Start up Truck	
							0.21	Wait other men mount truck	
							0.35	Minor travel to highway	
562.1							0.15	Stop for public Traffic	
567.2							9.95	Travel from garage to worksite	
							0.10	Dismount truck	
							0.25	Unload tools	
		0.12	1.15				0.51	Wait on prime hole	1 patch
					1.55		0.25	Light cigarette	4'x4'x4"
		0.10					0.15	Load Tools	
							0.15	Mount truck	
						2.02	0.32	Wait on load tools	
							0.22	Wait other men mount truck	
567.5	0.90						0.15	Dismount truck	
							0.28	Remove coat	
							0.18	Unload Tools	
		0.10	1.01				0.35	Wait on remove old pavement	2 patches
		0.12					0.20	Unload asphalt	2'x2'x4"
		0.10		1.25			2.75	Wait on shovel cold mix in hole	1'x3'x4"
	0.90	0.54	2.16	1.25	1.55	2.02	30.62	← COLUMN TOTALS | SHEET TOTAL →	39.04

Figure 4. Sample of data recorded during production studies

TABLE 59

LABOR TIME CHARGED TO PRINCIPAL OPERATIONS IN THREE-COUNTY CONTROL AREA

Operation	Before overhead distribution		After overhead distribution	
	Hours	Percent of TAWT	Hours	Percent of TAWT
I Overhead operations — undistributed				
A. Supervise maintenance activities	5,554	6.5	5,554	6.5
B. Service and repair equipment	14,153	16.4	14,153	16.4
C. Clean, repair or improve garage facilities	2,777	3.2	2,777	3.2
Subtotal	22,484	26.1	22,484	26.1
II Overhead operations — distributed:				
B. Stockpile materials:				
1. Stockpile aggregates	2,229	2.6	-	-
2. Stockpile salt	546	0.6	-	-
	2,775	3.2	-	-
C. Other:				
1. Patrol roads	1,503	1.8	-	-
2. Prepare bituminous cold mix	825	1.0	-	-
	2,328	2.8	-	-
Subtotal	5,103	6.0	-	-
III Direct operations — maintenance of existing system:				
A. Routine surface:				
1. Patch roadway surfaces with aggregate	2,018	2.3	2,612	3.0
2. Patch roadway surfaces with bituminous cold mix	2,808	3.3	4,297	5.0
3. Patch roadway surfaces with bituminous hot mix	973	1.1	1,176	1.4
4. Blade gravel surfaces	644	0.8	864	1.0
	6,443	7.5	8,949	10.4
B. Special surface:				
1. Mudjack concrete pavements	909	1.1	1,091	1.3
2. Rebuild gravel surfaces	768	0.9	965	1.1
3. Seal bituminous and concrete pavements	2,767	3.2	3,481	4.0
4. Resurface with bituminous mixes	1,095	1.3	1,520	1.8
	5,539	6.5	7,057	8.2
C. Shoulder and approach:				
1. Patch shoulders and approaches with aggregate	1,063	1.2	1,451	1.7
2. Patch shoulders and approaches with bituminous cold mix	755	0.9	1,170	1.4
	1,818	2.1	2,621	3.1
D. Roadside and drainage:				
1. Clean and repair unpaved drainage ditches	1,321	1.5	1,605	1.9
2. Mow roadsides with tractor	4,352	5.1	5,162	6.0
	5,673	6.6	6,767	7.9
E. Snow and ice:				
1. Remove snow from roadway surfaces and shoulders	9,033	10.5	11,187	13.0
2. Erect snow fences	2,019	2.3	2,504	2.9
3. Remove snow fences	1,306	1.5	1,599	1.8
4. Sand roadway surfaces	1,218	1.4	2,377	2.7
5. Salt roadway surfaces	764	0.9	1,363	1.6
6. Remove ice from roadway surfaces and shoulders	816	1.0	928	1.1
	15,156	17.6	19,958	23.1
F. Traffic service:				
1. Paint centerlines and edgelines on pavements	1,098	1.3	1,393	1.6
2. Erect, replace, repair or paint signs and guideposts	1,093	1.3	1,509	1.8
	2,191	2.6	2,902	3.4
Subtotal	36,820	42.9	48,254	56.1
Total principal operations	64,407	75.0	70,738	82.2
Other overhead operations — distributed (including travel 1/)	8,458	9.7	-	-
Other direct operations — maintenance of existing system	7,060	8.0	8,644	9.9
Direct operations — new construction	3,158	3.7	3,701	4.3
Major non-operational delays	3,142	3.6	3,142	3.6
TAWT	86,225	100.0	86,225	100.0

1/ Travel not covered by separate production studies but is included as part of other studies.

2. Overhead operations - undistributed

Three overhead operations in the undistributed category are reported. They are (a) supervise maintenance activities, (b) service and repair equipment, and (c) clean, repair, or improve garage and yard facilities. A discussion of each operation follows.

(a) Supervise maintenance activities. Labor time charged to supervise maintenance activities was 6.5 percent of TAWT in the three-county control area. Foremen accounted for nearly all of this time which averaged 1,851 hours of NAWT per county. By definition, the operation included all types of activities normally performed by supervisors plus related work and delays. The following list indicates the types of supervisory activities most commonly encountered and the specific tasks included in each.

(1) Paperwork — prepare or check payrolls, equipment records, requisitions, purchase orders, and inventories; read and answer correspondence; handle mail at postoffice.
(2) Inspect work — check on quality and quantity of work performed by maintenance crews.
(3) Inspect equipment - check on condition of equipment and the need for service or repair; test repaired equipment.
(4) Inspect facilities — check on condition of buildings, yards, etc.
(5) Inspect worksites — check on condition of worksites; plan future work; lay out future work.
(6) Contact public — confer with public about maintenance or any other highway functions.
(7) Confer with or assist superiors - confer with superior from residency, district or headquarters offices about maintenance functions, personnel, equipment, etc.; provide assistance to superior in carrying out any of his duties or responsibilities.
(8) Supervise operations — make up work schedules; give crews work assignments; direct crews while performing work; demonstrate work methods and train men; conduct meetings concerning safety or administrative policies and procedures; confer with Highway Commission personnel from other departments about maintenance functions; arrange for obtaining needed supplies, materials, and equipment (but not the paperwork involved) and many other miscellaneous activities.

By definition, work which was normally performed by equipment operators or by both foremen and operators was not included in supervision but instead was considered to be part of other operations. Foremen were charged to these other operations whenever they spent substantial periods of time on such work as patrolling roads, transporting men to worksites, servicing or repairing equipment, patching holes, or straightening signs. However, if these other operations were performed for only short periods of time while foremen were engaged primarily in supervision, the time so spent was considered to be nonsupporting work and was charged as part of supervise maintenance activities. Thus, we find, for example, that these small increments of time for patrolling add up to 6 percent of the foreman's time. Some work crews operated under the direction of lead operators or mechanics. Since these lead operators and mechanics spent only a minor amount of time on supervision, the time was charged to whatever operation the crew was performing instead of to supervise maintenance activities. However, these lead operators and mechanics did, on some occasion, perform supervisory activities and their time was charged to this operation. The amount varied widely depending on such factors as the supervisory workload, ability of individual operators and mechanics, and absence of regular foremen due to illness or other reasons.

The manner in which supervision was performed varied considerably from county to county. Contributing factors were the number of men in the county crew, number of garages, miles of road maintained, quality of personnel in crew, and personal preferences of foremen. Crew size appeared to be of primary importance. With crews ranging from 4 to 8 men, foremen were able to take care of practically all supervision and also spend a reasonable amount of time on other operations. Foremen who directed crews ranging in size from 9 to 13 men had to spend most of their time on supervision but were still able to put in some time on other operations. This was demonstrated in the control area where crews ranged from 9 to 13 men. On the average, foremen spent 75 percent of their time on supervision, 15 percent on patrol roads, and 10 percent on other operations or delays. When crews exceeded 13 men, foremen spent practically all of their time on supervision. The exact procedures used for performing each type of work included in supervision were developed by individual foremen. To some extent, they were influenced by the guidance received from superiors. Written supervisory guidelines were generally not available except for certain paperwork.

TABLE 60
SUPERVISE MAINTENANCE ACTIVITIES —
DISTRIBUTION OF 204 HOURS NAWT FOR FOREMEN

Location and item	Percent of NAWT		
Garage			
A. Primary work items:			
1. Paperwork	13		
2. Inspect work, equipment, or facilities	2		
3. Contact public	2		
4. Confer with or assist superior	5		
5. Supervise operations	14		
		36	
B. Supporting work items		5	
C. Delays — wait on primary work item		-	
D. Delays — other:			
1. Idle	8		
2. Personal	5		
3. Other	6		
		19	
Total — garage			60
Other			
E. Travel		18	
F. Primary work items:			
1. Paperwork	1		
2. Inspect work or worksites	2		
3. Contact public	1/		
4. Confer with or assist superior	1		
5. Supervise operations	4		
		8	
G. Supporting work items		1/	
H. Delays – wait on primary work item		-	
I. Delays – other		3	
J. Nonsupporting work items and delays:			
1. Patrol roads	6		
2. Transport men to and from worksites	2		
3. Other	3		
		11	
Total – other			40
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			67

1/ 0.5 percent or less.

TABLE 61
SUPERVISE MAINTENANCE ACTIVITIES —
DISTRIBUTION OF 97 HOURS NAWT FOR TRANSPORTATION TRUCKS AND PICKUPS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items		-	
B. Supporting work items		1	
C. Delays - wait on primary work item		7	
D. Delays - other		6	
Total - garage			14
Other			
E. Travel		36	
F. Primary work items		-	
G. Supporting work items		1/	
H. Delays — wait on primary work item		14	
I. Delays — other:			
1. Travel from foreman's residence in a.m. and to foreman's residence in p.m. 2/	10		
2. Other	6		
		16	
J. Unrelated work items and delays:			
1. Patrol road	12		
2. Transport men to and from worksites	5		
3. Other	3		
		20	
Total — other			86
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			37

1/ 0.5 percent or less.
2/ Foremen were permitted to garage pickups at their residences so that transportation would be available if they were called out on an emergency. Pickups were charged with delays for this travel time but foremen were not charged with any time since they were considered to be off duty.

A number of production studies were made on foremen. The study data presented cover their time while performing work included in supervision and time spent on other types of work which were carried out incidental to supervision. Major periods of time spent on other operations, such as patrolling, were excluded. Study data indicate that delays accounted for a relatively large proportion of foreman's NAWT. Incidental nonsupporting work also accounted for a large proportion of NAWT and often involved work which could have been done by other men. More effective use of foremen's time could be accomplished by (1) reducing delays, (2) reducing the amount of time spent on paperwork, and (3) reducing the time spent on incidental unrelated work. No conclusions can be drawn concerning time utilization for equipment operators and mechanics who performed work included in supervision since they were not studied to any extent.

(b) Service and repair equipment. This operation accounted for 16.4 percent of labor TAWT in the three-county control area. Time for men and equipment was charged to this operation only when they spent a continuous period of 30 or more minutes on service or repair work. Periods of less than 30 minutes were not charged; instead they were considered to be delays chargeable to other operations which were underway at the time. Most service and repair work performed by maintenance forces involved their own class "A" and "B" equipment units but they also worked on equipment units assigned to other Highway Commission organizations. Control study records show that 15.1 percent of labor TAWT was for service and repair of their own class "A" and "B" equipment while 1.3 percent was expended on equipment units assigned to other commission organizations. The amount of time expended on this operation varied considerably from season to season. A major peak occurred during winter months. The graph in Figure 5 indicates observed variations in the control area during the study year.

The bulk of service and repair work was handled by maintenance forces. One or more garages in each county were equipped with hand tools, chain or hydraulic hoists, air operated grease guns, welders, steam cleaners, air compressors, grinders, and other shop equipment required for servicing and routine repairs. They were not equipped for certain specialized

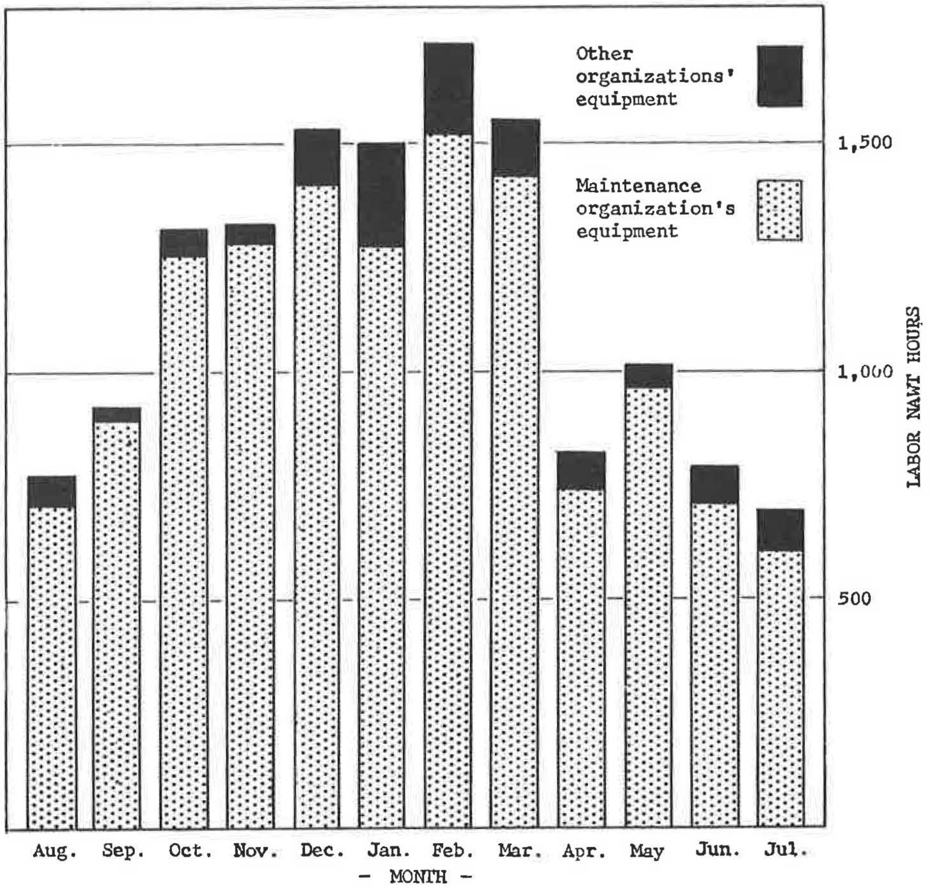


Figure 5. Labor time expended on service and repair equipment.

repairs such as reboring motor blocks, refacing brake drums, wheel alignment, and body work. Such work was handled by local commercial garages or the central shop in Ames. Occasionally, local commercial garages took care of routine repairs when county garages were overloaded and unable to work on critically needed equipment units.

Each garage had a small stock of frequently used supplies and repair parts. They were obtained from the Central Office stores, carried on inventory, and charged out as used. Other types of supplies and repair parts were obtained for immediate use. These latter items were either requisitioned from the Central Office stores or purchased from local commercial suppliers.

The crews assigned to this operation varied considerably, depending on the type of work, amount of work to be done, and availability of men. Usually, each garage had one or more mechanics who devoted most of their time to the operation. Equipment operators regularly assisted mechanics with major repair items and performed service and minor repair items. Crew sizes ranged from 1 to 10 men at any one time but fluctuated during each day. Equipment units used by these crews included trucks, pickups, tractors, and front-end loaders. Most work was performed at garages but some servicing and emergency repairs were done on the road or at worksites.

Service work accounted for about one-third of all labor time charged to the operation. It included such items as lubrication, changing oil, changing oil filters, cleaning air filters, checking tires, cleaning cabs, and washing. Most of these items were accomplished by equipment operators working under the general direction of mechanics and foremen. Crews ranged from 1 to 3 men, but one-man crews were most common since each major equipment unit was informally assigned to an operator. Work methods were about the same as would be encountered in any commercial garage or service station. As might be expected, the bulk of all service work was performed on trucks, since they outnumbered other types of major equipment units. Several common service items for trucks were studied repeatedly. Study data revealed that the average time expended on these common items was:

Service item	Average labor time expended per truck (min.)
Lubrication (including cleanup and routine checking)	60
Change oil	19
Change oil filter	20
Clean air filter	11

Figure 6. Mechanic repairing equipment in garage.

Figure 7. Operators repairing sickle bar mower in field.

Repair work accounted for two-thirds of all labor time charged to the operation. About half of the time was put in by mechanics, the remainder by equipment operators. Mechanics generally concentrated on the more difficult items. All types of routine repairs were done on motors, power trains, chasses, bodies, electrical systems and attachments. Equipment operators assisted mechanics with difficult repair items and did many minor items under their general direction. Crews ranged from 1 to 10 men and often worked on several equipment units at the same time. Many emergency repairs were done on the road or at worksites by equipment operators, but often mechanics made special trips to perform such work. A substantial portion of mechanics' time was spent obtaining supplies and repair parts. Numerous trips were made to local commercial suppliers for this purpose. When mechanics were busy, repair parts and supplies were usually obtained by foremen.

TABLE 62
SERVICE AND REPAIR EQUIPMENT —
DISTRIBUTION OF 530 HOURS NAWT FOR MEN ASSIGNED
TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items:			
1. Grease and oil	7		
2. Clean and wash	5		
3. Other service	5		
4. Repair motor and power train	7		
5. Repair chassis and body	6		
6. Repair hoist and attachment	6		
7. Repair tire	3		
8. Repair electrical system	3		
9. Other repair	2		
10. Change attachment or make other modification	2		
11. Inspect and test unit	2		
		48	
B. Supporting work items		12	
C. Delays - wait on primary work item		3	
D. Delays - other:			
1. Idle	8		
2. Personal	5		
3. Other	11		
		24	
Total — garage			87
Other			
E. Travel to, from, or between work-sites		5	
F. Primary work items		1	
G. Supporting work items		2	
H. Delays - wait on primary work item		1/	
I. Delays - other		1	
J. Nonsupporting work items and delays		4	
Total - other			13
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			68

1/ 0.5 percent or less.

A large number of production studies were made on this operation. Study data on all types of service and repair work have been grouped for presentation in this report. It should be noted that studied crews did not necessarily spend the same proportion of time on each type of work as all crews assigned to this operation in the control area during the study year. Study data indicated that delays due to personal reasons, idle, start late, excess lunchtime, and quit early averaged 16 percent of labor NAWT. A further investigation determined that delays due to these reasons averaged only 10 percent when crews consisted of one mechanic but was 18 percent when crews consisted of a mechanic and one or more equipment operators or entirely of equipment operators. The higher proportion of these delays for crews including equipment operators indicates that these men were often assigned to this operation when they had nothing else to do. This frequently happened during the winter season and other periods of inclement weather. Observations also indicated that some crews were so large that mechanics spent most of their time giving instructions or advice to operators and did not, themselves, accomplish much work. In general, the operation would be much more efficient if crews were limited to the number of men actually required to accomplish needed work and if the majority of repair work was performed by mechanics or regular mechanics' helpers. Accomplishment would also be greater if all garages were equipped with additional power tools, hydraulic hoists and a more complete stock of supplies and repair parts.

TABLE 63
SERVICE AND REPAIR EQUIPMENT — DISTRIBUTION OF 47 HOURS NAWT FOR TRANSPORTATION TRUCKS AND PICKUPS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items		-	
B. Supporting work items		7	
C. Delays — wait on primary work item		6	
D. Delays — other		12	
Total - garage			25
Other			
E. Travel to, from, or between work-sites		36	
F. Primary work items		-	
G. Supporting work items		3	
H. Delays — wait on primary work item		3	
I. Delays - other:			
1. Wait on obtain equipment parts and supplies	15		
2. Parked while men work	8		
3. Other	8		
		31	
J. Nonsupporting work items and delays		2	
Total — other			75
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			46

TABLE 64
SERVICE AND REPAIR EQUIPMENT — DISTRIBUTION OF 8 HOURS NAWT FOR TRACTORS AND FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items:		1/	
B. Supporting work items:			
1. Maneuver	14		
2. Load or unload supplies	5		
3. Other	5		
		24	
C. Delays — wait on primary work item		20	
D. Delays — other:			
1. Parked while men work	12		
2. Other	8		
		20	
Total — garage			64
Other			
E. Travel to, from, or between work-sites		10	
F. Primary work items		1	
G. Supporting work items		2	
H. Delays — wait on primary work item		-	
I. Delays — other:			
1. Stuck or tow stuck unit	9		
2. Other	6		
		15	
J. Nonsupporting work items and delays		8	
Total — other			36
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			37

1/ 0.5 percent or less.

(c) Clean, repair, or improve garage and yard facilities

Labor time charged to this operation accounted for 3.2 percent of TAWT in the three-county control area. Work was performed on buildings, fences, loading docks, yards, and all other facilities used in maintenance operations. Maintenance forces performed many different types of work in order to keep these facilities in operable condition. The following tabulation lists the most common types according to their approximate frequency of occurrence.

TABLE 65
TYPES OF WORK INCLUDED IN OPERATION

Types performed daily or weekly	Types performed one or more times each year	Types performed at irregular intervals
1. Sweep floors	1. Wash windows and walls	1. Repair buildings, sheds, fences, etc.
2. Clean workbenches	2. Clean oil sumps	2. Paint buildings and sheds
3. Clean restrooms	3. Remove snow from sidewalks and drives	3. Regrade yards
4. Clean and tend furnaces	4. Blade drives and yards	4. Remove sheds, docks, fences, signs, etc.
5. Dispose of trash	5. Restockpile materials	5. Erect new sheds, docks, fences, signs, etc.
6. Mow lawn	6. Dispose of unusable materials	6. Repair or replace utility lines
	7. Haul coal for furnaces	

Crews assigned to this operation varied considerably according to the type of work, amount of work to be done, and availability of men. The types of work performed daily or weekly were usually carried out by crews of 1 to 5 men. The types performed at longer intervals were handled by crews of 1 to 12 men. These crews utilized hand tools, trucks, draglines, motorgraders, tractors, front-end loaders and other types of equipment as needed. No general statements can be made concerning methods since there was so much variety in the work.

Production studies were conducted on crews performing several different types of work. Data have been grouped for presentation. It should be noted that the studied crews did not necessarily spend the same proportion of time on each type of work as all crews assigned to this operation in the control area during the study year. Study data showed delays due to start late, excess lunch time, quit early, idle and personal reasons amounted to 16 percent of labor NAWT. This is much higher than found for many operations and indicates that men were often assigned to this operation when no other work was available. This frequently happened during the winter season and other periods of inclement weather. The operation would be much more efficient if crews were limited to the number of men actually required to accomplish needed work. Some types of work, such as replacement of utility lines or erection of new facilities, could probably be done more efficiently by contractors since maintenance crews did not have the proper tools, training or experience.

TABLE 66

CLEAN, REPAIR, OR IMPROVE GARAGE AND YARD FACILITIES — DISTRIBUTION OF 83 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items:			
1. Erect or remove facility	29		
2. Clean building	13		
3. Clean yard	6		
4. Restockpile supplies and materials	6		
5. Dispose of trash	2		
6. Other	1		
		57	
B. Supporting work items		8	
C. Delays — wait on primary work item		4	
D. Delays — other:			
1. Idle	12		
2. Instructions	4		
3. Other	8		
		24	
Total — garage			93
Other			
E. Travel to, from, or between worksites (including haul)		4	
F. Primary work items		1	
G. Supporting work items		2	
H. Delays – wait on primary work item		-	
I. Delays – other		1/	
Total — other			7
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			71

1/ 0.5 percent or less

TABLE 68

CLEAN, REPAIR, OR IMPROVE GARAGE AND YARD FACILITIES — DISTRIBUTION OF 1 HOUR NAWT FOR DRAGLINES ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Other			
E. Travel to, from, or between worksites		-	
F. Primary work items		-	
G. Supporting work items:			
1. Load soil	8		
2. Other	4		
		12	
H. Delays – wait on primary work item		-	
I. Delays – other		88	
TOTAL			100
Total work items on assigned operation (E + F + G)			12

TABLE 67

CLEAN, REPAIR, OR IMPROVE GARAGE AND YARD FACILITIES — DISTRIBUTION OF 6 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items:			
1. Load trash		9	
B. Supporting work items:			
1. Load or unload materials	6		
2. Other	5		
		11	
C. Delays – wait on primary work item		2	
D. Delays – other:			
1. Instructions	10		
2. Parked while men work	6		
3. Other	14		
		30	
Total – garage			52
Other			
E. Travel to, from, or between worksites (including haul)		35	
F. Primary work items		1	
G. Supporting work items		6	
H. Delays – wait on primary work item		-	
I. Delays — other		6	
Total – other			48
TOTAL			100
Total work items on assigned operation (A + B + E + F + G)			62

TABLE 69

CLEAN, REPAIR, OR IMPROVE GARAGE AND YARD FACILITIES – DISTRIBUTION OF 2 HOURS NAWT FOR FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		
Garage			
A. Primary work items:			
1. Dispose of trash	22		
2. Restockpile aggregate	5		
		27	
B. Supporting work items		8	
C. Delays – wait on primary work item		1	
D. Delays – other:			
1. Wait on dispose of trash	29		
2. Parked while men work	16		
3. Other	19		
		64	
TOTAL			100
Total work items on assigned operation (A + B)			35

3. Overhead operations - distributed

In the category of overhead operations - distributed there are four principal operations on which production studies are reported. They are (a) stockpile aggregates, (b) stockpile salt, (c) patrol roads, and (d) prepare cold mix. Discussions and production study data for these four operations follow in the order named.

(a) Stockpile aggregates. This operation covered loading, hauling, and stockpiling all aggregates which were not destined for immediate use. Most aggregate stockpiled in the three-county control area was sand or cinders for use during winter maintenance operations. However, some crushed stone was also stockpiled for surface and shoulder maintenance operations.

Aggregates were obtained from several sources in the control area. Sand came from a leased river bottom pit; cinders from the power plant at a State institution; and crushed stone from commercial quarries. Outside the control area there were other sources such as State owned gravel pits. It should be noted that the State often contracted for loading, hauling and stockpiling aggregates when large quantities were involved.

Crews assigned to this operation varied considerably in size. Those observed ranged from one man and one truck up to 7 men, 6 trucks, a dragline or front-end loader, and a pickup. Generally speaking, smaller crews were used when aggregates were not loaded by State equipment; larger crews were used when loading was done by State owned draglines or loaders. The amount of aggregates handled at one time also varied considerably. Some small crews spent only a few hours on the operation while some large crews stockpiled for several days in succession. When aggregates were loaded by State equipment, one man operated a dragline or loader and 3 to 6 men operated trucks hauling to stockpiles. When aggregates were obtained from sources where loading was not done by State equipment, 1 to 4 men operated trucks hauling to stockpiles. Occasionally a dragline or loader was used for a short period reshaping dumped aggregates.

Production studies of this operation were limited. Studied crews hauled from one State stockpile to another, from a leased sand pit to a stockpile, and from the power plant at a State institution to a stockpile. In the first two cases, loading was done by a State dragline; in the latter case, aggregates were loaded from a bin. No studies were made on crews which obtained aggregates from commercial quarries. The haul distance observed on studies averaged 21 miles with a range from 1 to 32 miles. Haul and return speeds both averaged 35 mph. Average size of loads hauled was 4.6 cu yd.

Analyses of study data indicate that crews engaged in this operation were unbalanced when State draglines or loaders were used for loading aggregates. More trucks were needed to match hauling capacity to loading capacity. The incidence of delays due to wait on loading is also significant. It reflects "bunching" of trucks which caused them to wait on each other at times while the dragline waited on trucks at other times. Study data also revealed that the average dump time was over 5 minutes per load. An analysis showed that this average was heavily influenced by the very long (up to 20 minutes) dump time for trucks equipped with spreader beds.

TABLE 70
STOCKPILE AGGREGATES —
DISTRIBUTION OF 69 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Loading — Worksite				
A. Cyclic work items:				
1. Excavate and load aggregate	6			59.0 cu yd
2. Reshape stockpile	1/			50.0 cu yd
3. Maneuver to excavate or reshape	1/			
4. Maneuver to load (hauling unit exchange)	1			
		7		45.4 cu yd
B. Supporting work items		1		
C. Delays — wait on cyclic work item:				
1. Wait on load aggregate	5			
2. Other	3			
		8		
D. Delays — other		9		
Total - loading worksite			25	12.5 cu yd 2/
Unloading — Worksite				
A. Cyclic work items:				
1. Unload aggregate	7			48.2 cu yd
2. Reshape stockpile	2			48.3 cu yd
3. Maneuver to unload	1			
4. Maneuver to reshape	1/			
		10		33.3 cu yd
B. Supporting work items		1		
C. Delays — wait on cyclic work item		1/		
D. Delays — other		3		
Total — unloading worksite			14	23.8 cu yd 2/
Other				
E. Travel to, from, or between worksites (including haul and return)		48		
F. Supporting work items		3		
G. Delays		9		
H. Non-supporting work items and delays		1		
Total — other			61	
TOTAL			100	3.2 cu yd 2/
Total work items on assigned operation (A + B + E + F)			70	

1/ 0.5 percent or less.
2/ Based on aggregate hauled.

TABLE 72
STOCKPILE AGGREGATES —
DISTRIBUTION OF 5 HOURS NAWT FOR TRANSPORTATION PICKUPS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Loading and Unloading — Worksites				
A. Cyclic work items		-		
B. Supporting work items		1		
C. Delays — wait on cyclic work item		-		
D. Delays - other:				
1. Parked while men work	85			
2. Other	5			
		90		
Total — loading and unloading worksites			91	
Other				
E. Travel to, from, or between worksites		5		18 mph
F. Supporting work items		-		
G. Delays		4		
Total - other			9	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			6	

TABLE 71
STOCKPILE AGGREGATES —
DISTRIBUTION OF 55 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Loading — Worksite				
A. Cyclic work items:				
1. Load aggregate	6			63.5 cu yd
2. Maneuver to load	2			
		8		49.3 cu yd
B. Supporting work items:		1/		
C. Delays — wait on cyclic work item				
1. Wait on other truck load	4			
2. Other	1/			
		4		
D. Delays — other		6		
Total - loading worksite			18	22.4 cu yd 2/
Unloading — Worksite				
A. Cyclic work items:				
1. Unload aggregate	8			51.5 cu yd
2. Maneuver to unload	2			
		10		42.0 cu yd
B. Supporting work items		1		
C. Delays — wait on cyclic work item		1/		
D. Delays — other		3		
Total — unloading worksite			14	28.3 cu yd 2/
Other				
E. Travel to, from, or between worksites (including haul and return)		58		34 mph
F. Supporting work items		2		
G. Delays		8		
H. Non-supporting work items and delays		1/		
Total - other			68	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			79	

1/ 0.5 percent or less.
2/ Based on aggregate hauled.

TABLE 73
STOCKPILE AGGREGATES —
DISTRIBUTION OF 12 HOURS NAWT FOR DRAGLINES ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Loading — Worksite				
A. Cyclic work items:				
1. Excavate and load aggregate	27			64.3 cu yd
2. Reshape stockpile	2			50 cu yd
3. Maneuver to excavate or reshape	1			
		30		
B. Supporting work items		5		
C. Delays — wait on cyclic work item		2		
D. Delays — other:				
1. Shortage of trucks	26			
2. Other	6			
		32		
Total - loading worksite			69	25.5 cu yd
Unloading — Worksite				
A. Cyclic work items:				
1. Reshape stockpile	9			48.4 cu yd
2. Maneuver to reshape	1/			
		9		2/
B. Supporting work items		1		
C. Delays — wait on cyclic work item		-		
D. Delays — other		2		
Total - unloading worksite			12	2/
Other				
E. Travel to, from, or between worksites		9		20 mph
F. Supporting work items		2		
G. Delays		8		
Total - other			19	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			56	

1/ 0.5 percent or less.
2/ No accomplishment computed. This type of equipment has no regular pattern for time spent at unloading worksite.

(b) Stockpile salt. The State used bulk rock salt extensively in winter maintenance operations. Salt was purchased under contract and delivered to garages by commercial haulers in semitrailer trucks. This operation, therefore, involved only unloading the salt from commercial trucks and stockpiling it in sheds.

Crews assigned to this operation consisted of 4 to 6 men and a truck or front-end loader. In all cases observed, crews utilized a homemade drag bucket pulled by a cable attached to a truck or front-end loader to unload salt from the commercial trucks. Normally, two men took turns positioning and guiding the drag bucket; one man operated a truck or loader; one man signaled the truck or loader operator when to maneuver back and forth; and one or two men cleaned out the commercial truck bed with shovels and brooms. The commercial trucks usually were able to back part way into salt sheds so that the salt could be deposited directly in stockpiles. However, on some occasions front-end loaders were used to shape the stockpiles after unloading had been completed. The average quantity of salt in each load was about 20 cu yd or 38,000 lb.

Production studies of this operation showed that it was less efficient than many other types of maintenance work. There was too much hand effort and delays were relatively large. However, it should be noted that the delay for instructions principally consisted of the time one man spent signaling the operator of a truck or loader which operated the drag bucket. Performance under present conditions could have been increased somewhat if all crews had consisted of four men and a truck or loader.

An economic analysis should be made to determine if it is feasible to reconstruct existing salt sheds so as to eliminate a large portion of the labor and equipment time now expended on stockpiling. If possible, such reconstruction should also reduce the time required to load trucks with salt since this can be a critical factor during snow and ice control operations.

Figure 8. Unloading salt from commercial truck.

Figure 9. Unloading salt with drag bucket.

TABLE 74

STOCKPILE SALT –
DISTRIBUTION OF 33 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Unload salt by hand	5	1.4 tons
2. Unload salt with drag bucket	20	20.4 tons
3. Reposition drag bucket	7	
4. Maneuver to unload	5	
	37	11.0 tons 1/
B. Supporting work items	9	
C. Delays – wait on cyclic work item	3	
D. Delays – other:		
1. Instructions	12	
2. Taking well-earned rest	5	
3. Idle	4	
4. Other	19	
	40	
Total – worksite	89	4.6 tons 1/
Other		
E. Travel to, from, or between worksites	2	
F. Supporting work items	3	
G. Delays	6	
H. Non-supporting work items and delays	2/	
Total – other	11	
TOTAL	100	4.0 tons 1/
Total work items on assigned operation (A + B + E + F)	51	

1/ Based on salt unloaded with drag bucket plus salt unloaded by hand.

2/ 0.5 percent or less.

TABLE 75

STOCKPILE SALT –
DISTRIBUTION OF 9 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Unload salt with drag bucket	15	69.1 tons
2. Maneuver to unload	12	
	27	37.9 tons 1/
B. Supporting work items	7	
C. Delays – wait on cyclic work item:		
1. Wait on reposition drag bucket	6	
2. Other	1	
	7	
D. Delays – other:		
1. Parked while men work	36	
2. Other	11	
	47	
Total – worksite	88	20.3 tons 1/
Other		
E. Travel to, from, or between worksites	3	20 mph
F. Supporting work items	2	
G. Delays	7	
Total – other	12	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	39	

1/ Rate based on salt unloaded with drag bucket plus salt unloaded by hand.

TABLE 76

STOCKPILE SALT –
DISTRIBUTION OF 2 HOURS NAWT FOR LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Unload salt with drag bucket	31	60.9 tons
2. Maneuver to unload	22	
	53	36.5 tons 1/
B. Supporting work items	5	
C. Delays – wait on cyclic work item:		
1. Wait on unload salt by hand	6	
D. Delays – other:		
1. Refuel	7	
2. Other	5	
	12	
Total – worksite	76	25.8 tons 1/
Other		
E. Travel to, from, or between worksites	7	19 mph
F. Supporting work items	4	
G. Delays	13	
Total – other	24	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	69	

1/ Rates based on salt unloaded with drag bucket plus salt unloaded by hand.

(c) Patrol roads. State policy called for weekly inspections to ascertain the condition of surfaces, shoulders, roadsides, bridges, signs, guardrails, and other highway installations on all road sections. Most road sections were actually inspected more often than called for by the policy, particularly during winter months. These inspections were usually accomplished by patrolling. In some instances, however, they were handled by crews which covered road sections during other operations.

Most patrolling was performed by one-man crews equipped with a pickup or truck. In some counties, the bulk of patrolling was done by foremen; in others, patrolling was done in large part by equipment operators. The normal procedure was to travel over road sections at about 30 mph visually checking conditions. It was sometimes necessary to stop for a close inspection of certain areas. On some occasions, crews spent a small amount of time on other operations during patrolling. For example, a small hole might be patched with bituminous cold mix to eliminate a traffic hazard. The time so spent was considered nonsupporting work and included in the patrol road operation.

Production studies of this operation were very limited. They were confined to crews consisting of two men and a truck. Since the bulk of patrolling was done by one-man crews, study data are not entirely typical.

TABLE 77
PATROL ROADS —
DISTRIBUTION OF 15 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Patrol roads	58	16 lane-mi
2. Inspect problem area	1	
	59	16 lane-mi
B. Supporting work item	2	
C. Delays – wait on cyclic work item	-	
D. Delays – other:		
1. Personal	6	
2. Other	3	
	9	
Total - worksite	70	13 lane-mi
Other		
E. Travel to, from, or between worksites	9	
F. Supporting work items	2	
G. Delays	18	
H. Nonsupporting work items and delays	1	
Total — other	30	
TOTAL	100	9 lane-mi
Total work items on assigned operation (A + B + E + F)	72	

TABLE 78
PATROL ROADS —
DISTRIBUTION OF 8 HOURS NAWT FOR TRUCKS AND PICKUPS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (avg per hour)
Worksite		
A. Cyclic work item:		
1. Patrol roads	59	29 lane-mi
B. Supporting work item	1	
C. Delays – wait on cyclic work item	1	
D. Delays – other:		
1. Personal	6	
2. Other	4	
	10	
Total — worksite	71	24 lane-mi
Other		
E. Travel to, from, or between worksites	9	31 mph
F. Supporting work items	2	
G. Delays	17	
H. Nonsupporting work items and delays	1	
Total — other	29	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	71	

(d) Prepare bituminous cold mix. Considerable quantities of bituminous cold mix were used for surface and shoulder maintenance operations. In the three-county control area, State maintenance crews used approximately 2,800 tons or 1,900 cu yd during the one-year study period. About one-third of this total was obtained from commercial plants; the remainder was prepared by State crews. This operation covers the work done by these crews while preparing bituminous cold mix.

The bituminous cold mix consisted of aggregate and MC-3 or MC-4 asphalt. Aggregate was obtained directly from commercial quarries or drawn from State stockpiles. Asphalt was obtained from storage tanks located near most garages.

Crews assigned to the operation varied to some extent. A basic crew usually consisted of 4 men, a truck, a motorgrader, a front-end loader, a distributor, and sometimes, a Seaman mixer towed by a tractor. This crew was supplemented by 2, 3, or 4 men and an equal number of trucks when aggregate was being obtained from a commercial quarry or a distant State stockpile. Worksites were generally located at garages or a State stockpile. Aggregate was either hauled by trucks and dumped in a windrow or transferred by a loader from an adjacent stockpile to a windrow. On some occasions the windrowed dry aggregate was mixed by a motorgrader to insure uniformity of gradation. Then a distributor towed by a truck made one or more passes to spray asphalt. The aggregate and asphalt were mixed by a motorgrader until the asphalt was uniformly distributed. On some occasions, additional mixing was done by a Seaman mixer towed by a tractor. After completion of mixing, a motorgrader reshaped the windrow so that material could be easily loaded when needed for surface patching or other operations.

Crews engaged in preparing bituminous cold mix were studied on several occasions. Most of the time, aggregate was obtained at commercial quarries and hauled by State trucks to the worksite. The crews studied used a motorgrader for most of the mixing and were not equipped with Seaman mixers. Production study data indicate that this was a relatively inefficient operation. Generally, only one or two men and one or two equipment units were working at any one time. The remainder of the crew were in delay status. A better balance between labor and equipment and the use of men to perform more than one task would have resulted in greater efficiency.

TABLE 79
PREPARE BITUMINOUS COLD MIX -
DISTRIBUTION OF 49 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Mix dry aggregate with motorgrader	1			53.6 cu yd
2. Spray asphalt with distributor	2			1,840 gal 110.5 cu yd 1/
3. Mix aggregate and asphalt with motorgrader and loader	5			40.5 cu yd 1/
4. Reposition motorgrader blade	1			
5. Maneuver to mix or spray	5			
		14		14.1 cu yd 1/
B. Supporting work items		6		
C. Delays — wait on cyclic work items:				
1. Wait on mix aggregate and asphalt	11			
2. Other	2			
		13		
D. Delays — other		11		
Total - worksite			44	4.4 cu yd 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		28		
F. Supporting work items		4		
G. Delays:				
1. Wait on heat asphalt	5			
2. Wait on load aggregate and asphalt	7			
3. Other	12			
		24		
H. Non-supporting work items and delays		2/		
Total — other			56	
TOTAL			100	1.9 cu yd 1/
Total work items on assigned operation (A + B + E + F)			52	

1/ Based on aggregate mixed with asphalt.
2/ 0.5 percent or less.

The type of bituminous mixtures used in Iowa were of a perishable nature. Normally, they were not stockpiled for more than a few weeks. This prevented purchase of large quantities under contract for stockpiling or preparation of large quantities by efficient, large, properly equipped State crews. Other States have developed bituminous cold mixes which can be stored for months or even years. The development of such mixes for use in Iowa would result in a considerable saving in costs over present methods of procurement or preparation.

Figure 10. Motorgrader mixing aggregate and asphalt.

TABLE 80

PREPARE BITUMINOUS COLD MIX –
DISTRIBUTION OF 30 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spray asphalt with distributor	2	5,910 gal 217.5 gal 1/
2. Maneuver to spray	1	
	3	112.7 cu yd 1/
B. Supporting work items	4	
C. Delays - wait on cyclic work items:		
1. Wait on mix aggregate and asphalt	19	
2. Other	2/	
	19	
D. Delays - other	8	
Total - worksite	34	9.1 cu yd 1/
Other		
E. Travel to, from, or between worksites (including haul and return)	33	(30 mph)
F. Supporting work items	7	
G. Delays:		
1. Wait on load aggregate and asphalt	8	
2. Wait on heat asphalt	5	
3. Other	12	
	25	
H. Non-supporting work items and delays	1	
Total - other	66	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	47	

1/ Based on aggregate mixed with asphalt.
2/ 0.5 percent or less.

TABLE 81

PREPARE BITUMINOUS COLD MIX –
DISTRIBUTION OF 11 HOURS NAWT FOR MOTORGRADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Mix dry aggregate	4	53.6 cu yd
2. Mix aggregate and asphalt	20	45.2 cu yd 1/
3. Reposition blade	3	
4. Maneuver to mix	18	
	45	20.1 cu yd 1/
B. Supporting work item	7	
C. Delays – wait on cyclic work item	3	
D. Delays – other:		
1. Wait on unload aggregate	6	
2. Wait on men and other equipment units engaged in preparations, shut down, or travel	12	
3. Wait on heat asphalt	8	
4. Other	5	
	31	
Total – worksite	86	10.5 cu yd
Other		
E. Travel to, from, or between worksites	7	(22 mph)
F. Supporting work items	1	
G. Delays	6	
H. Non-supporting work items and delays	2/	
Total – other	14	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	60	

1/ Based on total aggregate mixed with asphalt by motorgrader and loader.
2/ 0.5 percent or less.

TABLE 82

PREPARE BITUMINOUS COLD MIX —
DISTRIBUTION OF 7 HOURS NAWT FOR FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Mix aggregate and asphalt	4			319.0 cu yd 1/
2. Maneuver to mix	1	5		287.5 cu yd 1/
B. Supporting work items:				
1. Transfer aggregate from stockpile to windrow	13			
2. Other	2	15		
C. Delays — wait on cyclic work items:				
1. Wait on mix dry aggregate	5			
2. Wait on spray asphalt	5			
3. Wait on mix aggregate and asphalt	31	41		
D. Delays — other:				
1. Wait on men and other equipment units engaged in preparations, shutdown, or travel	13			
2. Other	5	18		
Total - worksite			79	17.3 cu yd 1/
Other				
E. Travel to, from, or between worksites	17			
F. Supporting work items	1			
G. Delays	3	21		
Total — other			21	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			38	

1/ Based on total aggregate mixed by motorgrader and loader.

TABLE 83

PREPARE BITUMINOUS COLD MIX —
DISTRIBUTION OF 13 HOURS NAWT FOR DISTRIBUTORS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Spray asphalt	3			3,830 gal 230.0 cu yd 1/
2. Maneuver to spray	3	6		1,915 gal 115.0 cu yd 1/
B. Supporting work items:				
1. Heat asphalt	9			
2. Other	1	10		
C. Delays - wait on cyclic work items:				
1. Wait on mix dry aggregate	1			
2. Wait on mix aggregate and asphalt	18	19		
D. Delays - other:				
1. Wait on unload aggregate or transfer aggregate from stockpile to windrow	11			
2. Other	2	13		
Total — worksite			48	260 gal 15.6 cu yd 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		11		
F. Supporting work items:				
1. Heat asphalt	20			
2. Other	6	26		
G. Delays		15		
Total — other			52	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			53	

1/ Based on aggregate mixed with asphalt.

4. Direct operations

In the category of direct operations there are 20 principal operations on which production studies are reported. These principal operations are defined as those which accounted for 1.0 percent or more of labor TAWT (after distribution of overhead) as determined by comprehensive studies in the three-county control area. Many other direct operations were studied but they accounted for such a minor portion of the total work in the control area that they are not reported here.

The form of data presentation selected facilitates showing of production rates for several time increments but reduces somewhat the number of variables which can be included in the calculations of these rates. In the end, only the raw data itself will provide adequate detail for the variety of applications which individual readers may wish to make.

A discussion of the 20 principal operations follows in the order listed below:

(a) Patch roadway surfaces with aggregate
(b) Patch roadway surfaces with bituminous cold mix
(c) Patch roadway surfaces with bituminous hot mix
(d) Blade gravel surfaces
(e) Mudjack concrete pavements
(f) Rebuild gravel surfaces
(g) Seal bituminous and concrete pavements
(h) Resurface with bituminous mixes
(i) Patch shoulders and approaches with aggregate
(j) Patch shoulders and approaches with bituminous cold mix
(k) Clean or repair unpaved drainage ditches
(l) Mow roadsides with tractor
(m) Remove snow from roadway surfaces and shoulders
(n) Erect snow fences
(o) Remove snow fences
(p) Sand roadway surfaces
(q) Salt roadway surfaces
(r) Remove ice from roadway surfaces and shoulders
(s) Paint centerlines and edgelines on pavements
(t) Erect, replace, repair or paint signs and guideposts

(a) Patch roadway surfaces with aggregate. This operation accounted for 3.0 percent of TAWT in the three-county control area during the study period. As might be expected, most of the effort was expended on road sections which had gravel surfaces. However, there was also a considerable amount of aggregate patching on road sections with bituminous pavements, particularly those which had light bases.

During the spring thaw period, a number of surface failures developed on most gravel roads. They usually resulted from failures in wet subgrades. Aggregate was applied to stabilize the surface failures so that traffic could be accommodated. Throughout the year, gravel surfaced roads developed ruts and potholes due to traffic abrasion. Aggregate was used to fill these failures until such time as it was practical to blade and reshape the entire surface. Calcium chloride was often sprinkled on the surface of pothole patches to hold aggregate in place but usually was not used on patches covering larger distressed areas.

During the spring thaw period, some low-type bituminous surfaced roads also developed distressed areas which resulted from a wet base or subgrade. Aggregate was applied to stabilize these areas so that traffic could be accommodated. Calcium chloride was sprinkled on the surface of most of these patches to hold the aggregate in place, prevent dust, and promote drying of the base or subgrade through capillary action. All aggregate patches on bituminous surfaces were replaced with bituminous mixes as soon as conditions permitted. In some cases, bases were rebuilt and stabilized.

Aggregate used for all types of roadway surface patching was obtained either directly from commercial quarries or from State stockpiles. The stockpiled aggregate was often obtained under contract.

It was observed that this operation was usually performed by small crews. When calcium chloride was used, there normally were 2 or 3 men and one truck. When calcium chloride was not used, the crew ranged from 1 to 3 men, and sometimes each man had a truck. Front-end loaders were also utilized by crews when aggregate was obtained from State stockpiles. They did not use any spreading or compaction equipment. Aggregate was usually hauled directly from quarries to worksite. It was unloaded and spread with a truck spreader bed, dumped from a truck and spread by hand, or unloaded and spread by hand. Compaction was provided by traffic. When crews used calcium chloride, they carried it to the worksite in bags and sprinkled it sparingly on top of patches by hand. Occasionally, a road section required such extensive patching that large crews were assigned to the operation. These crews consisted of 5 or 6 men, 3 or 4 trucks for hauling, and a heavy duty truck with underbody blade or a motorgrader for spreading. A front-end loader was used if aggregate was obtained from State stockpiles. In some cases, the large crews also had a rubber-tired roller towed by a tractor for compaction. Although large crews were not studied in detail, observations indicate that they were often unbalanced. Usually more trucks were needed to match hauling capacity to the capacity of loading, spreading, and compaction equipment.

None of the crews studied used warning signs or flagged public traffic while assigned to this operation. Traffic volumes were low on most of the road sections in which work was done.

Production studies were confined to small scale patching and small crews. Men on these crews usually encountered only a few delays. However, men other than truck drivers did lose a considerable amount of time riding while aggregate was hauled from quarries or stockpiles. More extensive use of minimum size crews (often one man) would have increased average performance substantially.

Figure 11. Truck with spreader bed spreading aggregate in ruts.

TABLE 84

PATCH ROADWAY SURFACES WITH AGGREGATE – DISTRIBUTION OF 65 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Remove debris from hole by hand	1/			
2. Unload, spread or level aggregate by hand	8			3.4 cu yd 64 sq yd
3. Unload and spread aggregate with truck spreader bed	3			28.0 cu yd 375 sq yd
4. Unload and spread aggregate with truck (end dump)	1/			288.6 cu yd 3,300 sq yd
5. Spread $CaCl_2$ by hand	1			1,815 lb 554 sq yd
6. Move ahead to new work area	4			
		16		10.3 cu yd 151 sq yd 2/
B. Supporting work items		3		
C. Delays — wait on cyclic work item		1/		
D. Delays – other		4		
Total – worksite			23	7.3 cu yd 107 sq yd 2/
Other				
E. Travel to, from, or between worksites (including haul and return)		44		
F. Supporting work items:				
1. Load aggregate and $CaCl_2$	5			
2. Other	6			
		11		
G. Delays:				
1. Wait on load men, tools, aggregate or $CaCl_2$	5			
2. Other	17			
		22		
H. Non-supporting work items and delays		1/		
Total – other			77	
TOTAL			100	1.7 cu yd 25 sq yd 2/
Total work items on assigned operation (A + B + E + F)			74	

1/ 0.5 percent or less.
2/ Based on aggregate placed.

TABLE 85

PATCH ROADWAY SURFACES WITH AGGREGATE — DISTRIBUTION OF 37 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Unload and spread aggregate with spreader bed	5			28.0 cu yd 375 sq yd
2. Unload and spread aggregate (end dump)	1			288.6 cu yd 3,300 sq yd
3. Move ahead to new work area	3			(12 mph)
		9		33.2 cu yd 785 sq yd 1/
B. Supporting work items:				
1. Unload aggregate by hand	6			7.4 cu yd
2. Other	4			
		10		
C. Delays – wait on cyclic work item		-		
D. Delays – other		2		
Total – worksite			21	14.3 cu yd 210 sq yd 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		45		(28 mph)
F. Supporting work items:				
1. Load aggregate and $CaCl_2$	9			
2. Other	5			
		14		
G. Delays		19		
H. Non-supporting work items and delays		1		
Total – other			79	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			78	

1/ Based on aggregate placed.

TABLE 86

PATCH ROADWAY SURFACES WITH AGGREGATE – DISTRIBUTION OF 9 HOURS NAWT FOR FRONT-END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Other				
E. Travel to, from, or between worksites		1/		(21 mph)
F. Supporting work items:				
1. Load aggregate	36			36.4 cu yd
2. Other	5			
		41		
G. Delays:				
1. Standby	37			
2. Wait on men and other equipment units engaged in preparations, shutdown or travel	16			
3. Other	6			
		59		
TOTAL			100	
Total work on assigned operation (E + F)			41	

1/ 0.5 percent or less.

(b) Patch roadway surfaces with bituminous cold mix. This operation accounted for 5.0 percent of labor TAWT in the three-county control area and was the most prominent type of routine surface maintenance. It was carried out only on road sections with bituminous or concrete pavements. Bituminous cold mix patches were used to permanently correct several types of surface failures such as potholes, depressions or raveling. In some cases, the failures were basically due to weak spots or failures in bases and patching was done in conjunction with base reconstruction. Bituminous cold mix patches were also used for temporary correction of a failure that was hazardous to traffic. These temporary patches were eventually replaced with permanent patches using bituminous cold mix, bituminous hot mix, or concrete.

The bituminous cold mix used for roadway surface patching was a mixture of aggregate and MC-3 or MC-4 asphalt. Part of it was obtained from commercial plants; part was stockpiled at garages under contracts; the remainder was prepared by State forces using locally available aggregate. It was observed that these cold mixes were usually not stockpiled for any great length of time since they tended to harden in the pile.

This operation was normally carried out by a 2- or 3-man crew equipped with one truck. A front-end loader was often used when cold mix was drawn from a State stockpile but there was also some hand loading. Asphalt for priming holes was usually transported to the worksite in a bucket or hand sprayer, but sometimes a distributor was used. In a few cases, crews used a motorgrader to clean debris out of patch areas. It was observed that most crews worked on this operation for only part of a day. They frequently hauled partial loads of cold mix (average load about 2.6 ton) to worksites, and sometimes returned to the garage early because they ran out of material.

The general procedure used for the operation was as follows: A load of cold mix was obtained and hauled to the worksite; debris was cleaned out of holes with a broom, or shovel, or occasionally by a motorgrader; holes were primed or tacked with asphalt using a broom, hand-pump sprayer, or hand-held distributor spray bar; bituminous cold mix was unloaded, spread in holes and leveled by hand; and patches were compacted with a hand tamper or truck wheels. However, it was noted that one or more of the steps involving cleaning, priming and compacting were omitted for many patches. These omissions were more common when crews were putting in temporary patches but also occurred at other times. On most crews, men did not work by assigned tasks. Men switched from one task to another throughout the day.

Safety practices varied considerably from crew to crew. In most cases, they did not put out any warning signs. Most two-man crews did little or no flagging. Most three-man crews did a substantial amount of flagging and, in some cases, a man was flagging public traffic during the entire day.

Production studies show that men lost a substantial amount of time due to delays, particularly at the garage. Time was also lost by men other than truck drivers during travel. An analysis of study data indicated that a crew of two men and one truck would be the most efficient when patches are small and scattered. This is true even if one man devotes much of his time to flagging traffic. Only when patches are large or close together can a crew of three men and one truck operate efficiently. For some emergency situations, a crew of one man and one truck may be best.

TABLE 87

PATCH ROADWAY SURFACES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 196 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Remove debris from hole by hand	4	42 sq yd 1/
2. Remove debris from hole with motorgrader	2/	86 sq yd 1/
3. Prime hole with broom hand sprayer or distributor	3	61 sq yd 1/
4. Unload, spread or level bituminous cold mix by hand	15	0.7 cu yd 17 sq yd
5. Tamp bituminous cold mix by hand	4	15 sq yd 3/
6. Roll bituminous cold mix w/truck wheels	1	35 sq yd 3/
7. Walk ahead to new work area	1	
8. Move ahead to new work area	7	
	35	0.3 cu yd 7.0 cu yd
B. Supporting work items:		
1. Flag or direct public traffic	5	
2. Other	6	
	11	
C. Delays — wait on cyclic work item	3	
D. Delays — other	7	
Total — worksite	56	0.2 cu yd 4.1 sq yd 4/
Other		
E. Travel to, from, or between worksites (including haul)	21	
F. Supporting work items	6	
G. Delays	16	
H. Non-supporting work items and delays	1	
Total - other	44	
TOTAL	100	0.1 cu yd 2.1 sq yd 4/
Total work on assigned operation (A + B + E + F)	73	

1/ Not done at all patches. Based on area covered.
2/ 0.5 percent or less
3/ Not done at all patches. Based on one pass over area covered.
4/ Based on cold mix placed.

TABLE 89

PATCH ROADWAY SURFACES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 1 HOUR NAWT FOR MOTORGRADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Blade debris from hole	35	86 sq yd
B. Supporting work items	5	
C. Delays — wait on cyclic work item	-	
D. Delays — other	23	
Total — worksite	63	47 sq yd 1/
Other		
E. Travel to, from, or between worksites	35	(17 mph)
F. Supporting work items	2	
G. Delays	-	
Total — other	37	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	77	

1/ Based on area actually covered.

TABLE 88

PATCH ROADWAY SURFACES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 82 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Roll bituminous cold mix with wheels	3	36 sq yd 1/
2. Move ahead to new work area	8	(9 mph)
	11	2.3 cu yd 58.0 sq yd 2/
B. Supporting work items:		
1. Unload bituminous cold mix by hand	18	1.0 cu yd
2. Other	6	
	24	
C. Delays – wait on cyclic work item	17	
D. Delays – other	6	
Total – worksite	58	0.4 cu yd 10.0 sq yd 2/
Other		
E. Travel to, from, or between worksites (including haul)	19	(32 mph)
F. Supporting work items	6	
G. Delays	16	
H. Non-supporting work items and delays	1	
Total – other	42	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	60	

1/ Not done at all patches. Based on one pass over area covered.
2/ Based on bituminous cold mix placed.

TABLE 90

PATCH ROADWAY SURFACES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 8 HOURS NAWT FOR DISTRIBUTORS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Prime holes	7	91 gal 415 sq yd
2. Move ahead to new work area	6	(5 mph)
	13	48 gal 217 sq yd 1/
B. Supporting work items:		
1. Heat bituminous material	6	
2. Other	4	
	10	
C. Delays – wait on cyclic work item	35	
D. Delays – other	13	
Total – worksite	71	8.8 gal 40 sq yd 1/
Other		
E. Travel to, from, or between worksites (including haul)	9	(20 mph)
F. Supporting work items:		
1. Heat bituminous materials	5	
2. Other	6	
	11	
G. Delays	9	
Total – other	29	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	43	

1/ Based on asphalt sprayed and area covered.

TABLE 91

PATCH ROADWAY SURFACES WITH BITUMINOUS COLD MIX –
DISTRIBUTION OF 1 HOUR NAWT FOR FRONT-END LOADERS
ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Other		
E. Travel to, from, or between worksites	-	
F. Supporting work items:		
1. Load bituminous cold mix	54	12.9 cu yd
2. Maneuver to load	16	
3. Other	5	
	75	
G. Delays	23	
H. Non-supporting work items and delays	2	
TOTAL	100	
Total work items on assigned operation (E + F)	75	

Figure 12. Priming hole.

Figure 13. Priming hole and spreading cold mix by hand.

(c) Patch roadway surfaces with bituminous hot mix. This operation accounted for 1.4 percent of labor TAWT in the three-county control area during the study period. It was performed only on road sections which had originally been paved with bituminous plant mix, plant mix overlay, or concrete. Bituminous hot mix patches were used to provide permanent correction for surface failures such as spalled joints, settled areas, ruts, or potholes. In many cases, the hot mix replaced a temporary bituminous cold mix patch.

The hot mix used was a mixture of a selected aggregate and asphalt cement. Part of it was obtained directly from commercial plants; the remainder was prepared by maintenance crews using small portable plants which usually included both a dryer and a pugmill mixer. Sometimes only a pugmill mixer was utilized and aggregate was predried.

This operation was performed by fairly large crews. When hot mix was obtained from a commercial plant, there were usually 4 to 6 men, 3 trucks, a roller, and, sometimes, an air compressor involved. When hot mix was prepared at the worksite, the crew normally included 7 to 9 men, 4 trucks, a portable batch plant, a kettle, a roller, and an air compressor. The work was usually carried out in the following manner. First, old pavement and debris were cleaned out of the area to be patched. Part of this cleaning was done by hand, the remainder with a compressor and a jackhammer. On larger jobs, cleaning was frequently done by a group of 2 or 3 men who kept ahead of the men placing hot mix. Next, all patches were primed with a hand sprayer. On small jobs, hot mix was almost always obtained from a commercial plant. It was hauled to worksites, dumped or shoveled into patch areas, leveled by hand, and compacted with a steel-wheel roller or truck wheels. On the larger jobs, the mix was usually produced at the worksite by a small portable plant. It was transported to patch areas in wheelbarrows, dumped in place, leveled by hand and compacted with a roller or truck wheels. When using these plants, crews worked by assigned tasks. One man shoveled aggregate into the dryer or pugmill, one man measured and carried hot asphalt cement from kettle to plant, one man operated the plant, one man transported hot mix from plant to patch, one man primed holes and leveled hot mix, and one man operated a roller or truck for compaction.

The crews engaged in this operation put out warning signs at most worksites. Sometimes there was a full-time flagman, but on most occasions men took turns flagging public traffic during work breaks.

Production studies of this operation were limited to one crew using hot mix obtained from a commercial plant and one crew using hot mix produced by a portable plant which included only a pugmill. Observations of other crews engaged in this work indicated that this operation was carried out in a similar manner when crews used plants which included both a dryer and a pugmill. An analysis showed that delays due to waiting on other men working were quite high. This suggests that the studied crews included more men than required by the production rate of the pugmill mixer or they were not properly organized when using commercially produced hot mix. A realinement in duties would have permitted reduction in crew size without decreasing total accomplishment. Also, a working supervisor is needed to coordinate activities, particularly when the crew uses a portable plant in the operation.

Figure 14. Hand spreading bituminous hot mix.

TABLE 92

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX –
DISTRIBUTION OF 84 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Remove old pavement from hole with compressor and jackhammer	2			13 sq yd
2. Remove old pavement and debris from hole by hand or with air hose	3			11 sq yd
3. Prime hole with hand sprayer	1			88 sq yd
4. Unload, spread or level bituminous hot mix by hand	9			1.3 cu yd 19 sq yd
5. Roll patch with truck wheels	1			39 sq yd 1/
6. Roll patch with towed roller	2/			385 sq yd 1/
7. Maneuver to roll	2/			
8. Walk ahead to new work area	2/			
9. Move ahead to new work area	3			
		19		0.6 cu yd 5 sq yd 3/
B. Supporting work items:				
1. Flag or direct public traffic	7			
2. Other	10			
		17		
C. Delays – wait on cyclic work item:				
1. Wait on mix bituminous hot mix	9			
2. Wait on remove debris from hole	4			
3. Other	3			
		16		
D. Delays – other		9		0.2 cu yd 1.6 sq yd 3/
Total – worksite			61	
Other				
E. Travel to, from, or between worksites (including haul)		20		
F. Supporting work items		6		
G. Delays		11		
H. Nonsupporting work items and delays		2		
Total – other			39	
TOTAL			100	0.1 cu yd 1.0 sq yd 3/
Total work items on assigned operation (A + B + E + F)			62	

1/ All of the area patched was rolled. Based on one pass over area covered.
2/ 0.5 percent or less.
3/ Based on bituminous hot mix placed.

TABLE 93

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX –
DISTRIBUTION OF 34 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Roll bituminous hot mix with wheels	3			42 sq yd 1/
2. Roll bituminous hot mix with roller	2/			675 sq yd 1/
3. Maneuver to roll	1			
4. Move ahead to new work area	3			(15 mph)
		7		
B. Supporting work items:				
1. Unload bituminous hot mix or aggregate 3/	5			5.8 cu yd
2. Other	8			4.4 cu yd 38.6 sq yd
		13		
C. Delays – wait on cyclic work item:				
1. Wait on remove debris from hole	7			
2. Wait on mix bituminous hot mix	6			
3. Wait on spread or level bituminous hot mix	8			
4. Other	1			
		22		
D. Delays – other:				
1. Parked while men work	10			
2. Other	10			
		20		
Total – worksite			62	0.5 cu yd 4.0 sq yd 4/
Other				
E. Travel to, from, or between worksites (including haul)		25		(25 mph)
F. Supporting work items		4		
G. Delays		9		
H. Non-supporting work items and delays		2/		
Total – other			38	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			49	

1/ All of the area patched was rolled. Based on one pass over area covered by each method.
2/ 0.5 percent or less.
3/ Aggregate used in bituminous hot mix.
4/ Based on total bituminous hot mix placed.

TABLE 94

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX –
DISTRIBUTION OF 4 HOURS NAWT FOR TRANSPORTATION PICKUPS
ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items		-		
B. Supporting work items		3		
C. Delays – wait on cyclic work item		-		
D. Delays – other:				
1. Parked while men work	65			
2. Other	1/			
		65		
Total – worksite			68	
Other				
E. Travel to, from, or between worksites		20		(34 mph)
F. Supporting work items		1		
G. Delays		10		
H. Non-supporting work items and delays		1		
Total – other			32	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			24	

1/ 0.5 percent or less.

TABLE 95

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX –
DISTRIBUTION OF 7 HOURS NAWT FOR ROLLERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Roll bituminous hot mix	2			360 sq yd 1/
2. Maneuver to roll	3			
		5		160 sq yd 1/
B. Supporting work items		1		
C. Delays – wait on cyclic work item		13		
D. Delays – other		4		
Total – worksite			23	31 sq yd 1/
Other				
E. Travel to, from, or between worksites		45		(11 mph)
F. Supporting work items		3		
G. Delays:				
1. Wait on men and other equipment units engaged in preparations, shutdown, or travel	26			
2. Other	3			
		29		
Total – other			77	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			54	

1/ All of the area patched was rolled. Based on one pass over area covered.

TABLE 96

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX — DISTRIBUTION OF 9 HOURS NAWT FOR PUGMILL MIXERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Mix bituminous hot mix	23	1.0 cu yd
2. Move ahead to new work area	4	(14 mph)
	27	0.8 cu yd 1/
B. Supporting work items	5	
C. Delays — wait on cyclic work item:		
1. Wait or spread and level bituminous hot mix	6	
2. Other	5	
	11	
D. Delays - other	6	
Total - worksite	49	0.5 cu yd 1/
Other		
E. Travel to, from, or between worksites (including haul)	8	(18 mph)
F. Supporting work items	10	
G. Delays:		
1. Men idle	9	
2. Other	24	
	33	
Total - other	51	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	50	

1/ Based on bituminous hot mix produced and placed.

TABLE 97

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX — DISTRIBUTION OF 1 HOUR NAWT FOR KETTLES ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Other		
E. Travel to, from, or between worksites	-	
F. Supporting work items:		
1. Heat asphalt	73	
2. Unload asphalt	12	
3. Other	11	
	96	
G. Delays	4	
TOTAL	100	
Total work items on assigned operation (E + F)	96	

TABLE 98

PATCH ROADWAY SURFACES WITH BITUMINOUS HOT MIX — DISTRIBUTION OF 7 HOURS NAWT FOR COMPRESSORS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Remove old pavement with jackhammer	18	11 sq yd
2. Remove old pavement and debris from hole with air hose	4	146 sq yd
3. Move ahead to new work area	5	
	27	
B. Supporting work items	5	
C. Delays — wait on cyclic work item	27	
D. Delays - other	15	
Total - worksite	74	
Other		
E. Travel to, from or between worksites	11	(19 mph)
F. Supporting work items	1	
G. Delays	9	
H. Non-supporting work items and delays	5	
Total — other	26	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	44	

Figure 15. Self-propelled roller compacting hot mix patch.

(d) Blade gravel surfaces. Time expended on this operation amounted to 1.0 percent of labor TAWT in the three-county control area. Each of the counties had one or more gravel surfaced road sections on the primary system and one had detours over gravel county roads. The most intensive effort was required during the spring thaw period when these roads developed many wet spots and distressed areas. Sometimes daily blading was required to keep traffic moving. During the remainder of the year, blading was done periodically in order to repair ruts, potholes, and general surface deterioration caused by traffic.

Normally, this operation involved a crew of only one man and a motorgrader. A truck or pickup was also utilized for travel if the motorgrader was stored at a temporary parking area near the worksite. On some occasions, a heavy duty truck with underbody blade was used in lieu of a motorgrader. These heavy duty trucks operated at a higher speed while blading but more passes were required to accomplish the same amount of work.

Blading was done shortly after a rain, whenever possible, since surfaces were more workable at that time. Normally, the first two passes were made on outside edges of the roadway in order to pull in loose aggregate. The motorgrader or truck then made one or more passes over the center portion of the roadway to spread the loose aggregate. Most road sections also required extra passes at distressed or rutted areas. It was observed that each pass averaged about 10 feet in width and that the entire gravel surface was covered an average of 1.2 times.

Warning signs were not used on those occasions when the operation was studied. Motorgraders and trucks usually had flags mounted on the left end of their underbody blades and often had flags mounted on the cab.

Production studies indicate that this operation was relatively efficient. This could be attributed to the fact that almost all of the work was done by one-man crews. Accomplishment could be increased if travel time were reduced. This could be done by purchasing motorgraders equipped with a high speed travel gear.

Figure 16. Motorgrader blading gravel surface.

TABLE 99

BLADE GRAVEL SURFACES —

DISTRIBUTION OF 56 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Blade with motorgrader underbody blade	46			3.7 pass-mi 21,000 sq yd 1/
2. Blade with truck underbody blade	4			6.8 pass-mi 41,900 sq yd 1/
3. Reposition blade	1			
4. Maneuver to blade	3			
		54		3.6 pass-mi 20,900 sq yd 2/
B. Supporting work items		4		
C. Delays - wait on cyclic work item		-		
D. Delays - other		2		
Total - worksite			60	3.4 pass-mi 19,400 sq yd
Other				
E. Travel to, from, or between worksites		21		
F. Supporting work items		4		
G. Delays		14		
H. Non-supporting work items and delays		1		
Total — other			40	
TOTAL			100	2.3 pass-mi 13,100 sq yd 2/
Total work items on assigned operation (A + B + E + F)			83	

1/ Based on area bladed. Part of the roadway was covered more than one time. Based on area maintained is:

Motorgrader 3.3 lane-mi - 19,000 sq yd
Truck 2.9 lane-mi - 17,600 sq yd

2/ Based on area bladed. Part of the roadway was covered more than one time. Based on area maintained is:

Cyclic work items 3.0 lane-mi - 17,300 sq yd
Worksite 2.8 lane-mi - 16,000 sq yd
NAWT 1.9 lane-mi - 10,800 sq yd

TABLE 101

BLADE GRAVEL SURFACES —

DISTRIBUTION OF 7 HOURS NAWT FOR TRANSPORTATION TRUCKS AND PICKUPS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		Performance (Avg per hour)
Worksite			
A. Cyclic work items	-		
B. Supporting work items	1/		
C. Delays - wait on cyclic work item	-		
D. Delays - parked while men work	70		
Total - worksite		70	
Other			
E. Travel to, from, or between worksites	18		(30 mph)
F. Supporting work items	1/		
G. Delays	12		
Total — other		30	
TOTAL		100	
Total work items on assigned operation (A + B + E + F)		18	

1/ 0.5 percent or less.

TABLE 100

BLADE GRAVEL SURFACES —

DISTRIBUTION OF 6 HOURS NAWT FOR HEAVY DUTY TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Blade with underbody blade	34			6.8 pass-mi 41,900 sq yd 1/
2. Reposition blade	2			
3. Maneuver to blade	1			
		37		6.4 pass-mi 39,200 sq yd 3/
B. Supporting work items:		7		
C. Delays - wait on cyclic work item		-		
D. Delays - other		2/		
Total - worksite			44	5.2 pass-mi 32,200 sq yd 3/
Other				
E. Travel to, from, or between worksites		21		(28 mph)
F. Supporting work items		5		
G. Delays		29		
H. Non-supporting work items and delays		1		
Total - other			56	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			70	

1/ Based on area bladed. Part of the roadway was covered more than one time. Based on area maintained is 2.9 lane-mi - 17,600 sq yd

2/ 0.5 percent or less.

3/ Based on area bladed. Part of the roadway was covered more than one time. Based on area maintained is:

Cyclic work item 2.7 lane-mi - 16,000 sq yd
Worksite 1.1 lane-mi - 13,100 sq yd

TABLE 102

BLADE GRAVEL SURFACES —

DISTRIBUTION OF 48 HOURS NAWT FOR MOTORGRADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Blade with underbody blade	53			3.7 pass-mi 21,000 sq yd 1/
2. Reposition blade	2			
3. Maneuver to blade	3			
		58		3.4 pass-mi 19,500 sq yd 2/
B. Supporting work items		4		
C. Delays — wait on cyclic work item		-		
D. Delays - other		1		
Total — worksite			63	2.9 pass mi 16,800 sq yd 2/
Other				
E. Travel to, from, or between worksites		19		(14 mph)
F. Supporting work items		2		
G. Delays		15		
H. Non-supporting work items and delays		1		
Total - other			37	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			83	

1/ Based on area bladed. Part of the roadway was covered more than one time. Based on area maintained is 3.3 lane-mi - 19,000 sq yd

2/ Based on area bladed. Part of the roadway was covered more than one time. Based on area maintained is:

Cyclic work item 3.1 lane-mi - 17,500 sq yd
Worksite 2.7 lane-mi - 15,100 sq yd

(e) Mudjack concrete pavements. The labor time charged to this operation accounted for 1.3 percent of TAWT in the three-county control area. Work was confined to road sections which had concrete pavements or, rarely, concrete with a bituminous overlay. It was observed that most concrete pavements developed settled areas which were not only rough riding but also hazardous to high speed traffic. These areas were usually located at bridge approach fills or fills over culverts and pipes, but some occurred at other locations. In most cases, the apparent cause of settlement was consolidation and/or displacement of subgrades and natural ground. However, inadequate design or construction was a contributing factor in some cases. Mudjacking was used to restore the riding qualities of pavements at settled areas. It was also used infrequently for certain special situations such as raising pavement at railroad crossings when track elevations were changed.

A slurry of water, silty soil and cement was normally used for mudjacking. In some cases, lime dust was also added to provide better stabilization. The proportion of cement used varied from job to job but did not exceed $1\frac{1}{2}$ sacks per cubic yard of soil and lime dust. In a few instances, cement was omitted from the mixture.

This operation was always performed by large crews. Normally there were 6 to 12 men, 4 or 5 trucks, a mudjack machine, and an air compressor or air compressor truck. When an extensive amount of work was being done in a county, crews were often split into two independent groups. One group of 2 or 3 men went ahead to drill and/or clean out holes in pavement slabs; the other group of 6 to 10 men mudjacked settled areas. The men assigned to these groups always worked by assigned tasks. Drilling and/or cleaning holes was done by one or two men using jackhammers. If they worked ahead of the main group, a third man went along to flag traffic. The main group's activities were divided as follows: two men shoveled soil, lime dust, and cement into the mudjack machine; one man operated the machine; two men handled the mud hose; one man placed stringlines, observed slab movements and plugged holes; and one or two men flagged public traffic. A definite pattern was used for pumping. First, holes were given a final cleaning and, sometimes, "primed" with water. Then each hole was pumped until

Figure 17. Drilling hole with jackhammer.

Figure 18. "Priming" hole before starting to pump mud.

pavement slabs broke loose from the subgrade. Slabs were then raised to the desired level by pumping additional mud in each hole one or more times. In some areas, the joints were so tight that slabs could not be moved by pumping. Sometimes these joints were opened up with jackhammers. On other occasions, mudjacking was abandoned and settlements were corrected with bituminous patches at a later date. If the settled areas had to be raised more than 3 or 4 inches, the work was usually carried out in stages over a period of days or weeks.

Good safety practices were always followed by mudjacking crews. Warning signs and barricades were set up at all worksites, and one or more men flagged public traffic full time, since they were working on the roadway with one lane completely blocked.

Production studies showed that mudjacking crews were almost always too large. About 20 percent of labor NAWT was lost while men were idle or waiting on other men to perform work. In most cases studied, a 5-man crew would have been adequate for actual mudjacking. Additional men would be required for drilling and/or cleaning holes, and additional truck drivers would be needed if more than 10 cubic yards of soil, lime dust, and cement were used during a day.

Figure 19. Mudjacking.

TABLE 103

MUDJACK CONCRETE PAVEMENTS —
DISTRIBUTION OF 114 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Drill or clean out hole with compressor and jackhammer	1			9 holes
2. Drill joints with compressor and jackhammer	1			35 lin ft
3. Place stringline	1			8.3 cu yd 1/
4. Mix and pump mud with mudjack machine	3			2.0 cu yd 1/
5. Position or hold hose while pumping	5			1.1 cu yd 1/
6. Move hose to new hole	1			10.5 cu yd 1/
7. Install or remove hole plugs	2/			14.5 cu yd 1/
		12		0.52 cu yd 1/
B. Supporting work items:				
1. Flag or direct public traffic	13			
2. Unload soil and cement into mudjack by hand	4			1.6 cu yd 1/
3. Other	6			
		23		
C. Delays — wait on cyclic work item		6		
D. Delays — other:				
1. Clean or wash mudjack 3/	9			
2. Other	19			
		28		
Total - worksite			69	0.09 cu yd 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		8		
F. Supporting work items		7		
G. Delays		16		
H. Non-supporting work items and delays		2/		
Total — other			31	
TOTAL			100	0.06 cu yd 1/
Total work items on assigned operation (A + B + E + F)			50	

1/ Based on dry materials mixed and pumped.
2/ 0.5 percent or less.
3/ Cleaning out clogged valves and hose or general cleaning at shutdown.

TABLE 104

MUDJACK CONCRETE PAVEMENTS —
DISTRIBUTION OF 58 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items	-	
B. Supporting work items:		
1. Unload water	10	315 gal
2. Unload soil and cement by hand	5	2.3 cu yd
3. Other	2	
	17	0.69 cu yd 1/
C. Delays — wait on cyclic work item:		
1. Wait on mix and pump mud	8	
2. Other	3	
	11	
D. Delays — other:		
1. Parked while men work	13	
2. Clean or wash mudjack 2/	8	
3. Start up or shutdown equipment	6	
4. Other	14	
	41	
Total — worksite	69	0.17 cu yd 1/
Other		
E. Travel to, from, or between worksites (including haul and return)	6	(24 mph)
F. Supporting work items:		
1. Load soil, cement, or water	5	575 gal water 30.5 cu yd soil or cement
2. Other	3	
	8	
G. Delays	17	
H. Non-supporting work items and delays	3/	
Total — other	31	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	31	

1/ Based on dry materials mixed and pumped.
2/ Cleaning out clogged valves and hose or general cleaning at shutdown.
3/ 0.5 percent or less.

TABLE 105

MUDJACK CONCRETE PAVEMENTS —
DISTRIBUTION OF 13 HOURS NAWT FOR MUDJACK MACHINES ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Mix and pump mud	23	2.20 cu yd 1/
B. Supporting work items:		
1. Start up and shutdown	9	
2. Other	3	
	12	
C. Delays — wait on cyclic work item	9	
D. Delays — other:		
1. Clean or wash 2/	9	
2. Wait on haul soil, cement, or water	5	
3. Other	16	
	30	
Total — worksite	74	0.70 cu yd 1/
Other		
E. Travel to, from, or between worksites	6	(18 mph)
F. Supporting work items	1	
G. Delays:		
1. Repair ignition	6	
2. Other	13	
	19	
Total — other	26	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	42	

1/ Based on dry materials mixed and pumped.
2/ Cleaning out clogged valves and hose or general cleanup at shutdown.

TABLE 106

MUDJACK CONCRETE PAVEMENTS—
DISTRIBUTION OF 1 HOUR NAWT FOR FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Other		
E. Travel to, from, or between worksites	38	(12 mph)
F. Supporting work items:		
1. Load soil	24	31.2 cu yd
2. Other	3	
	27	
G. Delays:		
1. Standby	32	
2. Other	3	
	35	
TOTAL	100	
Total work items on assigned operation (E + F)	65	

TABLE 107

MUDJACK CONCRETE PAVEMENTS —
DISTRIBUTION OF 13 HOURS NAWT FOR COMPRESSORS OR COMPRESSOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work item:		
1. Drill hole with jackhammer or clean out hole	6	13 holes
2. Drill joints with jackhammer	2	73 lin ft
	8	
B. Supporting work items	3	
C. Delays — wait on cyclic work item	-	
D. Delays — other:		
1. Parked while men work	62	
2. Other	3	
	65	
Total — worksite	76	
Other		
E. Travel to, from, or between worksites	5	(25 mph)
F. Supporting work items	1	
G. Delays	18	
Total — other	24	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	17	

(f) Rebuild gravel surfaces. This operation accounted for 1.1 percent of labor TAWT in the three-county control area. Many distressed areas developed on gravel surfaced roads during the spring thaw period due to weak spots or failures in subgrades. Most of these distressed areas were spot patched with aggregate to keep traffic moving. However, some gravel surfaces continued to deteriorate, and conditions became so bad that it was necessary to cover large areas with a lift of new surfacing aggregate. Time spent by State forces on this latter type of work was classified as rebuilding gravel surfaces. It should be noted that such work was normally done by contract whenever an entire road section required rebuilding.

Aggregate for this operation was obtained from either commercial quarries or State stockpiles. Most stockpiled aggregate was obtained under contract.

Crews assigned to this operation consisted of 2 to 7 men, 2 to 6 trucks, a heavy duty truck with underbody blade or a motorgrader, and, sometimes, a rubber-tired roller towed by a tractor. When aggregate was obtained from State stockpiles, the crews also utilized a front-end loader. Crew sizes and equipment complements varied considerably from day to day or even during a day. Seldom was the operation carried out as a continuous process; instead it was done over a period of days. For example, a two-man crew would haul aggregate to a deteriorated area on Monday; on Tuesday, more aggregate would be hauled by a four-man crew; on Wednesday, three men would finish hauling aggregate and two men would spread and compact all aggregate placed in the area.

Usually, material was hauled by 2 to 6 men, each equipped with a truck. The aggregate was roughly spread on the road by means of a truck spreader bed or by dumping through a chained tailgate on an end dump bed. A minor amount of hand spreading was also done by truck drivers. Spreading was completed by heavy duty trucks with underbody blades or by motorgraders after all, or almost all, aggregate needed in an area was in place. Aggregate was generally compacted by traffic, but sometimes this was done by a rubber-tired roller towed by a tractor.

Most crews engaged in this operation did not use warning signs or flagmen. Traffic volumes were light, and they moved at below normal speeds because of the poor condition of roadway surfaces.

Production studies of this operation were limited. They covered only men and trucks which hauled and roughly spread aggregate. The average haul distance was 39 miles which was longer than would normally be encountered. No studies were made on men and equipment engaged in final spreading or compaction. The studied crews lost very little time in delays. This was mostly due to the fact that each man operated independently, and there was no attempt to set up a continuous process with men loading, hauling, spreading, and compacting simultaneously. The average speed attained by studied crews during travel, haul, and return was higher than normal. This was attributable in large part to the 39-mile average haul.

Figure 20. Truck spreading aggregate.

TABLE 108

REBUILD GRAVEL SURFACES —
DISTRIBUTION OF 63 HOURS NAWT FOR MEN ASSIGNED TO HAUL AND SPREAD AGGREGATE

Location and item	Percent of NAWT	Performance (Avg per hour)
<u>Worksite</u>		
A. Cyclic work items:		
1. Spread or level aggregate by hand 1/	2/	15.0 cu yd 1/
2. Unload and spread aggregate with truck spreader bed	4	23.3 cu yd
3. Unload and spread aggregate with truck (end dump)	2/	316.0 cu yd
4. Maneuver to spread	1	
5. Move ahead to new work area	2/	
	5	26.7 cu yd 3/
B. Supporting work items	2/	
C. Delays — wait on cyclic work item	2/	
D. Delays — other	1	
Total - worksite	6	22.3 cu yd 3/
<u>Other</u>		
E. Travel to, from, or between worksites (including haul and return)	75	
F. Supporting work items	3	
G. Delays	15	
H. Non-supporting work items and delays	1	
Total — other	94	
TOTAL	100	1.4 cu yd 3/
Total work items on assigned operation (A + B + E + F)	83	

1/ Aggregate was previously spread by trucks. Based on aggregate actually spread by hand.

2/ 0.5 percent or less.

3/ Based on aggregate hauled and spread.

TABLE 109

REBUILD GRAVEL SURFACES —
DISTRIBUTION OF 63 HOURS NAWT FOR TRUCKS ASSIGNED TO HAUL AND SPREAD AGGREGATE

Location and item	Percent of NAWT	Performance (Avg per hour)
<u>Worksite</u>		
A. Cyclic work items:		
1. Unload and spread stone with spreader bed	4	23.3 cu yd
2. Unload and spread stone (end dump)	1/	316.0 cu yd
3. Maneuver to spread	1	
4. Move ahead to new work area	1/	(26 mph)
	5	27.4 cu yd 2/
B. Supporting work items	1/	
C. Delays — wait on cyclic work item	1/	
D. Delays — other	1	
Total — worksite	6	22.0 cu yd 2/
<u>Other</u>		
E. Travel to, from, or between worksites (including haul and return)	76	(42 mph)
F. Supporting work items	4	
G. Delays	14	
H. Non-supporting work items and delays	1/	
Total — other	94	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	85	

1/ 0.5 percent or less.

2/ Based on aggregate hauled and spread.

(g) Seal bituminous and concrete pavements. Labor time charged to this operation accounted for 4.0 percent of TAWT in the three-county control area. Practically all of the work was done on road sections with bituminous pavements. These pavements developed distressed areas under traffic due to weak spots or failures in bases and subgrades. Such base and subgrade failures were most frequent during spring thaw periods but occurred at other times of the year especially if the roads were carrying abnormal truck traffic. Road sections paved with bituminous surface treatments exhibited far more failures than those paved with bituminous plant mix. The distressed areas were usually spot sealed if the pavement had cracked but not disintegrated. This prevented water from entering bases and subgrades and bound together broken pavement so that it would not be displaced by traffic. Such sealing was a temporary expedient in many cases as some areas were covered repeatedly.

Some bituminous and concrete pavements were also sealed to correct gradual deterioration caused by aging. The areas so treated were usually much larger than those covered while alleviating spot cracking. In rare cases, large pavement areas were sealed to correct slick conditions hazardous to traffic. When an entire road section required sealing, the work was usually contracted.

Aggregate used for sealing work was obtained directly from commercial quarries or from State stockpiles. The stockpiled aggregate was often obtained under contract. MC-3 or MC-4 asphalt was obtained from storage tanks located near most garages.

This operation was usually performed by crews consisting of 4 to 10 men, 2 to 5 trucks, 1 or 2 towed distributors, a rubber-tired or steel wheel roller pulled by truck or tractor, and, if aggregate was obtained from State stockpiles, a front-end loader. Occasionally, the crews also utilized a roll spreader and/or a broom. The composition of individual crews varied considerably depending on the size of the job, haul distances, equipment available, and personal preference of foremen.

Usually crews worked by assigned tasks. One man drove a truck towing a trailer-mounted distributor, one man operated the distributor, 1 to 4 men operated trucks hauling and spreading aggregate, one man operated a truck or tractor towing a roller, and one man flagged public traffic. Normally, work was confined to one or two areas at a time in order to minimize interference to traffic. At each area, the first step was for the distributor operator to inspect the pavement and decide on limits for sealing. The distributor was then moved into position and a pass made to spray MC-3 or MC-4 asphalt at the rate of 0.15 to 0.50 gallon per square yard. In most cases, trucks with spreader beds backed over areas several times spreading 18 to 61 pounds of aggregate per square yard. In a few cases, trucks with end dump beds were used and aggregate was spread through a chained tailgate or with a roll-type spreader. Spots missed by trucks were covered by hand spreading. Sometimes, towed drag or power brooms were used on the same day or on following days to redistribute the aggregate. Rolling was done by truck wheels, towed rubber-tired rollers, towed steel wheel rollers or, rarely, by a self-propelled steel wheel roller.

Crews working on this operation usually observed good safety practices. Warning signs were almost always erected at the limits of the worksite and a full time flagman was quite common.

Studies indicated that most crews assigned to sealing did not have the proper balance between men and equipment. Often there were not enough distributors or trucks to keep work progressing steadily and much time was lost waiting on hauling asphalt or aggregate. Further, the organization of crews and the work sequences followed resulted in men losing considerable time waiting on other men working. Another major source of delays was waiting on heating asphalt. A one-day planned operation supervised by study personnel indicated that it would be possible to substantially increase production for all but the smallest jobs by (1) advance heating of asphalt, (2) balancing men and equipment, (3) laying out work areas ahead of time, and (4) establishing a work sequence which coordinates the activities of each man on the crew.

Figure 21. Distributor spraying asphalt.

Figure 22. Truck with spreader bed applying aggregate.

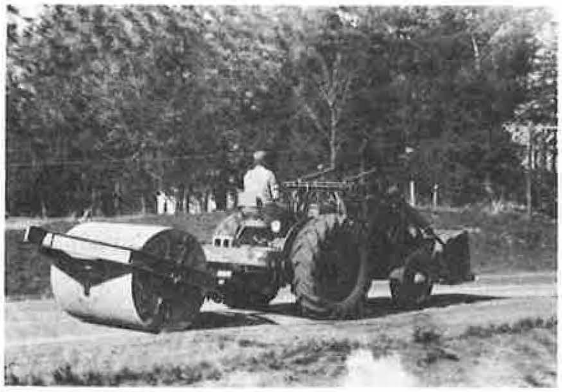


Figure 23. Tractor and steel wheel roller rolling sealed area.

TABLE 110

SEAL BITUMINOUS AND CONCRETE PAVEMENTS —
DISTRIBUTION OF 502 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spray asphalt with distributor	1	1,170 gal 3,900 sq yd
2. Unload or spread aggregate by hand	3	0.47 cu yd 125 sq yd
3. Unload and spread aggregate with truck spreader bed	3	11.4 cu yd 1,090 sq yd
4. Unload and spread aggregate with truck and roll spreader	1	12.1 cu yd 1,280 sq yd
5. Broom aggregate onto sealed areas with truck and power or drag broom	1	2,480 sq yd 1/
6. Roll sealed areas with truck wheels, tractor, or roller	3	1,100 sq yd 1/
7. Maneuver to spray, spread, or roll	1	
8. Move ahead to new work area	6	
	19	248 sq yd 2/
B. Supporting work items	9	
C. Delays — wait on cyclic work item:		
1. Wait on spread aggregate	6	
2. Other	2	
	8	
D. Delays — other:		
1. Wait on haul asphalt or aggregate	4	
2. Wait on heat asphalt 3/	3	
3. Other	9	
	16	
Total — worksite	52	91 sq yd 2/
Other		
E. Travel to, from, or between worksites (including haul and return)	19	
F. Supporting work items	7	
G. Delays:		
1. Wait on heat asphalt 3/	7	
2. Other	15	
	22	
H. Non-supporting work items and delays	4/	
Total — other	48	
TOTAL	100	47 sq yd 2/
Total work items on assigned operation (A + B + E + F)	54	

1/ Not all of the area sealed was broomed or rolled. Based on one pass over area actually covered. 2/ Based on area sealed. 3/ Total delay time for this cause was 10 percent. 4/ 0.5 percent or less.

TABLE 111

SEAL BITUMINOUS AND CONCRETE PAVEMENTS —
DISTRIBUTION OF 435 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spray asphalt with distributor	1	2,300 gal 7,560 sq yd
2. Unload and spread aggregate with spreader bed	5	12.3 cu yd 1,180 sq yd
3. Unload and spread aggregate with roll spreader	1/	35.0 cu yd 3,670 sq yd
4. Broom aggregate onto sealed area with power or drag broom	1	3,700 sq yd 2/
5. Roll sealed area	2	2,110 sq yd 2/
6. Maneuver to spray, spread, or roll	2	
7. Move ahead to new work area	6	(10 mph)
	17	455 sq yd 3/
B. Supporting work items	4	
C. Delays — wait on cyclic work item:		
1. Wait on spread aggregate	6	
2. Other	3	
	9	
D. Delays — other:		
1. Parked while men work	6	
2. Wait on haul asphalt or aggregate	3	
3. Wait on heat asphalt	3	
4. Other	7	
	19	
Total — worksite	49	168 sq yd 3/
Other		
E. Travel to, from, or between worksites (including haul and return)	22	(33 mph)
F. Supporting work items	6	
G. Delays:		
1. Wait on heat asphalt	6	
2. Other	17	
	23	
H. Non-supporting work items and delays	1/	
Total — other	51	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	49	

1/ 0.5 percent or less.
2/ Not all of the area sealed was broomed or rolled. Based on one pass over area actually covered.
3/ Based on area sealed.

TABLE 112

SEAL BITUMINOUS AND CONCRETE PAVEMENTS —
DISTRIBUTION OF 8 HOURS NAWT FOR ROLL SPREADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spread aggregate	16	35.0 cu yd 1/ 3,670 sq yd
2. Maneuver to spread	3	
3. Move ahead to new work area	6	(7 mph)
	25	23.0 cu yd 2,410 sq yd 1/
B. Supporting work items	4	
C. Delays — wait on cyclic work items	4	
D. Delays — other:		
1. Wait on haul asphalt or aggregate	15	
2. Wait on men and other equipment units engaged in preparations, shutdown or travel	10	
3. Wait on heat asphalt	3	
4. Other	9	
	37	
Total — worksite	70	8.2 cu yd 860 sq yd 1/
Other		
E. Travel to, from, or between worksites	8	(23 mph)
F. Supporting work items	3	
G. Delays:		
1. Repair equipment	11	
2. Other	8	
	19	
Total — other	30	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	40	

1/ Based on aggregate actually spread.

TABLE 113

SEAL BITUMINOUS AND CONCRETE PAVEMENTS — DISTRIBUTION OF 27 HOURS NAWT FOR TRACTORS AND FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Roll sealed area	12			740 sq yd 1/
2. Maneuver to roll	1			
3. Move ahead to new work area	4			(6 mph)
		17		530 sq yd 1/
B. Supporting work items		1		
C. Delays — wait on cyclic work item:				
1. Wait on spread aggregate	9			
2. Other	1			
		10		
D. Delays — other:				
1. Wait on haul asphalt or aggregate	4			
2. Other	4			
		8		
Total — worksite			36	255 sq yd 1/
Other				
E. Travel to, from, or between worksites		9		(16 mph)
F. Supporting work items:				
1. Load aggregate	19			36.0 cu yd
2. Other	11			
		30		
G. Delays:				
1. Wait on heat asphalt	6			
2. Standby	6			
3. Other	11			
		23		
H. Non-supporting work items and delays		2		
Total — other			64	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			57	

1/ Not all of the area sealed was rolled. Based on one pass over area actually covered.

TABLE 114

SEAL BITUMINOUS AND CONCRETE PAVEMENTS — DISTRIBUTION OF 108 HOURS NAWT FOR DISTRIBUTORS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Spray asphalt	3			2,300 gal 7,560 sq yd
2. Maneuver to spray	1			
3. Move ahead to new work area	6			(12 mph)
		10		660 gal 2,210 sq yd 1/
B. Supporting work items:				
1. Heat asphalt	5			
2. Other	2			
		7		
C. Delays — wait on cyclic work items:				
1. Wait on spread aggregate	11			
2. Other	2/			
		11		
D. Delays — other:				
1. Wait on haul asphalt or aggregate	5			
2. Other	10			
		15		
Total — worksite			43	156 gal 520 sq yd 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		13		(34 mph)
F. Supporting work items:				
1. Heat asphalt	19			
2. Load asphalt	6			
3. Other	4			
		29		
G. Delays:				
1. Standby	5			
2. Other	10			
		15		
H. Nonsupporting work items and delays		-		
Total - other			57	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			59	

1/ Based on area sealed and asphalt sprayed.
2/ 0.5 percent or less.

TABLE 115

SEAL BITUMINOUS AND CONCRETE PAVEMENTS — DISTRIBUTION OF 50 HOURS NAWT FOR ROLLERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Roll sealed area	24			1,400 sq yd 1/
2. Maneuver to roll	6			
3. Move ahead to new work area	10			(8 mph)
		40		845 sq yd
B. Supporting work items		3		
C. Delays — wait on cyclic work item:				
1. Wait on spread aggregate	11			
2. Other	1			
		12		
D. Delays — other:				
1. Wait on haul asphalt or aggregate	6			
2. Wait on heat asphalt	3			
3. Other	10			
		19		
Total — worksite			74	460 sq yd 1/
Other				
E. Travel to, from, or between worksites		10		(18 mph)
F. Supporting work items		2		
G. Delays		13		
H. Non-supporting work items and delays		1		
Total — other			26	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			55	

1/ Not all of the area sealed was rolled. Based on one pass over area actually covered.

TABLE 116

SEAL BITUMINOUS AND CONCRETE PAVEMENTS — DISTRIBUTION OF 6 HOURS NAWT FOR DRAG AND POWER BROOMS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Broom aggregate onto sealed area	26			3,690 sq yd 1/
2. Move ahead to new work area	1			(36 mph)
		27		3,510 sq yd 1/
B. Supporting work items		13		
C. Delays — wait on cyclic work item		-		
D. Delays — other		2		
Total — worksite			42	2,270 sq yd 1/
Other				
E. Travel to, from, or between worksites		22		(36 mph)
F. Supporting work items		5		
G. Delays:				
1. Standby	15			
2. Service (fuel, oil, grease, etc.)	6			
3. Other	10			
		31		
Total — other			58	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			67	

1/ Not all of the area sealed was broomed. Based on one pass over area actually covered.

(h) Resurface with bituminous mixes. Labor time expended on this operation amounted to 1.8 percent of TAWT in the three-county control area. This type of work was occasionally performed on road sections with concrete pavement, but the bulk of it was done on sections with bituminous pavement. These pavements developed distressed areas due to weak spots or failures in bases and subgrades during spring thaw periods. Most distressed areas were patched one or more times with bituminous cold mix or aggregate to keep traffic moving. However, some pavements continued to deteriorate until it became necessary to overlay or replace large areas with bituminous cold or hot mix. Time spent by State forces on this latter type of work was classified as resurfacing.

Bituminous cold mix used for this operation was a mixture of aggregate and MC-3 or MC-4 asphalt. Sometimes it was obtained directly from commercial plants; sometimes it was stockpiled at garages under contract, and at other times it was prepared by maintenance forces. Bituminous hot mix was a mixture of selected aggregates and asphalt cement. It was almost always obtained directly from commercial plants.

Crews assigned to this operation varied considerably in size. Generally, small jobs were handled by 4 men, 2 or 3 trucks, a motorgrader, a distributor, and a towed steel-wheel roller. Larger jobs were done by crews consisting of 8 to 11 men, 5 to 7 trucks, 1 or 2 motorgraders, a distributor, and a steel-wheel roller towed by a tractor. Crews also utilized a front-end loader when hauling cold mix from State stockpiles. In a few cases, a towed power broom was used to remove dirt and debris.

Normally, old pavement and debris were removed from the area to be resurfaced by hand or with a motorgrader. A tack coat of MC-3 or MC-4 asphalt was applied by a distributor. Then, bituminous cold or hot mix was hauled and dumped in place by trucks, spread and leveled by a motorgrader, and compacted by motorgrader wheels and/or a towed roller. In a few counties, crews sealed the resurfaced area as an integral part of this operation. It was done in a manner similar to that previously described for the operation seal bituminous and concrete pavements. In most counties, sealing was performed at a later date and was considered to be a separate operation. Crews normally worked by assigned tasks. On small crews, one man drove a truck pulling a distributor, one man operated the distributor, one man operated a motorgrader and towed roller, and one man hauled bituminous cold or hot mix. On large crews, one man drove a truck pulling a distributor, one man operated the distributor, one or two men operated motorgraders, one man operated a tractor pulling a roller, 3 to 5 men hauled bituminous cold or hot mix, and one man flagged traffic.

Most of the crews followed good safety practices while engaged in this operation. Warning signs were placed at all worksites. On small crews, men took turns flagging public traffic during work breaks; on large crews, there was usually a full time flagman throughout the day.

Production studies of this operation were not very extensive. One small crew and one large crew were studied while resurfacing with bituminous cold mix. The large crew sealed resurfaced areas as an integral part of their operation. As previously noted, such sealing was not done by all resurfacing crews. The studied crews and other crews observed during the study period almost always lost a high proportion of their time due to delays regardless of whether or not sealing was done. Small crews needed more trucks to match hauling capacity to the capacity of distributors, motorgraders and rollers. Large crews needed more supervision, better organization, and improved work methods to minimize delays.

TABLE 117

RESURFACE WITH BITUMINOUS MIXES –
DISTRIBUTION OF 124 HOURS NAWT FOR MEN RESURFACING WITH COLD MIX

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Remove old pavement and debris by hand or with motorgrader	1			
2. Spray asphalt for prime or seal with distributor	1			1,425 gal 6,100 sq yd
3. Unload, spread or level cold mix by hand	5			10.8 cu yd 795 sq yd 1/
4. Spread or level cold mix with motorgrader	2			24.4 cu yd 1,790 sq yd 1/
5. Roll cold mix or seal with motorgrader wheels or roller	2			2,600 sq yd 2/
6. Broom cold mix with truck and power broom	1			2,360 sq yd 2/
7. Spread aggregate for seal by hand	3/			
8. Unload and spread aggregate for seal with truck spreader bed	1			32.6 cu yd 2,620 sq yd
9. Reposition motorgrader blade	1			
10. Maneuver to spray, spread, roll or broom	3			
11. Move ahead to new work area	2			
		19		3.2 cu yd 238 sq yd 4/
B. Supporting work items:				
1. Flag and direct public traffic	7			
2. Other	9			
		16		
C. Delays – wait on cyclic work item:				
1. Wait on unload, spread or level cold mix	7			
2. Other	4			
		11		
D. Delays — other:				
1. Wait on haul asphalt, cold mix, or aggregate	5			
2. Other	11			
		16		
Total – worksite			62	0.8 cu yd 61 sq yd 4/
Other				
E. Travel to, from, or between worksites (including haul and return)		19		
F. Supporting work items		8		
G. Delays		11		
H. Nonsupporting work items and delays		3/		
Total — other			38	
TOTAL			100	0.5 cu yd 38 sq yd 4/
Total work items on assigned operation (A+B+E+F)			62	

1/ Most of the bituminous cold mix was spread and leveled both by hand and by motorgrader. Based on bituminous cold mix placed. 2/ Not all of the area resurfaced was broomed or rolled. Based on one pass over area actually covered. 3/ 0.5 percent or less. 4/ Based on bituminous cold mix placed.

TABLE 118

RESURFACE WITH BITUMINOUS MIXES –
DISTRIBUTION OF 67 HOURS NAWT FOR TRUCKS ASSIGNED TO
RESURFACING WITH COLD MIX

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Spray asphalt for prime or seal with distributor	1			2,880 gal 12,350 sq yd
2. Roll bituminous cold mix or seal with roller	3			3,540 sq yd 1/
3. Broom bituminous cold mix with power broom	1			4,720 sq yd 1/
4. Unload and spread aggregate for seal with spreader bed	1			56.8 cu yd 4,560 sq yd
5. Maneuver to spray, spread, roll, or broom	3			
6. Move ahead to new work area	2			(28 mph)
		11		9.0 cu yd 650 sq yd 2/
B. Supporting work items		7		
C. Delays – wait on cyclic work item:				
1. Wait on spread or level bituminous cold mix	18			
2. Wait on spread aggregate for seal	5			
3. Other	2			
		25		
D. Delays —other:				
1. Wait on haul asphalt, bituminous cold mix or aggregate	7			
2. Wait on heat bituminous material	4			
3. Other	6			
		17		
Total — worksite			60	1.6 cu yd 115 sq yd 2/
Other				
E. Travel to, from, or between worksites (including haul and return)		21		(31 mph)
F. Supporting work items:				
1. Load bituminous cold mix or aggregate	5			
2. Other	4			
		9		
G. Delays		10		
H. Non-supporting work items and delays		3/		
Total – other			40	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			48	

1/ Not all of the area resurfaced was broomed or rolled. Based on one pass over area actually covered.
2/ Based on bituminous cold mix placed. 3/ 0.5 percent or less.

TABLE 119

RESURFACE WITH BITUMINOUS MIXES –
DISTRIBUTION OF 7 HOURS NAWT FOR TRANSPORTATION PICKUPS ASSIGNED TO
RESURFACING WITH COLD MIX

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Move ahead to new work area		2		(23 mph)
B. Supporting work items		2		
C. Delays – wait on cyclic work item		-		
D. Delays – other:				
1. Parked while men work	65			
2. Other	1/			
		65		
Total – worksite			69	
Other				
E. Travel to, from, or between worksites		11		(40 mph)
F. Supporting work items		3		
G. Delays:				
1. Standby	10			
2. Other	7			
		17		
Total – other			31	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			18	

1/ 0.5 percent or less.

TABLE 120

RESURFACE WITH BITUMINOUS MIXES –
DISTRIBUTION OF 21 HOURS NAWT FOR TRACTORS AND FRONT-END LOADERS
ASSIGNED TO RESURFACING WITH COLD MIX

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Roll bituminous cold mix and seal with roller	3			2,980 sq yd 1/
2. Maneuver to roll	1			
3. Move ahead to new work area	1			(9 mph)
		5		1,470 sq yd 1/
B. Supporting work items		2/		
C. Delays – wait on cyclic work items:				
1. Wait on spread or level cold mix	10			
2. Other	3			
		13		
D. Delays – other		11		
Total – worksite			29	260 sq yd 1/
Other				
E. Travel to, from, or between worksites		1		(5 mph)
F. Supporting work items:				
1. Load cold mix or aggregate	17			31.1 cu yd
2. Other	2			
		19		
G. Delays:				
1. Standby	30			
2. Wait on men and other equipment units engaged in preparations, shutdown, or travel	17			
3. Other	4			
		51		
Total – other			71	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			25	

1/ Not all of the area resurfaced was rolled. Based on one pass over area actually covered.
2/ 0.5 percent or less.

TABLE 121
RESURFACE WITH BITUMINOUS MIXES —
DISTRIBUTION OF 23 HOURS NAWT FOR MOTORGRADERS ASSIGNED TO
RESURFACING WITH COLD MIX

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Blade old pavement and debris from roadway	1	2,400 sq yd 1/
2. Spread or level bituminous cold mix	12	24.4 cu yd 1,790 sq yd 2/
3. Roll bituminous cold mix with wheels	1	1,200 sq yd 3/
4. Reposition blade	2	
5. Maneuver to blade or spread	5	
6. Move ahead to new work area	2	(8 mph)
	23	11.6 cu yd 850 sq yd 4/
B. Supporting work items:		
1. Maneuver	8	
2. Other	1	
	9	
C. Delays — wait on cyclic work item	9	
D. Delays — other:		
1. Wait on haul asphalt, bituminous cold mix, or aggregate	15	
2. Instructions	4	
3. Other	11	
	30	
Total — worksite	71	4.0 cu yd 295 sq yd 4/
Other		
E. Travel to, from, or between worksites	7	(11 mph)
F. Supporting work items	7	
G. Delays:		
1. Wait on men and other equipment units engaged in preparations, shutdown, or travel	13	
2. Other	2	
	15	
Total — other	29	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	46	

1/ Not all of the area resurfaced was bladed. Based on one pass over area actually covered.

2/ Partially spread and leveled by hand. 3/ Not all of the area resurfaced was rolled. Based on one pass over area actually covered.

4/ Based on bituminous cold mix spread and leveled.

TABLE 123
RESURFACE WITH BITUMINOUS MIXES —
DISTRIBUTION OF 3 HOURS NAWT FOR POWER BROOMS ASSIGNED TO
RESURFACING WITH COLD MIX

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Broom bituminous cold mix	24	4,730 sq yd 1/
2. Maneuver to broom	2	
3. Move ahead to new work area	1	(27 mph)
	27	4,270 sq yd 1/
B. Supporting work items	12	
C. Delays — wait on cyclic work item:		
1. Wait on spread or level bituminous cold mix	12	
D. Delays — other	2	
Total — worksite	53	2,150 sq yd 1/
Other		
E. Travel to, from, or between worksites	25	(21 mph)
F. Supporting work items	2	
G. Delays	20	
Total — other	47	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	66	

1/ Not all of the area resurfaced was broomed. Based on one pass over area actually covered.

TABLE 122
RESURFACE WITH BITUMINOUS MIXES —
DISTRIBUTION OF 29 HOURS NAWT FOR DISTRIBUTORS ASSIGNED TO
RESURFACING WITH COLD MIX

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spray asphalt for prime or seal	3	2,880 gal 12,350 sq yd 1/
2. Maneuver to spray	3	
3. Move ahead to new work area	1	(17 mph)
	7	925 gal 3,950 sq yd 1/
B. Supporting work items:		
1. Heat asphalt	11	
2. Other	3	
	14	
C. Delays — wait on cyclic work item:		
1. Wait on spread or level bituminous cold mix	20	
2. Other	9	
	29	
D. Delays — other:		
1. Wait on haul bituminous cold mix or aggregate	15	
2. Other	6	
	21	
Total — worksite	71	96 gal 410 sq yd 1/
Other		
E. Travel to, from, or between worksites (including haul and return)	8	(28 mph)
F. Supporting work items:		
1. Heat asphalt	7	
2. Other	4	
	11	
G. Delays	10	
Total — other	29	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	40	

1/ Based on area resurfaced and asphalt sprayed.

TABLE 124
RESURFACE WITH BITUMINOUS MIXES —
DISTRIBUTION OF 16 HOURS NAWT FOR ROLLERS ASSIGNED TO
RESURFACING WITH COLD MIX

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Roll bituminous cold mix and seal	14	3,430 sq yd 1/
2. Maneuver	3	
3. Move ahead to new work area	3	(10 mph)
	20	2,400 sq yd 1/
B. Supporting work items	1	
C. Delays — wait on cyclic work item:		
1. Wait on spread aggregate	16	
2. Wait on spread or level bituminous cold mix	10	
3. Other	7	
	33	
D. Delays — other:		
1. Wait on men and other equipment units engaged in preparations, shutdown, or travel	14	
2. Wait on haul asphalt bituminous cold mix or aggregate	12	
3. Other	7	
	33	
Total — worksite	87	540 sq yd 1/
Other		
E. Travel to, from, or between worksites	2	(6 mph)
G. Delays:		
1. Wait on men and other equipment units engaged in preparations, shutdown, or travel	11	
2. Other	2/	
	11	
Total — other	13	
TOTAL	100	
Total work items on assigned operation (A + B + E)	23	

1/ Not all of the area resurfaced was rolled. Based on one pass over area actually covered.

2/ 0.5 percent or less.

(i) Patch shoulders and approaches with aggregate. This operation accounted for 1.7 percent of labor TAWT in the control area. Almost all of the work was done on road sections which had concrete or bituminous pavements. These sections developed distressed areas on shoulders and approaches due to settlement, erosion or traffic action. The most common type was a depression or "edgerut" immediately adjacent to the pavement that was hazardous to traffic. Most other distressed areas generally consisted of ruts or potholes at mailbox turnouts, road intersections, residential driveways and commercial entrances. Many edgeruts and practically all of the other distressed areas were patched with aggregate.

There were certain limitations on the maintenance of approaches, residential driveways, and field entrances. State policy did not permit work to be done beyond the curb line in urban areas, beyond the right-of-way line in rural areas, or, where rural rights-of-way were wide, beyond 60 feet from the roadway centerline. In addition, commercial entrances were not maintained beyond the shoulder line or for more than a nominal width.

The type of aggregate varied from county to county but was usually a crushed limestone. Part was obtained directly from commercial quarries; the remainder from State stockpiles which had been obtained under contract.

Crews assigned to this operation varied considerably in size. They ranged from 2 to 8 men, and 1 to 5 trucks. Large crews usually had a drag spreader or motorgrader. If aggregate was obtained from a State stockpile, the crews also utilized a front-end loader. It was observed that most shoulder and approach patching was done by two-man crews equipped with one truck. They hauled aggregate from quarries or stockpiles to the worksite, unloaded and spread it with a truck spreader bed or chained tailgate on an end dump bed, completed spreading by hand and rolled the aggregate with truck wheels. Large crews almost always utilized some type of spreading equipment. A drag spreader towed by trucks was common on edgerutting while a motorgrader was used when repairing approaches, driveways or entrances. One man was always assigned to operate the drag spreader or motorgrader. Rarely was any type of roller used for either shoulder or approach patching.

Figure 24. Spreading aggregate in edgerut by hand.

Figure 25. Spreading aggregate in edgerut with drag.

There was considerable variation in the safety practices by crews. Small crews did very little flagging of public traffic and rarely used warning signs. Large crews usually did more flagging and used warning signs. Sometimes, there was a flagman throughout the day.

A number of production studies were made on this operation. Study data have been grouped according to whether crews were patching edgeruts or other types of distressed areas. Crews engaged in this operation spent a relatively small proportion of their time hauling and placing aggregate. Since crews always included more men than trucks, men other than drivers were productive only while aggregate was being put in place. Study data indicate that many small jobs could best be handled by a one-man crew, especially where work is being done on turnouts or approaches. Larger jobs, usually edgerutting, could best be done by crews larger than those commonly used at the present time with a proper balance between hauling and spreading capacity. In many cases, full time supervision should be provided for these large crews.

Figure 26. Spreading aggregate at approach by hand.

TABLE 125
PATCH SHOULDERS AND APPROACHES WITH AGGREGATE —
DISTRIBUTION OF 89 HOURS NAWT FOR MEN ASSIGNED TO PATCH EDGERUTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spread or level aggregate by hand 1/	4	7.6 cu yd 2/
2. Unload and spread aggregate with drag spreader	6	21.3 cu yd
3. Unload and spread aggregate with truck spreader bed	3	32.1 cu yd
4. Roll aggregate with truck wheels	1	128.8 cu yd 3/
5. Reposition drag spreader	4/	
6. Maneuver to spread	4/	
7. Walk ahead to new work area	1	
8. Move ahead to new work area	1	
	16	13.7 cu yd 5/
B. Supporting work items	5	
C. Delays — wait on cyclic work item	2	
D. Delays -- other:		
1. Wait on haul aggregate	19	
2. Other	3	
	22	
Total — worksite	45	4.8 cu yd 5/
Other		
E. Travel to, from, or between worksites (including haul and return)	38	
F. Supporting work items	3	
G. Delays:		
1. Wait on load men, tools, or aggregate	5	
2. Other	9	
	14	
H. Nonsupporting work items and delays	4/	
Total — other	55	
TOTAL	100	2.2 cu yd 5/
Total work items on assigned operation (A + B + E + F)	62	

1/ Includes time for hand spreading aggregate dumped in pile or previously spread by truck or drag. 2/ Based on aggregate spread by hand.
3/ Not all of the area patched was rolled. Based on one pass over area actually covered. 4/ 0.5 percent or less. 5/ Based on aggregate placed.

TABLE 126
PATCH SHOULDERS AND APPROACHES WITH AGGREGATE —
DISTRIBUTION OF 47 HOURS NAWT FOR TRUCKS ASSIGNED TO PATCH EDGERUTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Unload and spread aggregate with drag	6	39.2 cu yd
2. Unload and spread aggregate with spreader bed	6	29.7 cu yd
3. Roll aggregate with wheels	2	157.8 cu yd 1/
4. Maneuver to spread	1	
5. Move ahead to new work area	2	(11 mph)
	17	23.9 cu yd 2/
B. Supporting work items	3	
C. Delays - wait on cyclic work item	3	
D. Delays — other	3	
Total - worksite	26	19.9 cu yd 2/
Other		
E. Travel to, from, or between worksites (including haul and return)	54	(33 mph)
F. Supporting work items:		
1. Load aggregate	5	91.7 cu yd
2. Other	4	
	9	
G. Delays	11	
H. Non-supporting work items and delays	3/	
Total — other	74	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	83	

1/ Not all of the area patched was rolled. Based on one pass over area actually covered.
2/ Based on aggregate placed.
3/ 0.5 percent or less.

TABLE 127

PATCH SHOULDERS AND APPROACHES WITH AGGREGATE - DISTRIBUTION OF 231 HOURS NAWT FOR MEN ASSIGNED TO PATCH OTHER TYPES OF DISTRESSED AREAS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spread or level aggregate by hand 1/	6	3.1 cu yd 2/
2. Unload and spread aggregate with truck spreader bed	3	13.3 cu yd
3. Spread aggregate with motorgrader	1	45.3 cu yd
4. Roll aggregate with truck wheels	3/	45.0 cu yd 4/
5. Maneuver to spread	1	
6. Move ahead to new work area	2	
	13	12.0 cu yd 5/
B. Supporting work items	7	
C. Delays — wait on cyclic work item	1	
D. Delays — other	7	
Total - worksite	28	5.4 cu yd 5/
Other		
E. Travel to, from, or between worksites (including haul and return)	43	
F. Supporting work items	9	
G. Delays:		
1. Wait on load men, tools, or aggregate	5	
2. Other	15	
	20	
H. Non-supporting work items and delays	3/	
Total — other	72	
TOTAL	100	1.5 cu yd 5/
Total work items on assigned operation (A + B + E + F)	72	

1/ Includes time for hand spreading aggregate dumped in pile or previously spread by truck or drag.
2/ Based on aggregate spread by hand.
3/ 0.5 percent or less.
4/ Not all of the area patched was rolled. Based on one pass over area actually covered.
5/ Based on aggregate placed.

TABLE 128

PATCH SHOULDERS AND APPROACHES WITH AGGREGATE - DISTRIBUTION OF 147 HOURS NAWT FOR TRUCKS ASSIGNED TO PATCH OTHER TYPES OF DISTRESSED AREAS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Unload and spread aggregate with spreader bed	4	13.3 cu yd
2. Roll aggregate with wheels	1	32.7 cu yd 1/
3. Maneuver to spread	1	
4. Move ahead to new work area	1	(26 mph)
	7	7.5 cu yd 2/
B. Supporting work items	6	
C. Delays - wait on cyclic work item	4	
D. Delays - other:		
1. Parked while men work	5	
2. Other	4	
	9	
Total — worksite	26	17.6 cu yd 2/
Other		
E. Travel to, from, or between worksites (including haul and return	41	(35 mph)
F. Supporting work items:		
1. Load aggregate	6	41.7 cu yd
2. Other	3	
	9	
G. Delays:		
1. Wait on load men, tools, or materials	5	
2. Parked while men work	4	
3. Other	15	
	24	
H. Non-supporting work items and delays	3/	
Total - other	74	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	63	

1/ Not all of the area patched was rolled. Based on one pass over area actually covered.
2/ Based on aggregate placed.
3/ 0.5 percent or less.

TABLE 129

PATCH SHOULDERS AND APPROACHES WITH AGGREGATE - DISTRIBUTION OF 8 HOURS NAWT FOR MOTORGRADERS ASSIGNED TO PATCH OTHER TYPES OF DISTRESSED AREAS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Spread aggregate	27	47.0 cu yd 1/
2. Maneuver to spread	19	
3. Move ahead to new work area	5	(14 mph)
	51	24.5 cu yd 1/
B. Supporting work items	9	
C. Delays - wait on cyclic work item	-	
D. Delays - other:		
1. Wait on haul aggregate	6	
2. Other	10	
	16	
Total — worksite	76	16.6 cu yd 1/
Other		
E. Travel to, from, or between worksites	15	(17 mph)
F. Supporting work items	5	
G. Delays	4	
Total - other	24	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	80	

1/ Not all of the aggregate was spread by motorgraders. Based on aggregate actually spread.

TABLE 130

PATCH SHOULDERS AND APPROACHES WITH AGGREGATE - DISTRIBUTION OF 22 HOURS NAWT FOR FRONT-END LOADERS ASSIGNED TO PATCH OTHER TYPES OF DISTRESSED AREAS

Location and item	Percent of NAWT	Performance (Avg per hour)
Other		
E. Travel to, from, or between worksites	4	(13 mph)
F. Supporting work items:		
1. Load aggregate	28	43.1 cu yd
2. Other	10	
	38	
G. Delays:		
1. Standby	37	
2. Wait on men and other equipment units engaged in preparation shutdown or travel	6	
3. Other	15	
	58	
TOTAL	100	
Total work items on assigned operation (E + F)	42	

(j) Patch shoulders and approaches with bituminous cold mix. Labor time charged to this operation amounted to 1.4 percent of TAWT in the three-county control area. Work was confined to those road sections which had concrete or bituminous pavements. These sections developed distressed areas on shoulders, approaches, driveways and entrances due to settlement, erosion and traffic action. As indicated for the previous operation, the most common type of distressed area was a depression or edgerut immediately adjacent to the pavement. Other distressed areas usually consisted of potholes or ruts at mailbox turnouts, road intersection, residential driveways and commercial entrances. Most of these areas were patched with aggregate. However, bituminous cold mix was frequently used for patching edgeruts, particularly when aggregate did not hold. Cold mix was also used for a minor amount of patching on bituminous surfaced approaches, driveways and entrances. Policy limitations described for the previous operation also applied to this operation.

The bituminous cold mix used for shoulder and approach patching was a mixture of aggregate and MC-3 or MC-4 asphalt. Sometimes it was obtained directly from commercial plants; sometimes it was stockpiled at garages under contracts; and at other times it was prepared by State forces using locally available aggregate. It was observed that these cold mixes were not stockpiled any great length of time since they tended to harden in the pile.

This operation was normally carried out by small crews consisting of 1 to 3 men and one truck. They also utilized a front-end loader when cold mix was obtained from State stockpiles. At worksites, the crews first removed debris from the area to be patched. Bituminous cold mix was then shoveled into place and spread by hand. Occasionally a truck spreader bed was used to unload the cold mix in piles which were then spread by hand. Patches were usually tamped by hand or rolled with truck wheels. Only rarely were areas primed before placing the cold mix.

Safety practices of crews varied considerably. Some put out warning signs. Others did not. Men spent very little time flagging public traffic.

During production studies of this operation the crews encountered were only patching edgeruts. Study data indicate that these crews lost a considerable amount of time due to delays and to men, other than the truck driver, riding while cold mix was hauled from plants or stockpiles to worksites. Unless a man is required for flagging, it would appear that most of this work should be done by a crew of one man and one truck for maximum efficiency.

Figure 27. Spreading cold mix in edgerut by hand.

TABLE 131

PATCH SHOULDERS AND APPROACHES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 51 HOURS NAWT FOR MEN ASSIGNED TO PATCH EDGERUTS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Remove debris from rut by hand	1			
2. Unload or spread bituminous cold mix by hand	26			2.0 cu yd
3. Tamp bituminous cold mix by hand	1/			11.5 cu yd 2/
4. Roll bituminous cold mix with truck wheels	5			8.4 cu yd 2/
5. Walk ahead to new work area	1			
6. Move ahead to new work area	6			
		39		1.3 cu yd 3/
B. Supporting work items:		5		
C. Delays - wait on cyclic work item		4		
D. Delays - other		7		
Total — worksite			55	0.9 cu yd 3/
Other				
E. Travel to, from, or between worksites		21		
F. Supporting work items		7		
G. Delays		17		
H. Non-supporting work items and delays		1/		
Total — other			45	
TOTAL			100	0.5 cu yd 3/
Total work items on assigned operation (A + B + E + F)			72	

1/ 0.5 percent or less.
2/ Only part of the area patched was tamped or rolled. Based on bituminous cold mix actually covered.
3/ Based on bituminous cold mix placed.

TABLE 132

PATCH SHOULDERS AND APPROACHES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 24 HOURS NAWT FOR TRUCKS ASSIGNED TO PATCH EDGERUTS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Roll bituminous cold mix with wheels	10			8.4 cu yd
2. Move ahead to new work area	9			(5 mph)
		19		
B. Supporting work items:				
1. Unload bituminous cold mix by hand	23			4.8 cu yd
2. Other	4			
		27		
C. Delays – wait on cyclic work item		2		
D. Delays – other		8		
Total - worksite			56	2.0 cu yd 1/
Other				
E. Travel to, from, or between worksites		21		(33 mph)
F. Supporting work items:				
1. Load bituminous cold mix	5			21.3 cu yd
2. Other	3			
		8		
G. Delays		14		
H. Non-supporting work items and delays		1		
Total – other			44	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			75	

1/ Rate based on bituminous cold mix placed.

TABLE 133

PATCH SHOULDERS AND APPROACHES WITH BITUMINOUS COLD MIX – DISTRIBUTION OF 3 HOURS NAWT FOR FRONT-END LOADERS ASSIGNED TO PATCH EDGERUTS

Location and item	Percent of NAWT		Performance (Avg per hour)
Other			
E. Travel to, from, or between worksites		14	(11 mph)
F. Supporting work items:			
1. Load bituminous cold mix	38		21.9 cu yd
2. Other	14		
		52	
G. Delays:			
1. Quit early	14		
2. Other	20		
		34	
TOTAL		100	
Total work items on assigned operation (E + F)		66	

(k) Clean or repair unpaved drainage ditches. Labor time expended on this operation amounted to 1.9 percent of TAWT in the three-county control area. Work was performed on all types of road sections, but not all sections in the control area were involved during the study year. Practically all of the work done covered cleaning dirt and debris from ditches. Repair of eroded areas was very infrequent in the three-county control area.

Observations indicated that sediment was deposited in unpaved drainage ditches on all road sections at certain locations. These trouble spots were generally caused by deficiencies in design or construction or excessive erosion on the right-of-way and adjacent property. Some deposits built up to the point where they impaired or blocked drainage in a year or two; others took 20 or even 30 years. Eventually, the deposits must be removed to prevent damage to the roadway and adjacent property.

Crews assigned to this operation usually consisted of 4 to 8 men, a truck mounted 3/8-cu yd dragline, 2 or 3 trucks, and a pickup for transportation. The men worked by assigned tasks. One man operated the dragline, one man moved the dragline ahead as needed, 2 or 3 men drove trucks, one man directed dumping and one or two men flagged traffic. On small crews, the dumpman flagged traffic and the dragline was moved ahead by its operator or a flagman. Normally, the dragline was left overnight at a temporary parking area. The crew drove out to the job, picked up the dragline, and proceeded to a work area. The dragline operator first inspected the ditch to be cleaned and decided what work would be done. Deposits of clay, silt, muck and sod were then excavated, loaded and hauled to a nearby disposal site. Sometimes the excavated soil was wasted but often it was used to build up eroded or settled shoulders and fills. Practically no handwork was done at excavation or disposal sites. However, they were sometimes leveled by a motorgrader at a later date. Crews normally followed good safety practices while engaged in this operation. Warning signs were erected and one or two men flagged public traffic throughout the day.

Production studies of this operation were confined to ditch cleaning since repair work was so minor. Data from studies indicate that there was often a lack of balance between excavating capacity and hauling capacity on ditch cleaning. Men lost almost 20 percent of their NAWT waiting on loading, hauling, and dumping. Usually, only two trucks were available, and three were needed. A rule of thumb was developed from study data to determine the number of trucks needed to match hauling capacity to the excavating capacity of a 3/8-cu yd dragline under average conditions.

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

Considerable time was also lost by men assigned to ditch cleaning due to instructions and inspection of worksites. Having a designated supervisor present and staking out work in advance would do much to eliminate these sources of delays.

Figure 28. Dragline cleaning sod and soil from ditch.

TABLE 134

CLEAN OR REPAIR UNPAVED DRAINAGE DITCHES – DISTRIBUTION OF 191 HOURS NAWT FOR MEN ASSIGNED TO CLEAN DITCHES

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Excavate and load soil with dragline	8			32.5 cu yd
2. Shape ditch or disposal area	3			
3. Haul soil to disposal area	3			86.2 cu yd
4. Dump soil	1			270.2 cu yd
5. Return to loading area	3			99.3 cu yd
6. Maneuver to excavate, load, or dump soil	4			
7. Move ahead to new work area	3			
		25		10.5 cu yd 1/
B. Supporting work items:				
1. Flag or direct public traffic	8			
2. Other	5			
		13		
C. Delays — wait on cyclic work item:				
1. Wait on load, haul or dump soil	20			
2. Other	2			
		22		
D. Delays — other:				
1. Instructions	4			
2. Inspection of work or worksite	3			
3. Other	10			
		17		
Total — worksite			77	3.4 cu yd 1/
Other				
E. Travel to, from, or between worksites		15		
F. Supporting work items		1		
G. Delays		6		
H. Non-supporting work items and delays		1		
Total — other			23	
TOTAL			100	2.6 cu yd 1/
Total work items on assigned operation (A + B + E + F)			54	

1/ Based on soil excavated.

TABLE 135

CLEAN OR REPAIR UNPAVED DRAINAGE DITCHES – DISTRIBUTION OF 78 HOURS NAWT FOR HAULING TRUCKS ASSIGNED TO CLEAN DITCHES

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Load soil	20			31.4 cu yd
2. Haul soil to disposal area	7			86.2 cu yd (24 mph)
3. Dump soil	2			270.1 cu yd 1/
4. Return to loading area	7			99.3 cu yd (23 mph) 1/
5. Maneuver to load or dump	8			
6. Move ahead to new work area	2			(15 mph)
		46		13.8 cu yd 1/
B. Supporting work items		4		
C. Delays – wait on cyclic work item:				
1. Wait on other truck load soil	8			
2. Other	3			
		11		
D. Delays — other		18		
Total – worksite			79	8.1 cu yd 1/
Other				
E. Travel to, from, or between worksites		13		(39 mph)
F. Supporting work items		1		
G. Delays		7		
H. Non-supporting work items and delays		2/		
Total – other			21	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			64	

1/ Based on soil loaded and hauled.
2/ 0.5 percent or less.

TABLE 136

CLEAN OR REPAIR UNPAVED DRAINAGE DITCHES – DISTRIBUTION OF 39 HOURS NAWT FOR DRAGLINES ASSIGNED TO CLEAN DITCHES

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Excavate and load soil	40			32.8 cu yd
2. Shape ditch	3			
3. Maneuver to excavate	4			
4. Move ahead to new work area	3			(13 mph)
		50		23.9 cu yd
B. Supporting work items		5		
C. Delays – wait on cyclic work item:				
1. Wait on haul and dump soil	5			
2. Other	3			
		8		
D. Delays — other		17		
Total – worksite			80	15.1 cu yd
Other				
E.. Travel to, from, or between worksites		8		(26 mph)
F. Supporting work items		1		
G. Delays		11		
H. Non-supporting work items and delays		1/		
Total —- other			20	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			64	

1/ 0.5 percent or less.

TABLE 137

CLEAN OR REPAIR UNPAVED DRAINAGE DITCHES – DISTRIBUTION OF 39 HOURS NAWT FOR TRANSPORTATION TRUCKS AND PICKUPS ASSIGNED TO CLEAN DITCHES

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Move ahead to new work area		5		(16 mph)
B. Supporting work items		3		
C. Delays — wait on cyclic work item		-		
D. Delays — other				
1. Parked while men work	57			
2. Other	8			
		65		
Total — worksite			73	
Other				
E. Travel to, from, or between worksites		21		(44 mph)
F. Supporting work items		1/		
G. Delays		5		
H. Non-supporting work items and delays		1		
Total — other			27	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			29	

1/ 0.5 percent or less

(1) Mow roadsides with tractors. This operation accounted for 6.0 percent of labor TAWT in the three-county control area during the study year. During the mowing season from May to October, it was the most prominent operation. Grassed right-of-way areas on all road sections were normally mowed once each year. Some areas were mowed a second time in years when vegetation growth was usually rapid. However, crews did not attempt to mow areas which were wet, steep, or badly eroded since tractors could not be operated safely. It was estimated that 75 percent of all right-of-way areas in the three-county control area were mowed 1 or 2 times during the study year. Grassed shoulders on all roadway sections were mowed from 1 to 4 times each year depending upon the rate of vegetation growth and other factors. Main routes generally received the most attention.

Only two types of equipment units were utilized on this operation during the study period. The machine used most frequently was a light farm tractor with a 5- or 6-foot sickle bar mower mounted immediately in front of the right rear wheel. The other type of machine was a medium farm tractor with a 5-foot rotary mower underslung between its axles. The sickle bar units were ordinarily used for mowing irregular ground, cut slopes and fill slopes; the rotary units mowed shoulders and other relatively smooth ground.

Crews assigned to this operation varied considerably in size. Practically all shoulder mowing was done by crews consisting of one man and a rotary mower. Occasionally shoulders were mowed by two-man crews equipped with two rotary mowers or one rotary and one sickle bar mower. Crews which mowed right-of-way areas usually consisted of 2 or 3 men, but crews of 4 to 7 men were not uncommon. Each man in the right-of-way crews normally utilized a sickle bar mower. If worksite conditions were favorable, one man sometimes had a rotary mower. Some right-of-way crews had a truck or pickup for transportation. Others were transported to and from worksites by foremen, mechanics or other operators. A few right-of-way crews and most shoulder crews drove their tractors to and from worksites.

Figure 29. Tractor with 6' sickle bar mower cutting high weeds on ROW.

Figure 30. Tractor with 5' rotary mower cutting weeds on shoulder.

Two passes were generally required to mow each shoulder. The first pass was made adjacent to the pavement edge in the direction of traffic. Obstructions, such as flumes or posts, were avoided by swinging the tractor out on the pavement without stopping.

The second pass was usually made after the first pass had been completed on both sides of a road over a work area which was 1 to 10 miles long. It was accomplished in a manner similar to the first pass but at a slower rate since there were more obstructions, heavier vegetation, and sometimes, rough or inclined footing. Occasionally, shoulder crews interrupted a pass to mow flat areas on the right-of-way.

Crews mowing rights-of-way generally divided road sections into work areas ranging from a few hundred feet to a mile in length on one side of the road. Each area was completed before the crew moved ahead or across the road. The first pass was usually made along the bottom of drainage ditches in the direction of traffic. Additional passes were made in both directions to cover ditches, foreslopes, backslopes, and natural ground. Tractors were not operated over uncut vegetation unless absolutely necessary since it made mowing more difficult. Usually, men did not make any attempt to mow areas which past experience had indicated were too wet, rough or steep for safe operations. Mowing rates were quite variable depending on type of vegetation, condition of ground, steepness of slopes, maneuvers required and number of units working in an area.

Crews did not always put up warning signs while engaged in mowing operations. However, all tractors working on shoulders and some tractors working on right-of-way areas had a warning flag mounted on a long pole.

A large number of production studies were conducted on this operation. Study data indicated that there was a substantial difference between the time utilization of shoulder and right-of-way mowing crews. The data also provided information on how production is influenced by working conditions and crew sizes. The following table presents production rates for selected conditions.

conditions.

TABLE 138. PRODUCTION RATES FOR MOWING ROADSIDES

Location and condition of worksites	Number and type of mowers in crew	Average acres per hour of tractor NAWT	Average acres per hour of tractor worksite NAWT
Right-of-way:			
Dry and level	2 sickle bar	0.95	1.12
Dry and level	3-7 sickle bar	0.69	0.89
Wet or rough	2 sickle bar	0.56	0.66
Wet or rough	3-7 sickle bar	0.51	0.65
Long work areas	2 sickle bar	1.64	1.89
Short work areas	2 sickle bar	0.84	1.03
Shoulder:			
All types	1 sickle bar	1.16	1.44
All types	1 rotary	1.83	2.28

This table indicates that rotary mowers were, on the average, much more productive than sickle bar mowers for shoulder work. It also demonstrates that average production per tractor declines as crew size increases. The comparison of production rates for long and short work areas indicates that average production is higher in long areas. However, no allowance was made for roughness of terrain or irregularity of right-of-way widths which may have influenced the lengths of work areas. The accomplishment of rotary mowers working on extensive right-of-way areas could not be determined with accuracy from available study data. It would appear that this type of unit could be used to advantage in many situations such as cutting ditch bottoms.

In late 1960, the State acquired a new type of rotary mower. This unit had three overlapping rotary sections mounted on a trailer and operated by a tractor power takeoff. A hydraulic suspension system permitted the two end sections to be raised to clear obstructions or lowered to conform to ground contour. Short studies indicated that this unit can mow 3 to 6 acres per hour of tractor worksite NAWT under reasonably favorable conditions. There appears to be a real need for this type of unit in many areas, particularly those which have interstate mileage. A need may also exist in almost all locations for a 10-foot rotary mower or a combination of a 5-foot rotary mower and a 5- or 6-foot sickle bar mower.

Figure 31. Tractor with 15' rotary mower cutting grass on ROW.

TABLE 139

MOW ROADSIDES WITH TRACTORS —
DISTRIBUTION OF 613 HOURS NAWT FOR MEN ASSIGNED TO MOW WITH TRACTOR SICKLE BAR MOWERS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Mow roadside with tractor	52			1.46 acres
2. Maneuver to mow	6			
3. Move ahead to new work area	3			
		61		1.25 acres
B. Supporting work items		2		
C. Delays — wait on cyclic work item		1/		
D. Delays — other		15		
Total - worksite			78	0.98 acres
Other				
E. Travel to, from, or between worksites		12		
F. Supporting work items		2		
G. Delays		8		
H. Non-supporting work items and delays		1/		
Total — other			22	
TOTAL			100	0.76 acres
Total work items on assigned operation (A + B + E + F)			77	

1/ 0.5 percent or less.

TABLE 140

MOW ROADSIDES WITH TRACTORS —
DISTRIBUTION OF 591 HOURS NAWT FOR TRACTOR SICKLE BAR MOWERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Mow roadside	54			1.46 acres
2. Maneuver to mow	6			
3. Move ahead to new work area	3			(6 mph)
		63		1.26 acres
B. Supporting work items		1		
C. Delays — wait on cyclic work items		1/		
D. Delays - other		15		
Total — worksite			79	1.00 acres
Other				
E. Travel to, from, or between worksites		5		(13 mph)
F. Supporting work items		1		
G. Delays:				
1. Wait on men and other units of equipment engaged in preparation, shutdown, or travel	10			
2. Other	5			
		15		
Total — other			21	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			70	

1/ 0.5 percent or less.

TABLE 141

MOW ROADSIDES WITH TRACTORS –

DISTRIBUTION OF 131 HOURS NAWT FOR MEN ASSIGNED TO MOW WITH TRACTOR ROTARY MOWERS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Mow shoulder with tractor	64	2.72 acres
2. Mow other area with tractor	3	0.87 acres
3. Maneuver to mow	1	
4. Move ahead to new work area	2	
	70	2.53 acres
B. Supporting work items	1	
C. Delays — wait on cyclic work items	1/	
D. Delays — other	7	
Total — worksite	78	2.27 acres
Other		
E. Travel to, from, or between worksites	13	
F. Supporting work items	2	
G. Delays	7	
H. Non-supporting work items and delays	1/	
Total — other	22	
TOTAL	100	1.77 acres
Total work items on assigned operation (A + B + E + F)	86	

1/ 0.5 percent or less.

TABLE 142

MOW ROADSIDES WITH TRACTORS –

DISTRIBUTION OF 127 HOURS NAWT FOR TRACTOR ROTARY MOWERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Mow shoulder	66	2.72 acres
2. Mow other area	3	0.87 acre
3. Maneuver to mow	1	
4. Move ahead to new work area	2	(6 mph)
	72	2.53 acres
B. Supporting work items	1	
C. Delays — wait on cyclic work items	1/	
D. Delays — other	7	
Total – worksite	80	2.28 acres
Other		
E. Travel to, from, or between worksites	5	(13 mph)
F. Supporting work items	1	
G. Delays:		
1. Wait on men and other equipment units engaged in preparation, shutdown, or travel	8	
2. Other	5	
	13	
H. Non-supporting work items and delays	1	
Total – other	20	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	79	

1/ 0.5 percent or less.

TABLE 143

MOW ROADSIDES WITH TRACTORS –

DISTRIBUTION OF 139 HOURS NAWT FOR TRANSPORTATION TRUCKS AND PICKUPS ASSIGNED TO THE OPERATION 1/

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	2/	(10 mph)
B. Supporting work items	1	
C. Delays – wait on cyclic work item	2/	
D. Delays – other:		
1. Parked while men work	65	
2. Other	1	
	66	
Total – worksite	67	
Other		
E. Travel to, from, or between worksites	21	(36 mph)
F. Supporting work items	2	
G. Delays	10	
H. Non-supporting work items and delays	2/	
Total — other	33	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	24	

1/ 131 hours of this time was chargeable to crews utilizing sickle bar mowers.

2/ 0.5 percent or less.

(m) Remove snow from roadway surfaces and shoulders. Labor time expended on this operation was 13.0 percent of TAWT in the three-county control area. By definition, time was charged only when maintenance crews were primarily engaged in plowing loose or lightly packed snow from roadway surfaces and shoulders. Time was not charged to this operation when crews plowed snow incidental to sanding and salting runs, shoveled snow from bridges, or removed hard packed snow from surfaces and shoulders. The latter type of work was not charged since it was considered to be removing ice.

Weather records indicate that 15 separate snow storms occurred during the winter of 1959-60. Snowfall in the three-county control area totaled about 55 inches which was well above the long-term average. About two-thirds of this occurred during six important storms. However, total snowfall does not necessarily equal the amount of snow which must be removed from roadway surfaces and shoulders. When ground temperatures are above 32° F., some snow melts as soon as it falls; more is melted if surfaces are salted; and a large percentage is blown off surfaces and shoulders by traffic action or wind. On the other hand, wind may deposit a considerable amount of snow on roadway surfaces and shoulders even when none is falling. Thus, it is very difficult to measure the quantity of snow to be removed from any given road network during one storm or an entire season. It might be expected that there would be a correlation between snow quantities and effort expended on this operation by maintenance crews. However, study records for the three-county control area indicate that effort expended per day during storm periods was about the same regardless of total snowfall, rate of snowfall, temperature and wind. The study records also showed that there was very little difference in total effort expended on different road sections although sections on main routes did receive first priority.

Figure 32. Light duty truck with one-way plow plowing shoulder.

Figure 33. Motorgrader with Vee plow plowing drift on roadway surface.

Maintenance crews utilized a wide variety of equipment for this operation. The basic unit was a light duty truck equipped with a straight plow or reversible straight plow. Vee plows were also available for most light duty trucks but were rarely used. Each county had from 1 to 3 medium or heavy duty trucks equipped with four-wheel drive, underbody blade, straight plow, Vee plow, and a side-mounted wing plow. Each county had one medium or heavy duty motorgrader equipped with an ice blade, Vee plow and side-mounted wing plow. A few counties also had a light duty motorgrader equipped for snow removal. Heavy duty trucks equipped with four wheel drive and rotary snowplows were not available on a continuous basis. They were stationed at strategic locations around the State and moved into a county only when needed.

Usually a few men were assigned to snow removal as soon as there was a visible accumulation of snow on roadway surfaces. If snow continued to collect, the crew was enlarged by transferring additional men from other operations such as sanding and salting. At night, men were kept on duty after regular shift hours or called in from home. Light, medium and heavy duty trucks equipped with straight plows were soon making regular runs over most road sections. The general objective was to remove snow as fast as it accumulated in order to prevent packing by traffic. Short storms presented few problems unless there was enough wind to cause drifting. During major storms crews usually encountered a number of problems. Snow accumulated on surfaces and was packed by traffic. Plowing built up high windrows on shoulders. Strong winds caused severe drifting. The high shoulder windrows were particularly troublesome because they trapped blowing snow and thus intensified drifting. When possible, medium duty trucks, heavy duty trucks, and motorgraders were sent out to push back and level these windrows with Vee and/or wing plows. If this was prevented by poor visibility or other adverse conditions, the larger units concentrated on drift removal. Light duty trucks equipped with Vee plows were also assigned to windrow and drift removal but were not always able to handle the work. During a few of the most severe storms, visibility became so poor due to darkness and blowing snow that it was necessary for crews to suspend operations. Most road sections were given a final coverage just prior to shutting down in order to clear the way for any remaining traffic. Crews returned to work when conditions improved. They first opened up blocked road sections and then resumed normal work patterns.

Most crews began cleanup as soon as it was apparent that storms were dying down. First priority was given to opening any blocked road sections and removing loose snow from the entire width of roadway surfaces. Crews then concentrated on clearing shoulders to prevent further drifting and to provide storage space in the event of another storm. Crews were gradually reduced in size during this phase as men were sent home for rest or transferred to other operations such as removing ice. All types of equipment were used for cleanup. The bulk of surface plowing was handled by light duty trucks equipped with straight plows. Drifts and shoulder windrows were plowed or leveled by medium duty trucks, heavy duty trucks and motorgraders using Vee plows and/or wing plows. A light duty truck often worked with each of the larger units to remove any loose snow which got on roadway surfaces. Sometimes heavy duty trucks equipped with rotary plows were brought into a county to remove exceptionally deep shoulder windrows or drifts. Generally one or two light duty trucks worked in conjunction with these rotaries.

Snow removal was also required on many days when it was not actually snowing. Usually it involved pushing back or leveling small drifts caused by high winds. These drifts were not numerous and consequently only a small portion of the time crews were out on the road was actually spent removing snow. Light duty trucks equipped with straight plows handled almost all of this work.

Production studied indicated that this operation was relatively efficient. However, many crews equipped with trucks consisted of two men. The second man did not perform any significant work. Unless these crews were using wing or rotary plows, many of these second men, in effect, lost a considerable amount of time riding during travel and plowing. The average accomplishment per man could be substantially increased if all truck equipped crews consisted of one man except when using wing or rotary plows. However, safety may be an overriding consideration on use of one-man crews until two-way radio becomes available.

Figure 34. Heavy duty truck with rotary plow removing drift on roadway surface.

TABLE 144

REMOVE SNOW FROM ROADWAY SURFACES AND SHOULDERS – DISTRIBUTION OF 580 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Plow with one-way plow	34			19.5 pass-mi
2. Plow with wing blade 1/	4			7.9 pass-mi
3. Plow with underbody blade 1/	1			10.3 pass-mi
4. Plow with Vee plow 1/	2			9.7 pass-mi
5. Plow with rotary plow	2			2,360 cu yd
6. Plow with combination of plows and blades 1/	3			11.4 pass-mi
7. Plow with one-way plow and sand or salt 2/	1			12.4 pass-mi
8. Maneuver to plow 1/	2			
9. Move ahead to new work area 1/	6			
		55		15.2 pass-mi 3/
B. Supporting work items:				
1. Ride while plowing	11			
2. Other	3			
		14		
C. Delays — wait on cyclic work items		1		
D. Delays — other		8		
Total - worksite			78	10.5 pass-mi 2/
Other				
E. Travel to, from, or between worksites		6		
F. Supporting work items		5		
G. Delays		10		
H. Non-supporting work items and delays		1		
Total — other			22	
TOTAL			100	8.1 pass-mi 2/
Total work on assigned operation (A + B + E + F)			80	

1/ Both trucks and motorgraders were used for plowing.
2/ Trucks only.
3/ Time and accomplishment for rotary plows were excluded when computing average rates. Based on miles plowed.

TABLE 145

REMOVE SNOW FROM ROADWAY SURFACES AND SHOULDERS - DISTRIBUTION OF 277 HOURS NAWT FOR LIGHT DUTY TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Plow with one-way plow	58			19.8 pass-mi
2. Plow with Vee plow	1			18.3 pass-mi
3. Plow with one-way plow and sand or salt	1/			12.8 pass-mi
4. Maneuver to plow	3			
5. Move ahead to new work area	6			(24 mph)
		68		17.2 pass-mi 2/
B. Supporting work items		2		
C. Delays - wait on cyclic work items		2		
D. Delays - other		7		
Total - worksite			79	14.8 pass-mi 2/
Other				
E. Travel to, from, or between worksites		6		(24 mph)
F. Supporting work items		4		
G. Delays		11		
H. Non-supporting work items and delays		1/		
Total - other			21	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			80	

1/ 0.5 percent or less.
2/ Based on miles plowed.

TABLE 146

REMOVE SNOW FROM ROADWAY SURFACES AND SHOULDERS - DISTRIBUTION OF 118 HOURS NAWT FOR MEDIUM AND HEAVY DUTY TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Plow with one-way plow	26			19.4 pass-mi
2. Plow with wing blade	9			11.2 pass-mi
3. Plow with underbody blade	4			16.4 pass-mi
4. Plow with Vee plow	5			9.9 pass-mi
5. Plow combination of plows and blades	11			12.9 pass-mi
6. Plow with one-way blade and sand or salt	3			20.4 pass-mi
7. Maneuver to plow	2			
8. Move ahead to new work area	7			(22 mph)
		67		13.9 pass-mi 1/
B. Supporting work items		3		
C. Delays - wait on cyclic work items		-		
D. Delays - other		9		
Total - worksite			79	11.8 pass-mi 1/
Other				
E. Travel to, from, or between worksites		5		(25 mph)
F. Supporting work items		6		
G. Delays		9		
H. Non-supporting work items and delays		1		
Total - other			21	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			81	

1/ Based on miles plowed.

TABLE 147

REMOVE SNOW FROM ROADWAY SURFACES AND SHOULDERS - DISTRIBUTION OF 23 HOURS NAWT FOR HEAVY DUTY TRUCKS EQUIPPED WITH ROTARY PLOWS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Plow with rotary plow	49			2,360 cu yd
2. Maneuver to plow	3			
3. Move ahead to new work area	10			(18 mph)
		62		1,880 cu yd 1/
B. Supporting work items		1		
C. Delays - wait on cyclic work item		2/		
D. Delays - other		8		
Total - worksite			71	1,630 cu yd 1/
Other				
E. Travel to, from, or between worksites		15		(27 mph)
F. Supporting work items		3		
G. Delays		11		
Total - other			29	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			81	

1/ Based on snow removed.
2/ 0.5 percent or less.

TABLE 148

REMOVE SNOW FROM ROADWAY SURFACES AND SHOULDERS - DISTRIBUTION OF 45 HOURS NAWT FOR MOTORGRADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Plow with wing blade	28			5.9 pass-mi
2. Plow with underbody blade	3			4.0 pass-mi
3. Plow with Vee plow	6			1.4 pass-mi
4. Plow with combination of plows and blades	6			5.4 pass-mi
5. Maneuver to plow	13			
6. Move ahead to new work area	5			
		61		3.6 pass-mi 1/
B. Supporting work items		7		
C. Delays - wait on cyclic work item		-		
D. Delays - other		7		
Total - worksite			75	2.9 pass-mi 1/
Other				
E. Travel to, from, or between worksites		11		(11 mph)
F. Supporting work items		3		
G. Delays		11		
H. Non-supporting work items and delays		2/		
Total - other			25	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			82	

1/ Based on miles plowed.
2/ 0.5 percent or less.

(n) Erect snowfences. Labor time expended on this operation was 2.9 percent of TAWT in the three-county control area. During the months of October and November, it was the most prominent type of work underway. Some snowfence was erected on almost all road subsections. The amount varied considerably from subsection to subsection depending upon such factors as roadside development, obstructions on the right-of-way or adjacent property, terrain, right-of-way width, roadway cross section design, and direction of prevailing winds. The two most important factors appeared to be roadside development and roadway design. The extent of roadside development was usually best indicated by whether the subsection was located in a rural or urban area; the type of cross section design by the period during which the road subsection was originally constructed. The following table shows the average amount of snowfence erected on control area road subsections classified by location and period of original construction.

TABLE 149

SNOWFENCE QUANTITIES ON ROAD SUBSECTIONS IN THREE-COUNTY CONTROL AREA

Location	Period of original construction	Average length of snowfence (lineal ft/mile)
Rural	1926-45	795
"	1946-59	110
"	1926-59	500
Urban	1926-45	175
"	1946-59	25
"	1926-59	105
All rural and urban	1926-59	470

The exact location and the length of snowfence installations were normally determined by past experience with drifting snow. Sometimes, a special survey was made during the winter to check on the need for additional installations. Whenever possible, fence was erected approximately 100 feet away from roadway shoulders to allow room for formation of drifts. Thus, most installations were located on private property. Landowners were contacted each year before crews began work. Sometimes this contact was made by foremen; sometimes by members of the crew which drove fence posts. Often landowners could not be located immediately or would not permit crews to enter their property until crops had been harvested. When this happened, crews had to make several trips to a road section in order to complete snowfence erection. At other times, landowners granted permission to erect fence but would not allow the use of trucks on their property. This meant that crews had to perform the entire operation by hand.

Snowfence erection was normally divided into three steps, each handled by separate crews. The first step involved loading, hauling, and driving fence posts. It was almost always performed by crews consisting of two men and a truck equipped with a power post driver. Posts were obtained from stockpiles located at garages. At work areas, one man paced off the location of each post, unloaded posts, and positioned them in the post driver. The second man moved the truck ahead and operated the post driver. At a few locations, trucks could not enter private property. Posts were unloaded on the right-of-way, carried to work areas and driven by hand.

Figure 35. Driving snow fence post with power driver.

The second step encompassed loading, hauling, and unloading rolls of snowfence. Usually, it was done by crews consisting of 2 or 3 men and 1 truck. Rolls were obtained from stockpiles located at the garage and several other points around a county. Whenever possible, they were hauled onto private property and unloaded at the locations where fence was to be erected. One man drove while the other man or men pushed rolls off the back of the truck. When trucks could not enter private property, rolls were unloaded on the right-of-way and carried to fence locations.

The third step involved unrolling, positioning and tying fence. Crews performing this step consisted of 3 to 5 men and 1 or 2 trucks. Often, they parked their trucks on roadway shoulders and walked to work areas. Usually, 1 or 2 men unrolled and tied fence sections together while the other 2 or 3 men positioned fence on posts and tied it in place. If additional fence or end brace posts were needed, this crew drove them by hand.

Figure 36. Erecting snow fence.

In some counties, the second and third steps of the operation were commonly combined and performed by a crew consisting of 3 to 7 men and 1 to 3 trucks. A few cases were also observed where all three steps were combined and performed by crews of 7 or 8 men. These large crews generally used about the same procedures as the small independent crews but men frequently switched from one task to another during the day.

A substantial number of production studies were conducted on this operation. Some of the crews studied performed only one of the three steps; others performed two at the same time. Data for crews engaged in hauling and driving posts (step 1) have been shown separately in the following tables. Data for crews engaged in loading, hauling, unloading, and erecting fence rolls (steps 2 and 3) have been grouped for crews which performed the work in two steps in order that they may be compared with crews which performed the two steps at the same time. Most of the crews studied spent a high proportion of their time in travel. Part of this was due to the skipping around which occurred when they did not have permission to enter some private property immediately. The remainder was attributable to time spent in travel by men other than truck drivers. An analysis of study data indicated that, under existing conditions, small crews would be most efficient. The first step should be done by crews of two men and one truck. For maximum efficiency, steps two and three should be combined and performed by crews of two men and one truck. However, it is recognized that conditions sometimes make it necessary to perform the second and third steps separately. If so, step two should be done by crews of two men and two trucks and step three by crews of two men and one truck.

TABLE 150

ERECT SNOW FENCES —
DISTRIBUTION OF 61 HOURS NAWT FOR MEN ASSIGNED TO
HAUL AND DRIVE FENCE POSTS AT SAME TIME

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Unload, position and drive posts with power driver	15			162 posts
2. Walk ahead to next post	5			
3. Move ahead to next post	5			
		25		96 posts 1/
B. Supporting work items:				
1. Maneuver	10			
2. Other	1			
		11		
C. Delays - wait on cyclic work item		3		
D. Delays — other:				
1. Obtain permission from landowner to erect fence	7			
2. Open or close farm gates	3			
3. Other	5			
		15		
Total - worksite			54	45 posts 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		31		
F. Supporting work items		7		
G. Delays		8		
H. Non-supporting work items and delays		2/		
Total — other			46	
TOTAL			100	24 posts 1/
Total work items on assigned operation (A + B + E + F)			74	

1/ Based on posts driven.
2/ 0.5 percent or less.

TABLE 151

ERECT SNOW FENCES —
DISTRIBUTION OF 31 HOURS NAWT FOR TRUCKS ASSIGNED TO
HAUL AND DRIVE POSTS AT SAME TIME

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Drive posts with power driver 1/	15			394 posts
2. Move ahead to next post	10			
		25		212 posts 2/
B. Supporting work items:				
1. Maneuver	11			
2. Other	2			
		13		
C. Delays — wait on cyclic work item		3		
D. Delays — other:				
1. Obtain landowner's permission to erect fence	8			
2. Other	5			
		13		
Total — worksite			54	90 posts 2/
Other				
E. Travle to, from, or between worksites (including haul and return)		32		(27 mph)
F. Supporting work items		7		
G. Delays		7		
H. Non-supporting work items and delays		3/		
Total — other			46	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			77	

1/ Operated by truck hoist or separate power source.
2/ Based on posts driven.
3/ 0.5 percent or less.

TABLE 152

ERECT SNOW FENCES — DISTRIBUTION OF 142 HOURS NAWT FOR MEN ASSIGNED TO HAUL AND ERECT FENCE ROLLS AT SAME TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Untie or unroll fence rolls	8	26.6 rolls
2. Tie fence sections together	1	130.2 rolls
3. Position fence on posts	4	47.5 rolls
4. Tie fence to posts	10	20.0 rolls
5. Drive posts by hand (extra or end brace)	1	46 posts
6. Walk ahead to new work area	5	
7. Move ahead to new work area	1	
	30	6.8 rolls 1/
B. Supporting work items	14	
C. Delays — wait on cyclic work item	1	
D. Delays — other	9	
Total — worksite	54	3.8 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul and return)	27	
F. Supporting work items	8	
G. Delays	10	
H. Non-supporting work items and delays	1	
Total — other	46	
TOTAL	100	2.0 rolls 1/
Total work items on assigned operation (A + B + E + F)	79	

1/ Based on fence rolls erected.

NOTE: Average roll of fence is 48 feet long.

TABLE 154

ERECT SNOW FENCES — DISTRIBUTION OF 199 HOURS NAWT FOR MEN ASSIGNED TO HAUL AND ERECT FENCE ROLLS AT DIFFERENT TIMES

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Untie or unroll fence rolls	5	45.6 rolls
2. Tie fence sections together	3	71.2 rolls
3. Position fence on posts	4	50.6 rolls
4. Tie fence to posts	7	29.5 rolls
5. Drive posts by hand (extra or end brace)	1/	54 posts
6. Walk ahead to new work area	3	
7. Move ahead to new work area	1/	
	22	9.5 rolls 2/
B. Supporting work items	11	
C. Delays — wait on cyclic work item	1	
D. Delays — other	8	
Total - worksite	42	4.9 rolls 2/
Other		
E. Travel to, from, or between worksites (including haul and return)	37	
F. Supporting work items	7	
G. Delays	13	
H. Non-supporting work items and delays	1	
Total — other	58	
TOTAL	100	2.1 rolls 2/
Total work items on assigned operation (A + B + E + F)	77	

1/ 0.5 percent or less.
2/ Based on fence rolls erected.

NOTE: Average roll of fence is 48 feet long.

TABLE 153

ERECT SNOW FENCES — DISTRIBUTION OF 52 HOURS NAWT FOR TRUCKS ASSIGNED TO HAUL AND ERECT FENCE ROLLS AT SAME TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	2	(11 mph)
B. Supporting work items	11	
C. Delays — wait on cyclic work item	-	
D. Delays — other:		
1. Parked while men work	39	
2. Other	3	
	42	
Total — worksite	55	10.2 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul and return)	27	(27 mph)
F. Supporting work items	7	
G. Delays	10	
H. Non-supporting work items and delays	1	
Total — other	45	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	47	

1/ Based on fence rolls erected.

TABLE 155

ERECT SNOW FENCES — DISTRIBUTION OF 84 HOURS NAWT FOR TRUCKS ASSIGNED TO HAUL AND ERECT FENCE ROLLS AT DIFFERENT TIMES

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	1	(10 mph)
B. Supporting work items	9	
C. Delays — wait on cyclic work item	-	
D. Delays — other:		
1. Parked while men work	27	
2. Other	4	
	31	
Total - worksite	41	12.0 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul and return)	40	(21 mph)
F. Supporting work items	7	
G. Delays	12	
H. Non-supporting work items and delays	2/	
Total — other	59	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	57	

1/ Based on fence rolls erected.
2/ 0.5 percent or less.

Hauling capacity of trucks in terms of volume rather than weight is an important factor in the efficiency achieved by crews engaged in snowfence erection and removal. Careful adherence by crews to the 8-foot width limitation on loads is a factor which effectively reduces the number of rolls of snowfence carried by each truck. A slight reduction in the height of fence, say, to perhaps 3 feet 9 inches, would permit a double row of rolls to be carried within limitations allowed.

(o) Remove snowfences. This operation accounted for 1.8 percent of labor TAWT in the three-county control area. Practically all of the work was done during April and May. As previously indicated, most snowfence installations in the control area were located on private property. Many landowners became anxious to have these installations removed as soon as frost went out of the ground so that field work could get underway. In order to preserve good relations with these landowners, it was essential for the crews to remove snowfences while the ground was still wet and soft. Often, trucks were not permitted to enter private property or were unable to maneuver in the wet ground and it was necessary to do a considerable amount of hand work.

This operation was accomplished in one to three steps. The number of steps and the tasks included in each step depended on local practice and conditions encountered at work areas. Some of the combinations observed are shown in Table 156.

TABLE 156
OBSERVED COMBINATIONS USED FOR REMOVING SNOWFENCES

Combination	Condition of work area	Steps
A	Ground soft - trucks not able to enter private property	1. Remove fence and remove posts 2. Haul posts 3. Haul fence rolls
B	Ground firm - trucks able to enter private property	1. Remove fence, remove posts, and haul posts 2. Haul fence rolls
C	Ground firm - trucks able to enter private property	1. Remove fence 2. Remove and haul posts 3. Haul fence rolls
D	Ground firm - trucks able to enter private property	1. Remove fence, remove posts, haul fence, and haul posts

Each step was done by crews consisting of 2 to 5 men and 1 to 3 trucks. Most commonly, there were 2 or 3 men and one truck. Sometimes crews performed two or three different steps during the same day.

Crews generally accomplished the various work tasks in the same manner regardless of how many steps were involved. Fence was removed from posts by cutting the wire ties. Sections were separated and rolled up. Posts were usually removed by hand, but in some cases were removed with mechanical pullers operated by raising truck beds. The posts and rolls of fence were loaded on trucks or carried to the fence line and tossed into the right-of-way, depending on whether or not trucks were able to enter private property. Posts and rolls of fence left on the right-of-way were loaded and hauled to a stockpile at a later time. Many of the tasks were performed by one man but others, such as loading fence rolls, required two. Men frequently switched from one task to another during the day or helped another man temporarily.

Production studies of this operation were limited because of the short span of time during which the work was performed. Only part of the combinations of steps used were covered. Study data have been grouped to show time utilization for crews engaged in the following steps: A1 and A2; B1; A3, B3, and C3; and C2. Analyses of available data indicated that this operation was one of the most efficient studied. The only significant loss of time occurred while men other than truck drivers were riding during travel, haul, or return. A gain in accomplishment per man would be realized if all steps except hauling fence rolls were performed by crews consisting of two men and one truck. When hauling fence rolls, the most efficient crew would be two or three men equipped with two or three trucks.

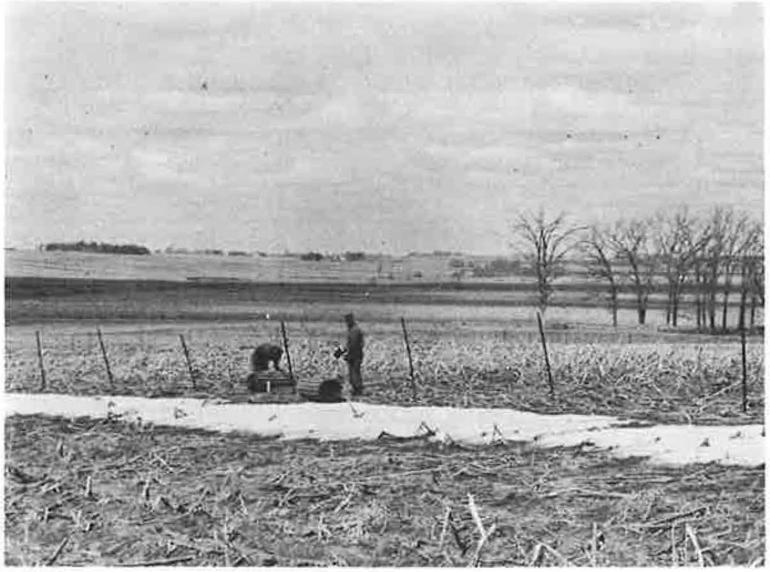


Figure 37. Removing snow fence.

TABLE 157

REMOVE SNOW FENCES — DISTRIBUTION OF 45 HOURS NAWT FOR MEN ASSIGNED TO REMOVE FENCE ROLLS AND POSTS AT SAME TIME; HAUL FENCE POSTS AT DIFFERENT TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Remove fence from posts	12	60.5 rolls
2. Roll or tie fence rolls	19	38.1 rolls
3. Pull posts by hand	6	443 posts
4. Walk ahead to new work area	4	
5. Move ahead to new work area	4	
	45	16.5 rolls 1/
B. Supporting work items:		
1. Transport fence or posts by hand	5	
2. Load posts	8	
3. Walk	4	
4. Other	2	
	19	
C. Delays – wait on cyclic work item	2/	
D. Delays – other	10	
Total — worksite	74	9.9 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul)	15	
F. Supporting work items:		
1. Unload posts	5	558 posts
2. Other	1	
	6	
G. Delays	4	
H. Non-supporting work items and delays	1	
Total — other	26	
TOTAL	100	7.4 rolls 1/
Total work items on assigned operation (A + B + E + F)	85	

1/ Based on fence rolls removed.
2/ 0.5 percent or less.

NOTE: Average roll of fence is 48 feet long.

TABLE 159

REMOVE SNOW FENCES — DISTRIBUTION OF 65 HOURS NAWT FOR MEN ASSIGNED TO REMOVE FENCE ROLLS, REMOVE FENCE POSTS AND HAUL FENCE POSTS AT SAME TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Remove fence from posts	12	46.9 rolls
2. Roll or tie fence rolls	19	30.8 rolls
3. Pull posts by hand	6	312 posts
4. Walk ahead to new work area	4	
5. Move ahead to new work area	3	
	44	13.0 rolls 1/
B. Supporting work items:		
1. Transport fence or posts by hand	7	
2. Load posts	4	
3. Walk	6	
4. Other	2	
	19	
C. Delays — wait on cyclic work items	1	
D. Delays — other	12	
Total — worksite	76	7.5 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul)	15	
F. Supporting work items	4	
G. Delays	4	
H. Non-supporting work items and delays	1	
Total — other	24	
TOTAL	100	5.7 rolls 1/
Total work items on assigned operation (A + B + E + F)	82	

1/ Based on fence rolls removed.

NOTE: Average roll of fence is 48 feet long.

TABLE 158

REMOVE SNOW FENCES — DISTRIBUTION OF 23 HOURS NAWT FOR TRUCKS ASSIGNED TO REMOVE FENCE ROLLS AND POSTS AT SAME TIME; HAUL FENCE POSTS AT DIFFERENT TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	4	(12 mph)
B. Supporting work items:		
1. Load posts	8	708 posts
2. Other	3	
	11	
C. Delays — wait on cyclic work items:		
1. Wait on remove fence and posts	2	
D. Delays — other		
1. Parked while men work	57	
2. Other	1	
	58	
Total — worksite	75	19.7 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul)	15	(29 mph)
F. Supporting work items:		
1. Unload posts	5	1116 posts
2. Other	1	
	6	
G. Delays	4	
H. Non-supporting work items and delays	2/	
Total — other	25	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	36	

1/ Based on fence rolls removed.
2/ 0.5 percent or less.

TABLE 160

REMOVE SNOW FENCES — DISTRIBUTION OF 26 HOURS OF NAWT FOR TRUCKS ASSIGNED TO REMOVE FENCE ROLLS, REMOVE FENCE POSTS AND HAUL FENCE POSTS AT SAME TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cycle work items:		
1. Move ahead to new work area	3	(7 mph)
B. Supporting work items:		
1. Load posts	5	955 posts
2. Other	2	
	7	
C. Delays —wait on cyclic work items:		
1. Remove fence and posts		
	38	
D. Delays — other		
1. Parked while men work	25	
2. Other	3	
	28	
Total — worksite	76	18.2 rolls 1/
Other		
E. Travel to, from, or between worksites (including haul)	15	(29 mph)
F. Supporting work items	4	
G. Delays	4	
H. Non-supporting work items and delays	1	
Total – other	24	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	29	

1/ Based on fence rolls removed.

TABLE 161

REMOVE SNOW FENCES — DISTRIBUTION OF 16 HOURS NAWT FOR MEN ASSIGNED TO REMOVE AND HAUL FENCE POSTS AT SAME TIME

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Pull posts with truck and mechanical puller	19			186 posts
2. Load posts	5			717 posts
3. Walk ahead to new work area	6			
4. Move ahead to new work area	6			
		36		100 posts 1/
B. Supporting work items:				
1. Maneuver	9			
2. Other	4			
		13		
C. Delays - wait on cyclic work items		4		
D. Delays - other:				
1. Personal delays	5			
2. Other	7			
		12		
Total - worksite			65	55 posts 1/
Other				
E. Travel to, from, or between worksites (including haul)		27		
F. Supporting work items		3		
G. Delays		4		
H. Non-supporting work items and delays		1		
Total - other			35	
TOTAL			100	36 posts 1/
Total work items on assigned operation (A + B + E + F)			79	

1/ Based on fence posts removed.

TABLE 163

REMOVE SNOW FENCES — DISTRIBUTION OF 24 HOURS OF NAWT FOR MEN ASSIGNED TO HAUL FENCE ROLLS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items		-		
B. Supporting work items:				
1. Load fence rolls	10			95.6 rolls
2. Other	10			
		20		
C. Delays - wait on cyclic work item		-		
D. Delays — other		5		
Total — worksite			25	37.8 rolls 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		50		
F. Supporting work items:				
1. Unload fence rolls	9			99.9 rolls 1/
2. Other	5			
		14		
G. Delays		10		
H. Non-supporting work items and delays		1		
Total — other			75	
TOTAL			100	9.4 rolls 1/
Total work items on assigned operation (A + B + E + F)			84	

1/ Based on fence rolls hauled.

TABLE 162

REMOVE SNOW FENCES DISTRIBUTION OF 8 HOURS NAWT FOR TRUCKS ASSIGNED TO REMOVE AND HAUL FENCE POSTS AT SAME TIME

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Pull posts with mechanical puller 1/	21			341 posts
2. Load posts	9			782 posts
3. Move ahead to new work area	12			(3 mph)
		42		170 posts 2/
B. Supporting work items:				
1. Maneuver	9			
2. Other	3			
		12		
C. Delays — wait on cyclic work item		-		
D. Delays — other:				
1. Personal	5			
2. Other	7			
		12		
Total - worksite			66	108 posts 2/
Other				
E. Travel to, from, or between worksites (including haul)		27		(19 mph)
F. Supporting work items		2		
G. Delays		5		
H. Nonsupporting work items and delays		3/		
Total - other			34	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			83	

1/ Operated by dump bed.
2/ Based on fence posts removed.
3/ 0.5 percent or less.

TABLE 164

REMOVE SNOW FENCES — DISTRIBUTION OF 8 HOURS NAWT FOR TRUCKS ASSIGNED TO HAUL FENCE ROLLS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items		-		
B. Supporting work items:				
1. Load fence rolls	12			230.5 rolls
2. Other	6			
		18		
C. Delays — wait on cyclic work item		-		
D. Delays — other		5		
Total - worksite			23	122.5 rolls 1/
Other				
E. Travel to, from, or between worksites (including haul and return)		51		(28 mph)
F. Supporting work items:				
1. Unload fence rolls	9			297.5 rolls
2. Other	6			
		15		
G. Delays		11		
Total - other			77	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			84	

1/ Based on rolls hauled

(p) Sand roadway surfaces. Labor time expended on this operation amounted to 2.7 percent of TAWT in the three-county control area. By definition, time was charged only when maintenance crews were primarily engaged in sanding. Time expended by crews on incidental sanding during plowing or ice blading runs was charged as part of other operations.

Ice and hard-packed snow accumulated on roadway surfaces during most of the storms in the winter of 1959-60. Often, these accumulations could not be completely removed by plowing, blading or salting and conditions became hazardous for the traveling public. Maintenance crews began sanding as soon as it became apparent that other means would not keep roadway surfaces in good condition. This operation continued as needed until the ice and hard-packed snow either melted or could be removed. Most of the work was done at hills, curves, intersections, railroad crossings and bridges since experience showed that they were the most dangerous areas. Only rarely were entire road sections completely covered with sand.

Throughout the report, the terms "sand" and "sanding" have been used to describe this operation. In actual practice, cinders constituted a substantial proportion of abrasives used in the three-county control area and throughout Iowa. Availability and cost generally determined which type (sand or cinders) would be used in each county. In the control area, all abrasives were loaded, hauled to garages and stockpiled by State forces. In some other parts of the State, abrasives were loaded, hauled, and stockpiled under contracts. Most of this work was done during fall months but stockpiles were replenished during winter months if necessary. Calcium chloride was mixed with all abrasives stockpiled in the control area. The ratio of chloride to abrasives was about one-half sack per cubic yard or 1:50 based on volume. Most of the time, additional calcium chloride or rock salt was added at the time trucks were loaded for sanding. The ratio of chloride and salt to abrasives was 1:10 in many loads and a few were observed with a 1:2 ratio. It was estimated that the average ratio for all loads used in the control area was 1:20 based on volume.

Crews assigned to this operation usually consisted of one or two men and one truck equipped with a spreader bed. In a few cases, crews utilized trucks equipped with an end dump bed and a detachable tailgate spreader. These latter crews always included two men since it was often necessary for one man to feed the tailgate spreader by hand. All crews also utilized a front-end loader to obtain abrasives from stockpiles. At each work area, the spreader bed or tailgate spreader was put into operation and the truck driven ahead to distribute abrasives on the roadway surface. Sometimes only one lane was covered; at other times the truck was driven down the center of the roadway to cover both lanes. Only rarely were abrasives unloaded and spread by hand.

Production studies of this operation indicated that the operation was relatively efficient. However, men other than truck drivers did not perform any significant work unless the crews were using trucks equipped with an end dump bed and a tailgate spreader. In effect, the second man lost considerable time riding during haul, travel, and sanding. The average accomplishment per man could be greatly increased if the work was always performed by crews consisting of one man and a truck equipped with a spreader bed. However, it is recognized that until two-way radio becomes available, a second man may make some contribution to safety of the operation.

TABLE 165

SAND ROADWAY SURFACES — DISTRIBUTION OF 32 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Unload and spread sand by hand	1			8.6 cu yd 1,850 sq yd
2. Unload and spread sand w/truck spreader bed or tailgate spreader	13			8.8 cu yd 113,200 sq yd
3. Move ahead to new work area	29	43		2.8 cu yd 32,900 sq yd 1/
B. Supporting work items:				
1. Ride while sanding	5			
2. Other	4	9		
C. Delays — wait on cyclic work items		-		
D. Delays — other		3		
Total - worksite			55	2.2 cu yd 26,000 sq yd 1/
Other				
E. Travel to, from, or between worksites (including haul)		29		
F. Supporting work items		6		
G. Delays		8		
H. Non-supporting work items and delays		2		
Total — other			45	1.2 cu yd 14,300 sq yd 1/
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			87	

1/ Based on sand spread.

TABLE 166

SAND ROADWAY SURFACES — DISTRIBUTION OF 25 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Unload and spread sand with spreader bed or tailgate spreader	16			9.4 cu yd 121,100 sq yd
2. Move ahead to new work area	27			(21 mph)
		43		3.5 cu yd 45,100 sq yd 1/
B. Supporting work items		5		
C. Delays - wait on cyclic work items		-		
D. Delays — other		3		
Total — worksite			51	3.0 cu yd 39,100 sq yd 1/
Other				
E. Travel to, from, or between worksites (including haul)		27		(32 mph)
F. Supporting work items:				
1. Load sand	4			39.0 cu yd
2. Other	3	7		
G. Delays		14		
H. Non-supporting work items and delays		1		
Total — other			49	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			82	

1/ Based on sand spread.

TABLE 167

SAND ROADWAY SURFACES — DISTRIBUTION OF 3 HOURS NAWT FOR FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Other				
E. Travel to, from, or between worksites		-		
F. Supporting work items:				
1. Load sand and add salt or C_aCl_2	47			41.0 cu yd
2. Maneuver	14			
3. Other	4	65		
G. Delays		33		
H. Non-supporting work items and delays		2		
TOTAL			100	
Total work items on assigned operation (E + F)			64	

(q) Salt roadway surfaces. This operation accounted for 1.6 percent of labor TAWT in the three-county control area. By definition, time was charged only when men were primarily engaged in salting roadway surfaces. Time spent on incidental salting while engaged in plowing or ice blading runs was charged to other operations. Each year, the State designated a network of highways which would be salted during winter months. This network basically consisted of routes with an overall ADT of 2,000 or more but also included some isolated spurs which might otherwise require special runs for sanding, plowing or ice blading if they were not salted. The salting network was divided into a series of runs which extended between towns or major road intersections. County lines were ignored when establishing these runs in order to avoid abrupt changes in the condition of roadway surfaces at an isolated location. Most counties were responsible for at least one salt run; some had as many as five.

Designated routes in the control area were salted on numerous occasions during the winter of 1959-60. Many storms involved only sleet, freezing rain, or light snow. They were melted or turned into a slush by one or more applications of salt, and road surfaces were often kept clear by traffic action. Salt was also applied during the early stages of major storms which involved heavy snow. The snow was not melted to any great extent, but a layer of slush was formed next to the roadway surfaces which facilitated plowing or ice blading operations. Sometimes salt was also applied after a storm was over to loosen ice or hard-packed snow which had accumulated at certain locations. Salt was rarely used when the temperature was below 20° and falling. Normally, each foreman decided when and how often the salt runs assigned to his county would be covered. Often, they were handicapped in making decisions because of inadequate weather indicators and forecasts.

The rock salt used in this operation was a coarse bulk product weighing about 1,890 pounds per cubic yard. It was obtained under contract and shipped in commercial trucks. State forces unloaded these trucks and stockpiled the salt in a shed or other enclosed storage space.

Crews for this operation consisted of 1 or 2 men and a truck equipped with a spreader bed. A front-end loader was used to load the salt. Each crew normally handled one salt run about 20 miles long but sometimes had

Figure 38. Truck with spreader bed salting roadway surface.

two shorter runs. Trucks were often loaded with salt even before ascertaining that salting would be necessary since timing was a critical factor. Once the decision was made, crews traveled to the near end of their run and began salting. The truck was driven near the roadway centerline and both lanes covered in one application. During return travel to the garage, selected areas were sometimes given a second application.

Production studies indicate that only the truck driver performs any significant amount of productive work while engaged in this operation. Thus, on two-man crews, the second man loses a considerable amount of time riding during travel and salting. Accomplishment per man could be substantially increased if the crew always consisted of one man and a truck. However, it is recognized that until two-way radio becomes available, a second man may make some contribution to safety of the operation.

TABLE 168

SALT ROADWAY SURFACES —

DISTRIBUTION OF 24 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Unload and spread salt with truck spreader bed	33			17.3 two-lane mi
2. Unload and spread salt with truck spreader bed and plow with one-way plow	6			Salt-11.0 two-lane mi Plow-21.9 pass-mi
3. Move ahead to new work area	2	41		15.8 two-lane mi 1/
B. Supporting work items:				
1. Ride while salting	14			
2. Other	2	16		
C. Delays — wait on cyclic work item		-		
D. Delays — other		3		
Total — worksite			60	10.8 two-lane mi 1/
Other				
E. Travel to, from, or between worksites (including haul)		16		
F. Supporting work items:				
1. Load salt	4			
2. Other	3	7		
G. Delays:				
1. Service truck hoist	6			
2. Other	11	17		
H. Non-supporting work items and delays		2/		
Total — other			40	
TOTAL			100	6.5 two-lane mi 1/
Total work items on assigned operation (A + B + E + F)			80	

1/ Based on miles salted. 2/ 0.5 percent or less.

TABLE 169

SALT ROADWAY SURFACES —

DISTRIBUTION OF 18 HOURS NAWT FOR TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Unload and spread salt with spreader bed	43			17.3 two-lane mi
2. Unload and spread salt with spreader bed and plow with one-way plow	8			Salt-11.0 two-lane mi Plow-21.9 pass-mi
3. Move ahead to new work area	2	53		(26 mph) 15.8 two-lane mi 1/
B. Supporting work items		2		
C. Delays — wait on cyclic work item		-		
D. Delays — other		2		
Total — worksite			57	14.6 two-lane mi 1/
Other				
E. Travel to, from, or between worksites (including haul)		19		(30 mph)
F. Supporting work items:				
1. Load salt	5			34.2 tons 2/
2. Other	3	8		
G. Delays		16		
H. Non-supporting work items and delays		3/		
Total — other			43	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			82	

1/ Based on miles salted.
2/ Based on 1,890 lb/cu yd.
3/ 0.5 percent or less.

TABLE 170

SALT ROADWAY SURFACES —

DISTRIBUTION OF 1 HOUR NAWT FOR FRONT END LOADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		Performance (Avg per hour)
Other			
E. Travel to, from, or between worksites		-	-
F. Supporting work items:			
1. Load salt	83		34.1 cu yd 32.3 tons 1/
2. Other	15	98	
G. Delays		2	
TOTAL		100	
Total work items on assigned operation (E + F)		98	

1/ Based on 1,890 lb/cu yd.

(r) Remove ice from roadway surfaces and shoulders. Labor time expended on this operation totaled 1.1 percent of TAWT in the three-county control area. By definition, time was charged to this operation only when maintenance crews were primarily engaged in blading ice or hard-packed snow. Time for blading ice incidental to plowing, sanding or salting runs was charged to other operations. Ice and hard-packed snow accumulated on roadway surfaces on many occasions during the winter of 1959-60. Often, these accumulations could not be removed by salting or traffic action, and driving conditions became hazardous. When such situations developed, crews resorted to ice blading in order to keep roads in good condition.

The operation was usually performed by crews consisting of either one man and a motorgrader equipped with an underbody ice blade, or two men and a heavy duty truck equipped with four wheel drive and an underbody ice blade. On a few occasions, the heavy duty trucks were operated by only one man. The same general procedure was used with both types of equipment. At each work area, ice blades were lowered and a downward pressure applied by hydraulic cylinders while the motorgraders or trucks moved ahead in low gear. Accumulations of ice and hard-packed snow were broken up and peeled off roadway surfaces by a combination of downward pressure and abrasion. Sometimes, several passes were required to remove the entire accumulation in an area. The operation was usually carried out during the middle of the day because higher temperatures at that time softened ice and hard-packed snow and made removal easier. Also, the slow moving equipment presented less of a hazard to traffic due to better visibility.

Production studies indicate that it would be possible to increase production to some extent if all heavy duty trucks were operated by one-man crews. There was little difference between the productivity of motorgraders and trucks while actually blading. However, studied trucks spent some time on incidental plowing which reduced their worksite and NAWT production rates below those for studied motorgraders which concentrated on blading ice and hard-packed snow.

TABLE 171

REMOVE ICE FROM ROADWAY SURFACES AND SHOULDERS -
DISTRIBUTION OF 67 HOURS NAWT FOR MEN ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Blade ice with truck underbody blade	28			35,400 sq yd
2. Blade ice with motorgrader underbody blade	11			36,400 sq yd
3. Move ahead to new work area	16			
		55		24,900 sq yd 1/
B. Supporting work items:				
1. Ride while blading ice	7			
2. Other	5			
		12		
C. Delays — wait on cyclic work item		-		
D. Delays — other		7		
Total - worksite			74	18,500 sq yd 1/
Other				
E. Travel to, from, or between worksites		5		
F. Supporting work items		4		
G. Delays		11		
H. Non-supporting work items and delays		6		
Total — other			26	
TOTAL			100	13,800 sq yd 1/
Total work items on assigned operation (A + B + E + F)			76	

1/ Based on area bladed.

TABLE 172

REMOVE ICE FROM ROADWAY SURFACES AND SHOULDERS – DISTRIBUTION OF 39 HOURS NAWT FOR HEAVY DUTY TRUCKS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		Performance (Avg per hour)
Worksite			
A. Cyclic work items:			
1. Blade ice with underbody blade	44		35,400 sq yd
2. Move ahead to new work area	18		(13 mph)
	62		23,900 sq yd 1/
B. Supporting work items	4		
C. Delays – wait on cyclic work item	-		
D. Delays – other	8		
Total – worksite		74	20,700 sq yd 1/
Other			
E. Travel to, from, or between worksites	5		(20 mph)
F. Supporting work items	4		
G. Delays	12		
H. Non-supporting work items and delays	5		
Total – other		26	
TOTAL		100	
Total work items on assigned operation (A + B + E + F)		75	

1/ Based on area bladed

TABLE 173

REMOVE ICE FROM ROADWAY SURFACES AND SHOULDERS – DISTRIBUTION OF 9 HOURS NAWT FOR MOTORGRADERS ASSIGNED TO THE OPERATION

Location and item	Percent of NAWT		Performance (Avg per hour)
Worksite			
A. Cyclic work items:			
1. Blade ice with underbody blade	80		36,400 sq yd
B. Supporting work items	1/		
C. Delays – wait on cyclic work item	-		
D. Delays – other	1		
Total – worksite		81	36,200 sq yd 2/
Other			
E. Travel to, from, or between worksites	2		(14 mph)
F. Supporting work items	5		
G. Delays	12		
Total – other		19	
TOTAL		100	
Total work items on assigned operation (A + B + E + F)		87	

1/ 0.5 percent or less.
2/ Based on area bladed.

(s) Paint centerlines and edgelines on pavements. Labor time expended on this operation in the three-county control area amounted to 1.6 percent of TAWT. In accordance with policy, centerlines, no passing zone lines, and edgelines in all paved road sections were painted once each year. Some main routes were painted twice a year. White dashed lines were painted along the centerlines of two-lane roadways and between inner and outer lanes on four-lane roadways. The dashes were 4½ inches wide, 15 feet long, and spaced 25 feet apart. Solid yellow lines, 3½ inches wide, were used to mark no passing zones. They were painted adjacent to centerlines on roadways where needed. Edgelines were relatively new in Iowa and were used only at particularly hazardous locations such as approaches to narrow bridges, and sharp curves. They were solid white lines 4 inches wide and of variable length. All three types of lines were reflectorized with glass beads to provide maximum visibility.

The centerline and edgeline painting operation was under the direction of district foremen who scheduled the work and supervised district paint crews. Centerlines and no passing zone lines on main routes received first priority. After they were completed, centerlines and no passing lines were painted on minor routes. Finally, edgelines were painted on all routes. Under normal conditions work was completed in all road sections, except those under construction, by September 1.

The operation was usually carried out in four steps. They were (1) mark centerlines and no passing zones; (2) clean dirt and debris from pavements; (3) paint centerlines and no passing zone lines; and (4) paint edgelines. The first step was performed by crews from local garages days or even weeks in advance of step 3. One or two men and a truck were sent out to relocate lines and paint index marks in road sections where they had been obliterated by traffic and weather. Step 2 was carried out only when pavements were unusually dirty. It was done by a group of 2 to 4 men from local garages. They utilized a truck, power broom and, sometimes, a grader to clean off mud and debris. Such work was usually done several days in advance of step 3, but on some occasions was done on the same day.

Step 3 was carried out by a district paint crew consisting of 11 men, a paint truck, a flatbed "nurse" truck, 2 pickups and 5 automobiles. The paint truck was equipped with paint tanks, glass bead bin, air compressor, pumps, sprayer and a two-way intercom system. The flatbed "nurse" truck carried a pump, barrels of paint, and sacks of glass beads. The district crew sometimes included two more men and a special acid truck equipped with tanks, pump and sprayer. Often, this district crew was augmented by men, trucks, and pickups from local garages. The various work items involved in step 3 were normally carried out simultaneously by groups of men spread out over several miles of road. The first group consisted of two flagmen from the district crew equipped with two automobiles. They stopped all public traffic, passed out leaflets which described the operation, and instructed drivers to stay off freshly painted lines. When new concrete pavements were being painted for the first time, the next group consisted of two men and a special acid truck. They removed curing compound from the concrete with a dilute acid solution. The next group in line operated the paint truck. An experienced man from the district crew drove while another controlled painting and beading equipment. Pavements were given a final cleaning by an air nozzle attached to the truck's front guide boom. A unit attached to the rear of the truck simultaneously sprayed white centerlines, yellow no passing zone lines, and applied glass beads. Two men from the district crew followed close behind the paint truck in a pickup. One man drove while the other sat in a special rear-mounted seat and put out red warning blocks. The blocks were picked up by a similar two-man group operating several miles behind the paint truck. The final group consisted of two flagmen from the district paint crew equipped with two automobiles. One man stopped all traffic on the road being painted; the other stopped traffic on intersecting roads. Both men passed out leaflets, and instructed traffic to stay off freshly painted lines. Sometimes, additional flagmen were needed to cover intersecting roads, particularly in urban areas. Local garages supplied the extra men and vehicles for their transportation. One man from the district crew did not work as part of the previously described groups. His task was

Figure 39. Paint truck putting down centerlines.

Figure 40. Paint truck and pickup truck used for placing warning blocks.

to operate the flatbed "nurse" truck hauling paint, glass beads, and extra warning blocks between garages and worksites or between worksites. However, this man did act as a spare flagman on many occasions.

The fourth and final step in this operation was painting edgelines. It was normally performed only after step 3 had been completed throughout a district. District paint crews handled practically all of the work and generally used about the same men and equipment as were used for step 3. However, there were some differences in procedures due to the fact that worksites were scattered and relatively small in size.

Crews engaged in this operation were usually quite conscientious about safety. Trucks were equipped with lights and warning signs. Most of the time a sufficient number of flagmen were available to provide good control over public traffic. The instructional leaflets passed out to drivers were particularly helpful.

Production studies were conducted on only steps 1, 2, and 3 of the operation. The data have been combined to show time utilization for these three steps. Step 4 was not studied but time utilization would probably be quite similar. The entire operation appeared to be well organized with a favorable balance between labor and equipment. This can probably be attributed to the fact that most of the work was done by specialized crews under the direction of a full time supervisor. Production rates obtained on studies may not reflect a true average for the operation since some of the crews observed were working under relatively adverse conditions. However, even under favorable conditions production per man-hour might be increased to some extent. Reduction of certain types of delays such as waits on hauling materials is possible. Also, the tasks of putting out and picking up warning blocks should be mechanized so that each item could be done by one man.

TABLE 174

PAINT CENTERLINES AND EDGELINES ON PAVEMENTS — DISTRIBUTION OF 164 HOURS NAWT FOR MEN ASSIGNED TO MARK PAVEMENTS, CLEAN PAVEMENTS, AND PAINT CENTERLINES OR NO PASSING LINES

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Blade dirt with truck and towed grader	1	4.6 two-lane mi
2. Broom dirt with truck and power broom	1	2.2 two-lane mi
3. Apply acid with sprayer	1/	4.8 two-lane mi
4. Paint index marks by hand	3	4.5 two-lane mi
5. Paint no-passing zone markers by hand	1/	20 posts
6. Paint centerlines and no passing lines with sprayer	3	4.7 two-lane mi
7. Put out or pick up warning blocks	6	2.2 two-lane mi
8. Move ahead to new work area	2	
	16	0.92 two-lane mi
B. Supporting work items:		
1. Flag or direct public traffic	15	
2. Other	9	
	24	
C. Delays - wait on cyclic work item	2	
D. Delays - other:		
1. Wait on haul glass-beads	7	
2. Instructions	6	
3. Other	5	
	18	
Total - worksite	60	0.25 two-lane mi 2/
Other		
E. Travel to, from, or between worksites	26	
F. Supporting work items	5	
G. Delays	8	
H. Nonsupporting work items and delays	1	
Total - other	40	
TOTAL	100	0.15 two-lane mi 2/
Total work items on assigned operation (A + B + E + F)	71	

1/ 0.5 percent or less. 2/ Based on miles covered.

TABLE 175

PAINT CENTERLINES AND EDGELINES ON PAVEMENTS – DISTRIBUTION OF 16 HOURS NAWT FOR PAINT TRUCKS ASSIGNED TO PAINT CENTERLINES OR NO PASSING LINES

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Paint centerline with sprayer	16			9.5 two-lane mi
2. Move ahead to new work area	1/			(30 mph)
		16		9.4 two-lane mi 2/
B. Supporting work items		5		
C. Delays — wait on cyclic work items		3		
D. Delays — other:				
1. Wait on haul glass beads	9			
2. Parked while men work	5			
3. Other	8			
		22		
Total – worksite			46	3.2 two-lane mi 2/
Other				
E. Travel to, from, or between worksites		31		(33 mph)
F. Supporting work items		10		
G. Delays		13		
Total — other			54	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			62	

1/ 0.5 percent or less.
2/ Based on miles covered.

TABLE 176

PAINT CENTERLINES AND EDGELINES ON PAVEMENTS – DISTRIBUTION OF 94 HOURS NAWT FOR OTHER TRUCKS, PICKUPS AND AUTOS ASSIGNED TO MARK PAVEMENTS, CLEAN PAVEMENTS, AND PAINT CENTERLINES OR NO PASSING LINES

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Blade dirt with towed grader	1			9.1 two-lane mi
2. Broom dirt with power broom	1			4.4 two-lane mi
3. Apply acid with sprayer	1/			9.9 two-lane mi
4. Put out and pickup warning blocks	4			5.9 two-lane mi
5. Move ahead to new work area	3			(12 mph)
		9		
B. Supporting work items		6		
C. Delays – wait on cyclic work item		1		
D. Delays – other:				
1. Parked while men work	34			
2. Other	9			
		43		
Total – worksite			59	
Other				
E. Travel to, from, or between worksites		27		(31 mph)
F. Supporting work items		4		
G. Delays		9		
H. Non-supporting work items and delays		1		
Total – other			41	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			46	

1/ 0.5 percent or less.

TABLE 177

PAINT CENTERLINES AND EDGELINES ON PAVEMENTS – DISTRIBUTION OF 5 HOURS NAWT FOR TOWED GRADERS ASSIGNED TO CLEAN PAVEMENTS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Blade dirt		8		9.1 two-lane mi
B. Supporting work items		3		
C. Delays – wait on cyclic work item		-		
D. Delays – other:				
1. Parked while men work	38			
2. Other	5			
		43		
Total – worksite			54	1.4 two-lane mi 1/
Other				
E. Travel to, from, or between worksites		30		(23 mph)
F. Supporting work items		8		
G. Delays		8		
Total — other			46	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			49	

1/ Based on miles cleaned.

TABLE 178

PAINT CENTERLINES AND EDGELINES ON PAVEMENTS – DISTRIBUTION OF 3 HOURS NAWT FOR POWER BROOMS ASSIGNED TO CLEAN PAVEMENTS

Location and item	Percent of NAWT			Performance (Avg per hour)
Worksite				
A. Cyclic work items:				
1. Broom dirt		32		4.4 two-lane mi
B. Supporting work items		5		
C. Delays – wait on cyclic work items		-		
D. Delays – other		4		
Total – worksite			41	3.4 two-lane mi 1/
Other				
E. Travel to, from, or between worksites		37		(33 mph)
F. Supporting work items		7		
G. Delays		15		
Total – other			59	
TOTAL			100	
Total work items on assigned operation (A + B + E + F)			81	

1/ Based on miles cleaned.

(t) Erect, repair, replace, or paint signs and guideposts. Labor time expended on this operation amounted to 1.8 percent of TAWT in the three-county control area. Signs, signposts, and guideposts were numerous on most road sections. An inventory disclosed that rural sections averaged 11 signs, 9 signposts, and 10 guideposts per mile. In urban areas, sections averaged 52 signs, 43 signposts, and 2 guideposts per mile. There were also many reflectors which were not counted although any work involving them was considered to be part of this operation. Maintenance crews performed many different types of work on these installations. New signs, reflectors, and posts were erected; existing signs, reflectors, and posts were replaced when they became damaged or illegible; posts were realigned when they became crooked; and guideposts were painted periodically.

Crews assigned to this operation usually consisted of 2 or 3 men and a truck or pickup. Most work was performed with hand tools but sometimes crews utilized electric power augers or tractors equipped with power augers. When these power augers were used, the crew almost always included three men. The exact procedure followed at each worksite depended on the type of work being done, crew size, and tools available.

Figure 41. Tractor with power auger digging hole for guidepost.

Figure 42. Digging hole for sign post by hand.

New signposts and guideposts were erected by two- and three-man crews. Two-man crews usually dug post holes by hand. They then installed posts and backfilled them with aggregate. A simple wood template and carpenter's level were used to position signposts at the correct distance and elevation from roadway surfaces. Three-man crews followed the same procedures for erecting new signposts and guideposts but usually partially dug post holes with power augers. New signs and reflectors were sometimes erected by the same crews which erected posts. Signs were installed on posts before they were installed in post holes; reflectors were installed after backfilling. In other cases, signs and reflectors were erected separately by two-man crews. Replacement of existing signs, reflectors, signposts, and guideposts was done by two-man crews. They removed existing installations and put in new ones using the same procedures described for erecting new signs, etc. In many cases, only posts needed replacement, so all existing signs or reflectors were transferred to new posts. Usually two-man crews handled repair work. They straightened bent signs and crooked posts, backfilled loose posts, replaced broken bolts, and took care of other minor work. Guideposts were sometimes painted by one man, but often there were two men on the crews which handled this work.

Production studies were made on crews engaged in several different types of sign work. Study data have been presented in four groups to facilitate comparisons. These studies showed that crews of 2 or 3 men lost 35 to 50 percent of their NAWT due to travel, move ahead and waits while other men worked. Observations and analyses indicate that many types of sign work could be physically performed by one man. If one-man crews were used for most work there would be a substantial decrease in the time lost on travel and delays, and production per man could increase to the point where one man could install, replace, or repair 70 to 85 percent as many signs and posts per day as the average 2- or 3-man crew.

TABLE 179
ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 79 HOURS NAWT FOR MEN ASSIGNED TO ERECT NEW SIGNPOSTS AND GUIDEPOSTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Dig post hole by hand	11	5.6 posts
2. Dig post hole with electric power auger 1/	1	16.1 posts
3. Dig post hole with tractor mounted power auger 1/	1	30.0 posts
4. Install post in hole	4	17.0 posts
5. Backfill post by hand	5	17.6 posts
6. Tamp backfill by hand	4	24.1 posts
7. Maneuver to dig post hole with tractor-mounted auger	1	
8. Move ahead to new work area	7	
	34	2.6 posts 2/
B. Supporting work items	11	
C. Delays — wait on cyclic work item:		
1. Wait on dig post hole	11	
2. Other	1	
	12	
D. Delays — other	12	
Total — worksite	69	1.3 posts 2/
Other		
E. Travel to, from, or between worksites	20	
F. Supporting work items	3	
G. Delays	7	
H. Non-supporting work items and delays	1	
Total — other	31	
TOTAL	100	0.9 posts 2/
Total work items on assigned operation (A + B + E + F)	68	

1/ These holes were partially dug by hand. 2/ Based on posts erected.

TABLE 180
ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 33 HOURS NAWT FOR TRUCKS AND PICKUPS ASSIGNED TO ERECT NEW SIGNPOSTS AND GUIDEPOSTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	6	(22 mph)
B. Supporting work items:		
1. Load or unload posts	8	
2. Load and unload men	5	
3. Other	3	
	16	
C. Delays — wait on cyclic work item	-	
D. Delays — other:		
1. Parked while men work	47	
2. Other	2	
	49	
Total — worksite	71	3.0 posts 1/
Other		
E. Travel to, from, or between worksites	18	(31 mph)
F. Supporting work items	4	
G. Delays	7	
H. Non-supporting work items and delays	2/	
Total — other	29	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	44	

1/ Based on posts erected.
2/ 0.5 percent or less.

TABLE 181
ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS - DISTRIBUTION OF 9 HOURS NAWT FOR TRACTORS ASSIGNED TO ERECT NEW SIGNPOSTS AND GUIDEPOSTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Dig post holes with power auger 1/	12	30.0 holes
2. Maneuver to dig post holes	5	
3. Move ahead to new work area	10	(17 mph)
	27	13.6 holes 2/
B. Supporting work items	4	
C. Delays — wait on cyclic work items:		
1. Wait on dig post hole by hand	4	
2. Wait on install post	22	
3. Other	2	
	28	
D. Delays — other	14	
Total — worksite	73	5.0 holes 2/
Other		
E. Travel to, from, or between worksites	8	(14 mph)
F. Supporting work items	2	
G. Delays	17	
Total — other	27	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	41	

1/ These holes were partly dug by hand. 2/ Based on holes actually dug.

TABLE 182

ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 9 HOURS NAWT FOR MEN ASSIGNED TO ERECT NEW SIGNS AND REFLECTORS (ON PREVIOUSLY ERECTED POSTS)

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Install sign on post	5	12.9 signs
2. Install reflector on post	11	113 reflectors
3. Walk ahead to new work area	5	
4. Move ahead to new work area	10	45.6 signs and reflectors 1/
	31	
B. Supporting work items	9	
C. Delays — wait on cyclic work item	-	
D. Delays — other	6	
Total — worksite	46	29.1 signs and reflectors 1/
Other		
E. Travel to, from, or between worksites	30	
F. Supporting work items	15	
G. Delays	8	
H. Non-supporting work items and delays	1	
Total — other	54	
TOTAL	100	13.3 signs and reflectors 1/
Total work items on assigned operation (A + B + E + F)	85	

1/ Based on signs plus reflectors erected.

TABLE 184

ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 23 HOURS NAWT FOR MEN ASSIGNED TO ERECT NEW SIGNS AND SIGNPOSTS AT SAME TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Dig post hole by hand	11	5.7 holes
2. Install post in hole	2	30.0 posts
3. Backfill post by hand	2	38.1 posts
4. Tamp backfill by hand	1	56.0 posts
5. Install sign on post	6	8.4 signs
6. Walk ahead to new work area	1/	
7. Move ahead to new work area	5	
	27	2.2 posts 2/
B. Supporting work items	4	
C. Delays — wait on cyclic work item	5	
D. Delays — other	3	
Total — worksite	39	1.6 posts 2/
Other		
E. Travel to, from, or between worksites	41	
F. Supporting work items	7	
G. Delays	10	
H. Non-supporting work items and delays	3	
Total — other	61	
TOTAL	100	0.6 posts 2/
Total work items on assigned operation (A + B + E + F)	79	

1/ 0.5 percent or less. 2/ Based on posts erected.

TABLE 186

ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 88 HOURS NAWT FOR MEN ASSIGNED TO REPAIR OR REPLACE SIGNS, SIGNPOSTS AND GUIDEPOSTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Dig post hole by hand	3	6.0 holes
2. Dig post hole with electric auger 1/	2/	36.0 holes
3. Install post in hole	3	10.2 posts
4. Backfill post by hand	3	16.4 posts
5. Tamp backfill by hand	1	47.1 posts
6. Remove old post by hand or with truck bed	1	6.3 posts
7. Remove old sign from post	3	22.5 signs
8. Install new sign on post	5	24.0 signs
9. Re-position existing signs	3	6.0 signs
10. Straighten existing posts	1	21.1 posts
11. Walk ahead to new work area	2/	
12. Move ahead to new work area	7	
	30	
B. Supporting work items	7	
C. Delays — wait on cyclic work items	2	
D. Delays — other	6	
Total - worksite	45	
Other		
E. Travel to, from, or between worksites	26	
F. Supporting work items	10	
G. Delays	16	
H. Nonsupporting work items and delays	3	
Total — other	55	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	73	

1/ These holes were partially dug by hand. 2/ 0.5 percent or less.

TABLE 183

ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 9 HOURS NAWT FOR TRUCKS AND PICKUPS ASSIGNED TO ERECT NEW SIGNS AND REFLECTORS (ON PREVIOUSLY ERECTED POSTS)

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	10	(28 mph)
B. Supporting work items	4	
C. Delays - wait on cyclic work item	-	
D. Delays - other:		
1. Parked while men work	29	
2. Other	2	
	31	
Total - worksite	45	62.3 signs and reflectors 1/
Other		
E. Travel to, from, or between worksites	30	(32 mph)
F. Supporting work items	3	
G. Delays	21	
H. Nonsupporting work items and delays	1	
Total - other	55	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	47	

1/ Based on signs erected.

TABLE 185

ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 10 HOURS NAWT FOR TRUCKS AND PICKUPS ASSIGNED TO ERECT SIGNS AND SIGNPOSTS AT SAME TIME

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Move ahead to new work area	5	(16 mph)
B. Supporting work items	4	
C. Delays — wait on cyclic work item	-	
D. Delays — other:		
1. Parked while men work	29	
Total — worksite	38	4.6 posts 1/
Other		
E. Travel to, from or between worksites	41	(30 mph)
F. Supporting work items	7	
G. Delays	12	
H. Non-supporting work items and delays	2	
Total — other	62	
TOTAL	100	
Total work items on assigned operation (A + B + E + F)	57	

1/ Based on posts erected.

TABLE 187

ERECT, REPAIR, REPLACE OR PAINT SIGNS AND GUIDEPOSTS — DISTRIBUTION OF 42 HOURS NAWT FOR TRUCKS AND PICKUPS ASSIGNED TO REPAIR OR REPLACE SIGNS, SIGNPOSTS AND GUIDEPOSTS

Location and item	Percent of NAWT	Performance (Avg per hour)
Worksite		
A. Cyclic work items:		
1. Remove old post with bed	1/	
2. Move ahead to new work area	7	(32 mph)
	7	
B. Supporting work items	7	
C. Delays — wait on cyclic work item	-	
D. Delays — other:		
1. Parked while men work	32	
2. Other	1	
	33	
Total - worksite	47	
Other		
E. Travel to, from or between worksites	26	(29 mph)
F. Supporting work items	7	
G. Delays	17	
H. Non-supporting work items	3	
Total — other	53	
TOTAL	100	
Total work items on assigned operation ((A + B + E + F)	47	

1/ 0.5 percent or less.

Section E

MANAGEMENT STUDIES

1. Background

Management functions involved in maintenance operations were studied by the special study group. These functions included (1) organizational structure, (2) staffing, (3) policies, (4) controls, and (5) utilization of supervisory personnel. These investigations were made by several management specialists who used recognized management study techniques.

Data and information were obtained from reviews of State records, publications, questionnaires, and interviews. The material obtained formed the basis for several of the conclusions and recommendations in the study report.

2. Utilization of supervisory time

One of the management investigations covered utilization of supervisory time. Since resident maintenance engineers comprised the largest single group of supervisors (above the foreman level), arrangements were made to sample the distribution of their TAWT. Each resident engineer was asked to keep a relatively detailed account of his time for 6 different weeks during a six-month period. The data submitted were averaged and summarized. Table 188 presents the results of this survey.

3. Management questionnaire

A management questionnaire was prepared and sent to a number of engineers having responsibility for maintenance operations. There were 68 questions on this questionnaire covering policy, operating procedures, personnel, and other matters. It should be pointed out that many of the questions were open to interpretation, and part of the variety of answers given to some of the questions can be attributed to individual opinion as to the response desired. Nevertheless, there existed a considerable difference of opinion as to who had responsibility for what operations and functions. It points up the need for adequate job guides and an up-to-date policy manual.

Table 189 gives 22 out of the total of 68 questions asked. Listed beside each question are 5 of the answers received from a total of 21 recipients who completed the form. Although each square represents an answer from one individual, all of the answers in a column are not necessarily those of one person.

TABLE 188

DISTRIBUTION OF WEEKLY TAWT FOR RESIDENT MAINTENANCE ENGINEERS 1/

Location and activity	Average for district						Average for State	Range for individual RME's			
	1	2	3	4	5	6		Average week		Single week	
								Low 1/	High 2/	Low 1/	High 2/
	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours	Hours
A. By location											
1. Residency office	25.4	22.5	20.7	20.9	24.3	20.6	22.6	16.7	28.9	9.0	41.0
2. All other	18.8	20.3	22.1	24.1	23.8	30.3	23.0	13.8	39.1	8.0	51.3
TAWT	44.2	42.8	42.8	45.0	48.1	50.9	45.6				
B. By activity 3/											
1. Paperwork	23.0	20.9	18.8	19.6	23.6	19.1	21.1	14.4	29.5	7.0	43.5
2. Travel	7.0	5.4	8.2	9.1	7.8	10.0	7.8	3.5	14.1	-	22.2
3. Inspect work or worksites:											
a. Alone	6.6	9.2	8.5	6.6	9.6	15.9	9.1	3.8	23.9	-	41.0
b. With subordinates (foremen etc.)	0.7	0.6	0.2	1.5	1.1	0.2	0.8	-	3.7	-	8.5
c. With other State personnel	0.2	1.3	-	0.5	0.6	0.4	0.5	-	4.6	-	16.8
4. Personal contacts 4/											
a. With superiors (Division engineers etc.)	1.0	0.5	1.3	1.5	0.8	0.4	0.9	-	2.8	-	6.0
b. With subordinates (foremen etc.)	3.4	2.2	2.8	3.3	2.4	1.7	2.7	0.5	6.3	-	18.2
c. With other State personnel	1.3	0.9	1.1	1.0	1.0	1.0	1.0	-	2.5	-	6.0
d. With city and county officials	0.2	0.4	0.4	0.4	0.2	1.3	0.5	-	2.0	-	6.5
e. With public	0.7	1.2	1.0	0.6	0.7	0.5	0.8	-	4.0	-	5.6
5. All other	0.1	0.2	0.5	0.9	0.3	0.4	0.4	-	1.8	-	9.2
TAWT	44.2	42.8	42.8	45.0	48.1	50.9	45.6				
Access control (included in above items)	4.4	4.3	4.0	2.2	2.9	3.7	3.7	0.4	8.5	-	16.0

1/ Data covering partial weeks were eliminated from the sample.

2/ The hours shown for a separate item in this column were reported by a single RME, except for those items where no time is indicated. Thus, the items cannot be added to obtain a weekly total.

3/ The time shown for each activity includes work items and associated major or minor delays.

4/ In addition to inspections.

TABLE 189

SELECTED RESPONSES TO MANAGEMENT QUESTIONNAIRE

Selected Questions	Action 1/	Selected Answers 2/				
Postpone maintenance betterment work in anticipation of reconstruction.	A	-	Dist. Engr.	RME	Dist. Engr.	Foreman
	B	Dist. Engr.	Chief Engr.	Dist. Engr.	Maint. Engr.	RME
	C	Maint. Engr.	Commission	Maint. Engr.	Div. of Engr.	Dist. Engr.
Give engineering supervision to the statewide force of District Maintenance Engineers.	A	-	Staff of M. E.	Dist. Engr.	-	DME
	B	-	Asst. M. E.	Central Office	-	Dist. Engr.
	C	Maint. Engr.	Maint. Engr.	Engr. Director	Asst. M. E.	Maint. Engr.
Give engineering supervision to Division Maintenance Engineers.	A	-	DME	RME	DME	-
	B	-	Dist. Engr.	Dist. Engr.	Dist. Engr.	-
	C	Dist. Engr.	Maint. Engr.	Central Office	Maint. Engr.	DME
Develop the annual maintenance program, select the force account and the contract work, and prepare an appropriate budget request for a statewide highway system.	A	Maint. Engr.	DME	Maint. Engr.	Dist. Engr.	-
	B	Chief Engr.	Dist. Engr.	Auditor	Maint. Engr.	-
	C	Commission	Maint. Engr.	Chief Engr.	Commission	Maint. Engr.
Have full responsibility for the maintenance of a system of highways within a District of 10 to 20 counties.	A	-	RME	Dist. Engr.	Foreman	RME
	B	-	DME	Maint. Engr.	RME	Dist. Engr.
	C	Dist. Engr.	Maint. Engr.	Chief Engr.	Dist. Engr.	Maint. Engr.
Give approval to city and village sign and signal maintenance contracts.	A	RME	Dist. Engr.	RME	(3/)	Dist. Engr.
	B	DME	Maint. Engr.	Dist. Engr.	(3/)	T & H Plan. Engr
	C	Maint. Engr.	Commission	Maint. Engr.	(3/)	Commission
Give approval to county, city, and village agreements for local road maintenance by the State.	A	RME	RME	Dist. Engr.	-	(3/)
	B	DME	Dist. Engr.	Maint. Engr.	-	(3/)
	C	Maint. Engr.	Maint. Engr.	Commission	DME	(3/)
Give approval to city and village agreements for maintenance of trunk routes.	A	Dist. Engr.	-	DME	RME	-
	B	Maint. Engr.	-	Maint. Engr.	DME	-
	C	Commission	-	Commission	Maint. Engr.	DME
Supervise the mechanical repairs including major overhauls.	A	County Mech.	Traveling Mech.	County Mech.	Foreman	Mechanic
	B	Dist. Mech.	RME	Dist. Mech.	RME	-
	C	Supt. of P & E	Dist. Engr.	Dist. Engr.	Dist. Mech.	DME
Determine number of mechanics, stock clerks, and other shop personnel to be employed, their location and org.	A	RME 4/	Supt. of P & E	Dist. Mech.	Supt. of P & E	RME
	B	Dist. Engr. 4/	Maint. Engr.	Supt. of P & E	-	DME
	C	Maint. Engr. 4/	Commission	Dir. of Services	Dir. of Services	Maint. Engr.
Make determination on pieces of equipment to be purchased and their location.	A	Dist. Engr.	Dist. Mech.	RME	RME	RME
	B	Maint. Engr.	DME	Dist. Engr.	DME	DME
	C	Chief Engr.	Maint. Engr.	Maint. Engr.	DME	Maint. Engr.
Make determination as to the number of foremen to be appointed, their jurisdictions, and the line of command.	A	-	DME	Maint. Engr.	RME	RME
	B	Maint. Engr.	Maint. Engr.	Personnel	Dist. Engr.	DME
	C	Chief Engr. & Com	Director of Engr.	Commission	Maint. Engr.	Dist. Engr.
Recommend or approve mild disciplinary actions.	A	-	RME	Foreman	Foreman	Foreman
	B	-	Dist. Engr.	RME	RME	-
	C	Foreman (2 days suspension) 5/	Maint. Engr.	Dist. Engr.	DME	RME
Within statewide policy, decide on extensiveness and frequency of roadside mowing within a district.	A	-	Dist. Engr.	Foreman	-	RME
	B	-	-	RME	-	-
	C	Dist. Engr.	Maint. Engr.	Dist. Engr.	Foreman	-
Determine whether storage garages are to be heated, provided with grease pits, etc.	A	-	Foreman	Supt. of P & E	RME	DME
	B	Dist. Engr.	RME	-	DME	Maint. Engr.
	C	Maint. Engr.	DME	Maint. Engr.	Dist. Engr.	Commission
Determine when equipment is to be traded or declared obsolete.	A	Dist. Mech.	Dist. Mech.	RME	Dist. Mech.	Dist. Mech.
	B	Dist. Engr.	RME	Traveling Mech.	RME	DME
	C	Maint. Engr.	P & E Engr.	Supt. of P & E & Maint. Engr.	P & E Engr.	P & E Engr.
Personally direct emergency work during and following extensive flooding of roadways.	A	RME	Foreman	-	-	-
	B	-	RME	-	-	-
	C	Maint. Engr.	DME	Dist. Engr.	Foreman	RME
Make final acceptance inspection for maintenance contract work.	A	-	RME	-	RME	-
	B	-	Dist. Engr.	-	Dist. Engr.	-
	C	RME	Commission or Maint. Engr.	DME	Maint. Engr.	Dist. Engr.
Determine adequacy of upkeep of traffic signs, markings, guard rails, lighting, signals, etc.	A	-	RME	Foreman	-	-
	B	-	DME	-	-	-
	C	Maint. Engr.	DME	RME	Dist. Engr.	T & H Plan. Engr
Erect stop sign where county road intersects State highway.	A	-	RME	Foreman	-	Foreman
	B	-	Dist. Engr.	RME	-	RME
	C	Foreman	Dist. Engr.	Hwy. Plan. Engr.	Hwy. Com.	DME
Temporarily close roads for repairs.	A	-	RME	Foreman	Foreman	Foreman
	B	Foreman	DME	RME	RME	RME
	C	RME	Dist. Engr.	Central Office	DME	DME
Designate temporary no passing zone.	A	-	Foreman	Foreman	-	-
	B	-	RME	-	-	-
	C	Foreman	T & S Engr.	RME	T & S Engr.	Dist. Engr.

1/ A = Initial recommendation or actions; B = Recommend approval; and C = Final decision.

2/ All answers in a column are not necessarily those from the same individual.

3/ No contracts with cities for signal maintenance and no contracts for local road maintenance, respectively.

4/ Ames Shop: Superintendent of Property and Equipment, Maintenance Engineer and Commission, respectively.

5/ Resident Maintenance Engineer makes final decision in cases of extended suspensions.

Section F

SPECIAL STUDIES

After early results from the field study program began to come into the study headquarters office, it became increasingly clear that special studies would be required of a variety of subjects to provide the overall picture of maintenance operations that was desired. This need continued throughout the field study period and on into the analysis period. Some of the special studies were made by consultants while others were by members of the study group.

It is believed that the information developed from some of these special studies will be of maximum benefit to those concerned with maintenance by leaving the reports in their original form. For this reason the identity of each report and its author is retained. The following five reports are presented in this section:

1. Study of Property and Equipment Division Shop — Ames, Iowa, by William C. Arnwine

2. Planning for the Operation Seal Bituminous and Concrete Pavements by Study Group Staff

3. Span of Control as it Applies to the Maintenance Foreman by Harold A. Cowles

4. Study of Work Efficiency During Overtime Periods by Harold A. Cowles

5. Analysis of Accidents Involving Field Maintenance Employees by H. A. Padgett

STUDY OF
PROPERTY AND EQUIPMENT DIVISION SHOP—AMES, IOWA

by

William C. Arnwine

SUMMARY

The results of this study showed the personal activity rating [1] of the property and equipment shop employees to be 77.4 percent. The percent of total time devoted to productive work (excluding supporting work) was 64.6 percent.

A comparison with the same type of activity in one of the nation's leading manufacturers show that the property and equipment shop employees had a higher personal activity rating than the maintenance employees of the manufacturing company.

Analysis of these data indicates that a future personal activity rating of 89.3 percent could be obtained. Achievement of this goal is directly dependent upon the adoption of an aggressive program which results in decreasing the time spent on walking, procurement of tools, and materials, preparation and cleanup, and nonproductive elements.

OBJECTIVES

Three objectives were established for this special study.

1. To determine the personal activity rating of the property and equipment division shop employees.
2. To establish a base point to which future performances can be related.
3. To point out the most profitable areas to be investigated to gain maintenance improvement.

PROCEDURE

This study was designed to measure the personal activity rating of the property and equipment shop personnel through use of the work sampling technique. It does not take into account the actual effectiveness of the work methods being used or the rate at which work is being accomplished.

1/ Personal activity ratings are described in the paragraphs devoted to discussion.

The rating reflects a measure of the time spent by the shop personnel on the job plus additional allowances for essential supplemental work, including necessary walking time.

Personnel covered

This study covered all the personnel in the equipment repair shop, the wood sign shop, the property and equipment warehouse, and the service garage, a total of 54 men. Sampling routes were so designed that the majority of the employees were covered on each trip. The number and employee group of personnel studied are shown in the following tabulation.

No.	Employee group	No.	Employee group
12	Engine mechanics	4	Supervisors
5	Car - bus mechanics	4	General store clerks
3	Machinists (mechanics)	1	Equipment parts clerk
4	Utilities mechanics	4	Store warehouse clerks
2	Miscellaneous laborers	6	Paint shop employees
1	Tool room clerk	4	Carpenter shop employees
1	Office clerk	3	Service garage employees
		54	Total

Method of sampling

All samples, or observations, were taken by Iowa maintenance study personnel. The activity of studied personnel was divided first into three broad categories which are essentially the same as used for production studies and then further into 13 elements. A complete description of the elements used are as follows:

1. Productive work items

(a) Working. A man is applying physical effort or attention to a tool, equipment, or material in the accomplishment of a job.

Example - Drilling a hole
Tending a lathe
Connecting a power tool
Oiling equipment
Using a wrench
Inspecting parts or equipment

2. Supporting work items

(a) Preparation and cleanup. A man is engaged in preparing for or shutting down a job or shift.

Example - Checking work order
Arranging work space
Cleaning work space during and at completion of the job
Wiping tools after job

(b) Procure tools. This element represents the procurement and disposal of tools necessary for job performance

Example - Transactions at the tool room window

(c) Procure materials. This element represents the procurement of material necessary for the job.
Example - Transactions at the storeroom.

(d) Walk empty. A man is walking to and from the job emptyhanded.

(e) Walk loaded. A man is walking to and from the job with tools and equipment.

(f) Give and receive instructions. Two or more men are talking about a job or a man may be receiving instructions from the foreman or supervisor.

3. Delays

(a) Waits associated with productive work. This element represents waits associated with operating cycle work items.
Example - Wait until another man completes a task such as drilling a hole or removing an engine head.

(b) Waits associated with related work. This element covers all waits associated with related work.
Example - Wait until man returns with tools or material.
Wait until man cleans spilled oil.

(c) Maintenance - repair shop equipment. This element represents any work done on shop machines or tools.

(d) Start late - quit early. This element represents late starts or early quits at morning, noon, and evening.

(e) Personal. Personal delays include all actions taken by men primarily for their own comfort.
Example - Put on or remove clothing
Coffee break or drink of —
Eating during working hours
Smoke
Blow nose - wipe forehead
Call of nature

(f) Idle. Idle delays occur when men kill time. Two or more may stop to talk or a man may just stand around.
Example - Talking
Dreaming
Sleeping
Horseplay

Randomness

Three procedures were used to minimize bias and assure that random samples would be taken:

1. The days on which the observations were to be made were selected for study on a random basis.
2. The time of day was selected on a random basis. When the study was completed it was observed that all parts of the day had been studied.
3. Five different sampling routes through the shops were selected on a random basis.

Accuracy

The statistical accuracy of this type of study is dependent on two things:

1. The total number of observations
2. The number of observations in the category to be measured.

The "productive category" is the basis for computing the personal activity rating. The final statistical accuracy of this overall study was ± 1.04 percent as shown by the following computation:

$$E = 2\sqrt{\frac{P(1-P)}{N}}$$

$$E = 2\sqrt{\frac{(0.646)(0.354)}{8,434}}$$

$$E = 0.0104 \text{ or } 1.04\%$$

Where E = the absolute accuracy
P = the percent of observations in the category being considered expressed as a decimal
N = the total number of observations taken in the study.

In other words, the true percent productive for all shops personnel will be between 65.64 percent and 63.56 percent 95 times out of a hundred. The study showed the percent productive was 64.6 percent.

RESULTS

Computation of personal activity

The personal activity rating was computed by taking the sum of the following:

1. Sampled productive effort (percent of time actually productive)
2. Supplementary allowances for preparation and cleanup, and procurement of tools and materials.
3. An allowance for walking.
4. An over-all allowance for personal needs and fatigue.

The personal activity rating may be expressed as a formula:

$$Y = (100\% + X\%)\ (A + 7.5\%\ A + T)$$

Where Y = personal activity rating
X = personal and fatigue allowance = 10%
A = percent of total time devoted to the productive category = 64.6% (See Table 190 for time utilization in percent)

7.5% A = supplementary allowance, covering activities not productive themselves, but required in order to accomplish productive work. The analysis of these data indicates that 7.5% of the "A" category realistically represents an acceptable allowance for supplementary activities. This supplementary allowance is then added to the "A" category to make it more representative of the activity of the property and equipment employees. Thus, 7.5% A = 7.5% x 64.6% = 4.8%.

T = Walking allowance = percent of day spent in walking = 1%. This is an estimated figure based on an average walking distance allowed. This average distance was multiplied by a constant of 0.4 minute per 100 feet of movement. This calculation indicated walking to be less than 1.0% per day, but the value of 1.0% per day was used.

Substituting in the formula, the personal activity rating during the study was:

$$Y = (100\% + 10\%)\ (64.6\% + 4.8\% + 1.0\%) = 77.4\%$$

TABLE 190
TIME UTILIZATION IN PERCENT 1/
(Corrected to include break periods)

Employee group	No. in group	Category A	Category B - Supporting work						Category C - Delays						
		Productive work	Preparation and clean-up	Get and return tools	Get materials	Walk empty	Walk loaded	Give and receive instructions	Personal	Idle	Wait for productive work	Wait for supporting work	Start late and quit early	Repair shop equipment	Total
Engine mechanics	12	63.8	1.7	1.3	2.6	5.7	3.5	4.7	7.8	6.6	1.3	0.5	0.5	0.1	100
Car - bus mechanics	5	59.2	2.1	2.0	4.8	7.9	5.5	4.6	6.9	5.3	1.3	0.1	0.4	-	100
Machinists - mechanics	3	69.0	7.3	0.9	0.2	3.8	2.8	5.1	6.6	3.4	0.4	-	0.4	0.4	100
Utilities mechanics	4	65.9	2.6	1.1	0.8	5.2	3.5	6.4	6.0	8.5	-	-	-	-	100
Miscellaneous laborers	2	63.5	3.8	-	0.6	9.8	7.1	0.9	6.6	7.1	0.3	-	-	-	100
Tool room clerk	1	63.2	2.0	0.5	0.5	7.4	2.5	1.0	9.2	12.8	1.0	-	-	-	100
Office clerk	1	64.9	3.5	-	-	5.9	5.9	4.1	9.5	5.9	-	-	-	-	100
Supervisors	4	63.6	0.2	-	0.8	15.5	3.2	-	6.9	9.5	0.3	-	0.2	-	100
General stores clerks	4	60.7	1.6	-	-	9.8	4.2	3.5	7.1	11.2	0.3	0.2	1.3	-	100
Equipment parts clerks	1	72.9	1.0	-	-	6.8	5.4	4.4	6.1	2.4	-	-	1.0	-	100
Stores warehouse clerks	4	57.1	2.4	-	-	8.0	2.1	1.1	7.0	19.6	0.4	-	2.3	-	100
Paint shop employees	6	75.9	3.5	0.1	0.3	4.7	3.5	1.2	7.1	2.9	0.7	0.1	-	0.1	100
Carpenter shop employees	4	68.6	3.1	-	0.6	7.5	4.3	2.8	7.2	4.5	0.8	-	0.5	-	100
Service garage 2/	3	60.3	1.7	0.5	-	6.2	1.7	1.5	7.7	19.0	0.3	-	0.8	-	100
Weighted average		64.6	2.5	0.7	1.3	7.3	3.7	3.1	7.2	8.0	0.7	0.2	0.6	0.1	100

1/ A total of 8,434 observations were made.

2/ The service garage was open hours during which no sampling was done, thus these figures may not be fully representative of conditions existing at the garage.

Improvement goals

To gain in the productive category, the percent of time spent in the supporting and delay categories must be reduced. These improvements can only be made if supervision has the opportunity of making a closer examination of the time spent in these categories and evaluating and devising programs which will increase the time spent in category "A", productive work. Study personnel made an analysis of this type.

In order to establish a realistic set of values, it was first necessary to determine the difference between the percent of time allowed in the personal activity formula for supplementary allowances as compared with the percent of time actually observed in these categories during the survey.

Element	Observed time	Calculated allowance	Variation
Preparation and cleanup, procure tools and equipment and give and receive instructions	7.6%	4.8%	2.8%
Walk emptyhanded or loaded	11.0%	1.0%	10.0%
Delay	16.9%	0	16.9%

The magnitude of the variation indicates possible potential for improvement. In order to determine realistic goal values, each of the elements shown above is adjusted from its current observed value by an amount equal to one-third the variation indicated. Experience with this type of work in industry has indicated that calculation of goal figures from an initial survey in this manner is realistic and can definitely be attained if a vigorous improvement program is inaugurated. Using the one-third variation principle, the goals for the elements shown above would become:

Element	Observed time	One-third of the variation cited	Goal
Preparation and cleanup, procure tools and equipment, and give and receive instructions	7.6%	-0.9%	6.7%
Walk emptyhanded or loaded	11.0%	-3.3%	7.7%
Delay	16.8%	-5.6%	11.2%
Productive then becomes	64.6%	+9.8%	74.4%
	100.0%	0	100.0%

The goal value for the personal activity rating can now be calculated by substituting the goal values in the regular formula, and adjusting the walk value proportionately to the change in the productive category (see formula below):

$$Y_g = (100\% + 10\%)\ (A_g + 7.5\%\ A_g + T_g)$$

$$Y_g = 110\%\ (74.4\% + 7.5\% \times 74.4\% + \frac{74.4}{64.6} \times 0.1)$$

$$Y_g = 110\%\ (74.4\% + 5.6\% + 1.2\%)$$

$$Y_g = 89.3\%$$

Computations which have been presented show how this study established an initial rating of 77.4 percent personal activity for the employees of the property and equipment shop of the State Highway Commission. Similar computations show how a realistic goal figure of 89.3 percent personal activity rating could be obtained if an aggressive program was undertaken.

AUXILIARY STUDY OF EQUIPMENT PARTS ROOM

Purpose

The purpose of studying the equipment parts room was to:

1. Determine if the mechanics were spending excessive time waiting at the parts window for parts.
2. Determine if enough clerical help was provided to receive, store and distribute equipment parts.
3. Determine if the demand for parts is evenly distributed throughout the day.

Conclusion

1. Time spent waiting at parts window. The total waiting time by all the mechanics at the parts window for one week amounted to only 68 minutes, or about 14 minutes per day. Of this 14 minutes, about 5 minutes were spent for reasons other than to get supplies or parts.

2. Workload of equipment parts clerk. The parts clerk actually spends about an hour per day servicing mechanics who come for parts, giving technical advice, engaging in personal conversation, etc. This time does not include receiving parts, storing them, or writing store requisitions. The clerk does productive work 73 percent of the time, does related or supplementary work 17 percent of the time and is nonproductive 10 percent of the time.

Since there is such a small amount of waiting time for the mechanics and since the clerk's workload appeared reasonable, one clerk is sufficient to handle the parts room.

3. Daily distribution of workload. The clerk's work is such that it can be planned and evenly distributed throughout the workday. The clerk cannot control the scheduling of servicing mechanics at the parts window; however, this amounts to only one hour a day and it is distributed over the whole day. The peakload happens during the first two hours of the day when six to seven mechanics per hour are served. After 2:00 p.m., the load drops to two to three mechanics per hour.

Discussion

Three different studies were made of the parts room operation. A production study was conducted in which one of the study personnel followed the parts clerk for one whole day timing with a stopwatch and recording the complete operation, including all delays, and a record of all personal time taken. From this production study, it was determined that it took on the average 1.84 minutes to service a mechanic at the parts window.

A work sampling study was conducted for a period of two weeks. It showed how the clerk spent his time during the day.

A third study was conducted for a period of one week. A record was kept of each trip the mechanics made to the parts window. This record also indicated the time of day that each trip was made and indicated when a mechanic had to wait to be served because someone else was already at the window.

The conclusions of this report are based on the following calculations.

TABLE 191

TOTAL NUMBER OF MECHANICS SERVED AT THE PARTS WINDOW FOR A PERIOD OF FIVE DAYS

Time of day	Number of mechanics going to parts window		Total for five days
	For parts	Not for parts	
7:45-8:45	27	12	39
8:45-9:45	22	9	31
9:45-10:45	14	7	21
10:45-11:45	10	7	17
11:45-12:45	LUNCH		
12:45-1:45	16	11	27
1:45-2:45	10	5	15
2:45-3:45	8	4	12
3:45-4:45	4	6	10
Total	111	61	172

TABLE 192

TIME REQUIRED TO SERVICE THE MECHANICS THAT WENT TO THE PARTS WINDOW

Reason for trip	Hours per week	Hours per day
For parts – $\frac{(1.84 \times 111)}{60}$	3.4	0.68
Not for parts – $\frac{(1.84 \times 61)}{60}$	1.9	0.38
	5.3	1.06

Total time to service mechanics = 5.3 hr/week or 1.06 hr/day.

The tabulation that follows shows how extensively use is made of the equipment parts room and the variation in use from person to person. For example, some mechanics did not use the parts room on a particular day, yet others used it as many as six times.

No. of trips to parts room	Distribution of 26 mechanics
0	9
1	5
2	3
3	4
4	4
5	0
6	1
	26

PERSONAL OBSERVATIONS AND OPINIONS

Most of the mechanics enjoy their work of repairing and reconditioning equipment and would prefer not having to search for parts and follow up on ordered parts. Once a mechanic has begun to repair a piece of equipment, he would prefer to complete it and start on another instead of disassembling several pieces and not being able to complete them because of lack of parts. Also, he would prefer to reach at arm's length to get frequently used inexpensive parts instead of making several trips to write requisitions, locate the stores clerk, and wait for the order to be filled.

It seems that inventory controls could be designed to permit automobile tuneup mechanics to keep a supply of parts, such as condensers, spark plugs, distributor points, etc., in a locked cabinet mounted on wheels to permit its being moved to the work areas.

Personal conversations increase when the mechanics are forced to come into contact with other employees while traveling to get parts and while waiting for the parts at the store window.

As hard as the employees work in the paint and sign shop, they would much prefer the feeling that they accomplished more with the same effort.

RECOMMENDATIONS

The recommendations which follow represent those operations or areas of work where, in the opinion of the study crew leader, it should be possible to:

1. Increase the personal activity rating
2. Reduce the number of employees
3. Increase the morale and incentive to work

Automotive and equipment shop

1. Provide self-service bins at the mechanics' work areas for small inexpensive parts, such as common nuts, bolts, screws, and other frequently used parts.

2. Provide locked bins mounted on wheels at the tuneup mechanics' work areas for more expensive and frequently used items, such as condensers, spark plugs, and distributor points, etc.

3. Make sure the mechanics use time and labor saving tools, such as power tools, semiautomatic equipment and speed wrenches.

4. Improve the availability of parts by the following actions:
    (a) Stock a greater number and variety of parts
    (b) Reorder parts earlier so that the parts room will not be out of stock while the order is being filled.
    (c) Persuade local parts dealers to stock parts that would be desirable to have but uneconomical to stock by the property and equipment stores because of limited space, infrequent use, or high cost.
    (d) Improve the practice of delivering parts to the mechanics at their work areas.

5. Relieve mechanics of work that could be done just as well by another employee such as sweeping the work areas and transporting parts and equipment.

Paint and sign shop

If the making of signs is to be continued as a regular program, then definite plans should be made toward designing or purchasing higher productive equipment. Almost all the work now done is manual.

It was determined from the study that the employees in this group spent more time working than any other group; therefore, most improvements will have to come from a change in methods, not a greater utilization of delay and idle times.

If the procurement of new equipment is accomplished, the following improvement will increase productivity while reducing the number of men required:

1. Construct a paint booth so racks with several wood barricade boards, or other types, could be pushed in and painted at one time with a spray gun. Presently, the painter gets the boards one at a time, lays them

down and paints one side with a roller, carefully turns each over and paints the other side and edges, then puts them aside.

2. Eliminate, if possible, the paper dividers used to separate the triangular shaped "No Passing" signs when they are packed for shipment. If this could be accomplished, it would reduce the crew by at least one man. To accomplish this, first, send a few small sample shipments to determine if the signs really do stick together. If they do, try drying them by sending them down a conveyor under heat lamps or putting them in an oven. This would also provide additional space by reducing the drying time and reducing the number of drying racks presently required.

3. Four, maybe five or more, rolls of scotchlite material from which the "No Passing" signs are made could be unrolled together so four or more signs could be cut at one time instead of one.

4. Redesign the silk screen stencil to include a power unit or some type of control linkage which would permit one man to stencil the letters on the signs instead of two men.

<u>Stores - property and equipment shops</u>

1. Reduce the store warehouse crew from four men to three men. The results of the study showed that the area was over-manned by one full-time man.

2. Continue to use one man in the parts room. This clerk's workload can be reduced by changing work methods. One example would be to use a light hand truck or cart to transport several items instead of carrying two or three at a time by hand over a long distance. A more organized method of stocking and labeling of parts would be desirable.

3. Use snapout carbon packs whenever forms need to be duplicated. Individual handling of single carbon sheets is very time consuming.

4. Streamline and update methods of processing stores records. Eliminate forms that are no longer useful and combine forms that give the same information. Use a small diazo type machine to duplicate printed material which is now rewritten by hand.

Some of the above recommendations could be put into effect using the present personnel but others will need the attention of someone, such as a methods engineer, who can provide expert assistance.

ACKNOWLEDGMENTS

All State Highway Commission personnel contacted during this survey were very helpful and completely cooperative without exception.

PLANNING FOR THE OPERATION SEAL BITUMINOUS AND CONCRETE PAVEMENTS

by

Study Group Staff

INTRODUCTION

This report covers an examination of the operation seal bituminous and concrete pavements. It also examines planning and other considerations which are essential to achieving improvements in this operation. The data providing the basis for this report were obtained from studies of sealing on 18 different jobs. Two of the studied jobs are presented in detail, showing chronologically the activity of each man and each unit of equipment during a day's operation. An examination is made of the factors affecting the productivity of these two jobs. In the light of this examination, a schedule is set up for a selected sealing job in order to test the idea that planning would improve efficiency and increase production. Finally, the results of a trial run on the selected job are reported.

MATERIAL APPLICATION RATES

The rates at which asphalt and aggregate are applied during sealing operations provide a limited indication of quality of work. They are also worthy of note because of their effect on accomplishment. Adequate control of these rates is necessary to produce quality work at minimum cost.

There are rather obvious consequences attendant to deficient or excessive rates of application of asphalt, or aggregate, or both. Aggregate in excess of that needed to cover the asphalt is whipped off by traffic and often wasted in the ditch. Excess asphalt requires excess aggregate cover and frequently requires follow-up applications of gravel because of bleeding. Seal coats which do not meet specification can logically be expected to need early replacement. On all of the jobs studied, experience and judgment of the workmen were the only means for determining the proper rates of material application.

State maintenance and construction standard specifications and the Construction Field Manual, provide for specific control in the quantities of asphalt and aggregate applied during sealing operations. These are as follows:

	Asphalt	Aggregate
Maintenance standard specifications	0.25 gal./sq. yd.	25 pounds/sq. yd.
Construction standard specifications	0.30 gal./sq. yd	30 pounds/sq. yd
Construction Field Manual	----	10 pounds/0.10 gal.

Asphalt application rates for the 18 sealing jobs studied varied between 0.15 and 0.50 gallon per square yard. Only on four jobs, did the rates fall between 0.20 and 0.35 gallon per square yard. Aggregate spreading rates for the 18 jobs varied from 18 to 61 pounds per square yard. On eleven of the jobs, rates fell between 20 and 35 pounds per square yard. For all 18 jobs the quantity of aggregate per 0.10 gallon of asphalt varied between 5 and 27 pounds. Rates on only 6 jobs fell between 8 and 12 pounds of aggregate per 0.10 gallon of asphalt.

Rates of accomplishment on the 18 jobs varied between 15 and 86 square yards of sealing completed for each man-hour of effort. From an examination of data on the various studies, it appears that variations in material application rates was one of the factors affecting accomplishment. Obviously, the number of square yards sealed with a 500-gallon distributor load of oil is a function of the amount of asphalt applied per square yard. On two jobs where the rate of accomplishment was 68 and 86 square yards per man-hour, respectively, the asphalt application rate was 0.15 gallon per square yard. On the other hand, one job was encountered where the asphalt application rate was 0.48 gallon per square yard, and accomplishment was at the rate of only 18 square yards per man-hour.

LABOR AND EQUIPMENT TIME UTILIZATION

Study data for the 18 jobs show very little uniformity either in crew sizes, number of equipment units utilized, and patching accomplishment per man-hour. This lack of uniformity is evident in the following figures:

	Minimum	Maximum
Number of men assigned to crew	4	11
Number of equipment units per crew	4	10
Square yards of sealing per man-hour	15	86

It is also significant that very little correlation exists between square yards per man-hour and the size of the crew or number of equipment units employed. Square yards of patching per man-hour were observed for different jobs to be both high and low for large crews, but this was equally true for small crews.

Data for all 18 jobs studied show, on the average, that about 45 percent of crew NAWT was nonproductive, 35 percent was expended on supporting work items (including travel, haul and return), and 20 percent was productively used for sealing. These figures suggest that perhaps the easiest way to increase sealing accomplishment, or productivity, is to identify and eliminate nonproductive time. For the most part this consisted of waiting on asphalt to heat, wait for spraying asphalt, wait for spreading aggregate, wait for hauling asphalt and/or aggregate, wait on instructions and inspections, personal and idle time.

The key to the problem of nonproductive time appears to be the lack of balance in equipment employed and the custom of initial heating of asphalt after the beginning of scheduled shift time (8 a.m.). An inadequate number of trucks for hauling and spreading aggregate means that an entire distributor load of asphalt cannot be sprayed without waiting for trucks to return to the stockpile for more aggregate. An inadequate number of distributors or insufficient distributor capacity means periodic waits between distributor loads while the asphalt is heating. For different job conditions and haul distances, equipment balance is obviously not static. This is an important area of responsibility of the foreman in planning and scheduling work assignments. As for heating asphalt in the morning, the cost of overtime for one man to do this before scheduled shift time can be recovered several times over by eliminating the time the entire crew loses while waiting for asphalt to heat.

Beyond the elimination or reduction of nonproductive time, better organization of the sealing operation in general offers possibilities for reducing time required for related work with a comparable increase in time available for productive work. Increases in accomplishment during productive time are also possible through improvement in (1) work methods and (2) individual effort.

DETAILED ANALYSIS OF TWO SEALING JOBS

In order to facilitate evaluation of the information obtained from detailed studies of sealing operations, two of the jobs studied, designated A and B, were selected for presentation on gang process charts. These charts are shown in figures 43 and 44. They provide for easier analysis of the operation by permitting visual evaluation of the extent to which coordination and balance were obtained between various men. Similar charts would be used to evaluate the coordination of equipment units. It should be noted that some short periods of work or delay time were not indicated on the two examples in order to avoid making the charts excessively complex. The following symbols were used on the charts.

■ Productive work

░ Time assigned to another operation

⬒ Supporting work

▦ Lunch time

▨ Haul, return, travel, and move ahead

□ Delay

From the charts it can readily be seen that there are opportunities for certain changes which will result in increased productivity. It is axiomatic that accomplishment can be no greater than the area sprayed with asphalt, yet during job "A" work directly associated with spraying asphalt amounted to only 40 man-minutes (for 2 men) out of a crew total of 1,570 man-minutes for the day's job. The 40 minutes include maneuvers and short move aheads between work areas. During job "B" work directly associated with spraying asphalt, including maneuvers, and short move aheads amounted to 86 man-minutes (for 2 men) out of a crew total of 2,470 man-minutes for the job.

On each of the jobs, the distributor operator spent more than 7 hours, which was either nonproductive or not directly contributing to accomplishment. This seven hours includes a variety of activity, but a major portion involves waiting for asphalt to heat. On job "A" the most time-consuming item was filling the distributor with asphalt. The delay that occurred most frequently was waiting for trucks to spread aggregate. Other lost time resulted from quit early, excess lunch time, wait for loading aggregate, and wait to receive instructions.

There is always an irreducible quantity of time required for morning preparations and evening shutdown whenever an array of men, equipment, tools, and materials perform work at a worksite located away from the maintenance garage. The starting up and shutting down routines generally require about the same amount of time and effort regardless of whether crew spends three hours or six hours at the worksite. This is quite possibly a significant reason why the actual accomplishment per man-hour on jobs "A" and "B" is not substantially higher. On job "A", only one distributor load of asphalt was used; on job "B" a little over one-half of a distributor load was used. Any increase in the amount of asphalt applied with accompanying greater accomplishment reduces the percent of total job time absorbed in morning and afternoon supporting effort. On the two jobs referred to, several of the crew members devoted and charged a portion of their total shift time for the day to other operations unrelated to the sealing operation. Even without lost motion involved in the transition from one assignment to the other, such practice does not contribute to the essential need for devoting a greater percentage of the day's effort to the actual work of sealing.

An examination of the study data on jobs "A" and "B" also points up several facts which have a direct bearing on accomplishment. On job "B" the principal assignment of two men on the crew was that of hand shoveling and brooming aggregate. Where it is practical for mechanical spraying of the asphalt, mechanical application of the aggregate should also be practical and of course much more productive per man-hour. The truck driver started after aggregate in the morning without knowing definitely where he could obtain it. He drove for 30 minutes to a quarry only to find no aggregate. After considerable confusion and further travel to stockpiles and garages, unhitching and hitching the roller, and securing a loader, he finally obtained a load of aggregate. Planning opportunities also exist in the placing and moving of warning signs at the worksite. Key men such as the distributor operator and aggregate truck drivers should not interrupt or delay operations to move or wait for the moving of signs. Where frequent moving of signs is desirable, a second set would permit placing at the next worksite while work is being completed at the previous worksite.

PLANNED SEALING JOB

Up to this point, we have discussed the 18 jobs studied and have indicated ways in which they might have been improved. In order to determine if planning would promote greater efficiency and higher productivity, an actual job was selected for a test. This job was located in the three-county control area and consisted of a road section about 6 miles long with numerous distressed areas. It was estimated that the total area in need of sealing exceeded 15,000 square yards, but not all of this was to be accomplished during the planned job. Aggregate for sealing had already been stockpiled at one end of the section under a contract. Ample numbers of men and equipment were available so it was decided to use a large crew in the planned job.

Figure 45 shows a proposed schedule for the selected job. This figure is a gang process chart similar to those presented for jobs "A" and "B". The chart provides a schedule for each man, based on time and performance observed during the 18 jobs studied. This schedule attempts to provide the best possible balance between spraying asphalt and hauling and spreading aggregate under the conditions anticipated to prevail at the selected worksite. For example, with the desired rates of application set at 5 tons

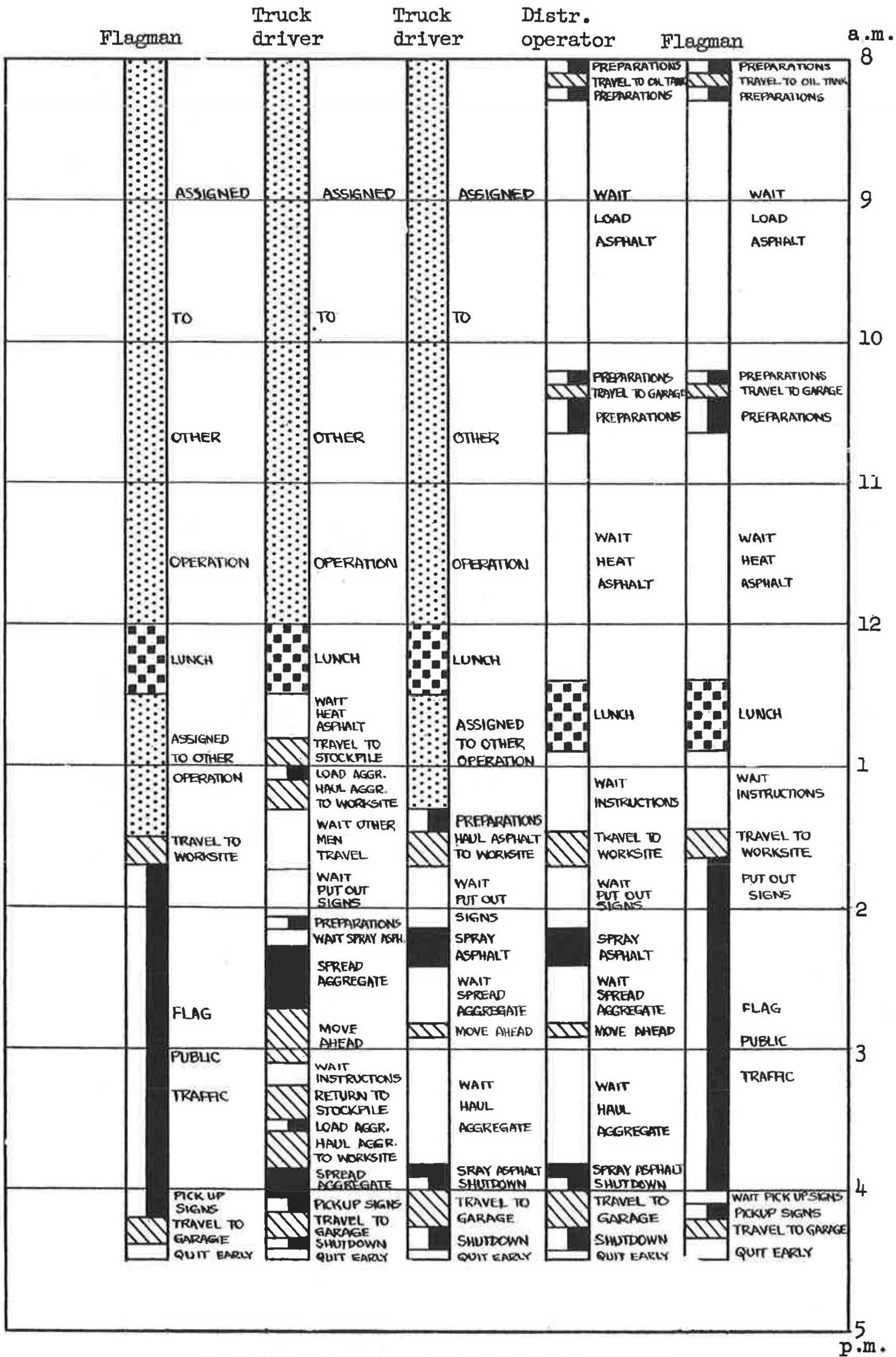


FIGURE 43. GANG PROCESS CHART FOR JOB "A"

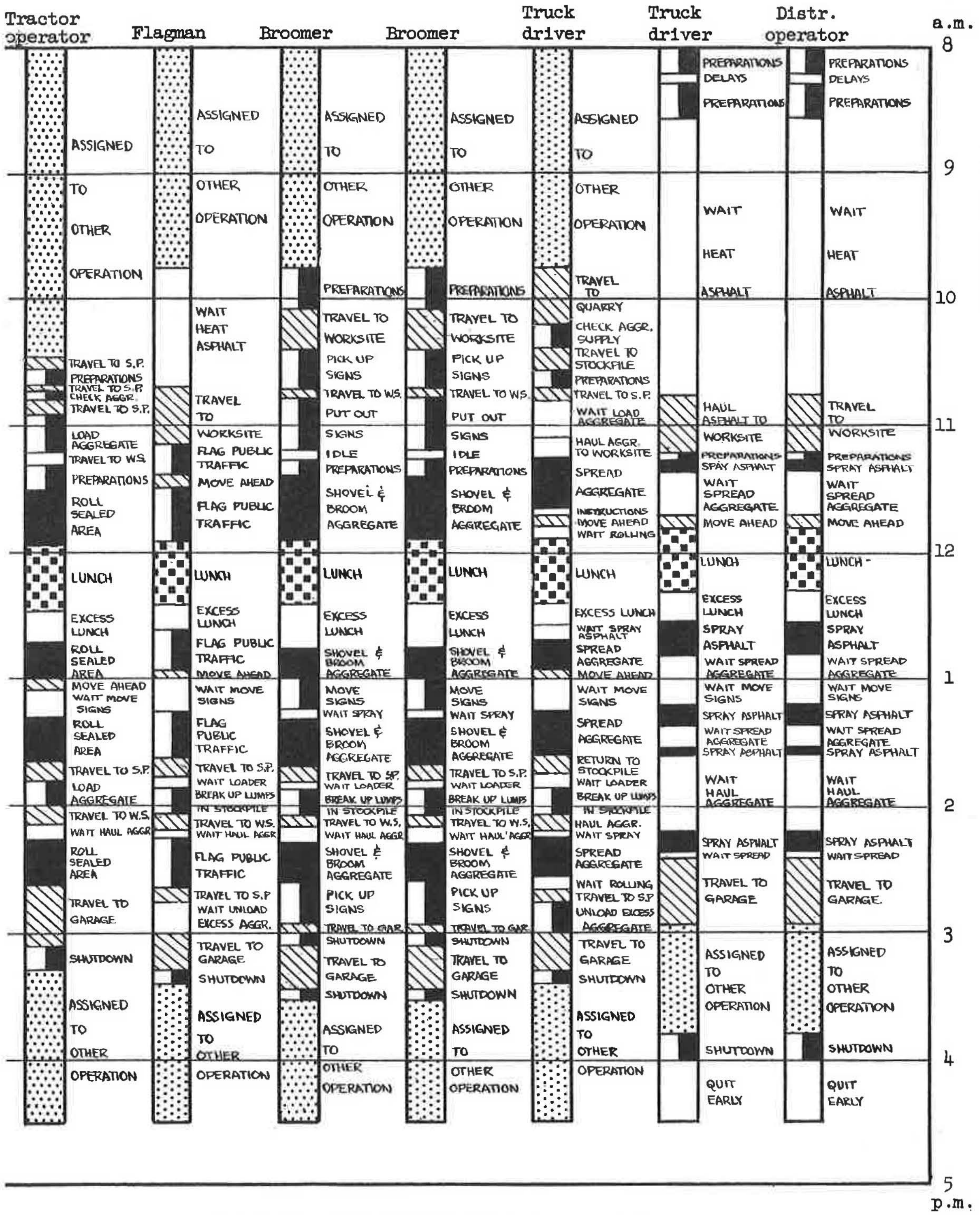


FIGURE 44. GANG PROCESS CHART FOR JOB "B"

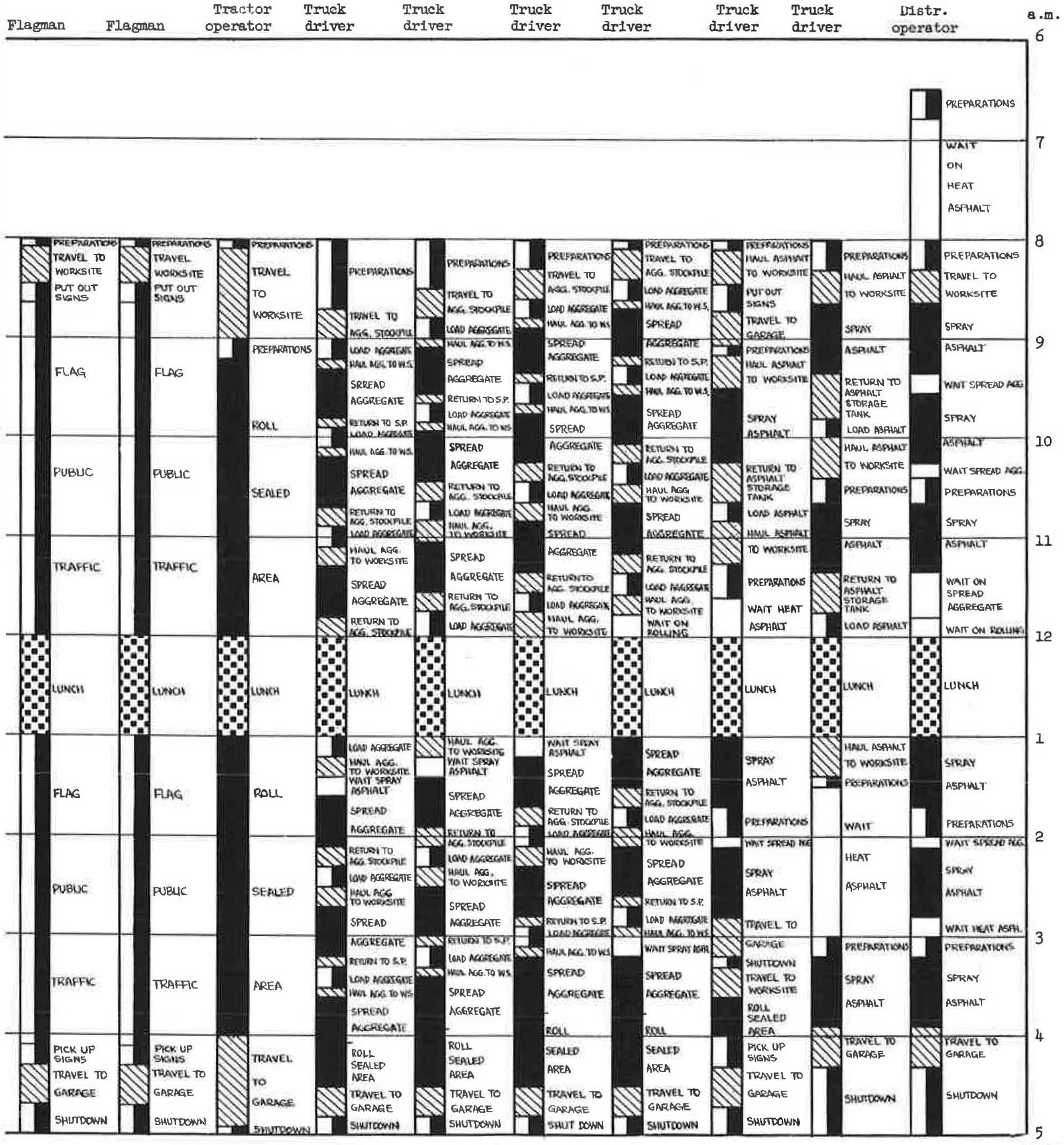


FIGURE 45.

GANG PROCESS CHART FOR PLANNED SEALING JOB of aggregate per 100 gallons of asphalt, 20 tons of aggregate should be ready at hand or on the way for each 400-gallon distributor load of asphalt. This would permit an entire distributor load to be sprayed without having to wait for aggregate. Since aggregate was already stockpiled adjacent to one end of the job, the allowance for aggregate haul distance ranged from zero to six miles. The asphalt storage tank was 10 miles from one end of the job. On the basis of these conditions, 10 men, three distributors and four trucks were deemed to provide a balanced crew for an efficient operation.

The complete listing of men and equipment for the planned job was as follows:

Men

1 Distributor operator
4 Truck drivers
2 Truck drivers
1 Tractor-roller operator
2 Flagmen

Equipment

3 Trailer-mounted distributors
4 Trucks with spreader beds to haul and spread aggregate
2 Trucks to tow distributors
1 Frontend loader
1 Wheel tractor
1 Towed rubber-tired roller

The planning for this job provided that the three trailer-mounted distributors be loaded with asphalt the night before and spotted at the garage. One man was then scheduled to report early so as to have the three loads of asphalt hot by the beginning of scheduled shift time (8 a.m.), thus avoiding any need for more than one man to mark time while the asphalt was heating. The plans also called for marking out the areas to be sealed on a prior day. In addition, the loader was to be spotted at the aggregate stockpile prior to the day of the job.

The total accomplishment considered feasible for the day's operation called for six distributor loads of asphalt. This meant that each of the three distributors would have to return to the asphalt storage tank, reload, haul to the worksite, and heat the asphalt during the course of the day's operation. For this particular job, the scheduled coordination was such as to provide for a quite satisfactory arrangement, whereby the lunch period occurred while two of the three distributors were in the process of heating. Had it been necessary for any of the three distributors to heat an additional load during the course of the afternoon, it might have been difficult to avoid an extensive wait, possibly affecting the entire crew, while the asphalt proceeded to heat.

Once the basic ingredients of equipment balance and coordinated operation, required for an efficient job performance, have been developed and adjusted through practice, much of the tedious detail of complete scheduling will become superfluous and unnecessary in the process of adjusting to routine variations in job conditions.

Aside from the efforts to obtain balance and coordination in equipment operations, the essential departure in this schedule from the pattern observed during studies involves utilization to the fullest possible extent of the entire crew for the full day on the operation of sealing. To facilitate coordinated effort, each man should know at the start what his scope of activity is for the entire day as well as any miscellaneous duties, so as to require a minimum of waiting for instructions, for other operations, etc.

The scheduled use of trucks to assist in the rolling operation was designed to complete the necessary rolling quickly at the close of the operation, thus avoiding any overtime on the part of the roller operator.

TRIAL OF PLANNED SEALING JOB

A trial of the planned sealing job took place on October 11, 1960. It was judged to be completely successful, and results, if anything, exceeded expectations. Except for some raggedness at the very start, all work was accomplished on time or ahead of schedule. This verified the fact that the schedule, based on data obtained from the various studies, was generally lenient. Total accomplishment for the day was 12,780 square yards sealed, using 6 distributor loads of oil. This reduces to a figure of 156 square yards per man-hour, based on a 10-man crew working 82-hours. However, a figure of 130 square yards per man-hour is obtained when all time properly chargeable to the job is included. Asphalt was applied at the average rate of 0.24 gallon per square yard; aggregate at the average rate of 28.4 pounds per square yard. Maintenance specifications call for 0.25 gallon of asphalt and 25 pounds of aggregate per square yard. Because of the size of this job, two flagmen were used, whereas only one was standard practice on jobs studied.

It should not be overlooked that several factors encountered on the trial run were all favorable to the results obtained. The spirit of the crew was excellent and it was evident that they were constantly striving to stay even with or ahead of the schedule with which each man was supplied. The areas sealed were considerably larger than those normally encountered and the length of section encompassing the day's operation was undoubtedly less than could normally be expected for that much accomplishment. The stockpile of aggregate was located adjacent to one end of the section being sealed. A new tractor frontend loader was used which was somewhat faster than the ones previously employed, although this meant that the loader was new to the truck drivers who had to operate it. The weather on the day of the trial run was highly favorable, being calm, clear, and in the low 80's. The mild morning temperature was favorable to prompt heating of asphalt.

The extent and quality of rolling obtained on this job was also considered to exceed that normally obtained. This was in part due to the fact that although the schedule called for rolling assistance from trucks at the finish of operations in the afternoon, the job consistently ran ahead of schedule and this permitted the trucks to assist in the rolling with their wheels before lunch as well as after 4 o'clock in the afternoon.

This report touches upon only a small parcel of the data available from the Iowa Maintenance Study. However, it is broadly indicative of the general opportunity available for careful examination and appraisal of total maintenance effort. The opportunities for improvement can be listed in accordance with the following five basic ingredients essential to an effective maintenance organization. These are: (1) planning, (2) scheduling, (3) work methods, (4) tools, materials, equipment, and (5) organization and supervision.

CONCLUSIONS

Although seasonal variations in the workload are inevitable, careful thought to long range planning can do much to anticipate and relieve the pressure from peak workload periods. Failures in this area are reflected in the less than desirable levels of maintenance quality which are frequently apparent. The solution should involve joint efforts of the foremen, the resident maintenance engineers, and their district superiors. The general size of the maintenance task forces and areas of responsibility deserve re-evaluation. For example, it might be desirable to place operation's responsibility for sealing work at the residency level. This would facilitate more experienced and highly skilled supervision, and use of larger and more productive equipment. The nucleous of this residency level crew could be supplemented as needed by men from county crews.

The responsibility of the foreman should begin when the general plan and pattern of the workload has been formulated. He is then in a position to schedule his work and assign his crews and equipment. Once the basic schedule of an efficient operation has been developed, the foreman should be able to modify the schedule for changing job conditions, with perhaps only occasional assistance.

A review of data obtained from comprehensive studies shows that maintenance crews sealed portions of a 0.62-mile section of road on eight different occasions within a 12-week period. The total area sealed was 10,800 square yards although there were only 7,030 square yards of pavement in this small section. In other words, parts of this section were sealed more than once during the 12-week period. Less than a week after the last day of sealing work on this section was completed, a contract was let for sealing the entire section. In preparation for the contractor's work, a state crew spent one day removing part of the seal previously applied by state forces since it was bleeding badly. Following the contract work, a state crew spread 34 cubic yards of aggregate over bleeding areas.

A thorough evaluation of all the factors and problems concerning case histories of the type cited for the 0.62-mile section of road may conceivably provide rational support for actions taken. However, such evaluation also offers excellent opportunities for planning and programing so that considerably less effort is involved in achieving the necessary accomplishment.

Perhaps the fact of greatest significance evident from production studies is that the planning and scheduling of a day's operation frequently failed to outline an adequate amount of work to permit efficient accomplishment by the crew. The amount of equipment used and size of the crew employed, must of necessity be flexible because of the operating variables attendant to individual job circumstances. For example, total length of road section over which the work is spread, size of sealed areas, haul distances from material stockpile to worksite, and from garage to worksite, are all variables affecting the amount of the end product which can be considered a reasonable day's accomplishment. But given these ingredients, the foreman should plan and lay out the work in suitable daily quantities to facilitate efficient operations. Data from the maintenance studies show that the foreman frequently planned the operations for the day after the crew reported for work. Numerous instances were encountered where the foreman performed various functions and chores while members of the crew were spending their time nonproductively.

SPAN OF CONTROL AS IT APPLIES TO THE MAINTENANCE FOREMAN

by

Harold A. Cowles

SUMMARY

This discussion was prepared as an adjunct to the Iowa State Highway Maintenance Study. It reviews the trends noted in the supervisory spans in industry and then presents an analysis of the factors influencing the span of control in the job of the Iowa State highway maintenance foreman assigned to each county. The conclusions are that the highway foreman operates in a more complex environment than his industrial counterpart and that the average foreman is overburdened if he supervises more than 12-15 employees.

The recommendations follow:

1. Take steps to improve communications between foremen and employees on the job,
2. Live with present spans but provide relief for the foreman by one of the following: (presented in order of preference of the author):
    (a) Provide foreman with a planning clerk (a functional staff position) and at least 2 working supervisors (gang bosses),
    (b) Provide the foreman with an assistant who would become essentially a "junior partner," He would speak for and make decisions in behalf of the foreman with who he would share duties.
    (c) Provide the foreman with an assistant who would be put in charge of a portion of the county's work force.

INTRODUCTION

It seems fairly safe to say that few topics have received as much attention in the literature of management and industrial organization as has the principle of Span of Control or Span of Management as it is sometimes called. Unfortunately, this attention has not produced much in the way of specific answers to the question, "How many subordinates ought an individual supervise?"

What this attention has shown and shown quite clearly is that no one knows the correct answer. In a given situation one supervisor might be taxed to his limit and another might easily assume new duties. Likewise, the same supervisor with the same number of subordinates placed in two different work environments might find himself on the verge of nervous collapse in the one case and in the other situation be a model of poise, confidence, and contentment. In other words, the answer to the question is simply, "It depends."

It depends, for example, on the man himself, his abilities, his work environment, his duties, the duties of his subordinates, their abilities and skills, the policies and the organizational structure of the firm, and so forth. Each situation will probably produce a different answer, and the variation among answers may be great.

It is interesting to note that it is this inability of the principle to specify or prescribe the optimum number of subordinates that has caused a number of writers recently to criticize the accepted tenets of Span of Control and to, in effect, suggest that the science of management abandon it completely. They cite the increasing number of successful organizations (e. g., Sears with 40 store managers reporting to one supervisor or the Bank of American with 600 branch managers reporting to its board) which have violated the accepted limits. They further suggest a much more satisfactory answer can be found in the application of the social sciences to the problem.

Of course, rebuttals have been equally vigorous in noting that the social sciences are still relatively undeveloped and, as yet, are incapable of handling the span problems with any degree of precision. They also cite the numerous successful organizations that have been designed with strict adherence to the principle.

Nevertheless, a definite trend in organizational development seems to be under way which is causing the upper limits of the span to be stretched. Most writers suggest that this pressure has resulted as a consequence of the current popularity of the decentralized organization. A wide span forces supervisors to delegate more and, hence, spawns greater independence in the actions of subordinates.

As one might gather the debate on what is to be gained -- or lost -- by widening the span continues. However, the fact remains that a limit in the number of men a supervisor can effectively and efficiently direct exists. The key is what is to be thought effective and efficient. To establish this and interpret it in terms of the span width still is one of the major problems confronting the organizational analyst.

Research on going concerns indicates that the span narrows as the summit of the organization is approached. The higher levels are referred to as the span of executive supervision and the lower levels as the span of operative supervision. The latter only is under concern in this discussion. Surveys have shown the operative span range from 10 to 70-80 for highly stable, standardized jobs. Graicunas 1/ predicted a range of 20 to 30 but the most frequent value seems to fall between 10 and 20 with 16.7 given as mean in one rather extensive survey 2/. These values are in contrast to the range of 1 to 20 for the executive span with a median generally shown to be 6 or 7.

It is apparent that essentially the same general factors would define the tolerable width of the span any place it was encountered, operative or executive. Newman lists the following as essential points to consider: (1) variety and importance of the activities supervised, (2) other duties the executive is expected to perform, (3) stability of operations, (4) capacity of subordinates and the degree of delegation, (5) relative importance of supervisory payroll, (6) practicality of relieving an extended span 3/. These are the factors that the analyst must weigh in terms of what is thought to be effective and efficient supervision.

1/ Graicumas, V. A., Relationships in Organization, in Gulick, L. and Urwick, L., eds, Papers on the Science of Administration, Institute of Public Administration, 1937, pp. 181-188.

2/ Baker, A. W. and Davis, R. C., Ratios of Staff to Line Employees and Stages of Differentiation of Staff Functions. Columbus, Bureau of Business Research, Ohio State University, Research Monograph No. 72, 1954, p. 31.

3/ Norman, W. H., Administrative Action New York, Prentice-Hall, Inc. 1951.

ANALYSIS

In considering the job of the maintenance foreman in light of these factors and the observed span widths one cannot but help compare the environment of the highway employee with that of the industrial foreman. The latter normally finds himself well supported by a considerable staff. Someone does his hiring, wage negotiations, training, production planning, timekeeping, maintenance planning, inspecting, and even his personnel and discipline problems are handled at least in part by the industrial relations people. Beyond that, the work he supervises is likely to be highly standardized and stable, particularly if he has a 30-man department or more.

In contrast the maintenance foreman under consideration here has essentially no staff and the work he supervises is anything but stable and unvaried. Further, the question of public relations is quite significant to the highway supervisor but it is practically unheard of in the industrial shop. The obvious conclusion is that the frequency and the severity of the contacts with his subordinates and the public are considerably greater in the case of the maintenance foreman than for the industrial supervisor.

The time available for supervision is another way of looking at the factor concerned with the "other duties of the supervisor." Rarely is the industrial foreman more than minutes from a trouble spot thanks to telephones, telautographs, or the blaring of the public address system. On the other hand, consider the maintenance foreman once more. Assuming that he can even be located, he may be twenty miles from the spot where a decision is required. And, the chance of his being informed of the difficulty immediately are not the best because the crew may not be near a telephone nor may he be any place where he could answer a call. Good supervision requires current information and personal attention to the subordinates. This is extremely hard with crews ranging over a whole county but even more difficult when communications are so poor.

Still another aspect of the foreman's job which consumes time is the amount of traveling required in the normal course of his duties. One of the explanations for the narrow span at executive level is that the varied duties of the executive leave only a small portion of his time for supervision, say 10-20 percent. The production foreman on the other hand may have 75-80 percent of his time available for direction of his subordinates. If the duties and requirements placed upon the highway supervisor were expressed in terms of time requirements, it appears that his "time available for supervision" would be considerably less than his industrial counterpart.

With regard to the question of delegation of foreman's duties to subordinates, it is essentially impossible because the organization as it now stands has no provision for it. The only possible exception may be in the maintenance and repair of equipment. It is true that the employees under him are fairly well trained and experienced, usually know what is to be done and are generally dedicated people. Yet, there is still no one to whom the foreman can delegate the authority and responsibility to see that a certain project gets done as he wants it done.

Finally, the possibility of reducing the span seems a little impractical. For example, if the county were divided into two groups and an assistant foreman placed in charge of each half, the foreman's span would be cut to two. This would certainly leave time for the outside duties already referred to, probably too much time and the solution would prove to be an expensive one. The foreman would be idle some of the time and the State would have added two more nonproductive employees to payroll. Further, another echelon of supervision would be created adding still more resistance to the effective flow of information up and down the organizational structure. And, of course, the workers themselves would be removed one more level from the source of authority.

CONCLUSIONS

In light of the above, my conclusions are that the maintenance foreman is operating in a somewhat more complex environment than the industrial foreman and, hence, ought not be expected to function effectively or efficiently with the span widths encountered in industry, even allowing for the current trend to greater span limits. Therefore, it is likely that if he is attempting to do this job well, the average foreman is overburdened if he supervises more than 12 employees, certainly if more than 15.

RECOMMENDATIONS

1. Take steps to improve communications between foreman and employees at work.

2. Live with the present spans but relieve the foreman of some of his duties by one of the following (presented in order of preference):

(a) Provide foreman with a planning clerk (a staff position) who would be in charge of communications at garage, do work planning for crews, be in charge of timekeeping and the preparation of the basic data for reports if not the reports themselves, be in charge of the office and handle routine public relations. Further, authorize and recognize in the payscale at least two working supervisors or gang bosses within the work force. These men would not hire or fire or do any of the other duties of supervision. They would merely be the men in the crew to whom the foreman would give his instructions and the ones who would make the decision whether or not the foreman should be contacted in case of trouble.

(b) Provide the foreman with an assistant who would be looked upon as a "junior partner." That is, he would speak for and make decisions in behalf of the foreman. The two could conceivably divide the foreman's duties or could share the work as it occurred. The possible problems developing here are many yet if the personalities of the two blended, it could work very well. Replacing one or the other would have to be done very carefully.

(c) Place an assistant foreman over a portion of the county's crew. This would create an imbalance in the organization since some employees would report to an assistant and the others to the foreman himself. But if this difficulty were recognized, it might prove to be a satisfactory solution.

STUDY OF WORK EFFICIENCY DURING OVERTIME PERIODS

by

Harold A. Cowles

SUMMARY

This study was undertaken to obtain information relating to the effect of hours of work on work efficiency; more specifically it was desired to learn what efficiency could be expected of snowplow crews operating in overtime periods.

The study produced considerable evidence relating to hours of work and efficiency. However, because of the many direct and indirect factors inherently present in work situations (for example, the highly important motivational factor present in snow removal operations), no precise quantitative evaluation of expected efficiency was deemed advisable or possible.

The data reviewed did seem to indicate that even with considerable motivation, efficiency falls noticeably near the end of the second shift. Continued deterioration may be expected on through the night with a small recovery possible at daylight. Because of this, as well as the added safety hazards present on the highways during storms, it is recommended that the work period be limited to 16 hours except in extreme situations. Further, 2-hour plowing tours during period of falling snow seem to be advisable, with a chance given the crews to rest and relax either on the road or at the garage. Finally, if the work period extends much beyond 18 hours, it is recommended that a crew not be assigned work in the next 12 hours, and preferably it should be held off until the following day. This recommendation was made because the data indicated the likelihood of quite inefficient performance until the crew members are thoroughly rested.

INTRODUCTION

The objective of all supervisors ought to be the accomplishment of the work under their direction in the most efficient manner. The conventional definition of efficiency can be used here; that is, the ratio of output to input. Since in seeking truly efficient operations management must consider all factors which can affect the work, the input term must have a broad interpretation. It must not be limited solely to the immediate expenditure of energy, for example, but should evaluate the effects of accidents, fatigue, loss of health, boredom, loss of free or leisure time as well. This liberal concept of input might best be thought of as the total cost of work. All input factors, favorable or adverse, are reduced to a common denominator, the dollar, and summed algebraically. Thus, an efficient operation can be assumed to be an economic operation. It is only in this sense that efficiency can have a truly significant influence in the design of effective work situations.

In order to properly interpret experimental work relating to efficiency as it has been defined, certain concepts must be understood. The first of these is a worker's capacity for work. A person performing a task according to a specified method has at any given moment an upper limit to the speed at which he can perform the work. This varying limit is known as his capacity. Second, the factors which cause this limit to vary are known as governors and include temperature, light, noise, rest periods, sleep or lack of it, hours of work, methods, etc.

The rate at which the work is actually performed is subject to the motivation and incentive present. It is related to capacity by effort. The closer the actual pace approaches the capacity limit, the greater the effort. Hence, effort will change with either a change in the rate of work or in the capacity. If work methods or procedures change such that the capacity is raised, the rate of work can be increased correspondingly with no increase in effort.

It can be seen that effort includes energy expenditure as well as additional factors. Effort is preferred in this general approach since it is appropriate even when little or no energy is consumed.

An optimum effort level is reached at maximum efficiency. Generally, this level is somewhat below maximum effort because as the rate of work approaches the capacity limit, wasteful methods are apparently adopted by the worker. The greater effort does not give a proportional increase in output. Similarly, below the optimum the input cost per unit produced would not be favorable. The optimum level is relative, however, since demands and values change, e.g., emergencies, war, boom or depression times. What is really wanted is the minimum effort level which is consistent with the demands of the work situation as well as of the efficiency index.

Fatigue can be thought of as the reduced capacity for work or a governor. Thus, the onset of fatigue reduces the capacity limit and the rate of work decreases unless the motivation changes.

The function of fatigue appears to be that of a protection, a warning device to prevent exhaustion of muscles, nerve fibers or brain cells. However, rarely under modern work situations is muscle or cell exhaustion approached, yet no one will deny that fatigue is present. On the other hand, some remarkable recoveries are made merely at the suggestion of an evening of bowling or perhaps bridge. An explanation for this inconsistency is given by Maier (1) 1/ in terms of motivation. Apparently in addition to setting the effort level, the motivation experienced strongly influences the energy or resource allotment made to a particular task. This assignment is normally considerably below the total energy available yet fatigue begins to appear as it is utilized, signifying the approaching end of the energy supply. The subject feels truly fatigued, yet additional motivation at any time can bring forth resources from the reserve and he "comes to life." This is the source of the energy for the

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1/ Figures in parenthesis following the mention of publications refer to the list of references at the end of this report.

seemingly superhuman activities that have been accomplished under great emotional strain. These activities appear to be superhuman only because they are compared with normal allotments of resources and effort levels.

It is quite obvious from the foregoing that the total input cost can never be precisely measured. Some of the factors cannot be adequately expressed in cost units or any other units of measure. Others are so complex or are so interrelated with still other factors that the individual effect cannot be isolated except possibly in the laboratory. Yet, management would be stopping short of the goal if it failed to consider efficiency from this broad viewpoint. What it must do is appraise the factors it can in terms of dollars and then measure the balance indirectly, using subjective as well as objective means along with common sense. These are not the most satisfying conditions for a scientifically trained person yet no other alternative exists at present.

Ryan (2) has summarized the measures that are available. First, there are those which show promise of developing into valid indices of fatigue and other costs of work but which are still in the developmental stages. These tests include muscle potential, skin resistance as an indication of tension, steroid excretion, flicker fusion. The principal problem here is determining at what level will efficiency be affected significantly. Certainly, the results in themselves can suggest the possibility of the nature or extent of the influence and common sense can carry on from there. The second group of tests are those which are appropriate only for certain types of work. These include oxygen consumption and perhaps pulse and heart recovery time. The third group are cruder indices from a scientific point of view but they are easy to apply. Admittedly, they are stopgap in nature until better techniques are perfected. This last group.includes output decrement curves, errors, variability and accidents during performance, long-term trends in productivity. It is obvious that these tests are subject to a host of variables (for example, any or all of the elements of the input) almost to the extent that the analyst may not know exactly what his data does show; yet, if properly interpreted, tests of this type provide helpful information as to the effect of certain factors on efficiency.

THE PROBLEM AND THE METHOD OF STUDY

In times of emergency certain activities may have to be continued or initiated after normal working hours. The opening of snow-clogged highways is one such situation. Maintenance supervisors must decide whether the intensity of the storm is great enough (and not too great) to continue or undertake plowing operations. If the decision is made to proceed, then the plows must be manned. Beyond this is the manning of work crews the following day for continued snow removal and routine assignments.

The question under consideration is how long is it advisable to keep men on duty without a period for normal rest. Analysts of the Iowa State Highway maintenance study group discovered that at times men would be on snowplow duty all night and then would continue on normal duty the following day, thus going close to 40 hours without a normal sleeping period.

Common sense immediately questions the advisability of such a long work period. However, before suggesting a policy change with regard to hours of work, the engineers assigned to the maintenance study group sought to discover what, if any, scientific data were available in the literature describing similar situations elsewhere and which might be of assistance to them in preparing possible recommendations.

This study, therefore, involves no original experimentation or data. Rather, a fairly extensive literature search was accomplished in an effort to gather together as much relevant material as possible. Then, the various aspects of the problem were considered in light of the findings.

LITERATURE REVIEW

The particular factors of work efficiency under surveillance are successive hours of work and the lack of sleep. An abundant supply of relevant articles and publications are available. Unfortunately, many have little original or additional information to offer.

The articles that are referred to below all appear to be fairly valid studies. They fall into four categories: general, industrial or production, automotive or truck, and aircraft - both military and civilian. For ease of presentation, only the more pertinent findings are summarized.

General

1. Classical ergograph studies on muscular activity produced among others the following results:

(a) Time for complete recovery increases rapidly as work period is increased (closer to complete exhaustion). Doubling the work period may quadruple the recovery time.

(b) Ability of muscles to do work is decreased by loss of sleep. (3)

2. Under special motivation, energy expenditure was shown to range from 14 percent to 68 percent greater than the control but less fatigue was apparent. This supports the contention that motivation increases amount of energy available. (4)

3. Evidence supporting energy distribution according to motivation presented in behavior of rats under normal and high motivation. (5)

4. Eyestrain produced easily by having subject in subdued light look at quickly flashing light. Rapid dilation and constriction of pupils is an example of muscular conflict which is quite fatiguing. No eyestrain appeared after 6 hours of continuous reading in normal light. (6)

5. Work which requires constant alertness or attention is subject to interference known as "blocking." In adding a column of numbers a person may be "stuck" at one sum and have to repeat it a number of times before the block is broken and he can proceed. Mistakes tend to occur at blocks. They are a few seconds in duration and may occur several times a minute. Continued work involving attention produces increases in the length and frequency of blocks. (7)

6. Seventeen subjects stayed awake without drugs for 100 hours. Psychomotor tests (muscular activity) showed very little change due to lack of sleep. Mental tests were performed with difficulty, however. (8)

7. Subject stayed awake 220 hours as part of disc jockey marathon. No significant behavioral effects observed in first three days. Likewise nothing significant could be measured in psychological and biochemical tests over this first period. However, deterioration was noted in all tests. Over the 9 days the subject had cyclic variation in performance experiencing irritability, paranoid thinking, visual hallucinations, episodic rage, deficits in thinking and visual-motor performance. (9)

8. A 5 mg. dosage of D-amphetamine (Dexadrine) effectively mitigated work decrement for a period of 7 hours. Test periods were 7 hours in length. (10)

Industrial or Production

1. (a) Production in afternoon shift shows effect of fatigue by being at a lower level than morning production, particularly in case of longer workdays. Ratios of afternoon to morning production for 7.5-hour day is 1.00; for 8.8-hour day, 1.0; for 10-hour day, 0.98; and for 12-hour day, 0.90. The "practice-efficiency" effect probably causes these ratios to be higher than they really are.

(b) Reduction of working hours per day and per week gave considerable production increase. For example, women working $74\frac{1}{2}$-hours per week and then shifted to $55\frac{1}{2}$-hours per week eventually increased average hourly output and exceeded total output of $74\frac{1}{2}$-hour week. However, men doing heavy work on a double shift (16 hours) once every 3 weeks maintained a production level only 4.7 percent below normal. Explanation given suggusted the motivational reserve plus the possibility of below normal vigor the next day or two. (11)

2. (a) Accident rates tended to increase with each successive hour work of the work period. Maximum rates may be 2 to 4 times greater than those experienced at start. Part of the increase was no doubt due to higher production rates but number of accidents increased disproportionately as output fell near end of work period. The effect was attributed to fatigue.

(b) Number of accidents experienced by women workers over a 12-hour day were 2.73 times greater than those experienced working a 10-hour day. Men who felt fatigue less had only 1.14 more accidents under similar conditions. (12)

3. (a) For light work performed beyond 8-hour day, 48-hour week, 3 hours were required to obtain 2 hours of output. For heavy work, 2 additional hours for 1 hour's output were needed. Five 10-hour days were not as effective as six 8-hour days.

(b) Injuries increased disproportionately as hours increased. One plant increased hours from 40 to 48 per week and got 50 percent increase in severity rate. Going from 48 to 60 hours nearly tripled frequency rate in another plant. (13)

4. Study of female employees in metal fabrication plant, light semi-skilled work, 40-hour week, hourly wages, showed the following:

(a) Production significantly higher in morning (decrease of 13 percent in afternoon).

(b) Lowest production in last hour of afternoon.

(c) Total delay time in afternoon greater by 50 percent over morning.

(d) Employees apparently influence in the non-working time to working time ratio rather adopt slower work methods when fatigued. (14)

Automotive

1. Studying the relationship between fatigue and hours of work in 900 truck drivers, U.S. Public Health Service analysts tested the drivers with regard to speed of tapping, reaction-coordination time, simple reaction time, manual steadiness, body sway, driving vigilance, and ability to distinguish flicker. Drivers who had not driven before the test had the highest efficiency, those who had driven under 10 hours had the next highest, and those who had driven over 10 hours had the lowest. Those who had been driving before the tests performed less efficiently with respect to aiming, resistance to glare, and speed of eye movements. No

significant difference was seen between the 1-10-hour men and those who had driven over 10 hours, however. (15)

2. (a) A 1935 survey indicated that less than normal sleep in past 24 to 48 hours was cause for most driver-asleep accidents. Five automobile drivers out of 8 having accidents had been without sleep for 16-20 hours and nearly 50 percent had less than 4 hours in last 24. Most common hour for driver-asleep accidents was 2 a.m.

(b) One in 3 driver-asleep accidents was a trucker-asleep accident. One-third had been driving from 4-8 hours since last sleep, one-third had been on the road 16 hours or more. Most common sleeping period was 2 to 3 hours. Eight in 10 lacked normal sleep in last 24 hours, 9 in 10 lacked normal sleep in last 48 hours. Most common hour for trucker-asleep accident was 5 a.m. (16)

3. Tests on drivers who drove about 300 miles every other day indicated the following:

(a) There is a demonstrable fatigue effect of long automobile drives on body reaction.

(b) Long automobile drives tend to decrease the fading time of vascular skin reaction; increases unsteadiness in standing; decreases the accuracy of hand-eye coordination; decreases visual efficiency; decreases the speed and accuracy of mental addition.

(c) The tendency of long automobile drives is to produce a loss of effectiveness and motor reactions similar to those required in driving. These observations suggest that the effect of a long automobile drive may render a driver temporarily prone to accidents. (17)

4. Based on experience of sport car drivers in France, recommendation is made for drivers to stop every 300 miles to exercise and to allow for 24 hours of rest before driving again if trips are of 650 miles or more. (18)

5. Use of drugs, caffein or the amphetamines (Benzedrine or Dexedrine) may be of assistance in combating fatigue or the tendency of drivers to go to sleep. Caffein is effective but is not as long lasting. The amphetamines could be safely used to prolong wakefulness at least 48 hours. (19)

Aircraft

1. In long duration flights a noticeable deterioration in a pilot's performance takes place. It was observable over a 40-minute interval and over the total 15-hour flight. More specifically:

(a) Errors in altitude and heading got progressively greater in second and third watches (fourth watch, the last showed slight improvement).

(b) Turbulence which tends to cause greater concentration than still air did not appear to cause pilots trouble until the third and fourth watches.

(c) Two-hour watches were recommended for pilots with opportunity to sleep and eat to minimize performance deterioration. (20)

2. Errors in performance of radio operators on 15-hour sortie, 5-hour watches were analyzed. Operators were on radio only one watch per sortie, changed radio watch each sortie, but did have duty assignments the full 15 hours.

(a) Decrement noted in performance over 5-hour watch.

(b) Performance dropped consistently from one watch to the next, the third roughly 20 percent poorer than the first.

(c) Twenty-four hours off duty between flights appeared to be sufficient to prevent fatigue accumulation. (21)

3. Subjective observations on Tokyo airlift confirm deterioration noted in 1 and 2 above. Irritability, sleepines, lack of tolerance. tension, loss of initiative and leadership ability all seemed to be present on long flights. (22)

4. The so-called Cambridge Cockpit Studies indicated the following:

(a) The fatigued pilot can see as small a difference in an instrument reading but he does not do anything about it until the difference is somewhat bigger than the deviation causing the rested pilot to act. After 2 hours ability to discriminate may not have changed but it may take 3 to 4 times as much deviation to cause corrective action to be taken. Pilot's concept of acceptable standards becomes lower as he becomes fatigued.

(b) Performance can be kept high if sufficient motivation is present. (23)

5. Review of CAB's report on Italian airliner crash on approaches to Idlewild in 1954 notes the Board believes fatigue was a factor in the crash. They cite the pilot's poor adherence to the localizer path, the last descent to a very low altitude before the sharp pull-up, and the evidence of abrupt control action. The crew was "on board" 22½ hours prior to crash but it was large enough so that duties could be rotated and adequate sleeping facilities were available. The presence of fatigue is explained by the high mental and physical demands placed on the pilots by the four landing approaches over the 22½ hours. Anxiety or worry was said to have similar effects as actual work accomplishment. The combination of anxiety over the flight and the actual strain apparently was not compensated by en route resting. (24)

Additional articles are believed pertinent to the subject matter but could not be obtained at the time of this study:

Civil Aeronautics Administration, "The Rate of Fatigue in Pilot Performance." CAA, Div. of Res. Report 61, Washington, May 1946

Davis, D. R., "Pilot Error." Some Laboratory Experiments, Air Ministry, A.P. 3139A, 1948.

Fraser, D. C. and Samuel, G. D., "Aircrew Fatigue in Long Range Maritime Reconnaissance, Effects on Vigilance." Air Ministry Rept, FPRC 907.10, 1956

McFarland, R.A., "Fatigue and Stress and Their Roles in Military Operations." O.R.O. Symposium, 1952.

McIntosh, B. B., et. al., "Pilot Performance During Extended Periods of Instrument Flight." USAF Tech. Rept., 6725, 1952

Reid, D. D., "Fluctuations in Navigator Performance During Operational Sorties." Air Ministry Air Pub., 3139, 321, 1947.

DISCUSSION

The condition of work being considered here is a very infrequent but quite long overtime period in which good motivation is present. The motivation factor is quite significant in the opinion of the writer since snow removal seems to be one of few work activities of highway maintenance personnel which really stimulates the entire crew. This may in part be due to the favorable recognition and publicity usually gained by the men as they clear the roads. It is quite easy to recognize the accomplishment and immediate worth of the service rendered by the crew's efforts. A sense of pride is attained here to an extent probably not matched in any other maintenance activity. In addition, if the activity takes place at night, one of few opportunities for additional pay is presented. In view of the prevailing wage structure, the opportunity for overtime pay is quite likely welcomed.

No studies were found which exactly duplicated the conditions described above. It would appear that the military would be interested in problems of this nature but many of the papers from that source examined for this study were concerned with the cumulative effects of a series of long duty periods. Because of the lack of data from essentially the same work conditions, the analysis must be based upon an extrapolation of evidence from what might be called cognate situations.

Much of the material reviewed and classified under the heading of General supports the contention that motivation influences the amount of energy made available to a certain task. This particular characteristic is quite important in the work situation under study because of the likelihood of fairly high motivation.

Of interest also in this group was the report on eyestrain caused by flashing light. It is quite possible that the flying snow produces strain of this type. This may be compounded somewhat, too, by snow flying up and back from the plow.

The evidence gathered on lack of sleep seems to be fairly uniform in showing little deterioration in muscular activity due solely to lack of sleep. Sleepiness or the distraction of fighting sleepiness appears to be of more importance to the problem at hand.

The Industrial or Production articles are helpful in two ways. First, it was reported that overtime, particularly without special motivation, is quite inefficient from a production point of view. It is quite true that the expected performance for a single overtime period (the situation under study) is likely to be greater than that obtained if the extra hours were worked every day. However, the decrement noted quite consistently over a normal shift was quite significant and it appears that considerable motivation would have to be present to overcome it. Of interest here is the effect of highly motivated second and third shift work on the output on succeeding days. Unfortunately, nothing but an assumption was available on the next day "vigor" of the men who loaded iron into a furnace for 16 hours straight every third Sunday. It is quite likely that the heavy added demand coming irregularly had considerable after effects.

Secondly, the relationships involving accidents are quite interesting. It is shown fairly well that accidents tend to increase with the speed of the operation. Thus, accident frequency rises as motivation and practice speed up the work. However, as fatigue slows the process down it also continues to make the employee even more susceptible to accidents. Finally, as length of working hours is increased, the chance of accidents goes up simply because of greater exposure. The cost of accidents and injuries is apparently a factor of considerable importance on the question of work efficiency.

Many of the articles reviewed under the Automotive heading refer to long mileage trips. It seems reasonable to assume that comparable results would have been observed had the subjects spent the same time going possibly at a much slower rate but under as much or more tension. If this assumption can be accepted, these data are quite pertinent to the present study. Also, in view of the possibility of the snowplow crews working all day and driving plows on into the night, the driver-asleep accident data seem particularly pertinent in appraising the length of the working period.

The conditions experienced by the aircraft crews probably come closest to those observed for the snowplow crews. Duties were rotated some providing for change of scene; the wakeful hours approached 24; fair motivation level present, particularly for the pilots; attention and alertness were required. It is interesting, then, to note the deterioration that takes place in performance in the later watches. In a few instances some improvement was noted in the last watch, it is true. This was explained as probably due to the arrival of daylight and the "end-spurt" frequently found when the end of a work period is approached.

The willingness of the aircrews to accept greater and greater deviations from normal operation as fatigue increases is also quite significant. It appears that a similar phenomenon existed in many of the work or performance studies reported under the Automotive and Industrial headings. Deterioration of output is not as critical in the present problem as is the tendency to relax normal safety precautions. It is quite possible that just such a relaxation is the major cause for the increase in the number of accidents experienced by fatigued or poorly motivated workers.

The failure of the study to uncover specific references to efficiency during irregular overtime periods is surprising as well as disturbing. The case of the men loading iron for 16 hours every third week stands alone in the study. However, it is believed that the provision for rest between flights makes the aircraft data reasonably descriptive of the situation under consideration in this study.

CONCLUSIONS

In view of the specific conditions believed present and the experience reviewed in this study, the following conclusions seem appropriate:

1. No quantitative estimate of work decrement can be made for maintenance employees involved in overtime snow removal operations. This is due in part to the difficulty of determining a satisfactory measure of work accomplishment but mostly due to the factor of motivation which is believed quite significant in this particular activity.
2. The efficiency experienced during overtime snowplow operations decreases with length of the work period but probably does not become a question for concern until after 16 consecutive hours of work. The decrease is due mainly to the increased likelihood of accidents but some work decrement may take place, particularly if motivation drops. The chances are very good that work decrement may become quite noticeable by the beginning of the third shift.
3. Removal of the special motivation factor associated with the plowing operation would cause the overtime operation to be quite inefficient. Saturday work during regular working hours would be preferred to night work on a normal work day.
4. Work periods longer than 24 hours would be extremely inefficient, particularly if the storm had abated and the employee was assigned to routine work.
5. Lack of sleep by itself probably has little effect on the ability to perform work. It may well be an important factor in the consideration of efficiency because of sleepiness and the distraction of fighting to stay awake.

RECOMMENDATIONS

1. Snow plow crews should be limited to 16 hours of continuous work. In an extreme situation this might be extended to 24 hours.
2. Operators should not be kept plowing continuously for longer than 2-hour periods. They should be allowed to rest either on the road or at the garage, encouraged to stretch or engage in some form of mild exercise, perhaps drink some coffee and eat some food. A warm meal should be considered if the work period extends beyond 16 hours.
3. If continuous plowing is required well into the night, alternate crews might be used to allow time for rest and relaxation.
4. For those men troubled with sleepiness, use of drugs such as caffein or the amphetamines might be considered.
5. Any man working much over 18 hours should be kept off the job for at least 12 hours or preferably held off until the following day. Any work performed by these individuals is likely to be highly inefficient until they are thoroughly rested.

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ANALYSIS OF ACCIDENTS INVOLVING FIELD MAINTENANCE EMPLOYEES OF THE IOWA STATE HIGHWAY COMMISSION[1]

MARCH 1960

by

H. A. Padgett

The following tabulations, Tables 193 through 201, present a summary of personal injury accidents to field maintenance employees of the Iowa State Highway Commission, from July through December 1959.

Equipment operators reported a larger number of injuries than did any other class of personnel, and these occurred more frequently while operating equipment than while doing other work. However, mechanics incurred the highest frequency of accidents per employee.

Although the part of body most frequently injured was the hand and fingers, back injuries caused the most lost time during November and December, the months for which this information was available.

Data presented in Tables 193 and 195 were obtained from the Maintenance Employee Record, January 1, 1960.

Tables which present numbers of accidents and injuries are not in numerical agreement because some accidents caused multiple injuries. Accidents and injuries data were obtained from Maintenance Department tabulations for the months July through November 1959 and from copies of the First Report of Injury for November and December 1959.

Time lost because of injury as shown in Table 201 was obtained from copies of the Supplemental Report of Injury.

TABLE 193
NUMBER OF EMPLOYEES BY DISTRICT AND JOB CLASSIFICATION

District	Foreman	Mechanic	Laborer	Operator	Total
1	18	21	-	255	294
2	18	19	-	180	217
3	17	11	-	163	191
4	20	21	2	210	253
5	19	17	2	167	205
6	13	18	4	190	225
Total	105	107	8	1,165	1,385
Percent of total	8	8	1	83	100

1/ Safety is one of the specialized aspects of maintenance operations and this subject is one of the several objectives of the maintenance study. The numerical data presented herein constitute a convenient reference for those who are concerned with management aspects of the safety problem. This analysis as well as additional facts and observations about safety were furnished to the Central Office early in 1960.

TABLE 194

NUMBER OF ACCIDENTS BY DISTRICT AND THE YEARLY MAN -HOURS WORKED PER DISTRICT

District	Accidents		Man-Hours Worked	
	Number of Accidents	Percent of Total	Number of Man-Hours Worked	Percent of Total
1	33	20	613,000	20
2	32	19	473,700	16
3	21	13	421,700	14
4	29	17	538,100	18
5	23	14	454,900	15
6	29	17	498,600	17
Total	167	100	3,000,000	100

TABLE 195

NUMBER OF EMPLOYEES AND NUMBER OF ACCIDENTS BY AGE GROUP

Age Group	Employees		Accidents	
	Number of Employees	Percent of Total	Number of Accidents	Percent of Total
Under 20	9	1	2	1
20-30	137	10	20	12
30-40	328	24	40	24
40-50	369	26	47	28
50-60	370	27	39	23
Over 60	172	12	19	12
Total	1,385	100	167	100

TABLE 196

NUMBER OF ACCIDENTS BY WORKMAN'S ACTION AT TIME OF ACCIDENT AND JOB CLASSIFICATION

Workman's Action at Time of Accident	Job Classification				Total	Percent of Total
	Foreman	Mechanic	Laborer	Operator		
Operating equipment	-	-	-	24	24	15
Using hand tools	1	4	1	15	21	13
Lifting, loading, unloading, carrying	-	-	-	20	20	12
Poison Oak or poisonous bites 1/	-	2	-	12	14	8
Struck by object	1	1	-	12	14	8
Hooking or unhooking equipment 2/	-	1	-	9	10	6
Struck by vehicle or equipment	-	2	-	6	8	5
Vehicle accidents	-	1	-	3	4	2
Welding or cutting	-	3	-	1	4	2
Using power tools	-	2	-	1	3	2
Getting into, out of, or on equipment	-	-	-	2	2	1
Repairing, adjusting, servicing equipment	-	-	-	2	2	1
Walking or climbing	-	-	-	2	2	1
Using hot asphalt or burners	-	-	-	1	1	1
Miscellaneous 3/	2	7	-	29	38	23
Total	4	23	1	139	167	100
Percent of total accidents	2	14	1	83	100	
Number of employees	105	107	8	1,165	1,385	
Percent of total employees	8	8	1	83	100	

1/ Poison oak and poisonous bite injuries occurred only during July and August.

2/ Hooking or unhooking equipment accidents mostly involved snowplows.

3/ Miscellaneous accidents were so classified when it was impossible to determine workman's action at the time of injury from the the tabulation sheet. During November and December, the months for which accident reports were available, only 4 of 59 or 7 percent of the accidents were classified as miscellaneous.

TABLE 197

NUMBER OF INJURIES BY JOB CLASSIFICATION AND PART OF BODY INJURED

Part of Body Injured	Job Classification				Total Injuries	Percent of Total
	Foreman	Mechanic	Laborer	Operator		
Finger and hand	3	11	1	35	50	28
Back	1	3	-	24	28	16
Arm	-	4	-	15	19	11
Leg and knee	-	1	-	15	16	9
Eye	-	3	-	12	15	9
Head, neck, face	-	-	-	13	13	7
Shoulder	-	1	-	8	9	5
Foot	-	1	-	7	8	4
Chest, abdomen, side	-	1	-	4	5	3
Hip	-	-	-	3	3	2
All other	-	-	-	10	10	6
Total	4	25	1	146	176	100
Percent of total	2	14	1	83	100	

TABLE 198

NUMBER OF ACCIDENTS BY AGE GROUP AND WORKMAN'S ACTION AT TIME OF ACCIDENT

Workman's Action at time of Accident	Age Group						Total Number of Accidents	Percent of Total
	Under 20	20-30	30-40	40-50	50-60	Over 60		
Operating equipment	-	3	6	11	3	1	24	15
Using hand tools	-	4	5	2	6	4	21	13
Lifting, loading, unloading, carrying	1	1	4	5	6	3	20	12
Poison Oak or poisonous bites	-	1	4	5	2	2	14	8
Struck by object	1	1	5	2	4	1	14	8
Hooking or unhooking equipment	-	3	2	1	3	1	10	6
Struck by vehicle or equipment	-	3	1	1	2	1	8	5
Vehicle accidents	-	1	-	1	1	1	4	2
Welding or cutting	-	1	-	2	-	1	4	2
Using power tools	-	-	1	1	1	-	3	2
Getting into, out of, or on equipment	-	-	1	1	-	-	2	1
Repairing, adjusting, servicing equipment	-	-	1	1	-	-	2	1
Walking or climbing	-	-	1	-	-	1	2	1
Using hot asphalt or burners	-	-	-	1	-	-	1	1
Miscellaneous	-	2	9	13	11	3	38	23
Total	2	20	40	47	39	19	167	100
Percent of total	1	12	24	28	23	12	100	

TABLE 199

NUMBER OF INJURIES BY AGE GROUP AND PART OF BODY INJURED

Part of Body Injured	Age Group						Total Number of Injuries	Percent of Total
	Under 20	20-30	30-40	40-50	50-60	Over 60		
Finger and hand	-	8	12	15	11	4	50	28
Back	-	3	9	9	4	3	28	16
Arm	-	-	4	4	7	4	19	11
Leg and knee	1	3	4	5	2	1	16	9
Eye	-	2	4	5	2	2	15	9
Head, neck, face	1	1	2	3	4	2	13	7
Shoulder	-	1	-	2	3	3	9	5
Foot	-	2	1	3	1	1	8	4
Chest, abdomen, side	-	-	1	-	2	2	5	3
Hip	-	-	1	1	1	-	3	2
All other	-	2	2	3	2	1	10	6
Total	2	22	40	50	39	23	176	100
Percent of total	1	13	23	28	22	13	100	
Number of Employees	9	137	328	369	370	172	1,385	
Percent of Total	1	10	24	26	27	12	100	

TABLE 200

NUMBER OF INJURIES BY WORKMAN'S ACTION AT TIME OF INJURY AND PART OF BODY INJURED

Workman's Action at Time of Injury	Part of Body Injured											Total Number of Injuries	Percent of Total
	Finger and Hand	Back	Arm	Leg and Knee	Eye	Head Neck Face	Shoulder	Foot	Chest Abdomen Side	Hip	All other		
Operating equipment	9	4	3	1	1	1	1	1	-	-	3	24	14
Using hand tools	14	-	2	-	2	1	2	-	-	-	-	21	12
Lifting, loading, unloading, carrying	1	6	1	3	1	1	1	4	1	1	-	20	11
Struck by object	2	-	1	-	7	4	1	-	-	-	-	15	8
Poison Oak or poisonous bites	1	2	5	2	-	-	1	-	-	1	2	14	8
Hooking or unhooking equipment	6	3	-	-	-	-	-	-	-	1	-	10	6
Struck by vehicle or equipment	2	-	1	3	-	1	-	-	-	-	2	9	5
Vehicle accidents	1	1	-	1	-	1	-	-	1	-	2	7	4
Welding or cutting	1	-	-	-	2	-	-	1	-	-	-	4	2
Repairing, adjusting, servicing equipment	1	1	-	-	-	1	-	-	-	-	-	3	2
Using power tools	2	-	1	-	-	-	-	-	-	-	-	3	2
Getting into, out of, or on equipment	-	-	-	1	-	-	-	1	-	-	-	2	1
Using hot asphalt or burners	1	-	-	-	-	1	-	-	-	-	-	2	1
Walking or climbing	-	1	-	-	-	-	-	-	1	-	-	2	1
Miscellaneous	9	10	5	5	2	2	3	1	2	-	1	40	23
Total	50	28	19	16	15	13	9	8	5	3	10	176	100
Percent of Total	28	16	11	9	9	7	5	4	3	2	6	100	

TABLE 201

TIME LOST BECAUSE OF INJURY DURING NOVEMBER AND DECEMBER 1959 BY WORKMAN'S ACTION AT THE TIME OF INJURY AND THE PART OF BODY INJURED

Workman's Action at time of Injury	Part of Body Injured																				Total		Average Days Lost per Injury
	Back		Finger and Hand		Head Neck Face		Arm		Foot		Hip		Chest Abdomen Side		Eye		Leg or Knee		Shoulder				
	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days Lost	No. of Injuries	Days	
Lifting, loading, unloading, carrying	6	88	-	-	1	5	1	30	3	13	1	40	1	10	1	2	1	1	-	-	15	189	12.6
Using hand tools	-	-	2	8	-	-	2	35	-	-	-	-	-	-	-	-	-	-	-	-	4	43	10.7
Vehicle accidents	-	-	1	10	1	5	-	-	-	-	-	-	1	10	-	-	-	-	-	-	3	25	8.3
Using power tools	-	-	2	9	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	9	4.5
Hooking or unhooking equipment	1	5	-	-	-	-	-	-	-	-	1	3	-	-	-	-	-	-	-	-	2	8	4.0
Repairing, adjusting, servicing equipment	1	1/	1	4	1	4	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	8	4.0
Using hot asphalt or burners	-	-	1	2	1	2	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	4	2.0
Getting into, out of or on equipment	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	3	-	-	1	3	3.0
Operating equipment	1	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	1	1.0
Miscellaneous	1	2	-	-	1	3	-	-	-	-	-	-	-	-	1	3	-	-	1	2	4	10	2.5
Total	9	96	7	33	5	19	3	65	3	13	2	43	2	20	2	5	2	4	1	2	36	300	
Average days lost per injury	10.7		4.7		3.8		21.7		4.3		21.5		10.0		2.5		2.0		2.0		8.3		

1/ Has not returned to work. Not included in totals.

Section G

PREDICTING PERFORMANCE FOR CREWS ASSIGNED TO MAINTENANCE OPERATIONS

Studies in Iowa disclosed that average performance was relatively poor for crews assigned to many maintenance operations. As previously indicated in the report, one of the major reasons for poor performance was lack of day to day planning by supervisors. Many supervisors do not believe it is possible to plan operations. Others do, but maintain that they do not have the necessary tools to do an effective job of planning. One of the principal tools needed is some means of predicting performance by crews operating under the widely varying conditions encountered on actual jobs.

Any successful method for predicting performance must take into account all of the factors which have a major influence on performance. These include crew size, number of equipment units utilized, and travel distances. Other factors, such as work methods, type of equipment, load size, average travel speed and time lost due to delays can have a great influence on performance but usually do not vary greatly from job to job in any given county. They may, however, vary substantially from county to county and must then be taken into account. One method of evaluating the influence of the factors listed above would be to study each operation until all possible combinations of factors had been observed and related to performance. This would require a vast expenditure of effort. The study group staff has developed a method for predicting performance which eliminates a great deal of the effort required by the first method. Operations must still be studied but only to a limited extent.

Basically, the study group's method involves developing an algebraic equation which accounts for crew labor (or in some cases equipment) NAWT expended on an operation. Since NAWT consists of various cyclic work items, supporting work items and delays, each one must be included in some term of the equation. In some cases, a term may represent a large group of work items and/or delays. The terms are expressed so that they include all major factors which influence performance. For example, the term covering a crew's travel time might be written as follows:

$$\text{Travel time (min.)} = \frac{\text{No. of men x travel distance (miles) x 60}}{\text{Average travel speed (mph)}}$$

As indicated, some factors do not vary to any great extent for any given work methods and type of equipment. They may be replaced by average values obtained from a limited number of studies. In the above example, the factors for number of men and travel distance vary from job to job but the factor average travel speed remains about the same with a given type of truck. After substituting for factors which do not vary to any extent, we have an equation in which terms include only those factors which vary substantially from job to job. Performance may then be predicted by substituting values known to exist on a given job for these variable factors. Also, it is possible to see how much performance will change if any factor is given a different value.

The following material shows how this method works. The operation "erect snowfence" is used as an example. We will confine our attention to that part of the operation where fence is hauled and erected on previously driven posts. Table 202 presents one method of summarizing expected performance but it is possible to develop graphs or charts which may be more desirable for use by field supervisors planning operations.

NAWT for a crew hauling and erecting snowfence on previously driven posts may be expressed as follows:

$$MX = MG + \frac{MD(X-G)}{100} + \frac{60MT_1}{S_1} + \frac{60MT_2}{S_1} + \frac{60MT_3}{S_1} + \frac{60AH}{LS_2} + \frac{60AH}{LS_2}\left(\frac{M-N}{N}\right) + \frac{60AR}{LS_3}$$

$$+ \frac{60AR}{LS_3}\left(\frac{M-N}{N}\right) + AP_1 + AP_2 + AP_3 + AP_4 + AP_5 + AP_6 + AP_7 + AP_8$$

Where:

A = total number of fence rolls erected by crew

D = average percent of time away from the garage each man loses due to delays

G = average time (Min.) each man on crew spends at the garage during the day including all work items and delays

H = average distance (Miles) fence rolls are hauled from stockpiles to worksites

L = average number of fence rolls hauled per load

M = number of men on crew (working as a team)

N = number of trucks crew uses for hauling fence rolls

P_1 = average time (Man-Min.) to untie and unroll one roll of fence

P_2 = average time (Man-Min.) to tie one roll of fence to adjacent rolls

P_3 = average time (Man-Min.) to position one roll of fence on posts

P_4 = average time (Man-Min.) to tie one roll of fence to posts

P_5 = average time (Man-Min.) per roll of fence to drive extra or brace posts (needed in addition to posts previously driven)

P_6 = average time (Man-Min.) per roll of fence for men to walk ahead or move ahead to next work area

P_7 = average time (Man-Min.) per roll of fence for supporting work items at stockpiles including loading fence rolls

P_8 = average time (Man-Min.) per roll of fence for supporting work items at worksites including unloading fence rolls

R = average distance (Miles) returned from worksites to stockpiles per load of fence rolls hauled (note that this is based on number of loads hauled instead of number of return trips actually made)

S_1 = average speed (MPH) during travel

S_2 = average speed (MPH) during haul

S_3 = average speed (MPH) during return

T_1 = average total distance (Miles) traveled by each man between the garage and worksites or garage and stockpiles during day

T_2 = average total distance (Miles) traveled by each man between worksites (but not between worksites and stockpiles) during day

T_3 = average total distance (Miles) traveled by each man between worksites and garage or between stockpiles and garage during day
X = average NAWT (Min.) each man spends on the operation

Note that:

MX = NAWT (Min.) the entire crew spends on the operation
(X-G) = average time each man spends away from the garage during the day
$\frac{A}{L}$ = number of loads of fence rolls hauled
$\frac{M-N}{N}$ = average number of men per truck other than drivers riding between stockpiles and worksites during haul and between worksites and stockpiles during return

Simplifying:

$$X = \frac{G(100-D)+DX}{100} + \frac{60(T_1+T_2+T_3)}{S_1} + \frac{60A}{LN}\left(\frac{H}{S_2} + \frac{R}{S_3}\right) + \frac{A(P_1+P_2+P_3+P_4+P_5+P_6+P_7+P_8)}{M}$$

Solving for A:

$$A = \frac{X - \frac{G(100-D)+DX}{100} - \frac{60(T_1+T_2+T_3)}{S_1}}{\frac{60}{LN}\left(\frac{H}{S_2} + \frac{R}{S_3}\right) + \frac{(P_1+P_2+P_3+P_4+P_5+P_6+P_7+P_8)}{M}}$$

After obtaining this type of expression for an operation, the next step would be to substitute values for each factor which would be relatively constant as long as the same type equipment units and work methods were used. For this example, we will use the following values obtained during production studies in Iowa:

D = 14% plus 2% times the number of men = 14 + 2M
G = 0.1X min.
L = 15 rolls of fence
P_1 = 1.7 man-min.
P_2 = 0.7 man-min.
P_3 = 1.2 man-min.
P_4 = 2.4 man-min.
P_5 = 0.2 man-min.
P_6 = 1.2 man-min.
P_7 = 1.8 man-min.
P_8 = 3.5 man-min.
R = 0.6 H miles
S_1 = 30 mph
S_2 = 20 mph
S_3 = 18 mph

We will also assume that the crew works a full day so X = 480 min.

$$A = \frac{480 - \frac{48\,[100 - (14+2M)] + 480(14+2M)}{100} - \frac{60(T_1+T_2+T_3)}{30}}{\frac{60}{15N}\left(\frac{H}{20} + \frac{0.6H}{18}\right) + \frac{(1.7+0.7+1.2+2.4+0.2+1.2+1.8+3.5)}{M}}$$

Simplifying:

$$A = \frac{371.52 - 8.64M - 2(T_1+T_2+T_3)}{\frac{0.33H}{N} + \frac{12.70}{M}}$$

If it is desired to obtain the production per man-hour, the above expression can be altered as follows:

A' = number of fence rolls erected per man-hour

$$A' = \frac{60A}{MX}$$

X = 480 minutes in the case assumed so

$$A' = \frac{A}{8M}$$

$$A' = \frac{371.52 - 8.64M - 2(T_1+T_2+T_3)}{\frac{2.64HM}{N} + 101.60}$$

The following table shows expected values for A and A' resulting from various combinations of values for other factors. Remember that:

A = total number of fence rolls erected by entire crew
A'= number of fence rolls erected per man-hour
H = average haul distance (miles)
M = number of men on crew (working as a team)
N = number of trucks used for hauling fence rolls
$(T_1+T_2+T_3)$ = total average travel distance per man (miles)

TABLE 202

EXPECTED PERFORMANCE FOR CREWS HAULING AND ERECTING SNOWFENCE ON PREVIOUSLY DRIVEN POSTS

$(T_1 + T_2 + T_3)$ →		20 miles				30 miles				40 miles			
H →		5 miles		10 miles		5 miles		10 miles		5 miles		10 miles	
M ↓	N ↓	A	A'	A	A'	A	A'	A	A'	A	A'	A	A'
2	1	39.3	2.45	32.6	2.03	36.8	2.30	30.5	1.91	34.3	2.14	28.4	1.77
2	2	43.9	2.74	39.3	2.45	41.0	2.56	36.8	2.30	38.3	2.39	34.3	2.14
3	1	52.1	2.16	40.6	1.69	48.5	2.02	37.9	1.58	45.1	1.88	35.2	1.47
3	2	60.5	2.51	52.1	2.16	56.5	2.35	48.5	2.02	52.5	2.19	45.1	1.88
3	3	63.9	2.66	57.4	2.39	59.8	2.49	53.5	2.23	55.5	2.31	49.8	2.07
4	2	74.4	2.32	61.6	1.92	69.3	2.17	57.4	1.76	64.3	2.01	54.4	1.70
4	3	79.9	2.49	69.5	2.17	74.5	2.33	64.9	2.03	69.1	2.16	60.2	1.88
4	4	83.0	2.59	74.4	2.32	77.4	2.42	69.3	2.17	71.8	2.24	64.3	2.01
5	2	85.8	2.14	68.8	1.72	79.9	2.00	64.1	1.60	74.0	1.85	59.3	1.48
5	3	93.3	2.33	79.2	1.98	86.9	2.17	73.8	1.84	80.3	2.01	68.3	1.71
5	4	97.7	2.44	85.8	2.14	91.0	2.28	79.9	2.00	84.2	2.11	74.0	1.85
6	2	95.2	1.98	74.1	1.55	88.2	1.84	68.9	1.44	81.3	1.69	63.5	1.32
6	3	104.8	2.19	86.8	1.81	97.2	2.03	80.5	1.68	89.7	1.87	74.3	1.55
6	4	110.5	2.30	95.2	1.98	105.0	2.19	88.2	1.84	94.5	1.97	81.3	1.69

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