HIGHWAY CONSTRUCTION MANAGEMENT

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

JUNE 1976

ROY JORGENSEN ASSOCIATES, INC.
Engineering and Management Consultants

HIGHWAY CONSTRUCTION MANAGEMENT

FINAL REPORT
ON A RESEARCH PROJECT
CONDUCTED JOINTLY

by the

MICHIGAN DEPARTMENT OF STATE HIGHWAYS AND TRANSPORTATION

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and

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June 1976

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June 24, 1976

Mr. Gerald J. McCarthy
Deputy Director, Michigan Department of
State Highways and Transportation
State Highways Building
425 West Ottawa
Post Office Box 30050
Lansing, Michigan 48904

Dear Mr. McCarthy:

We fully concur in your decision to write this report for top management officials rather than technical specialists. The research was unusually thorough. The results can be, most surely will be, significant to many agencies, with special reference to state transportation and highway departments.

We tried to write the report for easy reading—short, and free from ponderous language. Despite the quantities of data available, we deliberately limited charts and tables to those that make essential points rather than to document the research. Documentation is available to anyone who asks.

We also agree that this is a joint report. The project was uniquely successful (as demonstrated by the fact that implementation of the construction management system statewide was well under way before this report was written) because it was carried out jointly by your organization and ours. This summary of the research and its results must, therefore, be a joint effort as well. We particularly appreciate the guidance and reviews obtained from you and your staff.

Sincerely,

M. Ed Shaw
Director, Manpower and
Training Division

PREFACE

The Michigan Department of State Highways and Transportation made excellent progress toward reducing construction engineering costs during the years 1967 through 1971. Manpower charges, which represent roughly 85 percent of all construction engineering costs, were decreased approximately 12 percent despite a 23-percent increase in the work load (as measured in 1967 dollars). The two changes had the effect of cutting construction engineering costs by 29 percent.

Costs still ranged from 8 to 16 percent of contractor payments, averaging 13. Since the Federal Highway Administration participates only to the extent of 10 percent, there was need to do one of three things:

- cut costs to the Federal participation level; or
- document the higher costs and move for increased Federal participation; or
- accept the Federal rate and pay all additional costs with State funds.

The Department elected to solve the problem through controlled research. The systems approach had worked well in bringing about preconstruction and maintenance management improvements; it would now be applied to construction.

The project was financed with Highway Planning Research funds under Federal Highway Administration Contract Number 97614 and Department of State Highways and Transportation Contract Number 71-0667. Research and development work was initiated in 1971, and completed in 1975.

The construction management system developed through the research is simple, easy to administer. Its development was complex—but the presentation in this report is designed to provide an easy-to-follow synthesis. The first chapter is directed toward the need for a management system, and the criteria to be met. Each major component of the final system is then discussed in a separate chapter. Considerations relative to managing the system are discussed in Chapter Six.

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FOREWORD

References to who did what in connection with this undertaking are omitted from the text. Their inclusion, even as footnotes, would unnecessarily complicate the reading. Since they are important to understanding why the project was so successful, they are included here.

Project Organization

This project was carried out as a joint effort of the Department and the Consultant, as indicated in the organization chart on the next page. (Names and titles of individuals are included in Appendix F, starting on page 103.)

Deputy-Director—Bureau of Highways

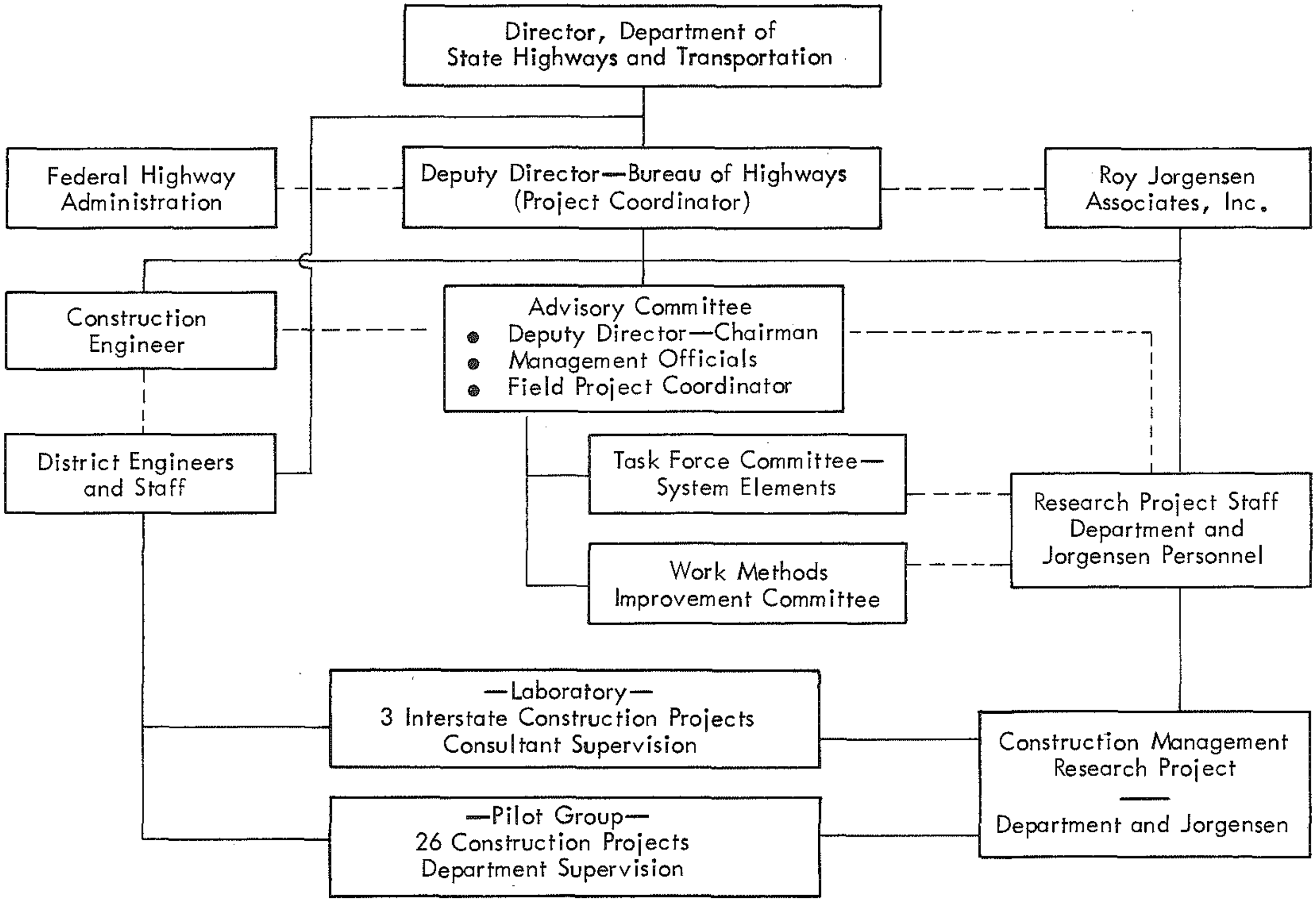
The Deputy Director of Transportation heads up the Bureau of Highways. The Bureau consists of eight divisions: Construction, Design, Maintenance, Right-of-Way, Testing and Research, Traffic and Safety, Route Location and Local Government.

The Deputy Director initiated this project, and served as Project Coordinator and Chairman of the Advisory Committee. He ensured access to useful data, field testing of models, adoption of work methods and other improvements, and prompt reviews of recommendations. He kept things going at the top-management level.

Advisory Committee

The Advisory Committee made recommendations to the Deputy Director, and provided guidance to the project staff. It reviewed and approved all parts of the

PROJECT ORGANIZATION



construction management system: the work base, the personnel classification base, productivity standards, staffing standards, and manpower management practices, together with policies and procedures.

The Advisory Committee consisted of the Deputy Director and management officials having vested interests in final results: a representative of the Bureau of Administration, the Assistant Deputy Director, the Construction Engineer, the Personnel Officer, the District Engineer in Jackson, a representative of the Michigan Division of the Federal Highway Administration, and the Assistant District Construction Engineer, Grand Rapids. (The Assistant District Construction Engineer at Grand Rapids also served as Field Project Coordinator—Assistant to the Deputy Director for Departmental supervision of the research.)

Research Project Staff

The project staff identified data needs, designed data collections, analyzed findings, developed model components of the management system, tested those components, and developed the final system. It worked closely with the Advisory Committee, the Work Methods Improvement Committee and the various task force committees appointed to deal with individual components.

The "immediate project staff" included Department and Jorgensen personnel specifically assigned to carrying out the research and development work. The project manager, a Jorgensen engineer, and the Field Project Coordinator, a Department engineer, had on-site responsibility. Senior Jorgensen personnel provided guidance based on experience in other states. Senior Department officials provided guidance based on Department objectives, authority, policies and practices.

The "expanded project staff" included officials and personnel of the Grand Rapids District—all of whom contributed consistently.

Task Force Committee

The Task Force Committee derived its name from the way members are appointed. Certain members were permanent; others served on short-term bases to participate in matters to which they could contribute specialized expertise.

This committee was active in nearly every phase of research and development. It identified and classified (1) contractor operations, (2) construction engineering activities, and (3) the knowledge, skills and abilities required by construction engineering personnel to perform the work well. It ranked activities by levels of difficulty, identified potential work methods improvements, and defined typical staffing and documentation requirements. The committee also assisted in system design, including development of standard units of measure, productivity rates, and manpower utilization controls.

Work Methods Improvement Committee

The Work Methods Improvement Committee concentrated on making changes in the ways construction engineering work is done. Each change had to meet two criteria: it had to be acceptable from a construction quality control standpoint, and it had to reduce manpower needs. Suggestions for changes were submitted by the project staff, by members of the committee, and by interested employees.

The Work Methods Improvement Committee has been made a permanent part of the Department organization. Its members, all operating experts in their respective fields, represent the Construction, Design, and Testing and Research Divisions.

Research Laboratory

Engineers and employees assigned to projects used for research made consistent contributions to the research.

Laboratory Projects

Three interstate construction projects were selected for controlled research. Referred to as "laboratory projects," they were used for testing alternative work methods and staffing complements, productivity rates and all components of the system. Detailed records were kept on experiments, tests and operations for use in adjusting models for statewide application.

Jorgensen staffed the laboratory projects and supervised all construction engineering work—to ensure objectivity on all reports, trials and test runs. In all other respects, the project crews functioned as though they were Department forces.

> NOTE: Giving Jorgensen independent responsibility for direct construction supervision provided unexpected spin-offs: Jorgensen personnel, not being accustomed to Department procedures and practices, were able to identify many potential improvements; and, they learned firsthand what project engineers must do to comply with all rules and regulations—forcing them to ensure that all system components were complete, logical and practical.

Pilot Projects

Twenty-six construction projects supervised by Department personnel were selected for data collections and test runs that required experience from more than the three laboratory projects for validity and reliability. The number of projects actually used in each test case varied according to need.

SUMMARY

The Department's objectives were:

1. to learn what the costs of construction engineering should be—based on essential work to be done, good work methods, acceptable workmanship requirements and effective manpower management;

2. to develop a system for controlling costs to those levels; and

3. to ensure acceptance and implementation of the system.

> Engineering Cost Items:
> - Wages and salaries;
> - Fringes and benefits;
> - Vehicles and equipment;
> - Travel expenses;
> - Laboratory charges; and
> - Field office expenses.

Defining Need and Criteria

Construction and top management officials knew costs had to be reduced. Paying 8 percent of contractor payments for construction engineering on large projects was, on the face of it, unreasonable—even if the Federal Highway Administration would participate up to 10 percent. Paying 13 to 14 percent as an overall average was disturbing—even if the 10-percent participation rate would ultimately be found unrealistic for several types of projects. But, if real changes were to come about, field engineers and supervisors would have to concur.

Documenting the Need. As a way of getting the point across, cost variations on comparable projects were identified. While some variations could be justified, in part at least, by differences in record-keeping, work load fluctuations, contractor performance, weather conditions, traffic volumes or other circumstances, the disparities found were too wide for acceptance by anyone.

Man-Hours Used Per $10,000
in Contractor Payments:

- Project Group A* — 67
- Project Group B — 90
- Project Group C — 120
- Project Group D — 215

* Each group included six projects.

The need for a system was clear.

Defining the Criteria. Major justifications for cost variations were used as bases for defining criteria to be met by the system. It had to be a construction management system—not dependent on other functions (except for off-season utilization of key personnel) and not dependent on changes in contractor behavior.

System Criteria:

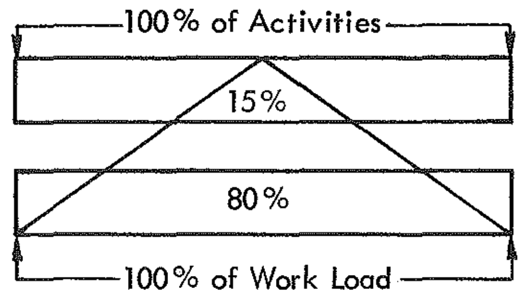
- No changes in planning, programming or design functions;
- No changes in contractor operations;
- Costs to be controlled; and
- System to be simple, practical, accepted and supported.

Establishing the Work Base

Management systems are designed to get work done—making the work itself the base of it all.

Identifying Key Activities. Personnel can charge time to 261 identifiable activities. Of these, 33 represent about 80 percent of all direct-work charges. Since manpower represents nearly 85 percent of all construction engineering costs, the Department could, in effect, control costs simply by controlling 15 percent of the activities.

33 Key Activities Represent
80% of the Work Done



Measuring Work Loads. If charges to 33 activities were to be controlled, manpower required to carry out those activities had to be known in advance—planned for, budgeted and provided. Manpower utilization had to be evaluated in terms of planned utilization after work was done.

Work Measurement Units:	
• Structure staking—	Span lane
• Earthwork—	10,000 c.y.
• Bituminous paving—	1,000 tons
• Concrete paving—	1,000 s.y.

The 33 work loads were identified, using such readily available values as cubic yards, square yards and tons.

Reducing Work Loads. The 33 key work loads being 80 percent of the base, it was critical that they represent essential work only, rather than unnecessary stakes, tests, reports or copies of reports—and never make-work. By cutting back to actual needs on these activities, the Department could cut back on manpower needs.

Establishing Productivity Rates. Key work loads must be translated into manpower needs. While various productivity values can be used to do this, the simplest and most effective—since manpower rather than equipment represents most costs—is man-hours per work unit.

Productivity Rates

Unit of Work	Rate
• 10,000 c.y. earthwork	12 m-h
• 1,000 tons bituminous paving	20 m-h
• 1,000 s.y. concrete paving	6 m-h

m-h = man-hours

Steps were taken first to identify current productivity rates, and then to improve them. Major improvements were attributable to using proper crew sizes and to reducing stand-by time—whether stand-by time is charged as stand-by or as office engineering, surveying or inspection.

Establishing the Personnel Base

Inasmuch as work loads and productivity rates must be used to determine manpower needs, a man-hour of work must represent a certain quantity of work—on the average. Just as important, a man-hour of time must represent usable time—which can be a problem if the employees have specialized and work loads fluctuate for their specialties. Employee versatility is a major factor in reducing stand-by time.

Evaluating the Existing Classification Plan. While reliable productivity rates are indispensable to any system of this kind, the existing personnel classification plan was designed for personnel management—not manpower management—purposes. It was, in effect, counterproductive to construction engineering cost control in that it supported employee specialization rather than versatility—thereby increasing stand-by time.

Existing Classification Plan:

- 14 subprofessional classes;
- Emphasis on employee specialization;
- Based largely on education and experience criteria, plus written tests; and
- Promotions as openings occur.

Designing a New Classification Plan. Analysis of all tasks performed by construction personnel revealed that 78 combinations of knowledge, skills and abilities are required to do the work. These fall into four levels of performance difficulty as far as staking, inspecting and office engineering are concerned, plus one for assistant project management.

New Classification Plan:

- 5 subprofessional classes;
- Emphasis on versatility;
- Based on demonstrated performance capabilities; and
- Promotions to third level as employees qualify.

The new plan, based on demonstrated performance capabilities, meets all personnel management requirements plus the need to translate man-hours into average productivity rates.

Managing Manpower In Season

At this point, the system consisted of the work base and the personnel base. In-season manpower management techniques were required.

Estimating Manpower Needs. Given work load quantities and productivity rates for 80 percent of the work to be done, manpower needs can be calculated for any project from start to finish. Major projects run for two to three years, making it necessary to estimate contractor progress (using the same work load measures) in one-year increments.

Determining Manpower Needs

Work Load Quantity	Productivity Rate	Manpower Needs
600,000 c.y.	12 m-h/10,000	720 m-h
80,000 tons	20 m-h/1,000	1,600 m-h

Staffing single projects leads to extensive stand-by time; week-to-week work load fluctuations can be severe. Combining three or more large projects or several of varying size within a commuting area levels peaks and valleys a great deal—enough so that a few short-term shifts of personnel between project groups are enough to control stand-by time. (Department project engineers are responsible for several construction projects.) So, manpower needs are estimated for groups of contiguous or nearby projects and adjusted at the district levels to avoid overstaffing.

Checking Manpower Estimates. Needs estimates are checked three ways:

- against total needs for district-wide work loads;
- against established guidelines to staffing; and
- against start-to-finish values for each project.

Established Guidelines to Staffing:	
Staking—	19%
Inspecting—	40%
Office engineering—	30%
Leave-taking—	11%
	100%

Guidelines vary by project type.

Establishing Shift Schedules. Staking, office engineering and considerable amounts of inspecting can be carried out on eight-hour, five-day work schedules. Most contractors work more than eight hours per day and many work more than five days per week, making it necessary to tailor-make some shifts. Tailoring can best be done at the project level, using ten- and eight-hour days, five- and four-day weeks, and planned overtime to find the best combination.

Principal Contractor Shifts:	
8.5 hours or more per shift—	81%
1 shift per day—	100%
6 shifts per week—	37%

Straight eight-hour days lead to excessive overtime or excessive stand-by time. Overtime, since time-and-one-half rates cost the Department only 20 percent more than straight time, can reduce costs.

Controlling Manpower Utilization. Work assignments must be scheduled a week in advance if all essential work is to be done and stand-by time is to be controlled. Schedules must be adjusted in response to contractor actions and weather conditions, but most carry through. Giving each employee two assignments—one for expected operations and another in case operations are interrupted—significantly reduces stand-by time.

> Controlling Manpower Utilization:
>
> - Weekly work schedules;
> - Alternate work assignments;
> - Personnel surplus and shortage notices;
> - Alerts to exceptions; and
> - Biweekly reviews.

The control system is designed to alert project engineers to deviations from planned performance and utilization. And it permits project engineers to alert district officials to upcoming manpower surpluses and shortages, permitting shifts to be made between project groups. District engineers compare actual work load completions and manpower utilization to planned values every two weeks.

Managing Manpower Year-Round

While in-season costs can be controlled through the process described above, off-season costs can throw everything out of line.

> Guideline to Size of the Year-Round Force:
>
> - Peak-season man-month needs,
> - Less 10 percent for overtime and other offsets,
> - Times 45 percent for winter-time construction needs (about 41 per 100 peak-needs),
> - Plus 35 percent for other off-season assignments (about 14 per 100 peak-needs).

Establishing the Year-Round Force. The larger the permanent force is, the more difficult it is to hold down in-season and off-season costs. But, versatility of the personnel being uniquely important in holding down costs, it must be large enough to ensure build-up and retention of that capability.

Work loads have been cut back, some work loads have been shifted from peak-season to off-season, and manpower controls have been tightened. As a result, off-season manpower needs for staking, inspecting and office engineering represent a higher percentage of peak requirements than has been the case.

The Department is aiming for 650 year-round employees—as compared with 968 in 1974 and 1,435 in 1967. The reduction will be achieved through attrition—as training increases versatility. The peak work force was 1,196 in 1974 compared with 1,575 in 1967—despite a 23-percent increase in actual work loads. The number of peak-season employees will vary to fit the actual needs defined by the system.

Establishing Off-Season Assignments. Due primarily to the versatility requirement, but also to early- and late-season needs, the year-round force must be larger than the minimum winter requirement. The Department reassigns surplus personnel to other functions during the off-season. Work loads are scheduled to accommodate these personnel and keep them fully productive.

Providing Versatile Seasonal Personnel. To keep the year-round force as small as possible, steps are being taken to increase the versatility of seasonal personnel.

Arrangements have been, and are being, made with engineering schools so that students can attend school for six months and work for six months. Schedules are based on the construction season.

Quick training courses that can be administered at project offices will be provided.

Managing the System

The system is complete, and is being implemented statewide. What does it take to manage it?

Collecting Essential Data. The 33 work load values are readily available from contract plans and project records. Productivity standards are known. Personnel classifications have been established. No new data are required.

Planning for Project Period. A total project manpower plan is developed in the central office, as soon as contract quantities are known, usually shortly after advertising and before letting. The plan includes estimated man-hours by activity and skill level.

Manpower requirements can be estimated as far into the future as projects can be described in quantitative terms.

Planning for One Year at a Time. Estimating manpower needs for each construction season is a short-term, slack-time effort.

Controlling One and Two Weeks at a Time. Work and manpower schedules must be developed and controlled weekly. Actual work load completions and manpower utilization must be compared with planned values every two weeks.

Implementing the System. Project engineers and district officials must be trained relative to the system, and guided in its initial use. The only real difficulty will come with weekly scheduling. All persons resist change, and this one represents a change in habit—not just a concept or approach.

Evaluating Results

Implementation was just getting under way at the close of the research project. Even so, indications of results are available.

Construction engineers statewide were fully aware of the research under way, and were informed of findings, model components and other developments. Also, all engineers were striving to reduce costs. Results thus far are indicated in the box.

Average Costs As Percentages of Contractor Payments

	1971	1975
• All projects	14.0%	10.5%
• Interstate	13.3	9.8
• Secondary	19.1	15.2

Large projects will always cost less than small ones, but the range will surely be reduced. It is safe to aim at less than 8 percent for large projects and, say, 12 for most small ones.

Chapter One

DEFINING NEED AND CRITERIA

Construction management officials have long recognized the need to keep engineering costs from being unreasonable. In evaluating requests for additional personnel, they have also recognized that many variables, most of which appeared unpredictable, affect manpower needs. They needed a way to: (1) determine in advance, within reasonable margins of error, how much it will cost to complete and document construction surveys and inspections; (2) control costs while construction is under way; and (3) evaluate costs after projects have been completed—to find ways of improving the system for upcoming projects.

This first chapter is directed toward defining research and development objectives, supporting those objectives with research data, identifying the major variables to be considered, and setting forth criteria to be met by the construction management system.

Objectives

The objectives of this project were to learn what the costs of construction engineering should be, develop a system that will result in those costs, and ensure acceptability of the system for implementation.

Costs

The costs must be based on completing all work essential to proper staking, inspecting and documenting of contractor operations. Any excess staking, sampling, testing, observing, recording, reporting, and even copies of reports had to be dropped.

The costs must also be based on good work methods and realistic workmanship requirements. Unusually time-consuming methods, such as continuously observing contractor operations for compliance with plans and specifications, had to be reevaluated. And, both overdoing and underdoing of the work being expensive, workmanship requirements had to be reviewed.

System

Once techniques were developed to identify proper engineering costs, the Department needed some way to plan and control operations so that they were not exceeded—or were exceeded by no more than acceptable amounts.

The costs were expected to vary by project type, contractor performance, and other influences. In fact, it was expected that one system might be required for rural freeway projects, another for urban freeway projects, a third for primary-system projects, and so on. (As it turned out, one system meets all these needs.) Regardless of such influences, the system had to pay off from a planning and controlling standpoint.

Acceptability

From the start, design, development and testing activities had to be carried out in such a way that the final system would be acceptable to officials and supervisors who finally would be responsible for making it work. Nothing could be done during the research that would preclude its implementation. To the contrary, interested personnel were to be involved in the research, or at least kept informed of progress.

Defined Costs

Construction engineering costs are expressed as percentages of contractor payments.

Engineering Cost Items

The Department defines construction engineering costs to include:

- wages and salaries paid to construction staking, inspection, documentation and supervisory personnel;[1/]
- fringe benefits paid to those personnel;
- travel expenses and vehicle charges;
- project office rentals, equipment and supplies;
- field equipment and supplies; and
- laboratory charges attributable to quality control and post-construction evaluations.

The Department conducts all surveys, places all stakes, takes all samples and runs all tests. (Contractors can be charged for restaking caused by their negligence, but this rarely is done.)

Cost Diversions

In developing the construction management system, the Department was willing to reassign selected staking and activities from its own crews to those of the contractors—without, of course, relieving the Department of final responsibility for quality control. Two conditions had to be met: (1) Quality control could not be compromised; and (2) Total construction costs had to be reduced. (The work could not be shifted simply to reduce the State's share of construction costs at the expense of Federal aid.)

Clearly, before any such reassignment could be made, the cost of doing the work under an effective system of planning and control had to be determined.

1/ District engineers, assistant district engineers and district office personnel are excluded, as are all headquarters construction personnel.

Documentation for the Objectives

Construction and top management officials knew that costs were too high. Some large projects were being completed for 8 percent of contractor payments, but the average even on those was 13 percent—placing some well over 13. Knowing that costs were too high was one thing; documenting the fact so that all concerned officials would agree was another.

System Averages

Engineering costs are shown by system and for the construction function as a whole in Figure 1.[2/]

Figure 1

CONSTRUCTION ENGINEERING COSTS

Highway System	1971	1972	1973	1974	1975
Interstate	13%	13%	13%	11%	10%
Primary	14	14	14	12	12
Secondary	19	20	15	15	15
Urban	18	12	16	10	13
Overall average*	14	13	13	11	10

* The overall averages reflect total contractor payments and total engineering costs—not averages of the system values shown in this table.

The data in Figure 1 show that costs on two of the systems were constant for the first three years. They ran 13 percent for interstate and 14 for primary projects.

Engineering costs on secondary projects dropped from 19 percent in 1971 to 15 in 1973. Those on the urban system fluctuated between 10 and 18, while the overall average dropped from 18 to 13.

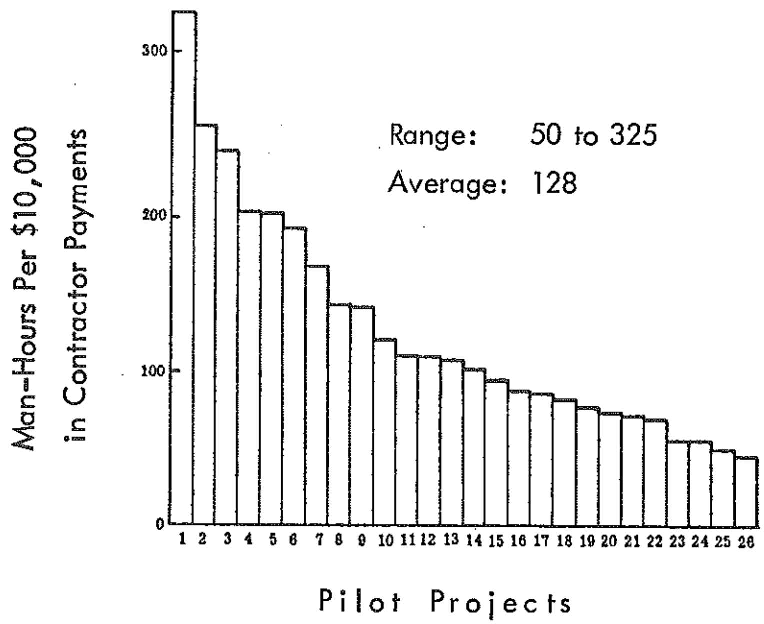
2/ Percentages of contract costs have been used to compare costs among state highway and transportation agencies. These comparisons are invalid. Each cost rating reflects levels of service provided to contractors, methods of accounting, pay rates, expense and relocation provisions, and quality assurance programs—all of which vary from state to state.

Project-by-Project Costs

Since salaries and fringe benefits account for approximately 85 percent of construction engineering costs, manpower expenditures on 26 reasonably comparable rural freeway projects were identified for construction-year 1973.[3/] The results are shown in Figure 2.

Figure 2

COMPARISON OF MAN-HOUR CHARGES ON INDIVIDUAL PROJECTS



The 26 projects varied in stages of completion, but they were too much alike to justify the wide variations shown in Figure 2. Note that manpower used ranged from 50 man-hours per $10,000 of contractor payments to 325. If the data for the highest and lowest projects shown in Figure 2 (Numbers 1 and 26) are dropped for being exceptional in some way, comparisons of man-hours used on the remaining 24 are still revealing.

3/ These were the pilot projects supervised by Department personnel. See page v.

Figure 3

ANALYSIS OF EXPERIENCE ON 24 PILOT PROJECTS

Projects	Average*	Percent of Total	Percent of Lowest
2 through 7	215	44%	320%
8 through 13	120	24	179
14 through 19	90	18	134
20 through 25	67	14	100

* Man-hours per $10,000 payments to contractors.

As shown in Figure 3:

- The six highest projects averaged 215 man-hours per $10,000 of contractor payments as compared with 67 for the six lowest;
- The six highest projects used 44 percent of the total manpower spent on the 24 projects as compared with 14 percent for the six lowest; and
- The six highest projects used 3.2 times the man-hours spent on the six lowest.

Clearly, the Department had reason to set the objectives defined earlier in this chapter.

Variables Involved

In trying to find reasons for wide ranges in construction engineering costs, Department engineers considered all major variables: daily weather conditions, seasonal weather conditions, construction work loads, traffic volumes, contractor performance, project-crew performance, and project characteristics.

Daily Weather

Contractors must shut down on bad-weather days, thereby increasing engineering costs. But the number of such days varies only slightly over a four-year period, and the number is quite predictable. Further, no correlation could be established between numbers of days lost due to weather and differences in manpower usage on eleven closely comparable projects.[4/]

Seasonal Weather

The length of the season can vary by several weeks from year to year. And there can be differences between districts in the north and those in the south.

On the eleven projects, no relationship could be found between the length of time for project completion and engineering costs. Project K, for example, had the highest cost per day of contract time but only one other project had fewer calendar days.

Figure 4
CALENDAR DAYS OF
TOTAL CONSTRUCTION TIME

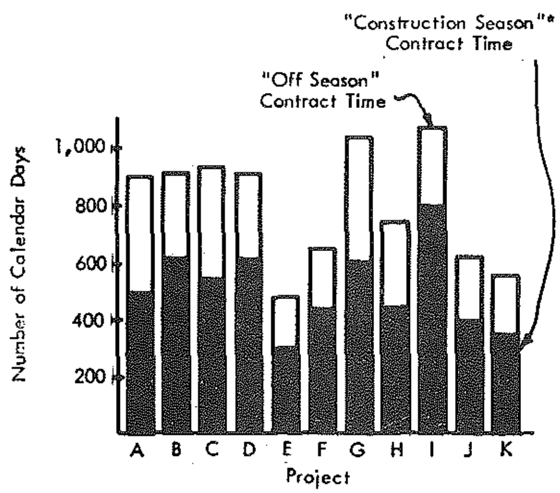
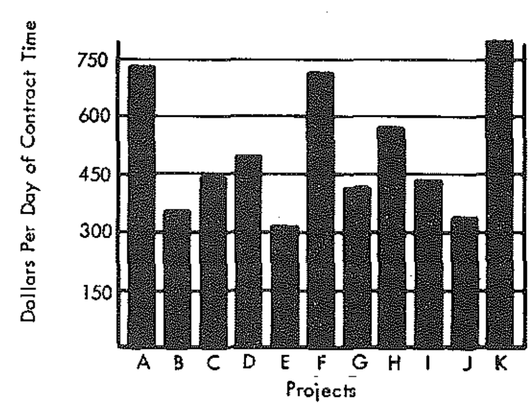


Figure 5
AVERAGE FIELD AND OFFICE
ENGINEERING COSTS PER
CALENDAR DAY OF CONSTRUCTION TIME



4/ A sample of over 30 completed rural freeway projects was selected for the analysis. It was later reduced to those most comparable.

While no correlation could be found between high-cost projects and short seasons or low-cost projects and long seasons, it is clear that short seasons increase costs to some extent—across the board.

Construction Work Loads

Work loads have fluctuated both in sizes and types of projects. Federal impoundments and releases caused much of it, but state funding and delays in completing contract plans for complex projects contributed as well.

While districts reduced manpower from year to year in compliance with Department policy, they tended to retain more than needed—to protect themselves against unknown work loads. This may well have been good insurance under the circumstances: individual employees were specialists in separate phases of the work; there was no way to train new personnel quickly; and being caught short could cause serious problems. But, construction engineering costs increased during cutback years.

Traffic Volumes

The need to carry heavy traffic through construction zones reduces contractor productivity and increases direct construction costs. It can affect construction engineering the same way, and in proportion—causing no change in the cost rate.

It can have a reverse effect as well, by increasing contractor payments and decreasing the percentage of those payments required for construction engineering.

The difference is too small to consider this variable in evaluating engineering costs.

Contractor Performance

The vast majority of contractors are reasonably uniform from a performance and productivity standpoint. Under the bidding system, they must be competitive or go out of business.

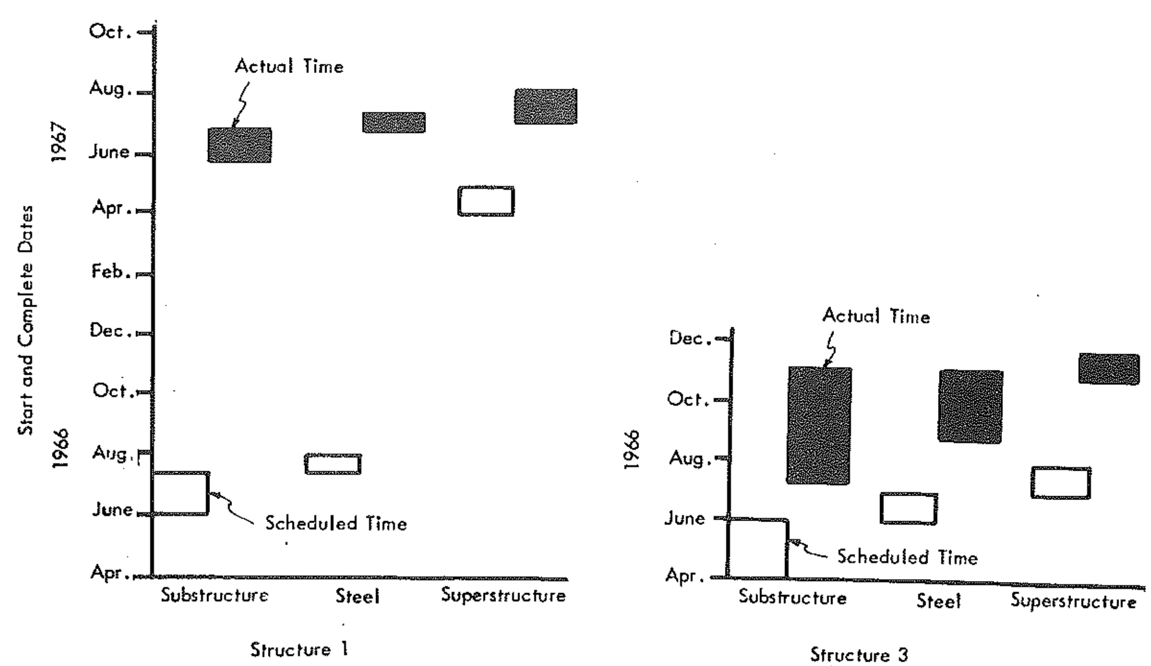
Certain contractor practices have been particularly expensive in terms of project staffing without much apparent effect on total contractor payments. For instance, contractors frequently promise to start a specific operation on a particular day, miss that date and promise another, and miss that one as well. Promised dates on laboratory projects were missed by as much as a year. Or the dates are met—with one scraper instead of ten.

If staking is completed according to contractor promises, and if inspectors are standing by during the delays, costs are increased sharply.

On Structure 1, in Figure 6, all work was done a year behind schedule but in the planned numbers of workdays. Inspection costs should have remained the same regardless of the delays, unless inspectors were assigned before construction was under way. Doubling the time to complete the substructure on Structure 3 increased inspection costs.

Figure 6

SCHEDULED AND ACTUAL PROJECT PROGRESS



Very few contractors cut corners so much that inspection costs are increased. The few who do must be treated as special cases regardless of any staffing guidelines made available to project engineers.

Project Personnel Performance

One project crew can include several individuals with extensive experience records and high salaries. Another can be made up largely of new employees, all at the low ends of their salary ranges. This will have some effect on costs.

But, productivity rates influence costs as much as salaries. If the experienced crew includes as many individuals as the inexperienced one, and attains the same productivity rate, costs will be high. If experience increases productivity and decreases manpower needs—as clearly it should—costs will be reduced. Note the difference when a three-man crew is used—taking full advantage of experienced personnel.

Figure 7

CROSS-SECTION AND SLOPE STAKING

Crew Size	Cost Per Crew Hour	Productivity Station/Man-Hour	Cost Per Station
4-Man Experienced	$22.00	1.43	$3.85
4-Man Inexperienced	$16.65	1.04	$4.00
3-Man Experienced	$17.13	1.63	$3.50

The manpower-performance variable obviously can be controlled through staffing controls.

Project Characteristics

Projects differ one from another in many ways: types of work, numbers of miles, numbers of lanes, numbers and types of bridges, and so on.

Eleven projects found to be similar in total construction time and cost were analyzed in depth. All were completed as planned and essentially as scheduled, and all were accepted by the Department and the Federal Highway Administration.

No correlation could be established between project characteristics and engineering costs. A variable that appeared to increase costs on one project seemed to decrease them on another.

It was known, of course, that engineering costs are relatively high on small jobs and low on large ones. Signalizing an intersection requires a great deal of inspection time in relation to the installation cost when compared with a base, grading and surfacing project. This variable is so significant that projects must be classified for cost-evaluation purposes.

System Criteria

With due consideration for the experience record on one hand and variable circumstances on the other, the Department defined criteria to be met by the construction management system. It must:

1. be responsive to fluctuations in annual work programs with respect to numbers and characteristics of projects;
2. be responsive to current contractor practices;
3. ensure completion of all construction engineering work;
4. control engineering costs overall and by project type—with exceptions for unusually difficult contractors;
5. be simple, practical and useful at the operating levels to ensure statewide acceptance and implementation; and
6. be fully supportable to top-management officials of the Department.

The system must be self-contained—not so interlocked with planning and programming, design, or contractor controls that it works only under certain conditions.

Summary

The Department knew the need and the major problems in advance. It had reduced construction manpower and engineering costs year by year. It could have continued the reductions by squeezing district and project forces until understaffing clearly occurred.

The alternative was to start again, from scratch: identify the work to be done, the manpower required to do it, and the manpower management approaches that would get best results. This being the orderly and logical way, having the best potential for success, the Department chose it.

In making the choice, the Department realized two major elements were involved: system design and system implementation. To ensure acceptance of the final design, data were collected to support the need. Those data made it clear to everyone that such variations as weather conditions, annual construction programs, contractor practices and crew-level salaries do not justify differences of 30 to 50 percent in construction engineering costs—much less differences of 300 percent and more.

The Department made no commitments to final system characteristics. It only had to pass certain tests: no programming changes, no contractor changes, and no risking of quality control, but full acceptance by operating and management officials.

Chapter Two

ESTABLISHING THE WORK BASE

Since work loads and their accomplishment represent the sole reason for establishing organizations, the work to be done is the base of every management system.

The types of work, quantities of work, and practices that most significantly affect productivity rates are discussed in this chapter.

Types of Work

All construction engineering activities are responses to contractor operations—either to service the contractor, ensure compliance with plans and specifications, or document results for payment purposes. To ensure that all work done by Department personnel meets one of these needs, activities carried out by contractors were identified first. They were used to build an inventory of construction engineering activities.

Contractor Activities

The work done by road and bridge contractors was identified and cataloged.

Each contractor operation was described on a separate statement. Each statement includes:

- a description of the work done;
- references to work that must be done before the contractor activity can begin;

- cross references to contractor activities normally under way at the same time;
- a list of equipment used in carrying out the activity; and
- brief descriptions of methods used by the Department to document contractor progress and completion.

The 26 contractor-operation titles for rural freeway projects are listed in Figure 8. Starting with receipt of the contract award and a review with the Department's engineers, the work proceeds through clearing and grubbing, excavation and embankment, and other operations to final cleanup. All contractor operations are covered.

Figure 8

TITLES OF CONTRACTOR ACTIVITY-STATEMENTS
Rural Freeway Projects

1. Review contract with project engineer
2. Move in
3. Place construction traffic controls
4. Clear and grub
5. Excavate muck
6. Excavate earth and construct embankment
7. Construct drainage and sewer items
8. Construct aggregate items
9. Pave with bituminous concrete
10. Pave with portland cement concrete
11. Construct bituminous shoulders—bituminous concrete pavements
12. Construct bituminous shoulders—portland cement concrete pavements
13. Construct curbs and gutters
14. Construct guardrails
15. Place sheet piling
16. Place foundation piling
17. Construct substructures
18. Erect structural steel
19. Construct superstructures
20. Drill rest-area wells
21. Construct sewage facilities
22. Construct rest-area buildings, facilities
23. Construct fences
24. Provide environmental protection and beautification
25. Install permanent traffic signs, delineators
26. Complete final trim and cleanup

Engineering Activities

The work done by construction engineering forces was described in detail in a separate series of statements. To ensure that the series was complete, individuals observed work under way on different types of projects at various stages of completion. A panel of experienced engineers then checked the entire inventory, statement by statement and task by task. The final inventory included all staking, inspection, office engineering and project supervision activities, plus such nonproductive time-charge items as stand-by, holidays, vacations, sick leave and compensatory time off.

A typical construction engineering activity statement, that for moisture density control by mechanical methods, is shown in Figure 9. As will be noted, each work-related statement contains a description of the work done, a list of the tasks involved, and the documentation requirements—including the specific forms used.

The total inventory consisted of 261 statements similar to the one shown. To eliminate unnecessary refinement of the remaining research, 144 were selected for detailed work load analysis.

Quantities of Work

Work loads must be measured before, during and after performance—for planning, control, and evaluation purposes. The key activities, those that represent the greater part of the total work load, were identified through work sampling.

Work Sampling

The 26 pilot projects were used as a sample for key-activity identification.[5/] Individuals on those projects reported time against the 144 activities for a full year.[6/]

5/ See the project organization chart, page ii.

6/ The 144 activities, ranked according to man-hour charges, are shown in Appendix A, starting on page 75.

Figure 9

TYPICAL ACTIVITY STATEMENT

Moisture-Density Control—Mechanical Methods

Activity Description

Moisture content is measured mechanically—by stove-drying samples or by using a carbide moisture tester. The four main parts of mechanical density tests are (1) a one-point proctor (T-99), (2) a one-point Michigan cone test, (3) in-place volume measurements using volumeters, and (4) sample weighing.

Controlled-density methods are used in all embankments and backfills unless specified to the contrary.

Tasks

- Select test site
- Take sample
- Conduct moisture test
  - + Stove dry, or
  - + Carbide tester
- Conduct one-point proctor
- Conduct Michigan cone
- Measure volume
- Weigh the sample
- Record test results
- Compute in-place density
- Retest failures
- Report findings—oral
- Report findings—written
- Maintain equipment

Documentation Requirements

- Draft record of results (rough copy of Form 582)
- Final record of results (clean copy of Form 582)
- Record of retests (Form 582A)
- Record of working time, mileage and expense (Form 1187)

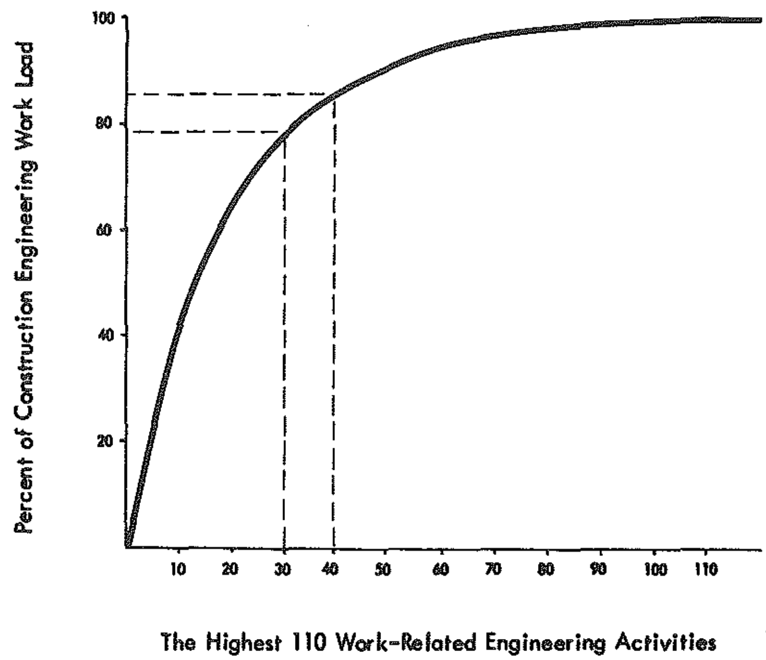
More than 237,000 man-hours were reported, of which 199,000 were charged to work-related activities. Leaves, holidays and stand-by time accounted for the remaining hours.

Key Activities

As shown in Figure 10, 30 work-related activities represent 78 percent of the total construction engineering work load, and 40 represent 87 percent.

Figure 10

DISTRIBUTION OF THE CONSTRUCTION ENGINEERING WORK LOAD TO WORK-RELATED ACTIVITIES



The work load, and costs attributable to getting it done, can be fully controlled by controlling 30 to 40 activities. Very limited attention needs to be given to the others, except to ensure that they are done.

It may be useful to state the concept another way:

- If all the man-hours spent on utility-relocation inspection had been eliminated, 180 man-hours would have been saved; but

- A 10-percent reduction in charges to documenting excavation and embankment quantities—not the inspection work itself—would have reduced manpower by 2,900 man-hours.

The 33 activities listed in Figure 11 were selected for construction management purposes: work load measurement, work methods improvement, staffing control and, through staffing control, engineering cost control.[7/] As can be seen, nine of the 33 are in the surveying group, sixteen are inspection activities, and seven represent office engineering. The final activity represents project supervision.

Units of Measure

The most important reason for identifying the key activities was to measure the work loads attributable to them. To repeat, the loads had to be measurable before, during, and after performance—for planning, control and evaluation purposes.

Typical work measurement units are shown in Figure 12 on page 20. Notice particularly that each work load can readily be measured from data in contract plans, daily inspection reports and final reports.

7/ Work methods improvements extended beyond those on the key list—when individuals not on the research staff made promising suggestions, and when staff members had time to explore ways to simplify the work.

Figure 11

KEY CONSTRUCTION ENGINEERING ACTIVITIES

Surveying Activities

1. Roadway layouts
2. Utility layouts
3. Cross-sections and slopes
4. Grades
5. Other roadway earthwork
6. Surfacing
7. Structures
8. Minor structures and drainage
9. Curbs, gutters and guadrails

Inspection Activities

10. Removal and relocation
11. Traffic control
12. Earthwork
13. Earthwork density control
14. Aggregate weighing
15. Aggregate placement
16. Aggregate density
17. Bituminous plant operations
18. Bituminous surfacing
19. Bituminous materials weighing
20. Concrete plant operations—paving
21. Concrete paving
22. Concrete plant operations—structures
23. Concrete structures
24. Concrete curbs, gutters
25. Minor structures and drainage

Project Office Activities

26. Record-system preparation
27. Earthwork documentation
28. Aggregate documentation
29. Bituminous documentation
30. Concrete documentation
31. Structures documentation
32. Minor structures documentation

Management Activity

33. Project supervision and management

Figure 12

TYPICAL WORK MEASUREMENT UNITS

Activity	Unit of Measure
Roadway layout staking	Roadway mile
Structure staking	Span lane
Earthwork inspection	10,000 cubic yards
Bituminous paving	1,000 tons
Portland cement concrete paving	1,000 square yards
Structure inspection	Span lane
Earthwork documentation (office)	10,000 cubic yards
Bituminous paving documentation (office)	1,000 tons

Work Load Reductions

Since the 33 key work loads represent approximately 80 percent of all construction engineering work done, it was critically important that they represent essential work. Any reductions among these 33 would reduce manpower needs. Reductions in nonkey work loads would count as well—but not significantly.

Testing Reductions

Project engineers must decide how many samples to take and tests to run. They must meet minimum requirements for final acceptance of their work. They must go above the minimums as necessary to ensure contractor compliance with specifications and to document results. But, excessive sampling and testing prevailed, with 100 to 150 percent over requirements being common.[8/] Instructions to density inspectors implied that as many tests as possible should be taken. Difficult contractors and troublesome operations are few, nowhere near numbers indicated by nonessential work being done (counterproductive work, since extra samples and tests add to work loads down the line).

8/ Consistently taking 15 to 20 percent more samples than required may be justified.

Requirement Reductions

Analysis of the requirements themselves identified several that could significantly be reduced. Some examples:

- The Department changed from one gradation test per 150 tons to one per 300 tons—cutting a key work load in half;

- One bituminous-mix sample is now being sent to the materials laboratory for every 2,000 tons instead of one per day;

- Certified stone is being accepted whenever project record tests prove the supplier's quality-control program is good instead of conducting one test per 300 tons; and

- Density inspectors are certified, reducing the need for progress-record tests—and the travel time connected with record tests.

"Watching" Cuts

The category identified as watchings (where inspectors continuously observe contractor operations for compliance with plans and specifications) proved particularly profitable in terms of work load reductions. Changing from progress inspections to end-result specifications for selected operations reduced man-hour expenditures sharply.

Productivity Rates

Two actions most affect productivity rates: using proper crew sizes, and using manpower only when productive work can be done.

Proper Crew Sizes

An extra man on a staking crew, a paving-inspection crew or a batch-plant crew can be justified, within reasonable limits, for training purposes. Unless they are there to flag traffic, cut brush, or speed work in unusual areas, fourth and fifth members of staking crews result in decreased productivity rates. A three-man crew can set more stakes per man-hour, in most cases, than can a crew of any other size.

Extra men on earthwork, paving, batch-plant and office crews have the same effect—decreased productivity rates and increased costs. Worse, they quickly become counterproductive through make-work assignments, unnecessarily increasing work loads in laboratories and offices.

Crew Utilization

Of equal importance to crew sizes is crew utilization—keeping personnel on productive assignments. Some stand-by time is unavoidable on construction, indeed on many types of work. Assigning manpower to projects when contractor operations are not yet under way or are closed down (except to set essential stakes or complete records) is nonproductive. It results in zero productivity rates for the hours charged.

Productivity Standards[9]

Productivity rates vary in response to many influences, such as individual capabilities, individual efforts, contractor production, weather conditions, terrain, traffic volumes and soils conditions. This is unavoidable. Yet most of the work, the vast majority of it, goes very well, making it possible for project forces to attain reasonable levels of productivity. More important, the rates are highly predictable—if the same work methods and crew sizes are used.

9/ The term "productivity standards" is used in this report to mean either average rates or ranges of rates. Two examples: 1.5 stations per man-hour, and 3 to 4 moisture-density tests per man-hour.

The predictability factor is indispensable. Work loads can be converted to manpower needs estimates only by applying productivity rates. The example rates shown in Figure 13 demonstrate how they are used.

Figure 13

TYPICAL PRODUCTIVITY STANDARDS

Activity	Measurement Unit	Man-Hours Per Unit
Roadway layout staking	Roadway mile	180
Structure layout staking	Span lane	40
Earthwork inspection	10,000 cubic yards	12
Bituminous paving inspection	1,000 tons	20
Portland cement concrete paving inspection	1,000 square yards	6
Structure inspection	Span lane	50
Bituminous paving documentation (office)	1,000 tons	7

NOTE: Productivity standards, expressed as man-hours per unit of work, were developed for all key activities. Those shown above, typical of the total series, are used in estimating manpower needs for total projects, full construction seasons, and controlling manpower usage to planned usage. Since they include allowances for time lost in doing only part of the work at a time, and for repeating some of the work, they must be reduced for any short-term scheduling.

The rates are used for planning purposes, not as on-site or day-to-day controls. Project engineers can use them for estimating numbers of days required to complete short-term work assignments, for comparing work and man-hours remaining, or for spot-checking performance—but they must first adjust the standards. Those shown include allowances for time lost to complete each activity work load in small increments, and for redoing some of the work. (The allowances vary according to experience with each activity: 180 man-hours per roadway mile for layout staking convert to about 1.5 stations per man-hour as an actual day-to-day average, but 20 man-hours per 1,000 tons of bituminous paving inspection drop only slightly—to about 19.5 for spot-checking.)

Summary

The work itself represents the first part of any management system. In this case:

- 261 separate activities, including time-off and stand-by charges, were identified;

- less than 15 percent of them represent approximately 80 percent of the total construction engineering work load—and 80 percent of the construction engineering costs;

- key-activity work loads and work accomplishments can readily be measured for manpower planning and control purposes;

- key-activity work loads can be reduced, thereby reducing manpower needs;

- key-productivity rates can be increased, further reducing manpower needs; and

- project engineers can control costs best through crew-size and day-to-day work assignment controls.

Once the work-base element was complete, it was ready for integration with other elements—such as personnel management—to create the total construction management system.

Chapter Three

ESTABLISHING THE PERSONNEL BASE

Work loads and productivity rates must be interpreted in terms of manpower needs—making the personnel classification element the second major foundation for a construction management system.

Each employee, particularly at the engineering technician levels, must represent a quantity of work to be produced. Performance capability is one major basis for classifying construction engineering technicians; the levels of performance difficulty involved are the second.

Capability Requirements

Demonstrated capability being essential to proper personnel classification, the capabilities required had to be identified and classified.

Task Analysis

Each of the activity statements prepared for work analysis includes task-by-task descriptions of the work to be done. These tasks were analyzed to identify capabilities required for their proper performance.

Capability requirements were expressed as indicated by these examples:

- "Knowledge of the relationships between contracts, contract plans, specifications, special provisions, change orders and supplemental agreements"; and

- "Ability to add, subtract, multiply and divide, rounding to two decimal places"; and

- "Ability to conduct a series of moisture-density tests according to specified procedures."

Notice that no references were made to educational attainments—courses taken, fields of study completed or diplomas earned. And no references were made to previous work assignments—prerequisite years of experience. The Department was concerned only with what individuals must know and be able to do in order to carry out the tasks.

Ability Statements

By analyzing all tasks (not just those pertaining to key activities), the staff completed an inventory of the knowledge and abilities required to perform all construction surveys, inspections and documentations. The inventory was set forth in a series of ability statements.

The ability statement covering bituminous paving inspection, shown in Figure 14, identifies precisely what individuals must be able to do in order to carry out the work. Note particularly that it is designed almost as a training course outline or a certification-examination outline.

Statement Series

The final inventory of performance requirements consists of 78 ability statements.[10/] Twenty-six are general in nature, being applicable to most construction engineering personnel. Fifty-two apply only to those individuals responsible for specific assignments. Essentially all activities require calculating capabilities, for example, while one requires individuals to know fine-grade inspection procedures.

10/ The complete list of ability-statement titles is included in Appendix B, starting on page 81.

Figure 14

TYPICAL ABILITY STATEMENT

Bituminous Paving Inspection

Inspectors must be able:

1. to determine adequacy of base course—
   - primed and cured,
   - grade and cross section, and
   - absence of depressions and pot holes.
2. to check the adequacy of the contractor's equipment—feeders, flow gates, spreader screws, screed plates, tamper bars and rheostats.
3. to coordinate bituminous plant inspections and operations with street inspections and operations.
4. to lay out, or check, the guideline for spreading operations.
5. to check bituminous materials for texture, consistency and temperature.
6. to identify and suggest solutions for common paving problems—
   - cold mix, cold screed, segregation of materials,
   - improper truck contact with paver, and
   - improper equipment adjustments.
7. to make yield checks—mat thickness.
8. to make crown checks.
9. to identify and correct improper transverse-joint construction—
   - proper stopping procedures, and
   - cut-joint and feathered-joint construction.
10. to identify and correct improper longitudinal-joint construction.
11. to inspect rolling operations—
    - heat-rolling relationships, and
    - time requirements.
12. to straightedge final surfaces, identify areas needing correction, and select correction methods.

Activity-Ability Relationships

The 78 ability statements were cross-referred to the activity statements and summarized in personnel classification plans. This tieback ensures that project engineers have access to the performance requirements for each work assignment.

Levels of Performance Difficulty

As indicated earlier, capability requirements were ranked according to difficulty of performance to provide the second element of a personnel classification plan.

Criteria for Ranking

Certain tasks must be performed by engineers. State law stipulates registration as a professional engineer for some; potential consequences of error preclude nonengineer performance for others. In general, tasks that require innovative application of engineering knowledge were reserved for engineers, and those that represent repetitive applications of standard solutions were not.

The nonengineering tasks, toward which this effort was directed, were ranked according to the relative:

- chances of error;
- costs of error corrections; and
- time required to train an individual from scratch—using modern training techniques.

Note again the absence of references to education and experience.

Four Levels of Difficulty

Analysis of the tasks in terms of performance requirements revealed that they fall into four definable levels of difficulty: basic, intermediate, journeyman and senior. Examples of the distribution are shown in Figure 15.[11/]

Figure 15

TYPICAL TASKS RANKED ACCORDING TO DIFFICULTY

Basic Level	Journeyman Level
Test gradation Inspect shapings and depths of subbases Reduce and check field books Rod and chain (beginning-level) Plot cross sections	Inspect bituminous surfacing Inspect substructure concrete placement Inspect structural steel work Stake excavation and embankment grades Prepare field-book data and sketches
Intermediate Level	**Senior Level**
Test concrete (air, slump) Inspect grade for bituminous paving Inspect pile driving (production) Rod and chain (fully competent-level)	Inspect concrete paving Inspect superstructure preparations Stake reference points and lines Compute and adjust deck grades Supervise survey, inspection and office crews

This analysis provided significant information:

- Tasks that can be mastered quickly, in a half-day or so with effective training materials, were found in all four major work categories—surveying, road inspection, bridge inspection, and office engineering;

- Instrumentman tasks, often treated as a lump-sum group, readily break down into different levels—indicating that inspectors can be trained to do much of the work survey crews are called back to do;

11/ The complete list of tasks ranked by levels of performance difficulty is included in Appendix D, starting on page 95.

- Office tasks range from basic to senior in difficulty, permitting greatly increased in-season shifts between office and field assignments for improved manpower utilization; and
- Experience on any task eases the training problems on the next one, regardless of shifts between specialties.

Three Levels of Supervision

While the hands-on tasks fell into four levels of difficulty, supervisory tasks fell into three—the journeyman- and senior-levels referred to above, plus a level for assistant project management.

Personnel Classification

With capability requirements and difficulty rankings complete, the existing personnel classification plan was analyzed for potential improvements. Since it met the needs for standard personnel management purposes (selection, placement, salary management and seniority for retention) but was not well adapted to manpower management, a replacement plan was developed.

Existing Plan

The existing plan included fourteen personnel classifications:

- Bituminous Street Inspector—1 class;
- Concrete Inspector—1 class;
- Engineering Aide—1 class;
- Highway Construction Aide—3 classes;
- Highway Construction Inspector—2 classes;

- Highway Construction Superintendent—3 classes;
- Student Engineer Aide—1 class; and
- Student Highway Technician—2 classes.

The titles alone make the classification scheme quite clear. Key personnel worked as specialists—in earthwork, asphalt or concrete, as assistant project engineers or non-licensed project engineers. Aides were classified according to student or nonstudent status.

Change in Approach

Construction engineering work loads are unique. Roadway projects progress from clearing and grubbing to excavation and embankment, pipe culvert placement, box culvert construction, base construction, surface construction, seeding, sodding and fencing. Inspection assignments change accordingly. This places a premium on employee versatility.

Employees who can perform a wide variety of tasks are worth more to the Department than specialists who can perform just a few. Specialists must (1) travel to locations where their special capabilities are required, (2) be paid travel time and expenses, and (3) be paid overtime when their work loads are high—since such specialties are then in demand. Furthermore, specialists must fill in as well as they can when their special capabilities are not required, or stand by in nonproductive status until work loads in their special areas of competence come along. If they were equally competent in several phases of the work, they could be fully productive on the same group of projects for the full season.

Clearly, as the percentage of highly versatile personnel within the total force is increased, the size of the force can be decreased—by reducing stand-by time. Decreases can be effected to the point where the number employed is equal to the number required for on-site work stations, plus an allowance for absenteeism. Also, as versatility increases, instances of working below pay grade must decrease—it being natural for project engineers to assign their best individuals to the most difficult tasks.

Bases of New Classification Plan

The replacement plan contains five classes (titled "Transportation Construction Technician I, II, III, IV and V") instead of fourteen.[12/]

Work loads must be converted into manpower needs in any management system. In the process, manpower performance capabilities—as represented by both productivity and versatility—become a major component. The new plan provides for assessing the employee's capabilities on a task-by-task basis. The accumulation of these capabilities determines the level of position for which the individual qualifies.

Part of the specification for Transportation Construction Technician III is shown in Figure 16.[13/] Note the detailed listings of tasks (many of which have been omitted from the figure), and the requirements that appointees be able to do specific levels and varieties of work.

Note also that the term "journeyman" is used to indicate the level of work difficulty, or level of employee competence. This is done for two reasons: individuals who have analyzed both tradesman and construction engineering tasks are firmly convinced that the two groups are reasonably equivalent at this level; and the term itself reflects broad capabilities. Technicians in the first two classes are really helpers.

Minimum experience requirements are included for two classes: six months as a Technician I before promotion to II, and two years as a Technician IV before promotion to V.

Promotions to the Technician II and III levels can be made as rapidly as individuals become qualified. Advancements to higher classes can be made only as vacancies become available.

12/ At the time of writing, the Michigan Department of Civil Service had yet to approve the replacement plan. Approval was imminent, and implementation was to follow immediately.

13/ The specifications for all five classifications are included in Appendix C, starting on page 85.

Figure 16

EXCERPTS FROM A CLASS SPECIFICATION

Transportation Construction Technician III

Classification Description

Transportation Construction Technicians III perform journeyman-level inspection, surveying and office functions. They also work at the basic and intermediate levels of difficulty as required.

Minimum Qualifications and Requirements

Persons assigned to this class must have qualified as Transportation Construction Technicians II, be recommended for this class by their supervisors, and meet the performance requirements listed below.

1. They must have demonstrated their abilities to perform effectively the following key tasks:

    - inspect minor drainage structures;
    - test concrete quality control—air, slump and temperature;
    - inspect placement and shaping of aggregate surfacing;
    - test density;
    - compute areas and volumes; and
    - rod and chain.

    and one of the following:

    - inspect grade preparation for bituminous paving; or
    - inspect grade for PCC paving; forms for PCC paving; load transfer devices; sawing and sealing joints.

Figure 16 (Continued)

2. They must have demonstrated their abilities to do at least five of these tasks:

- inspect topsoil removal;
- inspect detours and temporary roads;
- control and test fabricated materials for structures;
- inspect pile driving—production;
- identify construction and right-of-way limits;
- inspect landscaping; and
- inspect finishing and curing on PCC paving.

3. They must have demonstrated their abilities to perform as an instrumentman on at least four of the following tasks:

- make final measurements of traffic control devices, fencing, PCC paving, drainage and minor structures, and aggregate surfacing;
- set pile cutoffs;
- stake fence from previously established control points;
- stake line for bituminous surfacing;
- cross-section topsoil removal areas; and
- stake centerline.

4. They must have demonstrated their abilities to perform effectively at least two of the following project office tasks:

- check and post tested materials and post pay quantities;
- prepare field books and sketches for clearing limits; and
- set up file systems within prescribed guidelines and maintain files and records.

The one series of classes is used for both seasonal personnel and permanent, year-round employees.

Manpower Management Characteristics

Position classification plans (where the work to be done is classified, not the individual who does it) are effective whenever the total number of persons employed is not affected by productivity rates. A guard must be on each guard post, for example, regardless of other considerations. But one Engineering Technician III, being versatile and well trained, may well do the work of two or more Technicians I, making it good management practice to classify the individual rather than the position.

The Department's objective in this regard is illustrated in Figure 17.

The pyramid in Figure 17 represents the traditional concept: The number of employees in each classification decreases as status (reflecting difficulty, responsibility and salary) increases. (In military terms, there are more privates than corporals, and more corporals than sergeants.)

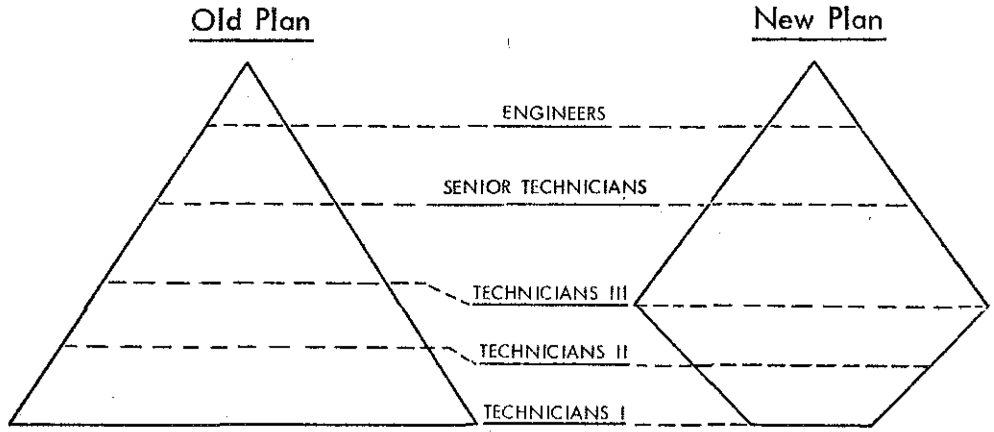
The pentagon in Figure 17 represents the Department's concept: (1) Transportation Construction Technician III is the key classification—the journeyman level; (2) the larger the percentage of the total force that can be advanced to that classification, within limits, the smaller the total force can be; and (3) Technicians III should outnumber Technicians II and I.

Out-of-Class Performance

By the nature of the new plan, employees rarely can work outside of their classifications. They can perform any tasks for which they are qualified, from the simplest to the most difficult, depending on the work to be done and the individuals available to do it. And an individual's classification is based primarily on the percentage of all tasks that fall within his or her capability, as distinguished from tasks included in a position description.

Figure 17

DEPICTED CHANGE IN STAFFING PLAN

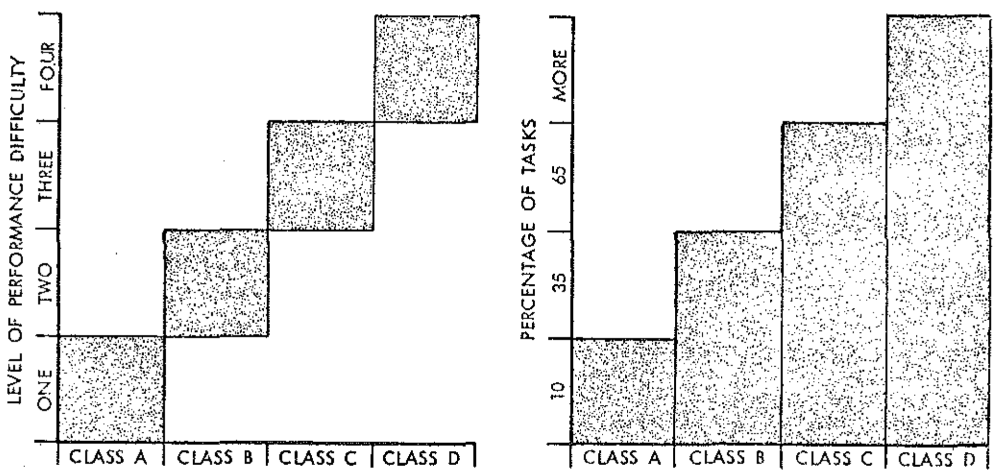


Pyramid: Technicians I outnumber Technicians II, which outnumber Technicians III, which then outnumber their immediate supervisors

Pentagon: Technicians III—representing versatile, nonsupervisory personnel, outnumber all other technician groups.

Figure 18

COMPARISON OF TWO PERSONNEL CLASSIFICATION PLANS



Position Classification Plan: Each classification can be depicted as a square, with each square starting on a new base line; employees are expected to work on tasks that fall between certain categories of difficulty, with the average level of difficulty being the basis for classification.

Employee Classification Plan: Each classification can be depicted as a rectangle, with each rectangle starting on the same base line; employees are expected to perform any task within the limits of their capabilities—with versatility and difficulty being the bases for classification.

This concept is illustrated in Figure 18. The four levels of difficulty (hands-on tasks) form the vertical axis in the position plan. Percentages of the tasks that make up the total work load from the vertical axis are in the employee plan.

Summary

Planning involves using productivity rates to convert work loads into manpower needs. Controlling involves attaining productivity rates that will result in work load completions with the manpower provided. Manpower management, then, is dependent upon predictable productivity rates. Management improvements are dependent, to a great extent, on productivity improvements.

Personnel classification plans must support manpower management. To do that in the construction engineering field, they must reflect levels of work difficulty plus employee versatility, with considerable emphasis on versatility. The more versatile the employee force is, with special reference to subprofessionals, the smaller the total force can be (within limits).

Since versatility is so important, and since the existing classification plan reflected specialization instead, the Department designed a new plan. In doing so, it found that five personnel classifications will meet the needs—as against the fourteen used heretofore. It also found that performance criteria can be used to classify employees—making it possible to interpret productivity rates from personnel classifications.

The Department's personnel classification plan represents the second element of its construction management system.

Chapter Four

MANAGING MANPOWER IN SEASON

Managing the construction engineering force during the construction year involves estimating manpower needs, adopting efficient work schedules, and controlling manpower utilization while work is under way.

Estimating Manpower Needs

Manpower needs must be estimated once annually, for planning purposes. Estimates are double- and sometimes triple-checked—as discussed below.

Multiple-Project Estimates

Work loads on any one project fluctuate too much to permit single-project staffing. Each project would have to be manned for near-peak operations, creating unacceptable stand-by charges.

Peaks and valleys are leveled considerably when three or more projects are treated as a unit. They can be leveled somewhat more by including all projects within a district, and a little more yet by including all those in the State. Leveling reduces manpower needs, making it tempting to control staffing on a statewide or district-wide basis. In actual practice, little is gained by going beyond project groupings of three to five major projects, and costs can quickly be increased by creating sophisticated, computer-based controls.

By giving each project engineer a number of projects within a local area, and holding the engineer accountable for effective manpower utilization, controls and the costs of controlling can be balanced.

Preliminary Estimates

Figure 19 is an incomplete work sheet for estimating manpower needs, but complete enough to demonstrate the procedure.[14/]

The limited breakdown of activities under "Inspecting" in Figure 19 is indicative. Each project must be analyzed in terms of:

1. its current status—new, ready for base construction, ready for surfacing, and so on;

2. the most probable contractor schedule for the year—based on standard sequences of work performance and average numbers of weeks or days used to complete each phase;

3. the work loads attributable to each activity—expressed as miles, sections, bridges, cubic yards, tons, and square yards;

4. engineering productivity rates—expressed as average man-hours per unit of work load;

5. the man-months of engineering services required if everything goes according to plan; and

6. the best distribution of those man-months to the levels of difficulty—indicating the mix of technicians required.

Single-project estimates must be summarized on the work sheet represented by Figure 19.

14/ A copy of the complete work sheet is included in Appendix E, starting on page 101.

Figure 19

TYPICAL MULTIPLE-PROJECT MANPOWER NEEDS ESTIMATE

Activity	Man-Months of Manpower Needs												
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
Staking	3	3	4	9	13	15	17	16	16	14	10	4	124
Inspecting													
• Earthwork, drainage	2	2	3	6	13	19	23	20	19	17	13	2	139
• Surfacing	--	--	--	--	--	3	7	12	12	3	--	--	37
• Structures	2	2	2	3	5	6	7	8	8	9	3	2	57
• Other	--	--	--	1	2	4	4	5	5	4	2	--	27
Office Engineering	26	26	24	14	10	10	12	10	12	14	18	18	194
Total on-site needs	33	33	33	33	43	57	70	71	72	61	46	26	578
Add 10 percent, leave time													58
Total needs													636

Adjusted Estimates

Working with on-site requirements only, the month-by-month estimates must be adjusted to improve manpower utilization. All actual on-site services to the contractors must be provided—allowing for no changes in values attributable to those services.

To a limited extent, adjustments can be made by advancing and delaying office engineering activities—without unduly delaying contractor payments. The office staff should be represented by about 18 man-months in June, for instance (30 percent of the total requirement), instead of the 10 shown in Figure 19. But engineering students become available toward the middle of the month, making it good practice to hold back. The planned man-months of office engineering can be somewhat below needs throughout the peak period as long as crew personnel are able to shift between field and office assignments; rainy days, equipment breakdowns, and mix-ups on materials deliveries will make additional personnel available.

Overall Guides

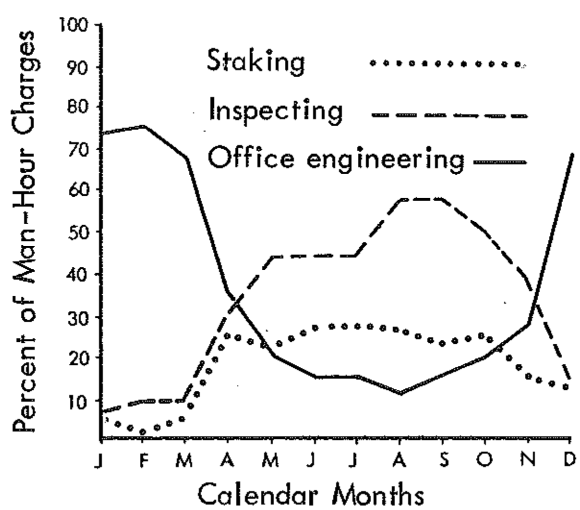
Figure 20 shows a typical distribution of man-hours to staking, inspection and office engineering activities. The data reflect experience on the 26 rural freeway projects in 1973.

The averages for the year were:

- staking—20 percent;
- inspecting—36 percent;
- office engineering—32 percent; and
- leave-taking and standing by—12 percent.

Figure 20

TYPICAL DISTRIBUTION OF ENGINEERING HOURS TO ACTIVITY GROUPS



In view of improvements made in work load controls, work methods and manpower utilization since those data were collected, the Department adjusted the above values to use them as guides in estimating manpower needs. The adjusted values currently being used, and those expected to be reached as further improvements are made, are shown below.

Activity Group	Current Guide	Anticipated Guide
Staking	19%	17%
Inspecting	40	46
Office engineering	30	25
Leave-taking, training	11	12
	100%	100%

The current and anticipated adjustments seem reasonable in view of overall staff reductions. The shift from four- to three-man staking crews may have a greater effect than indicated. And staking work loads will be reduced by limiting the quantities of staking done before contractors start projects.

Since office engineering served as a make-work activity for surplus personnel, particularly in winter months, and since the numbers of samples taken, tests run, and actual man-hours charged to inspections are decreasing, office engineering charges should decrease as well.

While the percentage of the work load attributable to inspections will increase, the volumes of inspection work and the numbers of inspectors are expected to drop. In the cases of staking and office engineering, percentages, volumes and numbers of personnel are expected to drop.

Estimate Checks

Needs estimates can be checked three ways.

First, the percentages of man-months to be used on staking, inspecting and office engineering can be compared against the overall guides. The total values from Figure 19 are compared below.

Activity Group	Total Man-Months	Percent of Total	Guide to Distribution
Staking	124	19.5%	19
Inspecting	260	41.0	40
Office engineering	194	30.4	30
Leave-taking	58	9.1	11
	636	100%	100

As can be seen, the planned values are close to the guideline values. The low estimate for leave-taking and training will take up any slack.

Second, work loads and manpower needs can be estimated for each project from start to finish. The man-months used in previous seasons, the numbers to be used in the current season, and the balance to remain at season's end can be compared with the three comparable divisions of the work loads.

Third, total work loads for the year can be multiplied by productivity rates to obtain man-months required by activity.

Individual project engineers can use all three approaches. The second and third represent Department policy. The percentage approach counters the tendency to over-staff staking and inspection crews. And the project-start-to-finish approach counters over-estimates of contractor performance—the tendency to assume that every contractor will move to the project sites quickly and in full force, and go at top speed to the end.

Adopting Work Schedules

Work loads and productivity rates determine manpower needs up to a point. Daily and weekly work schedules, including overtime performance, influence them as well.

Since contractors control the hours during which significant numbers of engineering personnel must be on project sites, contractor schedules were identified first. These were analyzed in terms of optional work schedules for engineering forces.

Contractor Daily Hours

Data were collected on the working hours of 54 contractors in 1973.

All contractors worked one shift per day. They extended whatever daily schedules they adopted to complete certain operations, such as concrete pours, and a few continued excavation and embankment work after darkness (under lights). None of them organized second shifts.

The data in Figure 21 show that 95 percent of the roadway contractors regularly worked more than eight hours per day. (They averaged 9.6 hours until late fall, and then dropped to 9.4.)

Figure 21

CONTRACTOR DAILY WORK SCHEDULES

Hours Per Day	Road Contractors	Bridge Contractors	Total
8	5%	46%	19%
8.5	5	8	6
9	10	46	22
10	65	--	44
11	5	--	3
12	10	--	6
	100%	100%	100%

Bridge contractors split evenly between eight- and nine-hour days, with 46 percent adopting each schedule. The rest worked 8.5 hours. (Bridge contractors averaged 8.9 hours until late fall, and then went to 9.4.)

Ninety-one percent of all contractors worked more than eight hours per day throughout the season.

Contractor Weekly Schedules

Figure 22 shows that 63 percent of the contractors worked five days per week, and 37 percent worked six days—on regular schedules throughout the season.

Figure 22

CONTRACTOR WEEKLY WORK SCHEDULES

Days Per Week	Road Contractors	Bridge Contractors	Total
5	52%	82%	63%
6	48	18	37
	100%	100%	100%

Road contractors split almost evenly between five- and six-day schedules. Bridge contractors favored five-day weeks. None of them changed the number of days worked per week after setting a schedule. [15/]

Engineering Daily Schedules

In demonstrating how the Department estimates manpower needs earlier in this chapter (Figure 20 on page 42), the on-site needs climbed from 33 in May to 43 in June, then 57, 70, 71 and 72. They dropped to 61 in October, 46 in November and 26 in December. Since the needs were first calculated in man-hours and then converted to man-months, they actually reflect long workdays put in by the contractors.

15/ One contractor, eliminated from the sample group for this report, actually changed the hours per day and days per week frequently. No pattern of changes could be identified.

For contractor operations on ten-hour and six-day schedules, a number of inspectors potentially can work four ten-hour days per week. Similar schedules can be worked out for five-day operations. Any combination of five employees can consistently provide four man-days of work daily on a ten-hour, four-day schedule. But, employee versatility is critical to making such schedules work.

Schedules can be put together using only eight-hour days and five-day weeks. Starting and quitting times vary by individual so they can overlap each other on contractor operations that exceed eight hours per day—which 91 percent do. Obviously, this results in excess manpower during the overlapping periods.

Overtime Performance

Ten-hour days will not in themselves decrease the total number of man-months required. Exclusive use of eight-hour days will increase the total. Overtime can be used to decrease the numbers of persons employed, particularly if the eight-hour schedule is adopted.

The Department pays time-and-one-half for overtime work. Overtime costs the Department 20 percent more than straight time. The remaining 30 percent represents leaves, holidays, insurance premiums and other fringe benefits earned during straight-time hours—that would be earned by any additional personnel employed to avoid overtime performance. In actual practice, these considerations come into play:

- Additional personnel must be hired on full-time bases—causing payments for eight hours plus fringe benefits to avoid two hours of overtime;
- Additional personnel increase the problems of in-season manpower utilization, since the percentage of utilization typically decreases as the number of employees increases;
- Additional employees add to the problem of off-season manpower utilization, since the size of the year-round force increases generally in proportion to increases in the peak force;

- Ten-hour straight-time shifts reduce productivity rates on days of rain, equipment breakdowns and other delays—as against productivity rates for eight-hour days plus overtime; and

- Continuity of inspection is important on many activities, causing some overtime performance even though extra personnel may have been provided to avoid it.

Unnecessary overtime work should be avoided insofar as possible, in all functions. Apparently, however, overtime can reduce costs in the construction function.

Compensatory Time

Federal statutes permit payments for overtime work through compensatory time off. The compensatory time must be taken within the pay period in which it is earned. Department policy permits employees to opt for compensatory time or cash. Time-and-one-half rates apply either way.

With rainy days, equipment breakdowns and other delays, and with extended days to complete segments of work under way, the compensatory-time provision can be applied to reduce costs—to the extent that employees elect to take it.

Tailored Schedules

Staking and office engineering personnel can work five eight-hour days weekly, with odd exceptions. Since ten percent of the contractors adopt that schedule, and since results-type inspections can be carried out on that schedule as well, roughly 25 percent of the inspectors can also work five eight-hour days.

Schedules including four ten-hour days and five eight-hour days plus planned overtime can be tailored to meet remaining needs. The best combination will always depend on actual contractor schedules. Each project engineer should design that combination of schedules that will give the best productivity rates. The plan that provides the highest productivity rates will produce the lowest engineering costs—despite the additional 20 percent it costs for overtime.

In the manpower needs example used earlier in this chapter, the peak numbers of man-months required can be reduced through overtime payments. Needs that reached 71 and 72 man-months per month can be cut. By combining overtime payments with ten-hour days, actual cash payments can be reduced.

Controlling Manpower Utilization

The central office plans total manpower requirements by project. Project engineers estimate their seasonal manpower needs and plan their staffing patterns. These are checked by members of each district engineer's staff, and minor adjustments are made in the total engineering force—by allowing short-term reassignments of personnel from one project group to another to overcome unusual work load fluctuations, for example. Utilization must then be controlled to ensure that actual staffing reasonably corresponds to planned staffing—so that actual engineering costs will be in line with planned costs.

Card System

The maintenance divisions of several highway departments, including Michigan, have adopted a system of crew-day cards for (1) authorizing work performance, (2) guiding maintenance foremen relative to crew sizes, equipment complements and productivity rates, and (3) reporting work done, manpower and equipment used, and productivity rates attained. These card systems permit foremen to compare results with planned results daily.

The Department tested a similar card system for the construction function. It failed.

While several reasons for failure of the card system can be cited, the main one has to do with daily work performance. Maintenance crews typically work at only one activity each day. Construction personnel must often switch from one task to another several times daily. The card system, a simple tool for maintenance operations, becomes unwieldy for the construction function.

Weekly Schedules

Research proved that manpower utilization can be controlled effectively without referring to productivity rates—just as effectively as through daily reports and evaluations. Planned productivity rates are attained if proper crew sizes are used, if individuals and crews consistently concentrate on essential tasks, and if they perform no more work than is necessary. Scheduling the work to be done and the individuals who will do it is critical.

Figure 23 shows the scheduling system that replaced the crew-day card. These schedules are posted on Thursdays for the upcoming week. Several items in the figure deserve special attention:

- Each employee is given specific assignments—as against crew-size assignments;
- Each employee is given primary and secondary assignments—one set to be done if contractor operations permit, and the other if weather is bad, equipment breaks down, or work is completed ahead of schedule;
- Each employee is told how many hours he is expected to work;
- A separate schedule is worked out for each project—as against the total group of projects; and
- Each schedule is prepared manually—as compared with computer preparation of maintenance crew-day cards.

To repeat, the schedules identify the work loads to be completed and the individuals who will complete them. Productivity rates (adapted from total-project rates) are

Figure 23

TYPICAL WEEKLY PROJECT SCHEDULE

Week beginning *October 7, 1975* MANPOWER SCHEDULE* Project No: *I 70024*

Name	Primary Activity	Location Remarks	M	T	W	T	F	S	Secondary Activity	Location Remarks
JOHNSON JOHNSON	Earthwork inspection Earthwork density control	Entire project Entire project	7 3	7 3	7 3	7 3	7 3		Final measure completed, pipe placement	Entire project 8 hrs. per day
OLSON	Aggregate placement inspection	W. Bd. 1217+00 to 1240+00	10	10	10	10	10		Final measure, completed, fence	Entire project 8hrs. per day
ALVAREZ	Weigh aggregate	Scale -- Contractor's pit	10	10	10	10	10		Final measure, completed, fence	Assist Olson above, 8 hrs. per day
WASHINGTON O'BRIEN KUWALSKI	Surface staking	E. Bd. 1315+00 to 1360+00 W. Bd. 1210+00 to 1300+00 See Sched. I70026			2 2 2	8 8 8	8 8 8			See Schedule, Project I70026

* In the example schedule above, activity code numbers have been omitted for simplicity.

used to ensure that everyone has enough to do, but the rates are not shown on the schedules. The personnel who prepare the schedules soon learn the relationships between work loads and productivity rates.

The schedule format is essentially immaterial. The need is to identify work assignments and personnel, regardless of circumstances that may come up.

Manpower Utilization Reports

Daily reports, also prepared manually, are used to compare actual manpower usage with planned usage:

- Each employee reports hours spent on each activity;
- Employee data are posted regularly—hours planned to date, hours spent to date, and hours remaining for each activity (employee names, dates and other nonessential data are omitted);
- Project engineers are alerted to exceptions—overruns and underruns by activity—and take appropriate actions; and
- District engineers confer with project engineers on unusual exceptions. They provide assistance as needed—particularly when manpower must be shifted from one project engineer to another to offset major work load fluctuations.

Final biweekly summaries are forwarded to the Construction Division. Data from randomly selected projects are used, together with corresponding quantities data, to confirm or adjust productivity rates used to estimate manpower needs.

Summary

No "system" can match dedicated, conscientious, knowledgeable project engineers in controlling manpower utilization. The principle that authority and responsibility should be delegated to the level where all decision-making data are available was confirmed.

Project engineers estimate manpower needs for the year, develop weekly work schedules, include bad-weather assignments in those schedules, and compare actual man-hour usage with planned usage while work is under way. Office engineering personnel alert project engineers to utilization exceptions early enough to permit corrective actions—or deliberate continuation of exceptions based on unusual circumstances.

District engineers are advised of anticipated manpower surpluses and shortages as weekly schedules are completed, permitting them to shift personnel from one group to another as required for balancing. They are made aware of exceptions to planned utilization every two weeks—in ample time to avoid unnecessary cost overruns. And the Construction Division has data for periodic evaluations of the productivity standards on which the entire manpower management system is based.

The entire process will become simpler as time goes on—as work load volumes and numbers of personnel are cut back.

Chapter Five

MANAGING MANPOWER YEAR-ROUND

Manpower expenditures while construction work is under way represent only part of the construction engineering costs. Expenditures during the off-season—including charges to projects for off-season stand-by time—represent the rest.

Year-round manpower management involves (1) establishing the size of the year-round force, (2) providing off-season work for surplus personnel in that force, (3) providing seasonal personnel to supplement the force, and (4) ensuring that both year-round and seasonal personnel are trained.

Establishing the Year-Round Force

The Department has been reducing the construction engineering force since 1967.[16/] As a result of the research, it has defined how far it intends to go, how it will get there, and how it will stay there.

Reductions to 1974

As indicated in Figure 24, the total force dropped from 1,575 in 1967 to 1,196 in 1974—24 percent. The actual work load, expressed in numbers of miles, bridges, cubic yards and tons, increased approximately 23 percent during the period.

16/ Successful efforts actually started in 1964.

Figure 24

FORCE REDUCTIONS, 1967 THROUGH 1974

Construction Years	Total	Year-Round Personnel	Percent of Total	Seasonal Personnel	Percent of Total
1967	1,575	1,435	91%	140	9%
1968	1,450	1,304	90	146	10
1969	1,390	1,249	90	141	10
1970	1,247	1,135	91	112	9
1971	1,253	1,078	86	175	14
1972	1,320	1,043	79	277	21
1973	1,304	1,004	77	300	23
1974	1,196	968	81	228	19

Figure 24 also shows that:

- the permanent force dropped from 1,435 to 968—33 percent;
- the temporary force increased from 140 to 228—63 percent; and
- the percentage of temporaries doubled in the eight-year period.

Minimum Year-Round Force

The Department intends to reduce its year-round force to approximately 650 persons, and to supplement that force with roughly 300 seasonal employees. The considerations involved in reaching that decision may be useful to other highway agencies.

The man-month needs for the group of projects represented in Figure 19 are repeated on the next page.[17/]

17/ Figure 19 can be found on page 41.

January	— 33 man-months;	July	— 70;
February	— 33;	August	— 71;
March	— 33;	September	— 72;
April	— 33;	October	— 61;
May	— 43;	November	— 46; and
June	— 57;	December	— 26.

The peak needs can be reduced to about 65 through planned overtime work.

The minimum force could be 33 from a basic needs standpoint. With proper training courses, and with a reasonable number of experienced seasonal employees, the 33 would also be sufficient from the standpoints of performance difficulty and performance capability. But, four considerations are involved:

1. The need will increase to 43 man-months in May—before engineering students will be available for seasonal employment;

2. The need will still be at the 61-man-month level in October—after students have returned to classes;

3. The more versatile the employees are, the smaller the total force can be—and year-round personnel can become highly versatile; and

4. The larger the year-round force is, the more difficult it is to keep engineering costs down.

The size of the peak-season force is determined by the system. The size of the year-round force is a somewhat arbitrary decision. The Department believes it should be less than two-thirds of the peak requirement—say, 60 to 65 percent. In the case above, it should be about 40-62 percent.

Providing Off-Season Assignments

Actual needs being as low as 33 and the permanent force being roughly 40, provisions must be made for effective utilization of 7 employees during winter months.

Departmental Practice

The Department has assigned construction engineering personnel to other divisions for many years.

Figure 25 shows that 131 permanent personnel were assigned to nonconstruction functions during the winter of 1968-1969. The surplus personnel were distributed to more than five operations, with most being used to supplement the winter maintenance force.

Figure 25

OFF-SEASON PERSONNEL ASSIGNMENTS
1968 to 1972

Division of Assignment	Winter Period 1968-69	1969-70	1970-71	1971-72
	(Numbers of Employees)			
1. Planning	--	8	--	1
2. Design				
• Surveys	8	72	73	46
• Office	--	--	--	--
3. Right-of-Way	6	4	4	9
4. Testing and Research	11	33	--	--
5. Maintenance				
• Field	83	--	28	65
• Utilities - Permits	--	--	--	--
6. Traffic and Safety	9	21	39	24
7. Other divisions	14	8	1	--
Total reassigned	131	146	145	145
Total year-round force	1,304	1,249	1,135	1,078
Percent reassigned	10%	12%	13%	13%

These observations should be made about the data in Figure 25:

- As the total construction force decreased, the numbers assigned to other divisions generally increased;

- Maintenance accepted 83 surplus employees in 1968-1969, none in 1969-1970 because of travel expense restrictions—forcing the construction division to find other off-season assignments;

- Maintenance accepted 28 in 1970-1971 and 65 the following winter—as parts of the manpower planning element of the maintenance management system then being installed; and

- The number assigned to Design Surveys and Traffic and Safety increased sharply in 1969-1970 and remained fairly constant in the following years.

Changes in Practice

As can be seen in Figure 26, the Department accelerated off-season reassignments as research provided additional guidelines. The numbers increased to 185 in 1972-1973, 190 the following year and 269 in the final year. The percentage of the total force reassigned nearly tripled from 1968-1969 to 1974-1975, partly due to the decrease in total employment.

More important, the nature of the winter assignments changed: three additional design squads were established in the districts, for a total of six; Maintenance planned for winter supplements; and Traffic and Safety worked out ways to reduce its backlogs with surplus construction employees.

Figure 26

OFF-SEASON PERSONNEL ASSIGNMENTS
1972 to 1975

Division of Assignment	1972-73	1973-74	1974-75
	Winter Period (Numbers of Employees)		
1. Planning	26	30	0
2. Design			
• Surveys	27	12	39
• Office	--	--	29
3. Right-of-Way	9	13	17
4. Testing and Research	--	--	4
5. Maintenance			
• Field	86	99	110
• Utilities - Permits	20	17	22
6. Traffic and Safety	17	19	41
7. Other divisions	--	--	7
Total reassigned	185	190	269
Total year-round force	1,043	1,004	968
Percent reassigned	18%	19%	28%

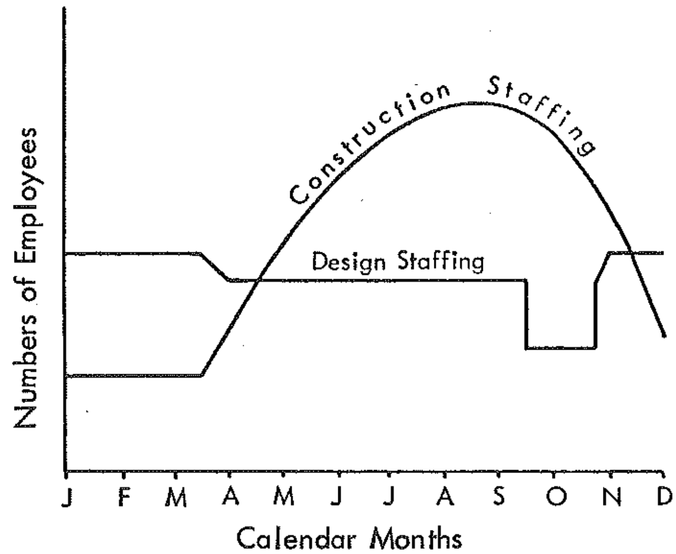
Planned Status

When the total force reaches its final size and configuration, 30 to 35 percent of the permanent employees will be reassigned during winter months. At that point, staffing plans will have been worked out to permit actions such as those depicted in Figure 27.

In Figure 27, the design function is shown to include construction engineering personnel from January through March, release those personnel for construction work until late October, and release regular design personnel for construction assignments during the particularly difficult period from mid-September to late October. Other divisions can take similar actions.

Figure 27

INTEGRATING TWO MANPOWER MANAGEMENT SYSTEMS



Providing Seasonal Personnel

Making the reduced permanent force effective depends on providing capable seasonal personnel. The Department is taking steps to meet this need.

Engineering Students

Engineering students make good seasonal employees, particularly those who return year after year.

The Department has arranged with engineering schools in Michigan to establish 50-50 cooperative programs. Students attend school six months out of the year and work for the Department the other six months—with the schedule designed to coincide with the construction season.

Returning Seasonals

Several nonstudent seasonals have returned for construction engineering assignments year after year. They have been trained as specialists, largely through experience. Most of them now will be given formal training to increase their versatility.

Nonengineering Student Seasonals

Thirty-five percent of the work done falls into the beginning level of performance difficulty. Personnel can be trained to carry out each task in a half-day or less.

Short-term employees, students from nonengineering schools particularly, can readily be employed and trained to fill out any project staff. They cannot be as productive or versatile as engineering students or returning seasonals, thereby decreasing productivity rates. But, relative salaries are low and individuals can be laid off as work loads decrease.

Permanent Intermittent

Permanent intermittent employees are on call at the convenience of the Department. They have no regular schedules. They work when needed and are paid only for the hours worked. The Department has had success in offering this type of employment to housewives and others seeking short-term seasonal work. Tasks performed are usually routine lower levels of difficulty such as gradation testing and weighing.

Providing Training

Seasonal personnel must be trained for beginning- and intermediate-level tasks.

The year-round force must be capable of performing a wide variety of construction engineering tasks. They must be able to accept staking, inspection and office engineering assignments. Some of them should also be able to carry out planning, design, right-of-way, traffic engineering and maintenance assignments.

Short Courses

The Department has provided a great deal of training over the years, primarily through workshops conducted during winter months. It is taking steps to provide each project engineer with specific courses to meet on-site needs. The new courses will depict work methods and workmanship requirements on colored slides, and explain the steps on cassette tapes. Workbooks will include sketches and steps for reference purposes. In some cases, such as moisture-density testing, trainees will perform simulated work as part of the training.

Once the series is available, project supervisors will assign personnel to training tasks in the same way they are assigned to production tasks. Each employee will train himself (or herself), subject to periodic checks for progress, performance and any needed assistance.

Seasonal personnel must be trained quickly, in the field, with limited expenditures of supervisory time. They need to know specific work methods and workmanship requirements only—as distinct from theories, historical information or research results.

Advanced Training

Year-round personnel will take the short courses as well. Whereas seasonal employees may take only one or two, year-round personnel will be expected to take them all. And they will take them in relatively specific sequences. In-depth courses will be developed to complete each work methods series.

Final design of the total training program is incomplete, but advanced workshops are contemplated covering tasks that involve (1) making decisions when several alternatives are available, (2) public relations, environmental considerations, and safety factors, (3) project management—including the construction management system, and (4) staking.

Summary

Reducing off-season construction manpower involved, among other things, reducing the year-round force and reassigning some of that force to other divisions. The Department had taken steps in both these directions for several years—quite successful steps. From that viewpoint, the Department needs only to estimate its wintertime needs and lay off the rest.

But, there are other considerations—a major one in particular: If the peak-season force is to be limited to reasonable numbers, it must include a significant percentage of versatile personnel. Some versatility can be gained through repeated seasonal employment, supplemented by effective training, but not enough to keep the total payroll in bounds.

Since efforts were taken to reduce peak work loads and improve productivity rates, peak manpower needs were being reduced—from 1,575 in 1967 to 1,196 in 1974. The question to be resolved is, "How many should be employed year-round?"

The peak-season need represents on-site and off-site manpower when work schedules and overtime are used to best advantage. Stopping overtime work could itself represent a manpower cut of nearly 10 percent.

With the work management refinements, it was found that construction work loads during winter months can run 45 percent of peak volumes. Early-season loads can jump 30 to 40 percent from there—another 75 to 85 percent later. That being the case, it seems best to employ approximately 60 to 65 percent of peak needs on a year-round basis and assign surplus personnel to other divisions.

All division directors would prefer to staff their organizations independently. Everything is easier when that is done—but expensive. Developing work schedules and staffing plans to accommodate peaks and valleys in other divisions takes extra time, attention and management skill. Even so, other divisions can schedule work loads to absorb surplus construction personnel.

Another major factor is represented by the seasonal force. The more versatile those personnel are, the smaller both the year-round and the seasonal forces can be. To increase seasonal versatility, the Department is arranging cooperative programs with engineering universities. Students attend school six months and work for the Department six months, with the Department getting first choice in scheduling the work section.

The Department is also taking steps to provide quick on-site training for seasonal personnel.

Chapter Six

MANAGING THE SYSTEM

The construction management system consists of many parts, 37 of which are identified in Figure 28. Treating them as individual items first and then as components—according to systems-approach technology—simplifies research and development work.

The parts and components are so interrelated that none of them can function properly without the others. Improving any one can improve the operation of several others.

With a system such as this one, improvements must simplify rather than complicate. Obviously, if work loads and staffing are reduced, and if manpower is provided in the numbers required to do the work without strain, the total operation is easier to manage.

The effects of the new system on management work loads are evaluated first below. Implementation concerns are discussed in the second section, and potential results in the third.

Effects on Management Work Loads

Parts of the management system are represented by one-time efforts, all others represent periodic management work loads.

Figure 28

COMPONENTS OF THE CONSTRUCTION MANAGEMENT SYSTEM

Contracting Component

- Qualifying, bidding and awarding system
- Contracts, supplemental agreements, change orders
- Contract plans, specifications, special provisions
- Damages and claims procedures

Manpower Component

- * Manpower needs
- * Crew sizes, productivity
- * Seasonal force characteristics
- * In-season assignments, schedules
- * Year-round force characteristics
- * Off-season assignments
- * Training

Engineering Component

- * Staking
- * Inspections
- * Records and reports
- ● Compliance checks (EEO, Davis-Bacon)
- ● Contractor payments
- Audits

Personnel Component

- * Personnel classification
- Salary management
- * Selection, placement, advancement system
- * Working hours, days
- * Overtime performance, compensation
- Tenure and other terms of employment

Laboratory Component

- Off-site sampling, testing
- Laboratory tests, forwarded samples
- Quality control audits

Management Component

- Objectives
- Programs
- Budgets
- Policies, procedures
- Organization structure
- * Responsibility-authority relationships
- * Cost controls

Work Management Component

- * Key-activity frequencies
- * Key-activity work loads
- * Key-activity work methods
- ● Other activity frequencies methods

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* The research project was concerned primarily with those identified by asterisks, and involved with those identified by bullets (●).

One-Time Efforts

Parts that can be used as they are for several years certainly add nothing to management work loads.

Work analysis identified the key activities and measurement units, making it easy to estimate full-project and annual work loads. Work analysis also provided requirements of levels of difficulty for the performance-based personnel classification plan.

Development of the new training program represents a one-time effort in most respects as well. The types of courses contemplated for work methods and workmanship training will be similar to manuals—available for use as needed.

Annual Items

Certain management actions must be taken once annually regardless of how they are done. Orderly procedures, adopted statewide, simplify the work for headquarters and district officials, and possibly for project engineers as well.

Work loads must be estimated in terms of miles, bridges, cubic yards, tons and square yards—at the start of each project and at times adjusted at the beginning of each year. They must be converted into manpower needs for each total project and, once each year, for each group of projects and each district. And manpower needs must be adjusted to reflect daily and weekly working hours, plus planned overtime performance.

Most guesswork, except that associated with estimating contractor progress, has been eliminated from this process, reducing the discussions that would otherwise take place to resolve differences of opinion between project engineers, district engineers and headquarters officials.

Weekly Efforts

Project engineers must schedule increments of work to be done, including job-site training, by project and activity. They must schedule individuals to carry out each work load, and designate working hours for each assignment. And they must provide alternative assignments for days on which contractors fail to make the primary assignments worthwhile. (Secondary assignments can be carried over from week to week until they are completed, of course.) The schedules must be changed during the week—but most will hold.

This type of scheduling simply replaces another—that of making assignments every day or several times daily. Since careful planning a week at a time reduces manpower needs, it reduces the management work load. It also reduces day-to-day frustrations.

Biweekly Efforts

Project engineers must compare actual manpower expenditures with planned expenditures at least every two weeks. They can arrange to check exceptions to planned utilization as they occur, but day-to-day fluctuations are of very limited significance.

District engineers are expected to review exceptions to planned manpower utilization every two weeks. Acceptable explanations for most exceptions accompany the reports, but a small percentage justifies conferences with the project engineers. Shifting personnel from one project force to another, always a district-level responsibility, can now be done with confidence that one crew is short while another has extra personnel—particularly since both project engineers want to keep costs down.

Intermittent Efforts

Productivity rates have been developed for 33 activities only; additional rates will be of no value.[18/] The 33 rates, being critical to manpower needs determinations, must be checked at least once each year. Random samples of data are sufficient.

Since crew sizes, work frequencies and work methods severely affect productivity rates, they must be reviewed every few years. A permanent work methods committee has been established for this purpose.

Manpower management objectives should be reviewed at least every two years. Four- or five-year construction programs provide work load data from which the overall size of the year-round and seasonal forces can be calculated. The potential for off-season assignments to nonconstruction functions should be evaluated at the same time.

Implementation

Formal implementation of the system began on rural freeway projects in 1974. Implementation—with standards to cover all major types of projects—will be completed in 1976.

Two major concerns relative to implementing the program are whether or not it will be accepted, and the extent to which staff development is required for its effective operation.

Acceptance of the System

Everyone resists change, including those specifically responsible for designing, developing and implementing management improvements. Other research has shown, and this project confirmed, that resistance to change largely represents resistance to the

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18/ Rates have been developed for five additional activities, making a total of 38. The five are used as needed.

unknown and the impractical. In this instance, extensive and continuous participation by representatives of all levels of construction management precluded any surprises to those affected. Participation also ensured that the system would be logical, complete and practical. Field tests eliminated the need for most adjustments during implementation.

Since major parts of the system have been implemented without unusual problems, acceptance of the system is certain. Weekly scheduling represents the only known problem, and it is being overcome. Weather conditions, contractor operations and contractor progress are unknowns, making it difficult to schedule work and manpower in advance. But habit is the major obstacle—the habit of scheduling day to day, even hour to hour. Habits being far more difficult to change than procedures, the Department continues to improve the scheduling forms—and to replace one habit with another.

Staff Development

All construction engineers and project managers must be trained relative to system objectives and technology. While most of them understand the workings in general, and several understand it in full detail, all need to know the concept on which it is based. They particularly need to know relationships among crew sizes, work frequencies, work methods, productivity rates and final costs.

While one-day workshops plus limited assistance during initial stages of implementation are essential, the system soon becomes standard operating procedure.

Results

It is too early to tell what the final results will be, but not too early to evaluate indications.

Construction Engineering Costs

Average engineering costs on all road systems dropped from 14 percent of contractor payments in 1971 to 13.4 percent in 1973, and to 10.5 percent in 1975. Costs on interstate projects dropped from 13.3 to 9.8 percent during the same period, and on secondary projects from 19.1 to 15.2.

Costs on the three engineering projects used for laboratory testing averaged 9.0 percent of contractor payments.[19/] This rate was achieved despite the research characteristics of the projects and pre-system practices for most of the research period.

As manpower becomes versatile, and as productivity rates increase, it can be expected that average construction engineering costs will drop below 9 percent. They may range from, say, 6 percent on large projects to 12 or 13 on small ones.

Staffing Controls

Pressures are on to reduce payrolls in all state agencies.

The Department is in a position to document construction manpower needs with work load, productivity and performance data. No organization can be expected to do more work than it is capable of doing. And no organization should expect to have more manpower than it needs.

The system should ensure that a balance will be reached to the satisfaction of everyone—Departmental management, budget review officers, the Governor and the Legislature.

19/ The 9.0-percent rate represents actual salaries paid plus Department-level overhead charges, plus Testing and Research Division charges, vehicles, supplies and other items.

Summary

This project was directly involved with 19 out of 37 parts of the total construction management system, and indirectly involved with 3 others. Most of them had to do with work to be done in the field, manpower management and personnel management.

System development was a one-time effort. Its refinement must be continuous—but largely in short, annual increments. System management involves annual, weekly and biweekly efforts: annual planning of work loads and manpower needs; weekly scheduling of work assignments; biweekly evaluations of manpower utilization; and annual evaluations of results.

Design and development of the system were complex undertakings, requiring numerous special reports for data collection and a wide variety of pilot runs. Management of the system is relatively simple—simpler than the old way.

Responsibility has been delegated to the levels where decisions can best be made—where responses to contractor actions can be immediate.

Appendix A

ACTIVITIES AGAINST WHICH PILOT PROJECTS CHARGED TIME

This list of 141 activities was used to identify the 33 that represent upwards of eighty percent of the work load. They are shown in rank order of man-hour charges. No time was charged to three activities.

Rank	Activity	Percent of Man-Hours	Cumulative Percent
1	Office engineering, excavation and embankment	12.1	12.1
2	Annual leaves	5.4	17.5
3	Final trim and cleanup inspection	3.8	21.3
4	Project inspection supervision	3.5	24.8
5	Office engineering, other reports	2.9	27.7
6	Stake clay grades	2.8	30.1
7	Holidays	2.7	33.2
8	Stake line and grade, PCC surfacing	2.7	35.9
9	Density testing, embankments	2.7	38.6
10	Staking cross-sections and slopes	2.5	41.1
11	Concrete placement inspection, PCC surfacing	2.3	43.4
12	Office engineering, construction reports	2.3	45.7
13	Sick leaves	2.2	47.9
14	Excavation and embankment inspection	2.1	50.0
15	Office engineering, structures	2.1	52.1
16	Slope inspections, shaping and grade	2.1	54.2
17	Office engineering, documentation	1.9	56.1
18	Staking earthwork	1.9	58.0
19	Inspecting other grading operations	1.8	59.8
20	Office engineering, establish and maintain files	1.7	61.5
21	Stand-by, weather reasons	1.6	63.1

Rank	Activity	Percent of Man-Hours	Cumulative Percent
22	Inspect placement, shaping and depth, aggregate surfacing	1.4	64.5
23	Stand-by, contractor reasons	1.4	65.9
24	Weigh aggregates	1.3	67.2
25	Prepare time sheets and expense reports	1.3	68.5
26	Test density, aggregate surfacing	1.2	69.7
27	Inspect minor drainage installation	1.2	70.9
28	Maintain office equipment and supplies	1.1	72.0
29	Inspect concrete plants, structures	1.1	73.1
30	Stake line and grade, aggregate surfaces	1.1	74.2
31	Project management, other	1.0	75.2
32	Training	1.0	76.2
33	Inspect superstructure-concrete placement	1.0	77.2
34	Inspect concrete plants, PCC surfaces	0.9	78.1
35	Locate or reestablish control points	0.8	78.9
36	Stake sewers and underdrains	0.7	79.6
37	Inspect bituminous plants	0.6	80.2
38	Inspect subbase shaping and depth, aggregate surfacing	0.6	80.8
39	Inspect materials and workmanship, cleanup	0.6	81.4
40	Office engineering, road layout	0.6	82.0
41	Compute and check yields, aggregate surfacing	0.6	82.6
42	Maintain equipment and vehicles	0.6	83.2
43	Stake cross-sections, topsoil removal areas	0.6	83.8
44	Inspect paving operations, bituminous surfacing	0.6	84.4
45	Inspect signs and barricades	0.6	85.0
46	Compensatory time off	0.6	85.6
47	Inspect structural steel erection and placement	0.5	86.1
48	Inspect substructure forming and resteel placement, structures	0.5	86.6
49	Stand-by, other	0.5	87.1
50	Office engineering, E.E.O. and O.J.T. reports	0.5	87.6
51	Stake or restake centerlines, excavation and embankment	0.5	88.1

Rank	Activity	Percent of Man-Hours	Cumulative Percent
52	Stake fences	0.5	88.6
53	Stake substructure lines and establish grades	0.5	89.1
54	Stake guardrails	0.4	89.5
55	Inspect forms, materials and equipment, concrete surfacing	0.4	89.9
56	Take final measurements, concrete surfacing	0.4	90.3
57	Contractor relations	0.4	90.7
58	Inspect slope protection, structures	0.4	91.1
59	Test density, structures	0.4	91.5
60	Test density, minor drainage structures	0.4	91.9
61	Inspect substructure-concrete placement	0.4	92.3
62	Inspect topsoil, grading	0.3	92.6
63	Office engineering, aggregate surfacing	0.3	92.9
64	Office engineering, clearing, grubbing and tree removal	0.3	93.2
65	Travel time	0.3	93.5
66	Office engineering, concrete surfacing	0.3	93.8
67	Stake culverts	0.3	94.1
68	Office engineering, drainage structures	0.3	94.4
69	Supervise project surveys	0.3	94.7
70	Stake curbs and gutters	0.3	95.0
71	Check grade preparations and conditions, bituminous surfacing	0.3	95.3
72	Check grades, concrete surfacing	0.3	95.6
73	Personnel management and training	0.2	95.8
74	Staking, miscellaneous roadway layouts	0.2	96.0
75	Inspect project cleanup, structures	0.2	96.2
76	Take beam elevations and lay out lines and grades, structure decks	0.2	96.4
77	Stake bridge layouts	0.2	96.6
78	Inspect major drainage structures	0.2	96.8
79	Conduct gradation analyses	0.2	97.0
80	Inspect demolitions and removals	0.2	97.2
81	Inspect detours and temporary roads	0.2	97.4

Rank	Activity	Percent of Man-Hours	Cumulative Percent
82	Take final measurements, right-of-way fence	0.1	97.5
83	Office engineering, bituminous surfacing	0.1	97.6
84	Stake for final measurements, culverts and drainage	0.1	97.7
85	Consult and assist other projects, divisions or personnel	0.1	97.8
86	Stake or restake centerlines, road layouts	0.1	97.9
87	Stake culverts and drainage, other	0.1	98.0
88	Office engineering, cleanup	0.1	98.1
89	Office engineering, traffic maintenance	0.1	98.2
90	Inspect piling operations, structures	0.1	98.3
91	Coordinate with other divisions	0.1	98.4
92	Leave without pay	0.1	98.5
93	Stake miscellaneous bridge layouts	0.1	98.6
94	Stake sign locations	0.1	98.7
95	Stake other structure	0.1	98.8
96	Stake to establish reference points or lines, bridges	0.1	98.9
97	Inspect utilities relocations	0.1	99.0
98	Public relations	0.1	99.1
99	Stake rights-of-way, road layouts	0.1	99.2
100	Other paid leave	0.1	99.3
101	Stake traffic controls	0.1	99.4
102	Office engineering, bridge layout	0.1	99.5
103	Conduct gradation analyses, minor drainage structures	0.1	99.6
104	Inspect protective treatments, structures	0.1	99.7
105	Control density, major drainage structures	0.1	99.8
106	Stake lines, bituminous surfacing	0.1	99.9
107	Inspect lighting, traffic maintenance	0.1	100.0
108	Stake sewage facility locations, rest areas		
109	Conduct gradation analyses, structures		
110	Stake rest areas		
111	Inspect excavation, structures		
112	Office engineering, rest areas		
113	Test density, utilities relocation		

Rank	Activity	Percent of Man-Hours	Cumulative Percent
114	Stake excavation limits, structures		
115	Stake box culverts and minor structures		
116	Measure and inspect tree and stump removal		
117	Locate or reestablish control points, bridges		
118	Inspect selective clearing		
119	Stake foundation piles		
120	Conduct gradation analyses, major drainage structures		
121	Identify construction and right-of-way limits, utilities relocation		
122	Inspect materials and equipment, bituminous surfacing		
123	Inspect construction of foundations, building and other facilities, rest areas		
124	Safety meetings		
125	Office engineering, utilities relocation		
126	Prepare for lettings		
127	Identify, measure and compute clearing limits		
128	Stake elevations, bridge layouts		
129	Make final measurements, box culverts and minor structures		
130	Stake other box culverts and minor structure staking		
131	Set pile cutoffs—structures		
132	Other clearing and grubbing inspection		
133	Gradation testing—utilities relocation		
134	Fabricated materials control and testing—minor drainage structures		
135	Inspect and test fabricated materials—structures		
136	Stake clearing limits		
137	Other clearing, grubbing and tree removal staking		
138	Make final measurements, traffic control		
139	Stake buildings and other facilities, rest areas		
140	Fabricated materials control and testing, major drainage structures		
141	Determine and maintain required clearance, utilities relocation		

Appendix B

ABILITY-STATEMENT TITLES

General Knowledge and Ability Statements

Statement Number	Statement Title
	Orientation:
1	Department orientation
2	Construction orientation
3	Contractor orientation
4	Property owner orientation
	Reading, Documentation and Interpretation:
5	Terminology and nomenclature
6	Source documents and manuals
7	Contract plan reading
8	Project documentation and sketches
9	Communications I
10	Construction drafting
	Mathematics:
11	Mathematics I
12	Mathematics II
13	Mathematics III
14	Mathematics IV
15	Mathematics V
	Survey:
16	Survey I
17	Survey II
18	Survey III

Statement Number	Statement Title
	Management:
19	Communications II
20	Communications III
21	On-site training
22	Formal training
23	Project safety
24	Supervision
25	Project management
26	Residency management
Specific Ability Statements	
	Utilities, clearing and grubbing:
27	Utilities relocation inspection
28	Clearing, grubbing and tree removal inspection
29	Selective clearing inspection
	Excavation and embankment:
30	Swamp excavation and backfill inspection
31	Topsoil removal inspection
32	Excavation and embankment inspection
33	Culverts, sewers and drainage structures inspection
	Aggregate construction:
34	Borrow area inspection
35	Aggregate yield inspection
36	Aggregate shaping, placing and compacting inspection
	Surfacing:
37	Fine grading inspection
38	Priming and sealing inspection
39	Bituminous paving inspection
40	Portland concrete forming inspection
41	Load transfer devices and steel placement inspection
42	Portland concrete paving inspection
43	Portland concrete joints and sealing inspection
44	Portland concrete finishing inspection

Statement Number	Statement Title
	Materials control:
45	Density testing
46	Gradation testing of granular material
47	Platform scale operation
48	Maintenance of tested materials inventory
49	Portland concrete testing
50	Portland concrete plant inspection
51	Bituminous plant inspection
	Right-of-way safety devices:
52	Construction traffic sign layout
53	Traffic sign placement and maintenance inspection
54	Guardrail inspection
55	Fence inspection
56	Seeding and sodding inspection
57	Landscaping inspection
58	Slopes, erosion and ditch inspection
59	Temporary pads and roads inspection
	Streams, piling and substructure:
60	Stream maintenance inspection
61	Cofferdams inspection
62	Sheet-piling inspection
63	Foundation-piling inspection
64	Excavation and foundation inspection
65	Forming and resteel placement inspection
66	Concrete placement inspection
67	Backfill inspection
68	Finishing and curing inspection
	Structural steel and superstructure:
69	Steel erection inspection and precast beams
70	Painting inspection
71	Forming and temporary supports inspection
72	Resteel placement inspection

Statement Number	Statement Title
73	Concrete placement inspection
74	Finishing and curing inspection
	Rest areas:
75	Water well inspection
76	Sewage facilities inspection
77	Site preparation inspection
78	Buildings inspection

Appendix C

PERSONNEL CLASS SPECIFICATIONS

Transportation Construction Technician I

Classification Description

Transportation Construction Technicians I perform basic inspection, surveying and office work. This is the beginning-level classification.

Work performed will normally be at the basic and intermediate levels of difficulty. Employees in this class exercise their basic capabilities in field construction activities as assigned.

Minimum Qualifications and Requirements

Persons classified as Transportation Construction Technicians I will meet the requirements identified below. They will:

1. be able to read, write and speak the English language;
2. be 18 years of age, or be a high school graduate;
3. be able to make basic mathematical calculations including adding, subtracting, multiplying and dividing whole, fractional and decimal numbers, and to apply recognized rules of rounding and rules of logic to arithmetic progressions;

4. be able and willing to work irregular hours, work outdoors and move about the State as required by the work; and

5. possess a valid Michigan driver's license.

Transportation Construction Technician II

Classification Description

Transportation Construction Technicians II perform assigned inspection, surveying and office work elements. Assignments normally represent basic, intermediate and journeyman levels of difficulty.

Minimum Qualifications and Requirements

Employees assigned to this class must have been employed as Transportation Construction Technicians I for at least six months, be recommended by their supervisors, and meet the performance requirements listed below.

1. They must have demonstrated their abilities to:

   - test gradation;
   - serve as a beginning-level rodman; and
   - reduce and check field-book notes.

2. They must have demonstrated ability to do at least four of the following tasks:

   - weigh materials (platform scales);
   - inspect protective treatments (structures);
   - inspect structure painting;
   - inspect fence construction;
   - inspect portland concrete joints (pre-pour), dowels (spacing, level, coating) and resteel placements;
   - inspect subbase shaping and depth of aggregate surfacing;
   - inspect tree and stump removal;
   - plot cross sections; and
   - check weigh tickets and sheets.

Transportation Construction Technician III

Classification Description

Transportation Construction Technicians III perform journeyman-level inspection, surveying and office functions. They also work at the basic and intermediate levels of difficulty as required.

Minimum Qualifications and Requirements

Persons assigned to this class must have qualified as Transportation Construction Technicians II, be recommended for this class by their supervisors, and meet the performance requirements listed below.

1. They must have demonstrated their abilities to perform effectively the following key tasks:

    - inspect minor drainage structures;
    - test concrete quality control—air, slump and temperature;
    - inspect placement and shaping of aggregate surfacing;
    - test density;
    - compute areas and volumes; and
    - rod and chain.

    and one of the following:

    - inspect grade preparation for bituminous paving; or
    - inspect grade for PCC paving; forms for PCC paving; load transfer devices (after pour); sawing and sealing joints.

2. They must have demonstrated their abilities to do at least five of these tasks:

    - inspect topsoil removal;
    - inspect structure cleanup and joints;

- inspect guardrail;
- inspect sodding;
- inspect detours and temporary roads;
- control and test fabricated materials for structures;
- inspect pile driving—production;
- inspect demolition or removal items;
- inspect selective clearing;
- inspect seeding, mulching and fertilizing;
- inspect erosion control;
- identify construction and right-of-way limits;
- inspect maintenance of traffic control devices;
- inspect rest area materials—certifications, documentation and storage;
- check equipment against shop drawings for proper type;
- inspect final project cleanup after punch list;
- inspect landscaping; and
- inspect finishing and curing on PCC paving.

3. They must have demonstrated their abilities to perform as an instrumentman on at least four of the following tasks:

- make final measurements of traffic control devices, fencing, PCC paving, drainage and minor structures, and aggregate surfacing;
- set pile cutoffs;
- stake fence from previously established control points;
- stake guardrail;
- stake line for bituminous surfacing;
- cross-section topsoil removal areas;
- stake centerline; and
- stake clearing limits.

4. They must have demonstrated their abilities to perform effectively at least two of the following project office tasks:

- prepare volume sheets;
- check and post tested materials and post pay quantities;

- prepare field books and sketches for clearing limits;
- review requirements for special programs and prepare reports such as E.E.O. and O.J.T.; and
- set up file systems within prescribed guidelines and maintain files and records.

Transportation Construction Technician IV

Classification Description

Transportation Construction Technicians IV perform senior-level inspection, surveying and office functions.

Minimum Qualifications and Requirements

Persons are appointed to positions in this class only when vacant positions are available.

To be considered for appointments to this class, individuals must be qualified as Transportation Construction Technicians III, be recommended by their supervisors, and meet the performance requirements listed below.

1. They must have demonstrated their abilities to perform effectively the following tasks:

   - inspect portland cement concrete plans and maintain materials quality control;
   - inspect bituminous surfacing;
   - inspect bituminous plants and maintain materials quality control;
   - prepare field books and sketches for minor drainage structures, structures, earthwork and grades, and curb and gutter; and
   - compute and check aggregate surfacing.

   and one of the following:

   - inspect substructure and parapet-wall concrete placement, substructure and parapet-wall forming, and steel placement; or
   - inspect headwalls, box culverts, curbs, gutters, or major drainage structures.

2. They must have demonstrated their abilities to perform effectively as an instrumentman on the following surveying tasks:

- stake excavation and embankment grades;
- cross-section and slope stake; and
- stake rights-of-way for road layout.

and one of the following:

- stake substructure lines and grades, foundation piles and structure-excavation limits; or
- stake curbs and gutters, sewers, underdrains, pipe culverts, box culverts, and minor structures.

3. They must have demonstrated ability to perform effectively at least two of the following tasks:

- identify, measure and compute clearing limits;
- inspect rest-area well location, development and testing;
- inspect utilities relocation;
- inspect rest-area sewage facilities;
- inspect structural steel erection;
- inspect dewatering operations and cofferdams; and
- inspect temporary and placements of traffic control devices.

Transportation Construction Technician V

Classification Description

Trnasportation Construction Technicians V act as assistant project engineers.

Minimum Qualifications and Requirements

Persons are appointed to this class only when vacant positions are available.

To be considered for appointments to positions in this class, individuals must have been employed as Transportation Construction Technicians IV for a minimum of two years, and must meet the requirements for recommendations, testing and performance defined below. They must:

1. be recommended by the project engineer and district construction engineer, and approved by the Chief—Construction Division;

2. pass a written Civil Service examination and random performance tests covering all Level-of-Difficulty-4 activities and selected Level-3 activities;

3. have demonstrated proficiency in inspection, surveying and office procedures for both roads and bridges;

4. have demonstrated abilities to supervise inspection and surveying operations; and

5. have demonstrated abilities to establish favorable working relationships with landowners, contractors, employees and the public.

Transportation Construction Project Manager

Classification Description

Transportation Construction Project Managers act as project engineers.

Minimum Qualifications and Requirements

Persons are appointed to this class only when vacant positions are available.

Persons considered for appointments to this class must have been employed as Transportation Construction Technicians V for a minimum of two years, and meet these requirements:

1. They must be recommended by the district engineer and approved by a Technician Classification Review Board to consist of two construction staff engineers and the Chief—Construction Division;

2. They must have demonstrated ability to manage all elements of both road and bridge construction projects effectively; and

3. They must pass a written Civil Service examination.

NOTE: This classification was recommended to the Department. It has not been adopted. The other five classifications have received initial approval.

Appendix D

TASKS RANKED BY LEVELS OF PERFORMANCE DIFFICULTY

Basic-Level-of-Difficulty Tasks

Inspection:

1	Test gradation
2	Weigh materials (platform scales)
3	Inspect protective treatments (structures)
4	Inspect structure painting
5	Inspect fence
6	Inspect portland concrete joints (pre-pour), dowels (spacing, level, coating) and resteel placements
7	Inspect subbase shaping and depth of aggregate surfacing
8	Inspect tree and stump removal

Staking:

9	All beginning-level rodman tasks

Office Engineering:

10	Reduce and check field books
11	Plot cross sections
12	Check weigh tickets and sheets

Intermediate-Level-of-Difficulty Tasks

Inspection:

13	Inspect minor drainage structures
14	Test for concrete quality control—air, slump and temperature

15	Inspect grade preparation for bituminous paving
16	Inspect load transfer devices for portland cement concrete paving (after pour), sawing, sealing; grade for PCC paving; and forms for PCC paving
17	Inspect placement and shaping of aggregate surfacing
18	Test density
19	Inspect topsoil removal
20	Inspect structure cleanups and joints
21	Inspect guardrail
22	Inspect sodding
23	Inspect detours and temporary roads
24	Control and test fabricated materials for structures
25	Inspect pile driving (production)
26	Inspect demolition or removal items
27	Inspect selective clearing
28	Inspect seeding, mulching and fertilizing
29	Inspect erosion controls
30	Identify construction and right-of-way limits
31	Inspect maintenance of traffic control devices
32	Inspect rest-area materials—certification, documentation and storage; check equipment against shop drawings for proper types
33	Inspect final project cleanups after punch list
34	Inspect finishing and curing on PCC paving

<u>Rodding and Chaining</u>:

36	All rodman and chainman tasks

<u>Instrumentman Tasks</u>:

37	Make final measurements of traffic control devices, fences, portland cement concrete paving, drainage and minor structures, and aggregate surfaces
38	Set pile cutoffs
39	Stake fence from previously established control points
40	Stake guardrails
41	Stake lines for bituminous surfacing
42	Cross-section topsoil removal areas

43	Stake centerlines
44	Stake clearing limits

Office Engineering:

45	Compute areas and volumes
46	Prepare volume sheets
47	Check and post tested materials and post pay quantities
48	Prepare field books and sketches for clearing limits
49	Review requirements for special programs and prepare reports such as E.E.O. and O.J.T.
50	Set up file system within prescribed guidelines and maintain files and records

Journeyman-Level-of-Difficulty Tasks

Inspection:

51	Inspect substructure concrete placement, substructure forming and steel placement, parapet walls
52	Inspect headwalls, box culverts, curbs, gutters, major drainage structures
53	Inspect portland cement concrete plants and maintain materials quality control
54	Inspect bituminous surfacing
55	Inspect bituminous plants and maintain materials quality control
56	Identify, measure and compute clearing limits
57	Inspect rest-area well locations, development and testing
58	Inspect utilities relocations
59	Inspect rest-area sewage facilities
60	Inspect temporary and permanent traffic control signs and traffic control devices
61	Inspect structural steel erections
62	Inspect dewatering operations and cofferdams

Instrumentman Work:

63	Stake substructure lines and grades, foundation piles, structure excavation limits
64	Stake curbs and gutters

65 Stake sewers and underdrains

66 Stake culverts, box culverts and minor structures

67 Stake excavation and embankment grades

68 Cross-section and stake slopes

69 Stake rights-of-way for road or bridge layout

70 Stake buildings and rest-area facilities

71 Stake sheet-pile layouts

72 Stake sign locations

73 Stake lines and grades for portland cement concrete paving

74 Stake lines and grades for aggregate surfacing

75 Stake sewage facilities

76 Stake bridges for construction controls

77 Stake utility relocations

Office Engineering:

78 Prepare field-book data and sketches for minor drainage structures, structures, earthwork and grades, curbs and gutters, sewage facilities, utilities relocations and rest-area facilities

79 Compute and check aggregate surfacing

Senior-Level-of-Difficulty Tasks

Inspection:

80 Inspect foundations, buildings and related rest-area facilities

81 Inspect superstructure preparations and resteel placements, forming and concrete placements

82 Inspect portland cement concrete paving

83 Inspect grading

84 Inspect test-pile driving

Instrumentman Work:

85 Establish structure reference points and lines

86 Establish beam elevations

87 Lay out deck lines and grades

88 Locate or reestablish control points for road or bridge layouts

Office Engineering:

89	Compute and adjust deck grades
90	Determine final pay quantities
91	Prepare field books and sketches for horizontal and vertical control and right-of-way
92	Prepare construction reports—biweekly progress reports, estimates, recommendations, record of days charged

Supervision:

93	Staking crews
94	Inspection personnel
95	Office personnel
96	Scheduling
97	Controlling
98	Personnel, policies and procedures
99	Communications, written and oral
100	Reference sources and priorities
101	Chain of authority and responsibility

Project Management:

102	All types of construction projects
103	Limited project responsibility without direct supervision for short periods, or small jobs
104	Contractor relations
105	Public relations
106	Employee relations
107	Leadership and motivation
108	Landowner relations
109	All project documentation requirements
110	All project survey requirements
111	All project inspection requirements
112	All record system requirements
113	All field elements, construction management system
114	Problem-solving
115	Field-design evaluations and changes

Appendix E

MANPOWER NEEDS WORK SHEET

The work sheet shown on the next page is used in estimating manpower needs on each project, and then each group of projects supervised by one engineer. A summary sheet is used for compiling district-wide and statewide needs.

Note that total man-months needed from start to finish on each project are shown first, needs for the current year are detailed by month, and the balance to complete the project in coming years is shown in the final column.

ANNUAL STAFFING PLAN FOR ____________

Prepared by: ______________

Project I.D.: ______________ Starting Date: ______________ Estimated Completion Date: ______________ Date: ______________

No.	Activity	Planned Total Project	Used to Date	Balance	Current Year													Balance to Complete
					Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total	
STAKING:																		
1	Roadway																	
2	Utilities																	
3	Cross-section and slope staking																	
4	Grades																	
5	Surfacing																	
6	Curb, gutter, and guardrail																	
7	Structures																	
8	Minor structures and drainage																	
9	Special feature																	
	Total Staking																	
INSPECTING:																		
10	Preparation																	
11	Traffic control																	
12	Earthwork																	
13	Earthwork density																	
14	Aggregate placement																	
15	Aggregate density																	
16	Aggregate weighing																	
17	Bituminous paving																	
18	Bituminous plant																	
19	Bituminous weighing																	
20	PCC joint repair																	
21	PCC paving																	
22	Curb, gutter, sidewalk, and miscellaneous concrete																	
23	PCC plant																	
24	Structures																	
25	Minor structures and drainage																	
26	Concrete plant for structures																	
27	Structural special features																	
	Total Inspection																	
OFFICE ENGINEERING:																		
PROJECT MANAGEMENT:																		
Total, All Needs																		

Appendix F

DEPARTMENT OFFICIALS DIRECTLY ENGAGED ON THE RESEARCH PROJECT

Coordinators

Project Coordinator: Gerald J. McCarthy
Field Project Coordinator: Roger Vander Meulen

Advisory Committee

Gerald J. McCarthy, Deputy Director-Highways, Chairman
Larry Beckon, Administrator-Computer Services Division
Thomas J. Clark, Manager-Management Methods Section
Max N. Clyde, Assistant Deputy Director-Highways
Robert J. Hamill, Personnel Manager
John G. Hautala, Chief-Bureau of Operations
Richard C. Mastin, District Engineer-Jackson
William A. Sawyer, Engineer of Construction
Robert R. Scraver, District Engineer-Jackson
Ralph Souchek, Manager-Systems Analysis Section
Al Steger, Area Engineer-Federal Highway Administration
Roger Vander Meulen, Assistant District Construction Engineer-Grand Rapids

Task-Force Committee

Roger Vander Meulen, Assistant District Construction Engineer-Grand Rapids, Chairman
Gerald J. Casey, Assistant District Construction Engineer-Kalamazoo
William C. Gustafson, Construction Office Manager-Lansing
Clyde O. Maylath, Resident Engineer-Districts 5 and 7
David W. Miller, Project Engineer-District 5
Noel Smith, Project Engineer-Metro
John VandenBerg, District Office Engineer-Grand Rapids
Robert A. Welke, Project Engineer-District 7

Construction Work Methods Improvement Committee

Gerald J. Casey, Construction Staff Engineer, Chairman
Paul Baumgartner, District Materials Engineer-District 6
Dwight A. Bell, Design Supervising Engineer
Keith Ferguson, Highway Construction Superintendent-District 8
Noel Smith, Project Engineer-Metro District
Roger Vander Meulen, Assistant District Construction Engineer-Grand Rapids
Robert A. Welke, Project Engineer-District 7