NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 51

CONSTRUCTION CONTRACT STAFFING

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

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

AREAS OF INTEREST:
PERSONNEL MANAGEMENT
CONSTRUCTION

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

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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

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

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

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

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PREFACE

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

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

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of special interest and usefulness to transportation administrators, personnel managers, construction engineers, and others seeking information on better management of construction manpower. Management systems used by several transportation agencies are reviewed in detail.

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

Transportation agencies need to know whether their construction engineering and contract administration are being performed in the most effective and efficient manner. This report of the Transportation Research Board compiles and evaluates current methods for determining staffing levels, resource allocations, and skill requirements for construction engineering and contract administration. Current practices with regard to manpower management systems are discussed in detail. Also discussed are state practices on personnel classification, training, temporary employees, and other management considerations.

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

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

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CONSTRUCTION CONTRACT STAFFING

SUMMARY

Interest in more effective management of engineering manpower has increased during the past several years. Many factors are responsible for this increased interest. In some cases the cost of the engineering effort has been higher than desired. The need to have a reliable method of determining manpower requirements has been a factor in some agencies. An increased interest by the legislature has provided the motivation in other states. The effects of inflation, reduced construction programs, and declining revenues also have sparked interest in better construction manpower management.

Construction engineering manpower is directly related to the scheduling of construction projects. Long-range manpower projections normally are completed at the state or district level. Short-range estimates often are completed at the project level and reviewed at the regional level.

The basic functions of management are planning, organizing, leading, and controlling, and these functions can be applied to engineering manpower. Particularly important is the need to measure performance and establish standards that can be used to prepare engineering manpower estimates for each major work activity on each project. Each headquarters office can summarize project requirements to obtain the total needs for specific types of manpower. Long-term upward trends can be met by hiring, training, and retraining as necessary. Short-term peaks can be met with temporary hiring, transfers, or overtime.

There are many ways to provide the necessary manpower for staffing construction projects. One way is to assign every person that is needed on each specific project. Some states have a pool of personnel that can be used as needed to supplement project personnel. Sometimes several projects are grouped under a single office so that there is more efficient use of personnel. The project engineer is responsible for the effective use of all personnel. The use of alternative assignments for each person has been successful in helping each person keep busy with specified project work. The use of optimum-size crews is another challenge for the project engineer; studies of survey crew size have shown that smaller crews are more efficient for some construction fieldwork.

Several agencies use fund-based manpower planning systems in which cost, project type, and miles of highway are the basis of estimating personnel requirements. The more detailed planning systems consider project characteristics, contractor activities, agency responsibilities, and contractor function flow diagrams.

The manpower management systems in Arkansas, Louisiana, Michigan, and Washington are reviewed in detail in this synthesis. Appendixes A and B provide information on priorities in other states.

Policies regarding personnel classification, training, temporary employees, off-season assignments, overtime, and travel have an important role in manpower management for construction projects. The synthesis discusses practices followed by several transportation agencies.

Effective construction manpower management begins with a management systems approach. The development of a suitable model is recommended as a first step for an agency just beginning a study in this area.

Several agencies have made progress in manpower planning, but many areas deserve further consideration. The general consensus is that short-term scheduling of project manpower is most efficiently done manually by the project engineer. Because computerized scheduling systems are so readily available, further study in this area is justified.

CHAPTER ONE

INTRODUCTION

Interest in effective construction manpower management has evolved within many state highway agencies during the past 10 years. This interest has been in response to a number of different forces, some external and some internal to the highway agency, and it has led to a number of extensive research efforts that have attempted to analyze the existing practices, suggest improvements, and in some cases develop management systems that completely revised the current practices.

In Michigan, according to Casey (1), the reasons for the interest were primarily financial. The Michigan Department of State Highways and Transportation was experiencing construction engineering costs that were averaging 14 percent of contract costs, whereas the Federal Highway Administration (FHWA) reimbursement was limited to 10 percent. Therefore, the main objective of the research effort in 1971 was to determine whether costs could be reduced while quality was maintained and, if so, to design a management system incorporating those techniques and procedures that would provide the desired results.

A second objective was to provide a logical and definable method for determining manpower needs based on workload for staffing and forecasting purposes. This need, evident in 1971, grew much more obvious as management, legislators, and the public increasingly scrutinized and questioned public expenditures and practices.

In Louisiana, according to Boagni (2), the legislature several years ago began severely challenging transportation budgets, particularly in areas of engineering costs. This occurred when it became evident that revenues for financing highway construction were severely limited. This prompted the Louisiana Department of Transportation and Development to begin a comprehensive construction management study in 1975 to identify ways of stretching the available funds and to demonstrate to the legislature and the people of the state that they were receiving a good return on their highway investment.

Tippin (3) notes that between 1968 and 1973 the Arkansas Highway and Transportation Department faced a 96 percent inflation in construction costs and had only a 54 percent increase in gross highway revenues. Therefore, in 1975 the construction division instituted an extensive research effort to determine how it could be more productive with the available manpower and equipment resources. The objectives of the study (4) were to (a) develop and test a management system to plan and control Arkansas Highway and Transportation Department manpower on construction projects, (b) determine interdivisional communication and structure, and (c) analyze the department's personnel policies as to classification plans, training programs, and other similar personnel programs.

According to Anderson and Goetz (5), the Washington State Department of Highways in the early 1970s was experiencing a decline in the highway construction program and the possibility existed that excess personnel would be employed for preliminary and construction engineering. It was felt that this possibility could be lessened if a system were developed that anticipated and accounted for most of the influencing factors in the planning process. Washington's legislators also became interested in the productivity and proper use of the department's engineering employees. An extensive study was begun in 1972 to develop the Manpower Management and Information System. The work plan was extremely ambitious, inasmuch as it affected engineering work activities for preconstruction, construction engineering, and right-of-way. The scope of the work plan involved refinements of project scheduling systems, labor standards development, flow-time standards development, and the design of an automated data processing subsystem to satisfy management information needs.

Similar experiences, under perhaps somewhat different circumstances, could be related for almost all 50 state highway agencies. Although a number of them may not have reacted as formally to the pressures for change, it is safe to say that they all reacted in some fashion to the forces of (a) a shift away from the "Interstate Era," (b) spiraling inflation, (c) soaring labor costs, and (d) dwindling financial resources.

A national pooled-fund study is in progress to develop a construction manpower management system that will use much of the available information to develop a set of user manuals (3). This study is concerned with field construction engineering and will include surveying, inspection, quality control, and office work. The participating states are shown in Figure 1.

OBJECTIVES AND OUTLINE

This synthesis is intended to present compilations and evaluations of present methods for determining staffing levels, resource allocations, and skill requirements for construction engineering and contract administration. Included here are present methods and standards that agencies use to evaluate construction quality.

To meet these objectives the following tasks were completed:

1. A literature study was performed to investigate construction manpower management efforts that have been documented by state highway agencies.
2. Personal interviews were conducted with highway agency personnel in California, Louisiana, Michigan, Pennsylvania, Washington, and West Virginia.
3. A questionnaire was sent to all 50 states.

A number of states that have examined construction

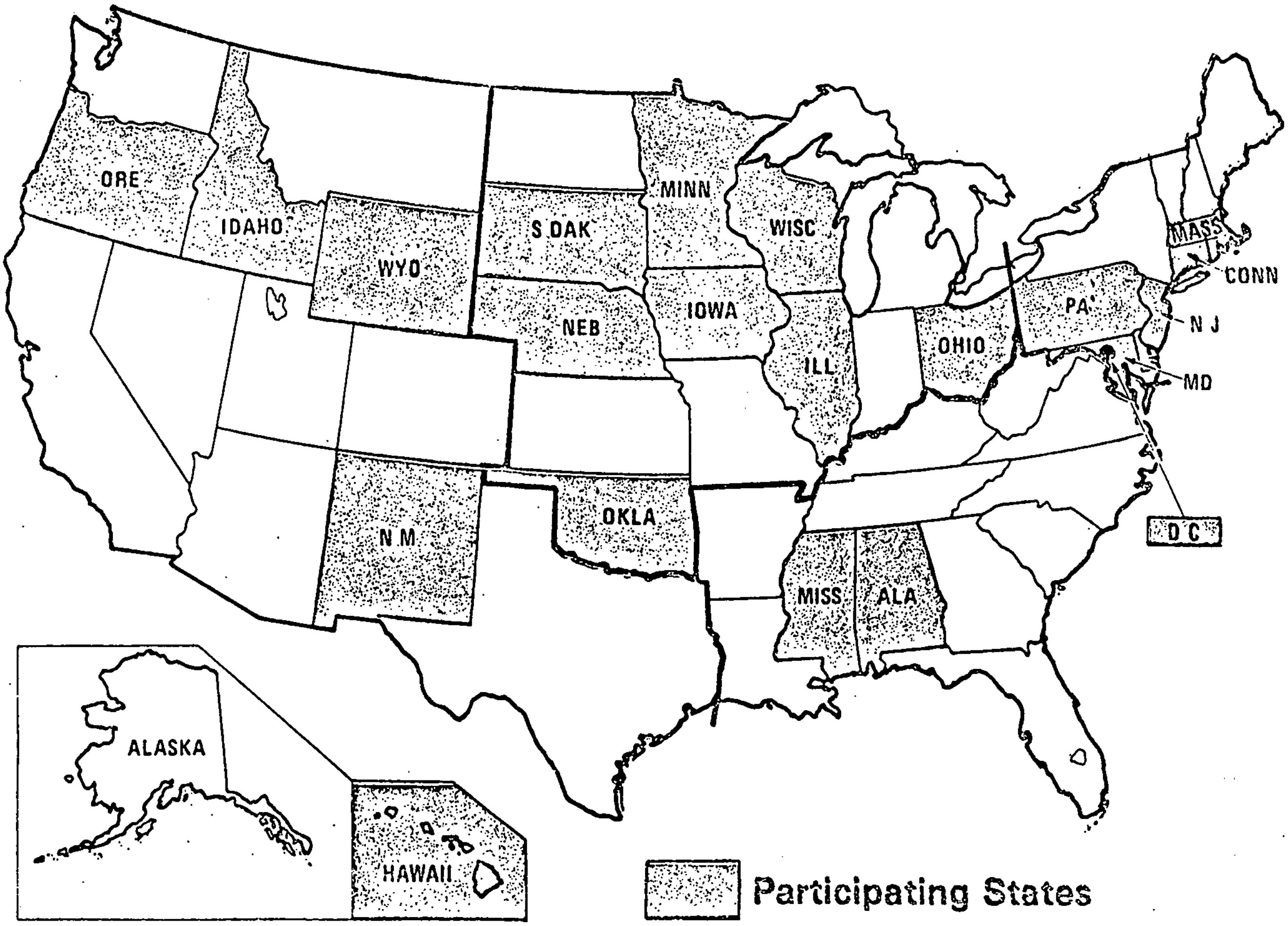


Figure 1. States participating in construction engineering manpower management project.

manpower management have used a two-phased approach involving the development of a management system and an analysis of current practices. This synthesis is organized along similar lines. Because it is felt that current practices can best be evaluated in terms of the total system of management of which they are a part, Chapters Two, Three, and Four are devoted to an explanation of how several state highway agencies have developed their manpower management systems. To provide guidance for states contemplating similar actions, these chapters explain in detail the various aspects of systems that are felt to be representative of what other states might want to consider. Naturally, this means that there is heavy emphasis on those states that have documented the results of their recent efforts in this area.

Chapters Five and Six define some of the specific manpower management practices that are currently in use or being developed by selected state highway agencies. The information in these two chapters is supplemented by the specific results presented in Appendixes A and B. Although these chapters deal only with existing practices in the states, they should provide a sufficient starting point for those interested in pursuing the subject in greater detail.

Chapter Seven provides a summary of the conclusions of the synthesis and some recommendations for further efforts in construction management research.

CHAPTER TWO

MANAGEMENT PRINCIPLES

The primary objective of this synthesis is to examine the construction manpower management practices of state highway agencies. To put into proper perspective the practices cited later in this synthesis, a suitable framework of management should be established. A functional approach defines the four primary functions of management as planning, organizing, leading, and controlling (6). To relate properly to the state highway agency situation, however, it is also necessary to consider construction manpower management from a systems approach by overlaying these primary functions of management onto the different levels of the organizational structure. Both of these approaches are discussed in this chapter.

FUNCTIONS OF MANAGEMENT

Planning

Planning, at any level of management, is the work that is performed to determine the course of action that will be taken. One of the basic principles of planning that must be recognized is that the stability of a plan tends to vary inversely with its extension into the future. As an example, the planning of manpower for a state highway agency is directly related to a knowledge of the letting date of projects; this knowledge becomes less precise as the time frame is extended into the future. This fact has led many state highway agencies to take a multiphased approach that includes both long-range (i.e., three to six years) and short-range (i.e., one to two years) manpower planning and that typically uses a periodic review and updating technique to mesh the two time frames.

Another basic planning principle is that the higher the level of management planning, the broader the scope and the further the projection. Headquarters-level planning, therefore, typically concentrates on balancing the long-range total highway program with the manpower resources that are available at the district levels. The requirements for individual projects often are addressed only at the district level.

Planning can be further divided into the following activities:

1. Forecasting. Manpower planning is influenced strongly by an estimate of future highway needs, particularly the magnitude, timing, and direction of the highway program. Hiring or retrenchment often is based on a prediction about the total size of the highway program for a particular time period as well as an estimate of the type of projects that will be designed and built. Precision forecasting is extremely difficult for many state highway agencies because it is so closely tied to shifts in the levels of federal and state financing and shifts in program emphasis, factors over which the agencies have no control.
2. Establishing Objectives. Once the forecasts have been analyzed, they usually are translated into a fairly definite highway program for a stated time frame. These general objectives for the highway program typically are used for manpower planning at headquarters level, and the more specific objectives represented by individual projects within the program become the basis for manpower planning at the district or project level of management.
3. Programming. The sequence of action steps is determined according to the priority necessary to accomplish the objectives.
4. Scheduling. Time limits associated with each of the action steps are determined, and the over-all time frame for the total program is assessed.
5. Budgeting. This activity (sometimes called staffing in the manpower context) involves the determination of the level of resources that will be required to carry out the programs and reach the objectives within the limits established by the schedule.

As noted in more detail later in this chapter, activities 3, 4, and 5 first appear in the process of manpower planning when the idealized manpower requirements for future projects are determined. Typically, headquarters-level management uses this information in a summary fashion for all projects to define the size of the highway program that can be accomplished with the available manpower resources. These activities are used again later at the district or project level to definitively plan the manpower requirements for individual projects that are at the construction stage.

Organizing

Organizing is necessary so that the work to be done is arranged in such a way that it can be performed most effectively. Of critical importance is a clear understanding of the work that must be accomplished and the organizational positions in which this work can best be performed. This fact led highway agencies in some states (e.g., Michigan, Louisiana, and Arkansas) to begin their efforts toward more effective manpower management with a research program that identified the tasks (i.e., activities) their people were to perform on construction projects. The agencies then determined how these tasks could best be related to the typical positions (i.e., job classifications) that existed on their projects. The agencies then defined the technical qualifications required for each of these positions.

Organizing can be further divided into two activities:

(a) developing organizational structure and (b) delegating management.

Developing Organizational Structure. One of the time-tested principles that often has been applied when the required work is grouped into positions within an organizational structure is that specialization is basic to effective management. It is felt that the more specialized the work assigned to a position, the greater the potential for efficient performance. Because of pressure for staff reductions and shifts from large Interstate-type projects to a proliferation of smaller projects, many state highway agencies have found it necessary to modify this approach at the project organizational level by instituting multiqualification requirements for the various positions.

The design of the organizational structure also must consider the basic question of how many projects or how many people a manager can supervise effectively. A formula for span of control is difficult to establish for highway projects because it is so dependent on the diversity present on particular projects as well as the dispersion, complexity, and volume of the projects. All these factors must be considered when projects are staffed. In this regard, manpower management has proven more effective for a district's projects than for single projects.

Delegating Management. By definition, the position of project engineer has more work assigned to it than can be performed by one person. The project engineer must therefore delegate to others the office engineering, surveying, and inspection work. At the same time, the project engineer must create an obligation to do this work and make decisions about the work according to established performance standards. The term "responsibility" is used to identify the work assigned to a position. "Authority" is the sum of the powers or rights necessary to do the work. "Accountability" is the obligation to perform. Responsibility and authority must be delegated, but a manager's accountability can never be delegated safely. It is important to realize that, to delegate, one must give prime consideration to the existence of effective controls. It is commonly accepted that the availability of controls limits the extent of delegation (6). Because of this, a number of highway agencies have established the necessary performance standards by which the previously mentioned project responsibilities can be evaluated.

Leading

At all levels of management, leading is the work that is performed to cause people to take more effective action. It is generally accepted that there is no "one best" management personality for leadership (6).

Different people and situations require different approaches. The proper blend of authoritarian and democratic leadership knowingly applied is probably best. This suggests that, from a manpower management viewpoint, one of the most cost-effective efforts a state highway agency can make is to provide leadership educational programs for first-line management personnel at the project level. A major educational effort to upgrade the technical skills of inspection-level personnel can be short-circuited if proper leadership education for project engineers is not also provided.

A basic principle of leadership is that a leader should concentrate his or her efforts on work activities that individual members of the group can not perform effectively themselves. In many highway agencies the statements that define the authority and responsibility of the difficult management levels have been guided by this principle.

Five commonly accepted activities of leading are described in the following paragraphs.

1. Decision-Making. This is the work that is performed to enable people to arrive at conclusions and judgments. The six basic steps of decision-making determine (a) the apparent problem, (b) the facts, (c) the real problem, (d) the possible solutions, (e) the best solution, and (f) the course of action to be followed. To take effective action with regard to making improvements in the manpower management area, a number of state highway agencies have undertaken extensive research studies (described in later chapters) that have been based on these six steps.
2. Communicating. Communicating consists of those efforts that are undertaken to create understanding.
3. Motivating. Motivating consists of those efforts that are undertaken to inspire, encourage, and impel people to take required action.
4. Selecting People. The selection of people for current positions and promotion is one of the most vital responsibilities of management. It is worthwhile to note some steps in the selection process, because they directly apply to the construction staffing situation in state highway agencies, particularly where changes in the level of personnel in a particular district of a highway department are necessary. These steps are (a) organize the job (i.e., define the position), (b) plan short- and long-term personnel needs, (c) prepare qualification specifications, (d) locate candidates (for present employee selection, develop a skills inventory program), (e) review applications, (f) administer tests (e.g., technical qualification demonstration tests), (g) conduct preliminary interviews, (h) investigate previous history, (i) conduct final interviews, (j) provide physical examination, and (k) maintain follow-up on the job.
5. Developing People. One of the primary leadership activities is the development of personnel. A number of state highway agencies are involved actively in this process, particularly during the off-construction months, when many training schools are run. The results of these training efforts may be wasted, however, unless the specific needs of the individuals involved are determined before training begins. The process of developing individuals should begin with a performance appraisal, which is the evaluation of the individuals' current performance and their potential for advancement. Following appraisal, individuals should receive counseling so they can be helped to recognize their strengths and weaknesses. Once this is done, a plan for personal improvement can be developed. This process certainly is more involved than the process of simply assigning an office engineer or an inspector to a number of winter training courses, but it probably will pay more dividends in the long run.

Controlling

Controlling is necessary because effective management requires that completed work or work in progress be assessed and regulated by various levels of management. Control is simply a means of making sure that the level of performance and the results obtained are satisfactory. Personal inspection is often used as a method of control, but this limits the scope of control to what the manager can observe and appraise. Furthermore, the manager tends to judge the work in terms of whether it is performed the way he or she would do it.

Control by exception is the preferred method. If properly employed, it is one of the most valuable tools a manager can use. It is more difficult to apply than other methods, because it requires the establishment of a clear means of differentiating between acceptable and unacceptable performance. As long as the work is being performed according to plan, there is little need for the manager to become involved. However, if the operation falls behind in any respect, the manager will be alerted by the control system and can immediately attend to the variance.

Controlling is receiving considerable attention from many state highway agencies for the purpose of evaluating (a) the accuracy of the manpower planning estimates that are made before a project is started and (b) the level of performance of the personnel that have been assigned to these projects. Following is a list of the four controlling activities plus comments related to manpower management.

1. Establishing Performance Standards. The performance standards (e.g., the number of stations surveyed per day for each survey crew) by which methods and results will be evaluated must be established. The logical requirement of any good standard is that it must provide a test of performance. To achieve better control of the work, a number of state highway agencies are implementing or seriously considering the implementation of performance standards. Although performance standards may present some problems, they appear to be the first step toward a more cost-effective operation. If human and technical factors are considered adequately when these standards are developed, the standards should provide satisfactory indications of field-related activities.

2. Measuring Performance. Once the standards of performance are set, some means of recording and reporting performance must be instituted. Reports must be timely and must provide meaningful information. In addition to the conventional time-reporting systems that most state highway agencies use, it may be appropriate under certain circumstances to consider using various work-sampling techniques to report performance. It appears, however, that few state highway agencies currently are considering the adoption of techniques of this type.

3. Evaluating Performance. The next step in the process is to compare actual performance with the standard to identify variances and determine why they occurred. The important requirement of evaluation is to provide for control by exception, which necessitates the determination of the allowable limits of tolerance within which variances may occur. State highway agencies that are contemplating the use of a more extensive control approach with regard to the personnel on existing projects must incorporate an evaluation step in their system.

4. Correcting Performance. The final step in control is to implement corrective action that will bring discrepancies and variances into line. If a state highway agency continues to this step in its control system, the agency can obtain improvements that will result in a cost-effective managementsystem.

CONSTRUCTION MANPOWER MANAGEMENT SYSTEMS

The preceding section presents a basic functional approach to construction manpower management, the primary elements being planning, organizing, leading, and controlling. From a management systems approach, however (7), the primary elements often are considered to be planning, staffing, scheduling, and controlling. If the word budgeting is substituted for staffing, the first three elements are logically included in the planning element of the functional approach and the fourth element agrees with its counterpart, also called controlling.

Even with this modification, however, there is still some difficulty in explaining the systems approach, because these elements occur at various organizational levels within a state highway agency. A full appreciation of how a construction manpower management system operates, therefore, requires that these elements be overlaid on a typical state highway agency organizational structure.

In its simplest form, such an organization consists of three levels: a headquarters or central office level that is usually at one convenient location in the state, a district or regional level that includes a number of district office locations throughout the state, and a field or project level that includes a number of project locations within a particular district. The major difference among states appears to be in the amount of central control that is exercised. In most states, control is maintained at the central office. In some states, however, the districts have such extensive responsibility and authority that they can be assumed to be autonomous entities.

Following is a description of a typical construction manpower systems model that incorporates the management elements in the overlay fashion mentioned previously. It is a composite of the systems that have been developed recently in Louisiana (8) and Washington (5).

Headquarters Level

Initial decisions in program development usually are controlled by ongoing needs studies, priority programming, accident histories, and physical inventories within the state. These factors, together with the policies and goals established by the state legislature, the highway commission, and top highway agency managers, usually establish the broad scope of the highway construction program. Within these guidelines, headquarters construction is charged with (a) developing actual construction programs, budgets, and over-all manpower plans and (b) monitoring, evaluating, and guiding the execution of this program by the districts.

Program Development

As shown in Figure 2, program development is actually an iterative process that occurs between the headquarters and district levels. Headquarters makes a preliminary distribution of dollar allocations to each district. Districts then generate a preliminary work plan by selecting and identifying those projects from a five- or six-year program that has been previously established. Balancing the desired program with the manpower resources that are available at the headquarters and district levels may lead to several modifications of the work plan before a reasonable balance is achieved.

It should be evident that statewide and district programs are simply accumulations of individual projects. To develop district and statewide manpower plans, therefore, it is necessary to have knowledge of project schedules and manpower estimates at the district level. This applies to all projects in the program that are at some point in either the preliminary engineering or the construction stage.

Project Schedules

At this stage individual project schedules should be available at least in bar chart format, with each potential contractor activity (i.e., work task) indicated. Also needed are estimates of the time the contractor will complete these activities. Preliminary project schedules of this type can be developed by (a) defining the major characteristics of each project, estimating the quantities of work required, and identifying tentative starting dates; (b) applying appropriate construction standards to the project scope definition to estimate the number of workdays needed to complete each contractor's activities; and (c) applying a standard workday calendar to convert workdays into calendar days. The depth of detail with which individual state highway agencies approach these three steps depends largely on the historical data file they have established. Examples of several such approaches are presented in Chapter Three.

Manpower Estimates

Estimated state highway agency manpower and skill requirements can be applied to each of the defined contractor work activities by the use of manpower standards, if they are available in the data file. This produces an estimated total project man-hour requirement by function and personnel classification title. Schedules for estimating when manpower requirements will be needed are developed by bringing total manpower estimates together with the project schedule. The result is a manpower plan divided into perhaps four-week increments for each project in terms of the total man-hours needed. At the headquarters level these individual project manpower plans typically are summarized to represent the entire district program.

Schedule Adjustments

District schedule summaries are evaluated to identify unusual peaks and valleys in both district and state workload and staff so as to ensure that the best balance of human resources is attained on a statewide basis. For balancing purposes, adjustments of project contract letting dates often are simulated at this stage. Close cooperation is required between the headquarters and district levels if the optimal decisions are to be made.

Final Programs and Budgets

After the balancing process is complete, zero-based budgets can be prepared by applying standard labor costs (by personnel classification) to the total man-hours planned for the year. After the proposed programs and budgets are reviewed by top management, the appropriate budget requests can be made to the state legislature. On approval by the appropriate authorities, headquarters allocates the financial and human resource quotas to the various districts and to headquarters support groups. These allocations are related to the approved program.

Manpower Allocations

Approved programs and budgets give districts the authority to staff to planned levels and totals and to take the needed actions. To provide guidance in the state of Washington, for instance, the computerized Manpower Management Information System produces an operational plan that provides, for each approved project, a schedule and manpower plan that is then distributed to each district office (5). It provides a yearly operational plan to aid a project manager in scheduling activities and coordinating any support work needed from headquarters. It is important to note that in Washington the computerized system does not provide the day-to-day detailed manpower scheduling required to accomplish the project. Manual systems, tailored to meet each project manager's needs, fulfill this requirement. (These points are discussed in greater detail in Chapters Three and Four.)

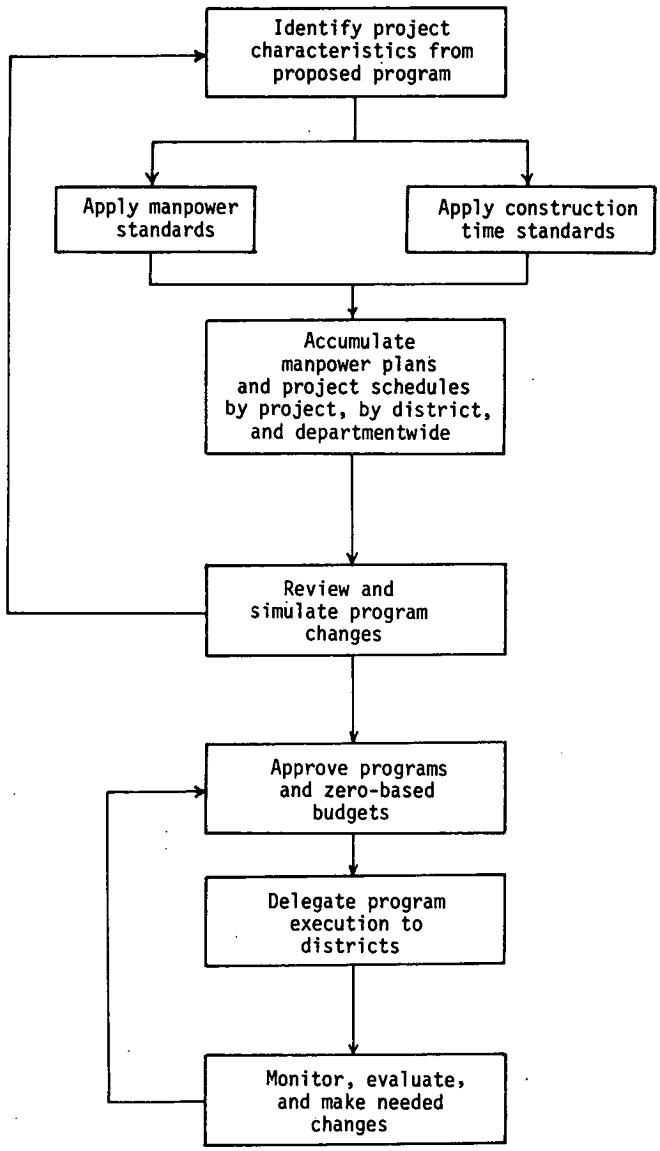


Figure 2. Headquarters-level manpower management in Louisiana (8).

With regard to manpower allocations, it is interesting to note that in Louisiana all actions to increase or reduce the number of employees as a result of the approved program take place at the headquarters level to ensure a coordination of manpower actions throughout the entire state (8).

Monitoring (Controlling)

When highway agency employees work on projects appearing in the approved program, their respective labor time charges are reported through a labor-accounting reporting system. Management at all levels will have the opportunity to monitor, compare, and evaluate the progress and performance of planned accomplishments and expenditures by reviewing the reports that result from these data. In this way headquarters personnel can monitor and evaluate district program execution and progress. A part of this process involves an evaluation of the need to change system standards.

Headquarters Level Summary

A planning process like the one outlined in the previous paragraphs allows long-term staffing trends to guide current staffing decisions. Long-term upward trends probably would necessitate hiring and training additional construction personnel. A short-term peak with a long-term downward trend probably would require temporary hirings. Using temporary employees to meet peak requirements prevents the need for layoffs after the peak has passed.

District Level

As noted earlier, district offices typically evaluate the proposed programs and budgets during the balancing process. On receiving the approved programs and budgets, they establish project management groups and assign project responsibilities, allocate personnel, start needed personnel actions, and then monitor work progress. These steps are shown in Figure 3.

Project Assignments

There are many variables and schemes one may use when making project assignments. The two extremes are (a) to create one pool of personnel based on the headquarters allocation that is used to cover all the projects within the entire district and (b) to staff each project as a single management unit. A number of states have found that a more reasonable approach is to group a number of projects under an individual project engineer and then assign that engineer enough personnel to manage these projects properly. The project engineer can then use the operations of several contractors to level staffing requirements within the limits set at the district level and to minimize the effects of short-term peak requirements on one project.

Although multiproject manpower management has been found beneficial, the number of projects that can be managed effectively depends on such factors as geographical dispersion (which will affect travel time), the number of separate contractors working on the projects, the size and type of projects, and the availability of seasoned and effective assistants.

Assigning Personnel

The optimum mix of personnel can be provided by the manpower management system reports from headquarters in terms of classification levels, if such a data file has been developed by the state highway agency. Districts can use these reports as starting points. Adjustments may have to be made at this organizational level in staff mix and numbers of personnel assigned to project engineers because of such factors as weather conditions, delayed project starts, and the relative speeds of the contractors working on the projects. Manpower management systems must include an option that takes advantage of the fund of knowledge available as one gets closer to the actual project level. Because of their closeness to the projects, districts have the ability to evaluate staffing levels on a continuous basis. They are in the proper position in the organizational structure to coordinate short-term transfers between project engineers as well as to request headquarters assistance in meeting unusual conditions.

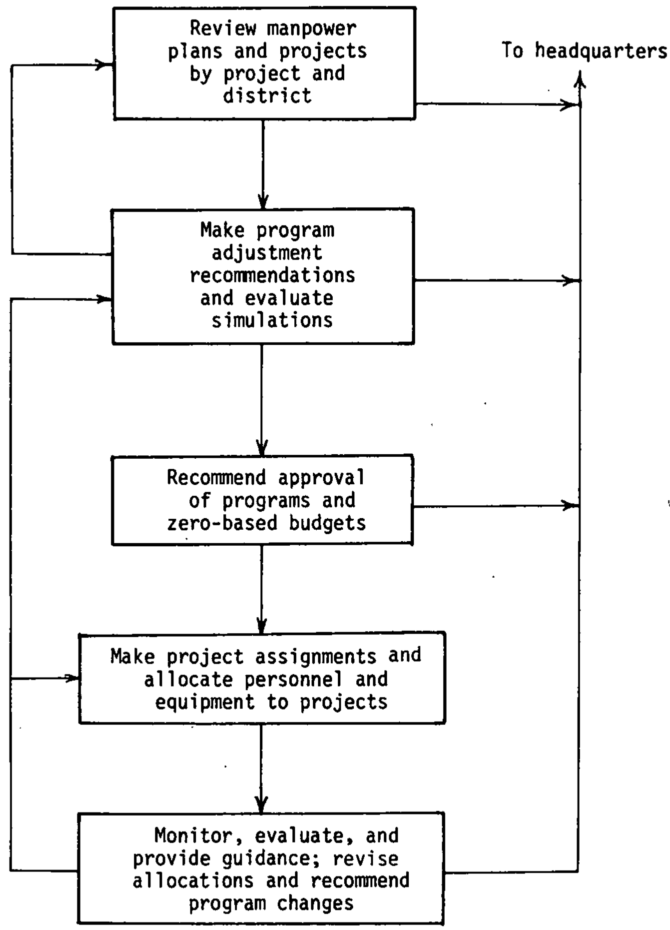


Figure 3. District-level manpower management in Louisiana (8).

Monitoring (Controlling)

Districts should receive timely reports from the construction manpower management system so they can evaluate resource expenditures as well as compare progress against what was planned. These reports can provide guidance, coaching, and assistance to project engineers who have problems.

Project Level

Project engineers are responsible for effectively using the resources assigned to them. They are also responsible for completing work in accordance with the standards set by the state highway agency. Figure 4 shows these responsibilities.

The project engineer must have leeway in balancing manpower among the projects he or she controls. Also, the project engineer must alert the district if short-term transfers within the district are necessary.

At this level of the organization, all the functions of management described at the beginning of this chapter are applied directly to meet well-defined project objectives. The problems that arise at this level are typically a result of what is being done by the contractor. In other words, the project engineer for the state highway agency is managing a project organization that is reactive—it responds to the actions of an outside force. This is the level at which the buck stops, because the entire construction manpower management system rests on the project engineer's ability to ensure that the project is successfully completed and, further, to accomplish this in response to the actions of the contractor. This makes the job extremely difficult, unless the contractor is required to plan and schedule activities in advance.

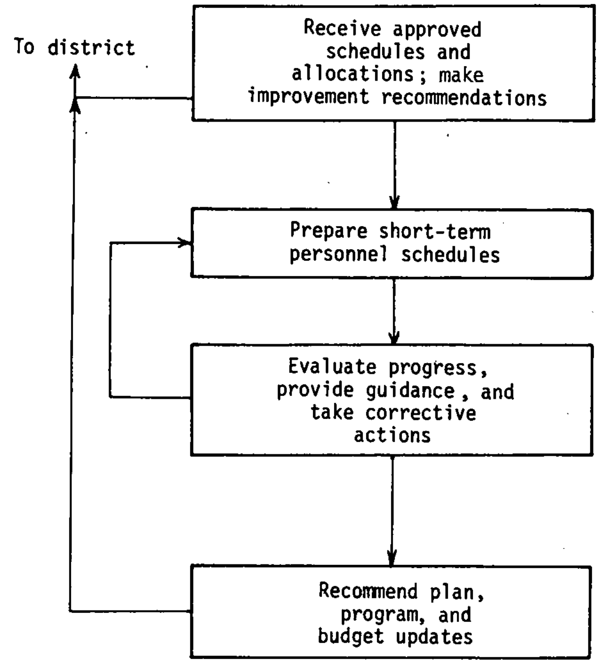


Figure 4. Project-level manpower management in Louisiana (8).

CHAPTER THREE

PREDICTION OF MANPOWER NEEDS

The first element of the systems approach to construction manpower management is planning, which is used to predict the manpower needs of the state highway agency at the project, district, and headquarters levels. Although each state differs in handling manpower planning, they all follow the same basic approach. This approach begins with an analysis of individual projects and the use of some standard of conversion whereby project characteristics are transformed into manpower needs. The analysis of several planning approaches currently being used by state highway agencies illustrates this point. (Appendixes A and B provide insight into the procedures used in other states.)

BROAD-BASED PLANNING SYSTEMS

Several state highway agencies presently use manpower planning systems that are broad-based; that is, the states use summary-type variables (e.g., cost, project type, and miles of highway) as the basis for determining manpower needs. A discussion of three of these systems follows.

Use of Index Numbers

Perhaps the simplest approach is one that estimates the required manpower resources on the basis of one over-all index, such as the number of miles of roadway on the project, the total cost of the contract, or the total number of bridge installations. This type of index usually is acquired from historical records taken from previously completed projects. This approach may be satisfactory for obtaining a long-range estimate that establishes ballpark figures, and it may work for a small state highway agency that has a limited program, but it neglects many of the project variables and contractor schedule influences that must be considered for more definitive estimates. An example of this type of system is given in Table 1.

Typical Organization by Type of Project

In this approach a typical organization for projects of various sizes and types is developed, perhaps by the use of data from past projects. The organization includes typical values for number of inspectors for the various highway agency activities that will be required on the project. Projects may be classified as major or minor, and further subdivisions may specify whether the projects involve new construction or reconstruction and whether they involve urban or rural construction. Examples of typical organization charts are shown in Figures 5 and 6.

North Dakota's System

In the spring of 1967 the North Dakota State Highway Department initiated a study to determine, among other things, realistic ways in which the construction workload could be anticipated in terms that were meaningful to manpower planners (12, 13). The department felt that a procedure based solely on relating manpower requirements to contract dollar volume was unsatisfactory, because historical data indicated that these expenditures fluctuated widely, particularly at the district level. A similar conclusion was reached about the method of relating manpower needs solely to miles of highway.

It was felt that three basic elements were needed for realistic planning and control of the number of persons in field construction inspection and engineering:

1. A classification of similar types of construction projects. This classification had to be directly comparable to other planning classifications used by the department.
2. Estimates of the length of time that personnel would be needed on individual projects. This was necessary to ensure maximum use of personnel.
3. The number of persons to be required on each project.

The study resulted in a system that uses highway miles on a project as an intervening variable in the process of determining manpower needs. The first element of the system is a chart that gives the normal calendar days of construction time per mile for each of the 19 basic types of improvement obtained from the historical data (Table 2). The second element of the system uses a standard level of staffing for each of the 19 basic types of improvement. The standard for structural work defines how many persons of each classification are required, whether they are permanent or temporary employees, and how many vehicles are required (Table 3).

By April 1 of each year, the construction and personnel divisions must furnish each district with a two-year manpower staffing plan. The plan is reviewed, revised if necessary, and adopted. This plan provides staffing and funding guidelines. Because the district engineer is responsible for staffing projects effectively and efficiently while maintaining adequate project control, inspection, and documentation, he or she makes the final decisions based on actual project progress.

The North Dakota system is more detailed than the index method. Because it relates the type of improvement to miles of roadway, however, the North Dakota system still represents a somewhat broad-based approach. The number of box culverts per mile, for instance, could vary considerably from project to project, thus distorting the analysis. Therefore, several highway agencies have found it necessary to develop either manual or computerized systems that consider the variables on individual projects in greater detail.

DETAILED PLANNING SYSTEMS

In agencies that use the more detailed planning systems, it generally is felt that some or all of the following factors must be taken into consideration if manpower needs are to be planned satisfactorily:

1. Project characteristics.
2. Contractor activities.
3. State highway agency responsibilities.
4. Contractor function flow diagrams.

The interrelationships among these four factors is clarified in the following discussion of the systems in use in Michigan, Louisiana, Arkansas, and Washington.

Michigan's Manpower Management System

In 1971 Michigan instituted a rather extensive research program that has led to a systems approach to manpower management (1, 7, 14, 15). In this system, planning involves the determination of the man-hours required to administer a construction project based on certain standards per measurement unit of the work activities. The planning is done at the headquarters level by the manpower management section and reviewed by district and project engineers. The factors used in the Michigan system are discussed in the following paragraphs.

Project Characteristics

By analyzing the types of projects that had been built in the past, Michigan developed a project classification system that consists of two basic categories: major and minor. Table 4 gives the 12 different project types within these two categories. It was felt that the project type had a direct impact on the amount of contractor effort and department manpower that would be required to administer the contract and inspect work. Using the project type as a guide, Michigan could select the proper contractor activities and department functions.

Contractor Activities

All state highway agency construction 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 and then used to build an inventory of construction-engineering activities. The contractor-activity statements for a rural freeway project are given in Table 5. Once the contractor activities for a particular project are identified, it is possible to use the contract quantities for each activity in conjunction with a predetermine time standard to ascertain how long a contractor is likely to be working on an activity.

Department Responsibilities: Major Projects

The key to the entire Michigan system was based on the research results that defined the work typically performed by that state's departmental forces in response to the contractor activities on highway projects.

1. Activity Definitions. An analysis of data indicated that 261 separate activities, complete with a statement of definition and a list of tasks, could be identified for major projects. Of these, it was found that the 38 activities given in Table 6, although they comprise only about 15 percent of the total number of activities, represented about 87 percent of all the direct work charges. Because manpower represents nearly 85 percent of all departmental construction-engineering costs, the department could, in effect, plan a project and later control costs simply by concentrating on approximately 15 percent of the activities. In addition to these activities, nonproductive time-charge items such as standby, holidays, vacations, sick leave, and compensatory time off also were included.

2. Units of Measure. The most important reason for identifying the key activities was to measure the workloads attributable to them. These workloads had to be measurable before, during, and after performance for planning, control, and evaluation purposes. Work measurement units, which define the amount of work to be done, are used for this purpose. They are based on work quantities that can be related directly to projects and can be determined readily as the project design stage nears completion. Table 7 gives some of the units that were developed.

3. Standards of Performance. The remaining information that was acquired during Michigan's research effort involved the development of productivity standards, optimum mix of personnel needed to perform activities, optimum crew sizes, and maximum number of persons to be assigned to projects. Of these, productivity standards are the most important.

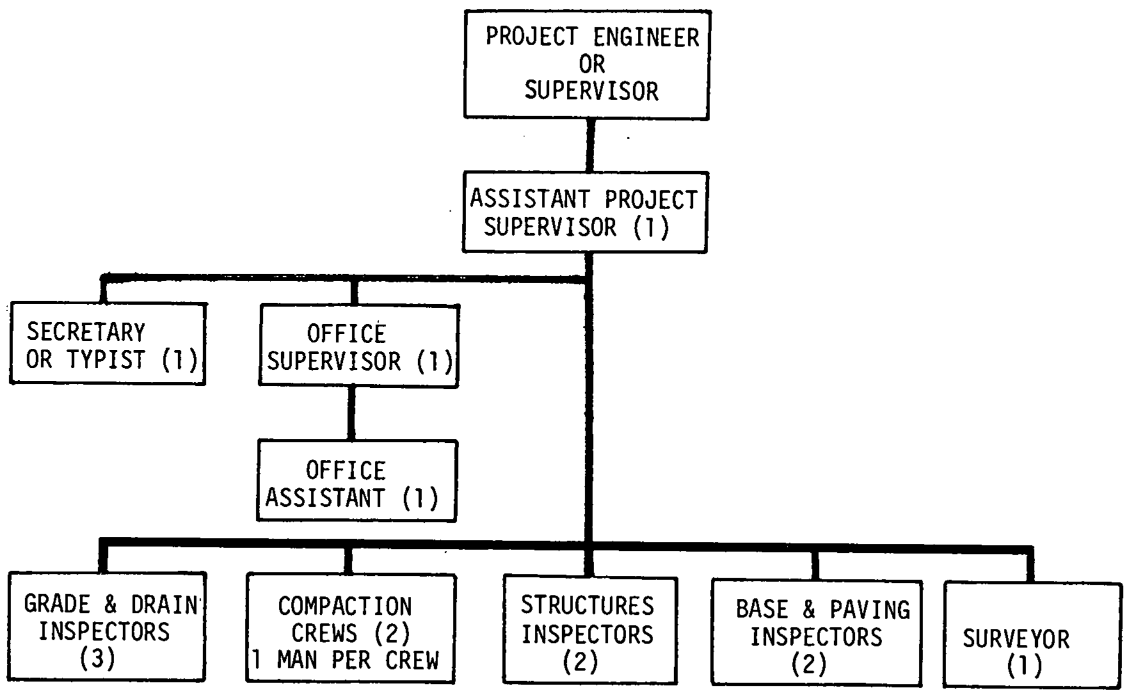
Productivity standards for major projects were developed for each activity and project type used. They are expressed as a planned number of man-hours per unit of measure. It was found that productivity rates vary in

TABLE 1

VERMONT'S CRITERIA FOR ESTIMATING PROJECT MANPOWER REQUIREMENTS (9)

Size Project ($)	Manpower
0 - 50,000	1 Tech B
50,000 - 250,000	1 Engr B or Tech C
250,000 - 500,000	1 Engr C or Tech D 1 Engr B or Tech C
500,000 - 1,000,000	1 Engr C or Tech D 1 Engr B or Tech C 1 Engr A or Tech B 1 Tech A or Temp
1,000,000 - 2,000,000	1 Engr C or Tech D 2 Engr B's or Tech C's 2 Engr A's or Tech B's 1 Tech A or Temp
2,000,000 - 3,000,000	1 Engr C or Tech D 2 Engr B's or Tech C's 2 Engr A's or Tech B's 2 Tech A's or Temps
etc.	

TOTAL 14 MEN



Note: The Organization Chart represents a maximum as all phases of the work will not be active at the same time (for example, the base and paving inspectors can be used for any of the other phases until base and paving begin). Adjustments will be required for multi-shifts on a project. Survey party may service more than one project. The office assistant should be material oriented. The second man in charge should be designated at beginning of project. The secretary/typist should be capable or oriented to perform minor project documentation.

Vehicle Requirements

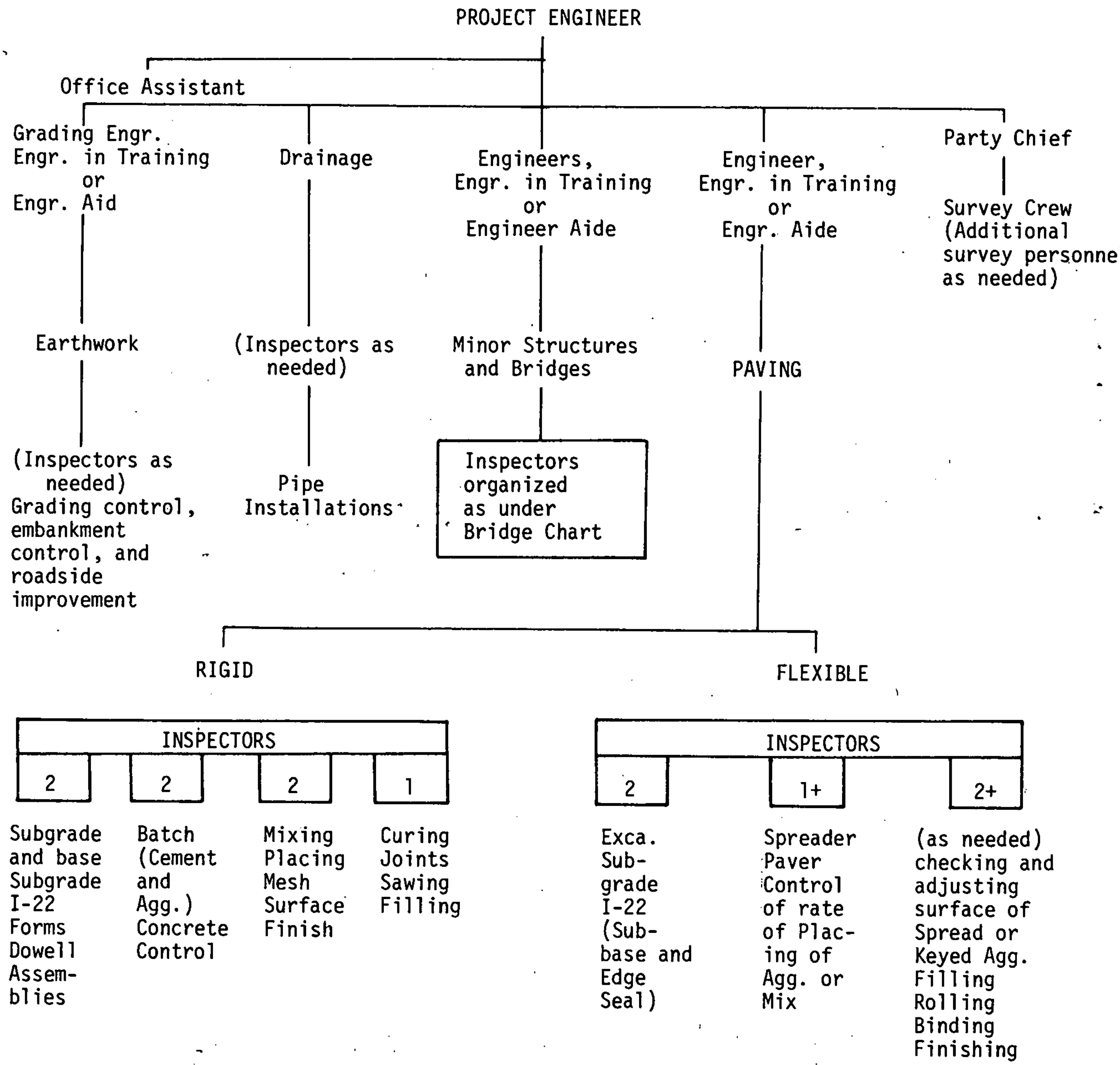
Project Engineer/Supervisor -	1	
Asst. Project Supervisor -	1	(Pick-up)
Structures (Testing) -	1	(Van)
General -	3	(Pick-up)
Sub-total	6	
Plus: Compaction -	2	(Panel)
Total	8	

Figure 5. West Virginia's typical organization chart for a large grading, drainage, and paving project (10).

response to many influences, such as individual capabilities, individual efforts, contractor production, weather conditions, terrain, traffic volumes, and soil conditions. This is unavoidable. Yet most of the work 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. The predictability factor is indispensable. Workloads can be converted into manpower needs estimates only if productivity rates like those given in Table 8 are applied.

In Michigan these rates are used for planning purposes, not as on-site or day-to-day controls. They are used for estimating manpower needs for total projects and full construction seasons and for controlling manpower use against planned use. Project engineers can use the rates for estimating the number of days required to complete short-term work assignments, for comparing work- and man-hours remaining, or for spot-checking performance; first the standards must be adjusted, however, because they include allowances for time lost in completing each activity workload in small increments and in redoing some of the work.

The optimum personnel mix portion of the standard is



The above project organization is typical for maximum production when all the operations indicated are being performed concurrently. The number of project personnel will be reduced when these conditions do not exist. Duties listed and others required shall be combined and reassigned as the ability of the inspectors will allow.

Figure 6. Ohio's typical organization chart for a major grading, drainage, structure, and paving project (11).

TABLE 2

MANPOWER PLANNING CONSTRUCTION TIME BY TYPE OF IMPROVEMENT (13)

Code	Type of Improvement	Calendar Days per Construction Mile
10	Grade and aggregate surface	19.0
11	Grade and bituminous surface	17.0
:		:
30	Structural: box culverts	46.0
	All other structures	100.0

used for manpower planning, for budgeting, and for guiding field personnel in making work assignments. Mixes are based on the difficulty of an activity or, when more than one person is used, the difficulty of the tasks making up an activity. Typical optimum mix designations are given in Table 9.

For planning purposes, man-hours normally are converted to equivalent man-years. For project staffing purposes, man-hours normally are converted to man-months so that periods of contractor operations and manpower requirements can be matched more readily.

Crew size designations were established primarily for surveying activities. For instance, it was found that more stakes are placed per man-hour by a three-person crew than by a crew of any other size. This fact has led to a standard productivity rate based on a three-person crew. Standards controlling the maximum number of persons to be assigned to a project also were developed for quick check purposes.

4. Basic Manpower Calculation for Planning Purposes. The basic formula for converting an activity into manpower requirements is:

Man-Hours Required	=	Number of Work Measurement Units	X	Productivity Standard

Figure 7 shows a completed form for a rural freeway project based on this formula. The project being analyzed requires 17,041 man-hours, or 89.8 equivalent man-months, of departmental work spread over five skill levels.

Department Responsibilities: Minor Projects

Michigan has adopted a simpler approach for minor projects, because it was found that (a) the average size of such a project is about 1/35 the size of a major project; (b) the project usually is completed quickly; and (c) the project is staffed with only a few persons, who perform many activities each day. For these reasons, minor projects do not require detailed, long-term staffing plans and schedules. Also, activity definitions are not used for minor projects, because it is felt that precise activity planning can burden managers and employees with large amounts of paperwork without significantly improving the accuracy of manpower plans, schedules, or use.

It was recognized, however, that minor projects were a significant portion of the workload and probably would increase in number in the future. Because of this, the approach that was adopted used units of measure and standards such as those given in Table 10. The units were adopted for the four groups of activities: staking, inspection work, office work, and other. Allowances for

TABLE 3

MANPOWER PLANNING STAFFING STANDARD (13)

Type of Improvement: Code 30, Structural (Interstate or Other Major Structure)

Major Activity	Number of Full-Time Personnel: Permanent	Temporary	Total
Supervisor	1	-	1
Survey Crew and General Inspector	1	-	1
Concrete Plant Inspector	-	1/2	1/2
Utility Inspector	-	1/2	1/2
Total	2	1	3
Permanent Personnel by Classification			
Senior Technician	1		
Technician III	1		
Vehicle Requirements			
Automobile	1		
Panel Truck	1*		

*May require one or more units, depending on location of ready-mix plant.

project supervision, standby, and leave are made as a standard percentage of direct labor-hours.

Contractor Function Flow Diagrams

Michigan does not directly use a standardized display diagram that lists the most likely sequence of contractor activity performance during the planning stage. In the staffing phase, however, the total manpower needs of a project must be divided over the months during which they are expected to occur. Therefore, a project engineer must informally use his or her knowledge of the contractor's operational sequence to incorporate timing into the analysis.

Results Achieved by the System

As reported by Casey (1), in the 1975 construction season all rural freeway projects were placed on the management system, and test reporting began on approximately 100 projects in other categories. At the end of the season, a task force committee established standards for all types of projects based on review of the test reporting and the experience of the 1975 season.

Beginning with the 1976 construction year, all projects were placed on the system, and by the end of the year over 600 projects were involved. Of these, about 300 were completed or were near enough to completion to permit a reliable analysis of results.

The results indicated that, in general, the planning function was valid in determining staffing needs from the project level on up. It was found that for a large number of projects, such as the entire construction division workload or a district workload, man-hours could be

TABLE 4

MICHIGAN'S PROJECT CLASSIFICATION SYSTEM

A. MAJOR PROJECTS

1. Rural freeway construction (i.e., new construction)
2. Urban freeway construction (i.e., new construction)
3. Rural reconstruction (i.e., removal and replacement, upgrading, etc., of existing highways)
4. Urban reconstruction (i.e., removal and replacement, upgrading, etc., of existing highways)
5. Rural bituminous construction (i.e., resurfacing)
6. Urban bituminous construction (i.e., resurfacing)

B. MINOR PROJECTS

1. Bridge deck repairs	4. Intersection improvements
2. Landscaping	5. Signing
3. Rest area buildings	6. Miscellaneous

TABLE 5

MICHIGAN'S CONTRACTOR-ACTIVITY STATEMENTS FOR 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

TABLE 6

MICHIGAN'S KEY CONSTRUCTION ENGINEERING ACTIVITIES

Surveying Activities

1. Roadway layouts	6. Surfacing
2. Utility layouts	7. Structures
3. Cross sections and slopes	8. Minor structures and drainage
4. Grades	9. Curbs, gutters, and guardrails
5. Other roadway earthwork	10. Special features
	11. Other

Inspection Activities

1. Removal and relocation	10. Bituminous materials weighing
2. Traffic control during construction	11. Concrete plant operations (paving)
3. Earthwork	12. Concrete paving
4. Earthwork density control	13. Concrete plant operations (structures)
5. Aggregate weighing	14. Concrete structures
6. Aggregate placement	15. Concrete curbs, gutters, and miscellaneous concrete
7. Aggregate density control	16. Minor structures and drainage
8. Bituminous plant operations	17. Special features
9. Bituminous paving	18. Other

Project Office Activities

1. Record-system preparation for construction	5. Concrete documentation
2. Earthwork documentation	6. Structures documentation
3. Aggregate documentation	7. Minor structures documentation
4. Bituminous documentation	8. Special features
	9. Other

accurately predicted and planned for. At the headquarters level, for instance, 96 percent of man-hours planned were used. The variation at the district level was from 79 to 103 percent of plan (with the exception of one district, where 137 percent of plan was used because of the delay of several large expressway contracts after field offices had been partially staffed). At the project level, man-hour planning was fairly accurate if the workload was grouped into five or more projects and the projects varied in type. Below that level, planned man-hours were found to be highly inaccurate in certain instances if used on the basis of an individual project or individual activity. For individual projects the use varied from 20 to 300 percent of plan, as shown in the distribution curve in Figure 8.

This discrepancy might have resulted from improper categorizing at the planning stages or from erratic reporting, but the sample was large enough to lead to the conclusion that there just are no "typical" projects. As Casey (1) notes, "Given enough projects, the totals will be valid but it is unlikely that planned man-hours for any individual project will be accurate."

Louisiana's Manpower Management System

In April 1975 the Louisiana Department of Highways (now Department of Transportation and Development) undertook a highway management improvement research and development project that covered both the preconstruction and the construction portion of its operations. The research study was completed in March 1977 (2, 8). In many ways this system parallels the work that was done in Michigan. The following discussion is restricted to the construction phase of the study and highlights the similarities of and differences between the Louisiana and Michigan systems.

Project Characteristics

Louisiana classifies projects according to the following characteristics: (a) new construction, (b) reconstruction, (c) overlay and widening, (d) under traffic, (e) urban areas, (f) wetlands, and (g) hilly terrain. These project characteristics are designed to be used in any combination and act as modifiers to the workload of any departmental function, such as taking cross sections.

Contractor Activities

As a first step, a series of contractor operations statements were prepared for each work task (i.e., activity) that contractors typically perform on highway projects. Then, three different types of time allowances were developed to match the various types of contractor activities. Lump sum allowances were developed for such activities as temporary signing; constant production rate allowances were developed for pile driving and other activities that require the same rate of time for construction, regardless of the number of units required; and variable production rates were developed for such quantity-dependent activities as earthwork. An "unusual features" category also was developed. These standards are used to determine the estimated duration of each

TABLE 7

TYPICAL MICHIGAN 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

activity on a project based on the quantity of work to be performed.

Department Responsibilities

To define departmental responsibilities, a special reporting system was implemented for a six-month period on a sample of 54 highway projects. More than 190,000 man-hours were reported and analyzed to arrive at the following conclusions.

1. Activity Definitions. The data indicated that a series of 98 work-function statements could be written to define departmental activities and that approximately 80 percent of all man-hours were devoted to only 30 of these. These 30 functions, divided into four categories, are used to estimate the manpower that the department must expend in construction engineering. These categories are (a) survey, 7 functions; (b) inspection, 16 functions; (c) office, 2 functions; and (d) miscellaneous, 5 functions.

2. Units of Measure. Ten units of measure (stations, lineal feet, tons, man-hours, etc.) are used either to directly measure the work to be done or to provide allowances based on contract time and direct man-hours.

3. Standards of Performance. Each of the 30 functions is defined in terms of a manpower standard. Each standard provides a unit of measure, characteristics of projects that will influence the amount of work that must be done, and factors for weighing these characteristics. For example, the base standard for grade-line staking may be 1.5 man-hours per station. If this activity is performed on an overlay and widening project, however, the weighing factor that might be applied is 0.3, because less of this work is required on such a project.

The last element of the standard is a description of skill levels needed to complete the work. In the research effort, skill levels were established for each of the 30 functions. They are expressed as a percent of total man-hours by personnel classification. For grade-line survey, for example, Aide II's represent 33 percent, Aide III's 33 percent, and Aide IV's 34 percent of the man-hours that will be expended.

4. Basic Manpower Calculation for Planning Purposes. The system in Louisiana, except for the use of an

TABLE 8

TYPICAL PRODUCTIVITY STANDARDS FOR MAJOR PROJECTS IN MICHIGAN

Activity	Unit of Measure	Number of Man-Hours Per Unit: Rural Freeway Projects	Urban Freeway Projects
Roadway layout staking	Roadway mile	180	260
Bituminous paving inspection	1,000 tons	20	20
Structure office work	Span lane	20	20

TABLE 9

OPTIMUM PERSONNEL MIX EXAMPLES IN MICHIGAN

Activity	Total Man-Hours	Man-Hours by Classification: Tech I	Tech II	Tech III	Tech IV
Roadway layout staking	1530	510	510		510
Bituminous paving inspection	85			85	
Structure office work	60			60	

DISTRICT 9
CONTROL SECT. 82125
JOB NUMBER 06772A
PROJECT TYPE 01 RURAL FREEWAY

BASIC MANPOWER PLANNING REPORT
CONSTRUCTION MANPOWER MANAGEMENT SYSTEM

PROJECT ENGINEER JOHN BAXTER

DATE PROCESSED 05/19/76
MDSHT REPORT 356
PAGE 1

ACTIVITY		PLANNING UNIT	STANDARD MAN-HOURS PER UNIT	NUMBER OF UNITS	MAN-HOURS REQUIRED	EQUIVALENT MAN-MONTHS					
ACT. CODE	ACTIVITY TITLE					TOTAL	LEVEL 1	LEVEL 2	LEVEL 3	LEVEL 4	LEVEL 5
	STAKING:										
06	GRADE	ROADWAY MILES	100.0	16.0	1,600	9.2	3.1	3.1	3.1		
09	OTHER ROADWAY EARTHWORK	ROADWAY MILES	75.0	16.0	1,200	6.9	2.3	2.3	2.3		
11	SURFACING	ROADWAY MILES	100.0	16.0	1,600	9.2	3.1	3.1	3.1		
17	CURB, GUTTER, AND GUARD RAIL	STATIONS	1.0	65.6	66	.4	.1	.1	.1		
19	OTHER	ROADWAY MILES	15.0	16.0	240	1.4	.5	.5	.3	.1	
	TOTAL STAKING ACTIVITIES				4,706	27.1	9.1	9.1	8.9	.1	
	INSPECTION:										
22	TRAFFIC CONTROL DURING CONSTR	ROADWAY MILES	40.0	16.0	640	2.9		2.3	.6		
24	EARTHWORK	10,000 CYDS	12.0	19.6	235	1.1	.1	.1		.9	
25	EARTHWORK DENSITY CONTROL	10,000 CYDS	3.0	19.6	59	.3		.3			
31	AGGREGATE PLACEMENT	ROADWAY MILES	65.0	16.0	1,040	4.8	1.0	3.8			
32	AGGREGATE CONST DENSITY CONT	ROADWAY MILES	25.0	16.0	400	1.8		1.8			
33	WEIGH AGGREGATE	ROADWAY MILES	40.0	16.0	640	2.9	2.9				
46	CONCRETE PAVING	1,000 SYDS	6.0	290.7	1,744	8.0	2.4	2.4		3.2	
47	CURB, GUTTER	STATIONS	1.0	4.5	5						
48	CONCRETE SURFACING PLANT	1,000 SYDS	2.5	290.7	727	3.4			3.4		
69	MISCELLANEOUS	ROADWAY MILES	110.0	16.0	1,760	8.1	.4	7.7			
	TOTAL INSPECTION ACTIVITIES				7,250	33.3	6.8	18.4	4.0	4.1	
	OFFICE WORK:										
71	IN PREPARATION FOR CONSTRUCT	ROADWAY MILES	30.0	16.0	480	2.8		.8		2.0	
72	ROADWAY EARTHWORK	10,000 CYDS	10.0	19.6	196	1.1	.3	.3	.3	.3	
73	AGGREGATE CONSTRUCTION	ROADWAY MILES	10.0	16.0	160	.9	.7			.2	
75	CONCRETE SURFACING	1,000 SYDS	5.0	290.7	1,454	8.4			5.9	2.5	
79	MISCELLANEOUS	ROADWAY MILES	225.0	8.0	1,800	10.4		7.3		3.1	
	TOTAL OFFICE ACTIVITIES				4,090	23.6	1.0	8.4	6.2	8.1	
	PROJECT MANAGEMENT AND MISC:										
81	PROJ SUPERVISION AND MANAGEMT	LUMP SUM	1.0	500.0	500	2.9					2.9
82	STANDBY	% HOURS 1-81	2 %		330	1.9	.4	.5	.8	.2	.1
89	MISCELLANEOUS	% HOURS 1-81	1 %		165	1.0	.2	.3	.4	.1	.1
	TOTAL PROJ MGMT AND MISC				995	5.8	.6	.8	1.2	.3	3.1
	PROJECT TOTAL				17,041	89.8	17.5	36.7	20.3	12.6	3.1

Figure 7. Basic manpower planning report—Michigan's construction manpower management system (1).

idealized construction work sequence, is very similar to the system in Michigan. The manpower calculation in the Louisiana system, therefore, is basically the same as that in Michigan.

5. Vehicle Standards. Louisiana also adopted vehicle standards as guidelines for all personnel to use in developing or evaluating vehicle assignments and needs. Standard allowances were divided into three basic categories: survey, inspection, and project management.

Contractor Function Flow Diagram

Each of the more than 150 potential contractor activities is stored in the system computer in a standard work sequence network. The diagram is used to show the most likely sequence of contractor activity performance. Any one project uses a small number of these activities. When the proper activities are selected, a unique diagram is developed for the project. Based on the contractor activity time allowances and the quantity of work to be performed on the project, the duration of each contractor activity can be determined. This information then becomes the basis for determining the critical path. When the department functions are correlated with the time that each contractor activity is most likely to occur, a manpower needs profile for the project (based on employee grade classification) can be determined. Also, the contract days can be converted to a calendar day sequence (based on a Louisiana study that identified the average expected number of contract days available throughout the year).

Results Achieved by the System

As reported by Boagni (2), the system first was applied in one fairly representative district in 1976. Based on existing and anticipated workload and an application of the yet untested manpower standards, the management research team recommended a maximum level of staffing of 79 persons instead of the 124 that were being used. After a series of meetings, it was agreed that 92 persons would be used (a 26 percent cutback) and that the other 32 would be given other assignments.

At the end of January 1977, at the request of the district construction engineer, the district's workload and manpower were reevaluated and the level of staffing set at 70 persons. In addition, a permanent crew of 10 was to do location survey and design work. The remaining positions in the district were abolished, and the employees in these positions were either reassigned, promoted, or demoted, or they resigned.

When the system was implemented in two other districts, it was found that the level of staffing in one district was deficient by 15 percent (15 engineering students were hired for the summer of 1977 to handle the peak load) and that there was a 19 percent overstaffing in the other district. All districts were to have implemented the system by midsummer 1977; it is conservatively estimated that the statewide construction force can be reduced by 20 percent. At the same time, there will be a concentrated effort in Louisiana to train managers in basic management techniques and in the application of the management system.

Arkansas' Manpower Management System

The Arkansas Highway and Transportation Department construction management research project began in October 1975 and was completed in January 1978 (3, 4, 16). The broad objectives of the project were to (a) develop and test a management system that would plan and control department manpower and equipment on construction projects, (b) investigate interdivisional communication and structure, and (c) analyze the department's personnel policies in relation to the needs of the construction division.

To accommodate the various manpower information needs of the users, two subsystems were developed for planning and scheduling construction division manpower: the basic scheduling system and the long-range fore-

TABLE 10

EXAMPLE OF UNITS OF MEASURE AND STANDARDS FOR BRIDGE DECK REPAIR IN MICHIGAN

Activity Group	Unit of Measure	Number of Standard Man-Hours
Staking	Span lane	8
Inspection	Contractor workday	11
Office work	Contractor workday	2

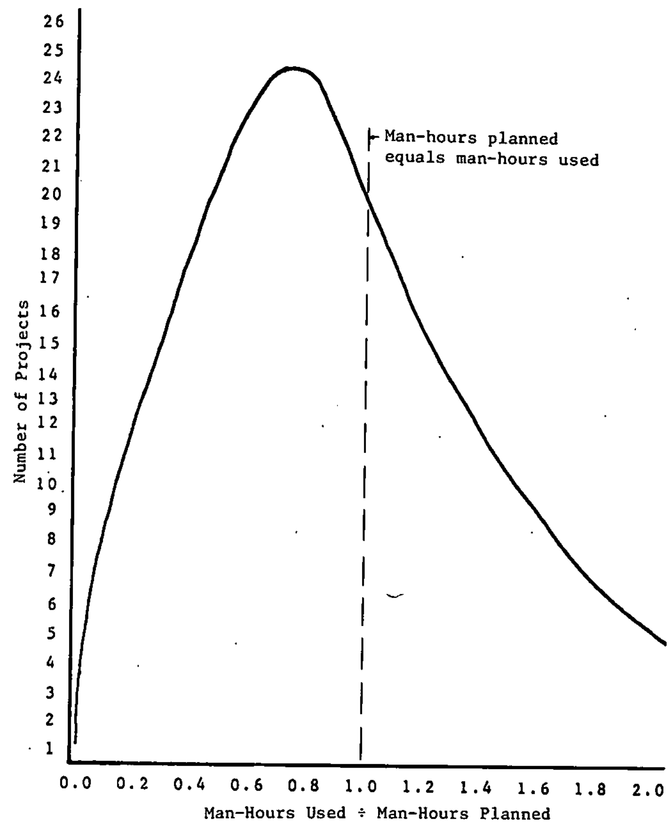


Figure 8. Distribution of individual projects by ratio of used to planned man-hours (Michigan) (after Ref. 1).

casting system. For equipment assignments, a regression analysis model was designed to correlate actual employees to actual number of jobs, by resident and district engineer, and to predict the number of automobiles. This tool is to be used by the construction engineer for making interdistrict transfers of equipment. The district and resident engineers will still assign vehicles on a traditional basis.

In addition to these planning systems, an organization, management, and personnel study of the construction division was undertaken. This research illustrated that the organizational structure of the division was appropriate for the highway construction task structure; however, recommendations were made for improving interdivisional communication and certain personnel policies (e.g., overtime). Following is a brief description of the two subsystems.

The Basic Scheduling System

The basic scheduling system is considered a management tool to be used primarily by the resident engineer in determining the proper distribution of personnel for making job assignments. Developing this system involved identifying and defining work activities (80 separate work activities were used to classify all engineering fieldwork), job skills, staffing standards, and man-hours of a specific job skill required to perform a specific work activity under a given set of conditions.

The final system combines a contractor schedule with planning units, or factors that represent the typical accomplishment for each defined activity by man-hours, to estimate the hours required for each residency. These estimates then are compared to the total man-hours available. The resulting analysis (whether the residency has a surplus, a shortage, or the correct amount of manpower) is communicated to the district engineer. The district engineer, in turn, is responsible for transferring personnel, if necessary, or requesting assistance from the construction engineer for the transfer or addition of personnel on an interdistrict basis. Figure 9 is a flow diagram of this system.

The Long-Range Forecasting System

The long-range forecasting system is a computer model that typically provides this information:

- The number of total man-hours required on any future construction project.

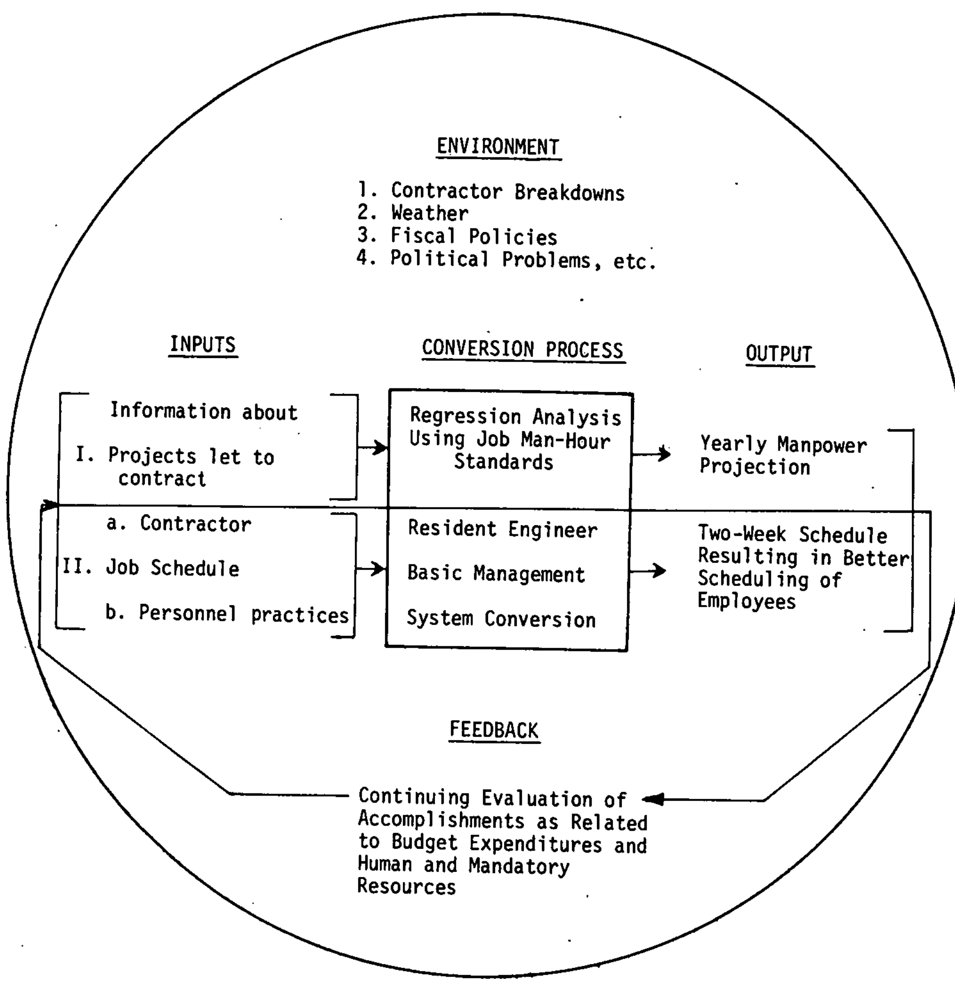


Figure 9. The Arkansas Highway and Transportation Department construction management system (3).

- The number of man-hours, distributed by month, required on any future construction project.
- The monthly staffing required by each resident and district and/or the staffing required throughout the entire state for the anticipated construction projects during the next 24-month period.
- The impact of any future project and/or any group of future projects on the staffing of a district office or on the entire state.

Following is a simple description of the model:

The input is composed of information (e.g., job number, contract cost, length, type of improvement, start date, completion date, and other similar data) about ongoing and future projects.

The model calculations are composed of two distinct operations. The first computes the total man-hours required on each ongoing and future project; the second distributes those total man-hours over the time period that the project is expected to be under construction.

The output is a summary table that groups projects by resident and district and totals the monthly man-hours required for each project to obtain the monthly man-hours required. This output is used as the basis for long-term staffing decisions. Table 11 gives a sample.

It is anticipated that this model will greatly help the construction engineer and district engineer determine their staffing needs. It will also aid the chief engineer and assistant chief engineer for operations in their planning and budgeting operations.

Vehicle Allocation

The Arkansas Construction Management Research Project developed a simple yet valuable tool to aid the construction engineer in making vehicle allocation decisions. The researchers used a statistical technique called regression analysis, which defines the quantitative relationship between two variables on the basis of the historical relationship between them. The key, or dependent, variable for this study was the number of vehicles assigned to the residency. This variable was tested against several variables (e.g., number of employees in a residency, number of construction projects in a residency, dollar value of the construction work in a residency) to determine existing relationships between the variables. It was found that the number of vehicles assigned to a residency is related to the number of people working in that residency and the number of projects in that residency. From this finding, an equation was developed to predict equipment needs. This equation does not state the number of vehicles a residency should be assigned, however; it simply states that in the past the number of vehicles assigned generally has been related to the number of people and jobs assigned. Therefore, this equation should be used as

TABLE 11

MAN-HOUR FORECAST (ARKANSAS)

September 02, 1977

COUNTY	JOB	START DATE	COMP DATE	TOTAL MANHRS	ALREADY DISTRIB	JULY 77	AUG. 77	SEPT. 77	OCT. 77	NOV. 77	DEC. 77	JAN. 78	FEB. 78	UND. BAL.
32	F-31-1	5-76	3-77	2276	2276	0	0	0	0	0	0	0	0	0
37	S-55-4	2-77	8-77	869	616	137	115	0	0	0	0	0	0	0
35	3794	5-77	10-77	1674	473	389	281	170	0	0	0	0	0	0
RESIDENT 31				22626	11803	1850	2341	1862	1601	1811	805	208	180	100
31	S-29-6	6-77	7-77	715	373	341	0	0	0	0	0	0	0	0
31	3-679	10-77	11-77	1704	0	0	0	0	1021	682	0	0	0	0
RESIDENT 32				8257	3556	759	499	510	1340	937	164	131	121	500
34	GF-3-2	7-77	8-77	681	0	357	323	0	0	0	0	0	0	0
34	3725	7-77	8-77	3547	0	1861	1685	0	0	0	0	0	0	0
34	3-680	8-77	12-77	1001	0	0	200	303	261	157	79	0	0	0
RESIDENT 34				22327	8331	3225	4399	2432	1040	771	511	378	364	0
31	3821	12-76	3-77	942	942	0	0	0	0	0	0	0	0	0
34	3801	2-76	9-77	669	577	33	28	28	28	0	0	0	0	0
33	3776	3-78	3-80	8847	0	0	0	0	0	0	0	0	0	0
39	State Aid	7-77	3-81	19164	0	207	438	657	707	687	594	525	594	260
Future Jobs & State Aid				94311	9451	193	516	729	938	842	736	671	766	460
DISTRICT 3				147521	33143	6128	7756	5534	4822	4363	2218	1390	1431	1060

a guide when the vehicle needs of any one residency are assessed.

Organization, Management, and Personnel

The analysis of the central-office construction division and its relationships with the districts revealed no serious defects or shortcomings in the structure of the organization. Accordingly, no structural changes were proposed. However, there were opportunities for improving functional relationships between certain central office divisions and for reconciling statewide responsibilities and concerns with the substantial autonomy and local concerns of districts. Following is a partial list of recommendations for the construction division:

- Attend weekly preconstruction staff meetings.
- Have a representative on the project planning committee to select future projects and assign design priorities to them.
- Form a work methods and management committee to provide an effective forum for the free exchange of information, ideas, and common problems; for the introduction of new work methods; and for the explanation of management techniques, principles, and tools to the resident engineers.

From the analysis of both the technical and administrative aspects of the construction division's operations, it was evident that the personnel management component posed two basic challenges: (a) to find some orderly and economical means for adjusting manpower to the seasonal work cycle of the construction program without sacrificing quality control and (b) to concentrate on fostering a hierarchy of incentives to improve the availability, quality, and motivation of construction staff.

With these two challenges as a framework, a number of recommendations were made. These included employment of a core staff and identification of temporary help (e.g., contracting services), equal pay for equal work, flexible work hours, and a training coordinator.

It should be stressed that sound personnel policies are vital for success in the design of a construction management manpower planning and scheduling system. If it is decided that extra hours must be worked, a fair and equitable policy must be available.

Washington's MMIS

In July 1972 the Washington State Highway Department began a study to develop a Manpower Management and Information System (MMIS) (5, 17, 18). The viewpoint that was adopted is that construction manpower planning does not exist by itself within a highway agency; it is strongly influenced by each of the project-development phases from preliminary engineering to construction engineering. The approach in Washington, then, differs from that used in Michigan, because the Washington system can be viewed as a total system approach to manpower planning that considers all the project phases. Following are some of the more important aspects of Washington's system.

System Definition

These are the six basic steps in Washington's manpower management system:

1. Evaluation of Alternatives. A priority listing of highway improvements at headquarters level.
2. District Resource Balancing. A balancing of program and manpower availability at the district level.
3. Statewide Planning and Resource Balancing.
4. Budget Approval.
5. Operational Planning. Development of detailed project schedules and manpower spreads after budget approval from the state legislature for the program has been obtained.
6. Project Direction and Control. Performance and management of the work.

Throughout each of these steps there is an interface with the MMIS automated system that generates the computerized schedules, manpower forecasts, and other aids to decision-making. The system of planning described in the first five steps is similar to the system in Michigan and the principles cited in Chapter Two.

There is, however, a very basic difference: five stages, or phases, of a highway project are incorporated into the system (see Fig. 10). The manageable unit of work is called a planning unit project, and it is subdivided into four phases of preliminary engineering and one phase of construction engineering. Note that in phases 2 to 5 a number of individual "projects" can be defined.

According to Maresca (19), the primary emphasis of MMIS at this point is to provide more efficient planning for the first four phases so that estimated expenditures can be reflected more accurately. The planning approaches for the various phases, outlined in the following paragraphs, indicate this degree of emphasis.

The Role of Performance Standards

The backbone of most manpower systems, as noted earlier, is the standards of performance that are developed. In MMIS, man-hour work or performance standards and flow time or long-range planning standards are used. These standards were developed specifically for work performed during preliminary engineering, right-of-way, and construction engineering activities. They are based on actual time analysis, judgment, and work experience. As noted by Anderson and Goetz (5, p. 71):

"A person-hour work or performance standard is the criterion on which actual performance is evaluated for quality, quantity, and productivity. A flow-time or long-range planning standard prescribes the number of days allowed to complete an activity, milestone, or project.

"Each preconstruction engineering activity was defined early in the project development. There are 140 work activities identified as preconstruction engineering and 60 as construction engineering. Each activity is described in a specific work control statement. The work control statement gives the scope of the work involved, the purpose, significant decisions needed, and the necessary staffing by number and skill level. Work performance standards and flow-time standards were developed for each activity. These standards are stored in the computer and are the basis for resource calculations when the construction program is developed."

Development of Project Plans: Preconstruction Phase

The first step of planning in MMIS involves quantifying each of the "projects" within the five phases according to several important project characteristics. Until this is done, schedules and manpower resources can not be generated by the computer. The most important of these characteristics is project type, which is categorized as follows for the MMIS system:

Preliminary Engineering	Construction Engineering
Major construction, rural	Major construction
Major construction, urban	Reconditioning (overlay)
Overlay/pave only, rural	Safety
Overlay/pave only, urban	Bridge only
Safety	Aggregate production
Miscellaneous (minor)	Beautification
Bridge only	
Landscape	

Additional project characteristics that must be quantified include, but are not limited to, project length, action plan group, heavy vegetation, mountainous terrain, environmental studies required, type and number of interchanges, miles of frontage roads, number and sizes of bridges, volume of earthwork, and right-of-way information. Opportunities to update the project characteristics are provided throughout the life of the planning unit project.

Description of the project type and project features will key the computer to calculate a scheduling network for each of the four preliminary engineering phases, because standard CPM (critical path method) networks, such as shown in Figure 11 for the design phase, are stored in the computer's data bank. The computer also will calculate an estimate of planned man-hours for these phases, because work control statements also are stored in the computer's data bank for each activity within the scheduling network. Each statement consists of a narrative of the activity; the narrative includes the activity's purpose, significant decisions, documentation, and tasks. The work control statement also lists man-hour standards by organization and flow-time standards for all variables associated with a specific activity. Skill-level distribution by organization also is shown.

The use of a CPM-based approach for the preconstruction phase raised questions from a number of sources. As noted by Anderson and Goetz (5, p. 73):

"Using a critical path scheduling network to develop engineering manpower requirements has been contested by many in the highway field. The primary argument is that, because preconstruction engineering work is so strongly influenced by public reaction, environmental impacts, and dynamic changes in general, it is difficult to determine a final design and schedule; therefore, it is impractical to develop a manpower management system. We take exception to that argument. Changing conditions in planning for construction projects actually

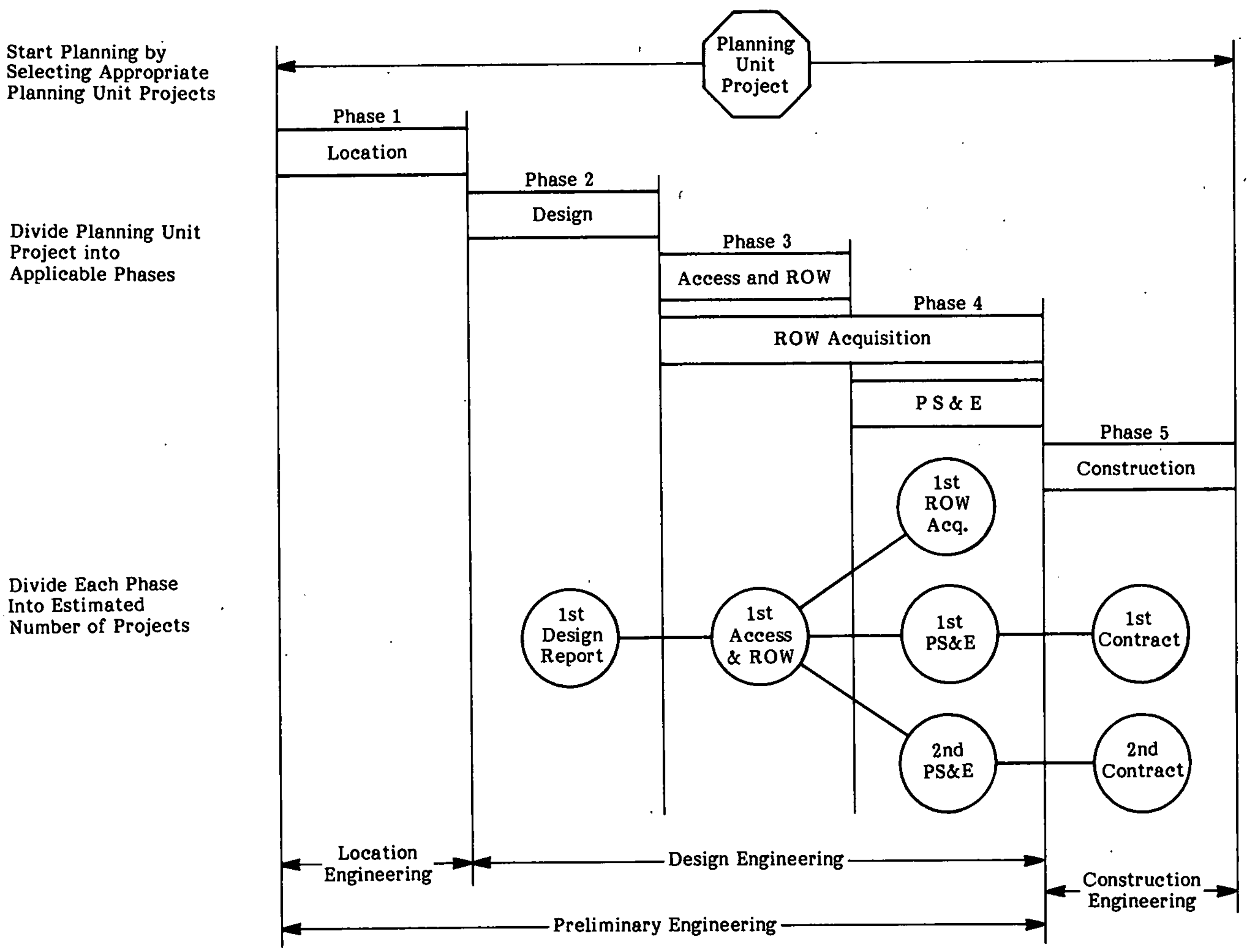


Figure 10. Definition of Washington's planning unit project.

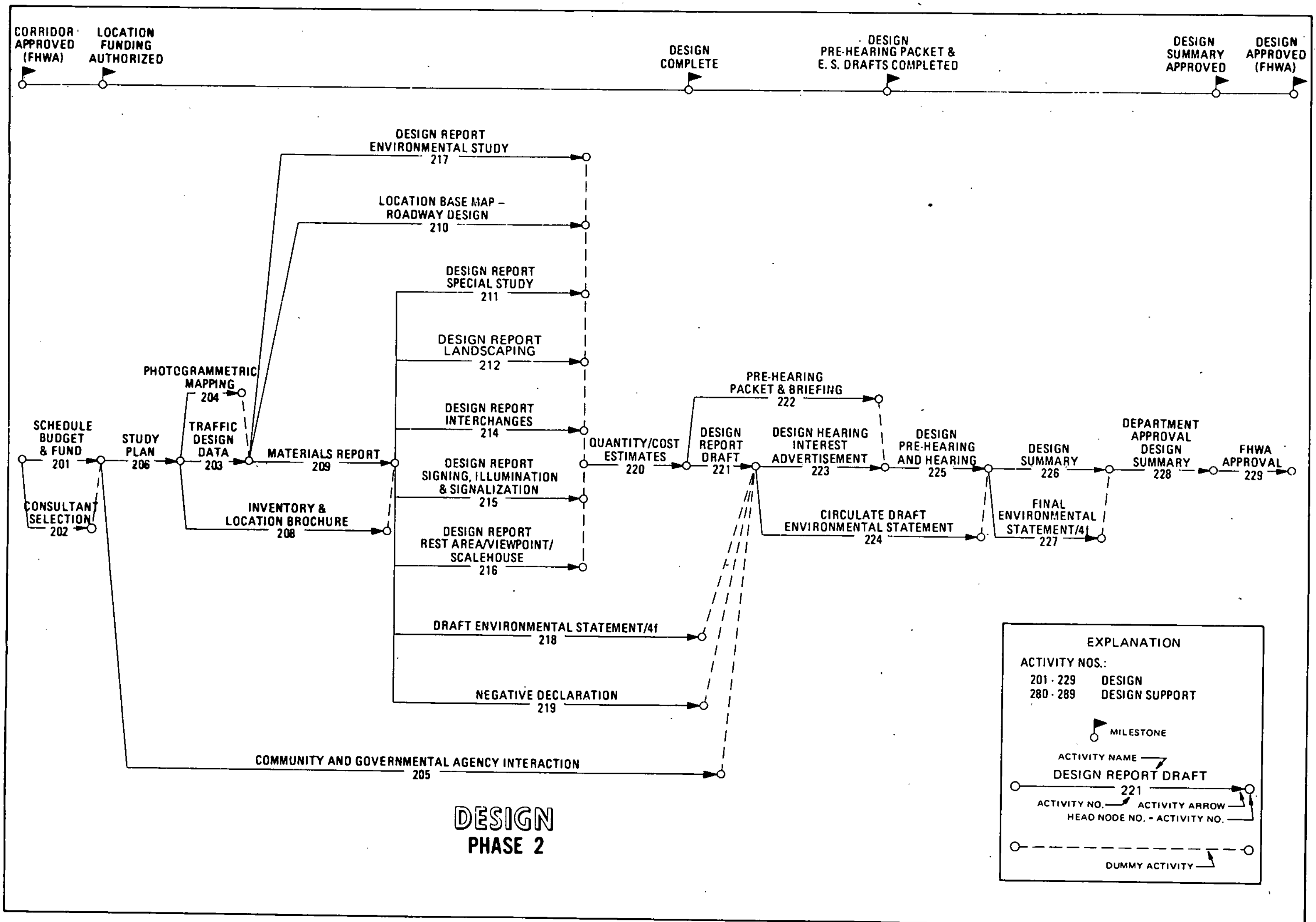


Figure 11. Design phase standard network (Washington) (18).

justify the development of a manpower management program because it becomes more essential to maintain control and direct the efforts being expended."

Development of Project Plans: Construction Phase

For the construction phase projects, input on the project type and project feature will key the computer to calculate the planned man-hours and spread this manpower over contract flow-time based on construction workable-day prediction calendars that are stored in the computer. In MMIS, predetermined flow-time percentages of the total project also are stored in the computer for each of the functional activities.

A bar-charting technique is used for the construction phase, as illustrated in Figures 12 and 13. The work standards for major construction are given in Table 12, which lists the man-hour standards by activity groups. Activity groups are explained where clarification is required. Standards statements also include skill-level distributions by activity group.

Results Achieved by the System

According to Maresca (19), MMIS will be fully implemented early in 1978. When implemented, it will allow Washington to plan and control all phases of engineering on highway projects more effectively. The system is complex from a developmental standpoint, and full implementation will require the cooperation of all six district offices in a state highway agency that is very much decentralized (except for a centralized bridge design unit). Maresca does note that the development of the standards already has had beneficial effects within the department. He feels that, once implemented, MMIS would be of benefit mostly as a manpower planning technique, not as a detailed, day-to-day manpower scheduling technique.

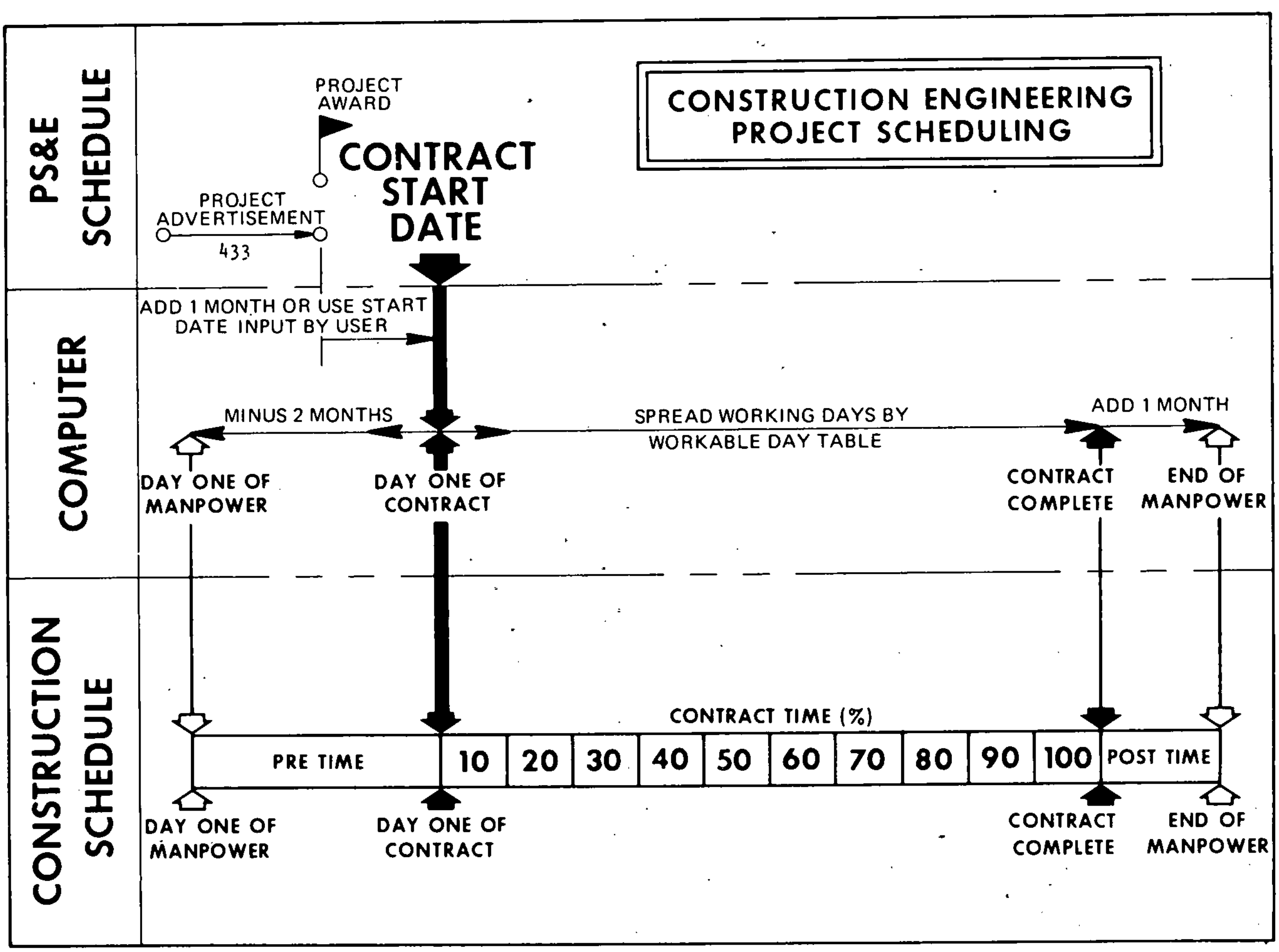
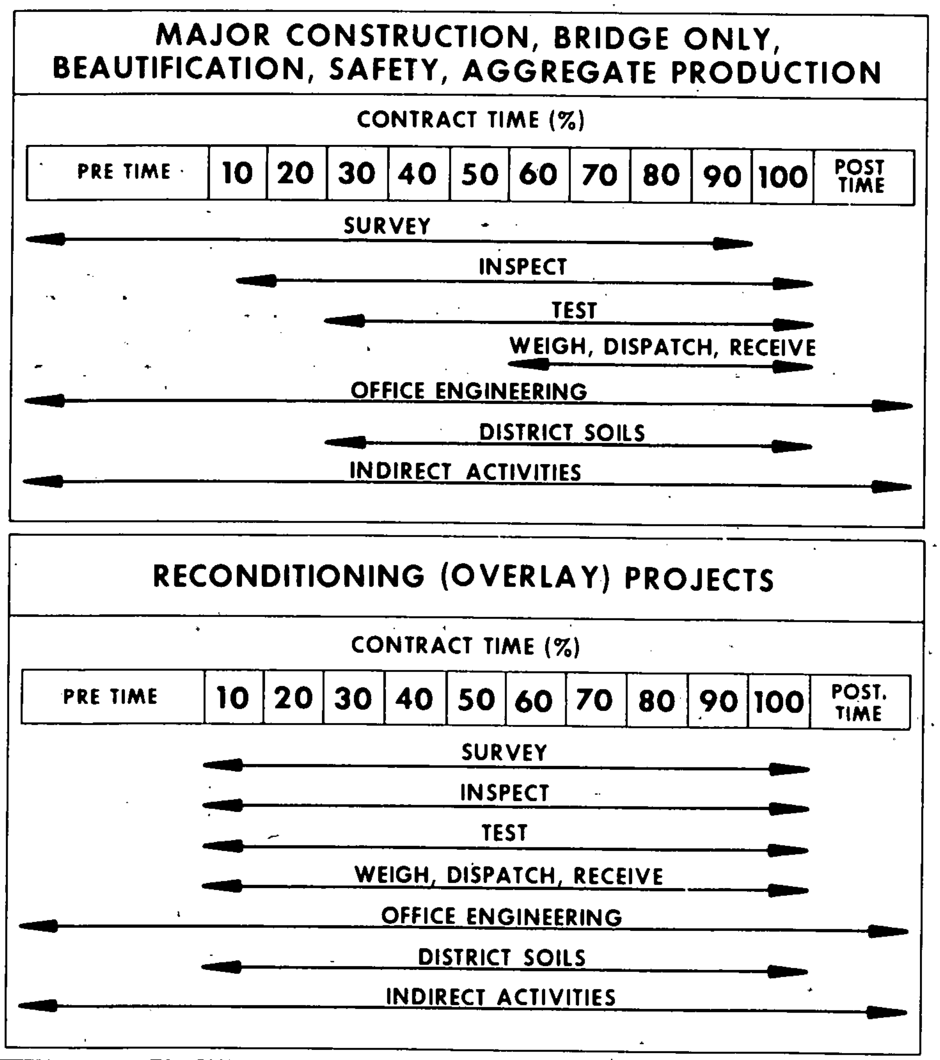


Figure 12. Construction phase scheduling (Washington) (18).



ACT. GROUP	ACTIVITIES	ACT. GROUP	ACTIVITIES
SURVEY	– 00-05, 10-19, 52, 53	WEIGH, DISPATCH, RECEIVE	– 50-51
INSPECT	– 20-26, 30-36, 54, 76, 77	OFFICE ENGINEERING	– 63-65, 67, 68
TEST	– 40-48	DISTRICT SOILS	– 81

Figure 13. Construction project activity group scheduling (Washington) (18).

TABLE 12

EXAMPLE OF MMIS PROJECT WORK STANDARD (WASHINGTON) (18)

MAJOR CONSTRUCTION	CODE 001
A project which usually involves clearing, grubbing, grading, draining, and/or surfacing and paving of a new highway on either new or old alignment.	

ACTIVITY GROUP	STANDARD HOURS	SKILL LEVEL % 1	2	3	4	5
Survey	96 HRS/Project	50	15	20	15	
	638 HRS/Rdwy Mile	40	15	20	15	10
Inspect	100 HRS/Rdwy Mile		10			90
Test	10 HRS/Rdwy Mile	100				
Office Engineering	200 HRS/Project			60		40
	425 HRS/Rdwy Mile			60		40
District Soils*	96 HRS/Project					60
	30 HRS/Rdwy Mile			70		20

*Standard Includes Soils Engineer

ACTIVITY GROUP DESCRIPTION

Survey
Project hours to establish pit boundaries, any measure or remeasure of stripping, etc., and staking for reclamation on one pit. Roadway mile hours to establish alignment, right of way, clearing and grubbing, x-section and slope staking. Standard does not include hours for drainage, structures, walls, surface or paving. See additive standards.

Inspect
To perform inspection for clearing and grubbing, right of way, fence, earthwork and other miscellaneous project inspection normally required.

Test
To perform miscellaneous testing that occurs but not readily identifiable from project to project. Basic testing included in additive standards.

Office Engineering
Project hours to establish records, accomplish progress and final estimates and record. Roadway mile hours allows for volume factor.

District Soils
Project hours to make routine contacts. Roadway mile hours for materials approvals, progress inspector and lab work.

CHAPTER FOUR

USE OF MANPOWER ON PROJECTS

The construction manpower management system element of planning was discussed in detail in Chapter Three. The procedure by which the estimated manpower needs are used on actual construction projects can be understood more clearly after the other elements of staffing, scheduling, and controlling also are considered.

1. Planning: During planning, the basic construction program is analyzed, project by project, in terms of defined contract units and planning standards to develop total man-hour requirements.
2. Staffing: During staffing, the man-hour requirements are converted to monthly manpower requirements by suitably grouping activities and "aging" them according to an estimate of when the activities will occur.
3. Scheduling: Based on a knowledge of the contractor's proposed schedule on a project, all the construction engineering activities are identified in their proper time frames and translated into both primary and secondary work assignments. An excess or deficiency of personnel is identified during the scheduling process.
4. Controlling: Through the use of daily activity reports, completed quantities and costs, monthly progress estimates, and contract time use, actual man-hours used to date are compared with the total planned use. Exceptions are identified and corrective measures taken.

A number of construction management systems are being used by the various highway agencies to accomplish these four elements. The current practices used in Michigan, Arkansas, Louisiana, and Washington are cited in this chapter. (Appendixes A and B provide insight into the procedures used in other states.)

MICHIGAN'S MANPOWER MANAGEMENT SYSTEM

The Michigan Department of State Highways and Transportation has adopted a construction manpower management system that includes the elements of planning, staffing, scheduling, and controlling (1, 7, 14, 15).

The planning part that involves the determination of man-hours required to administer a construction project was discussed in detail in Chapter Three. The output of this phase (see Fig. 7) indicates the total man-hours, by skill level, required for each project. This information is useful at the organization's headquarters level for planning purposes.

The remaining three parts of the system transform this information into terms that are useful at the district and project levels. The basic elements of the remainder of the Michigan system are explained in the following paragraphs as they were developed originally (7), because the development represents a fairly complete approach to construction manpower management, against which the systems developed by other state highway agencies can be compared. Modifications to this ideal system, which were necessitated by the practical problems of implementation in Michigan, are noted at the end of this section.

Staffing

The district construction engineer makes an annual forecast of monthly manpower needs based on the predicted construction program, the characteristics of the individual projects, and the man-hour standards. In January of each year an annual staffing plan is prepared for each district in two phases.

In the first phase, all project engineers complete an annual staffing plan, such as that shown in Figure 14, for each active project assigned to them. Note that for ongoing activities the man-month balance that remains from the planned man-months is spread over 12 months (or longer if the project extends more than a year). This spreading action requires an understanding of the contractor's level of performance on the project as well as the effects of weather, because estimates of when each activity is likely to occur must be made. This plan is submitted to the district office.

In the second phase, similar plans are developed at the district office for all projects that are scheduled for letting in the coming year.

The total man-month requirements for each project are used at the district level to prepare the district staffing summary shown in Figure 15. Note that, when the total number of personnel available in the district is included (shown as 35 in Fig. 15), the data for the manpower profile shown in Figure 16 can be obtained. This information can be extremely useful to district personnel when they attempt to identify the level of temporary employees required or the number of off-season assignments that must be made.

Scheduling

The meshing of planning and staffing decisions for the project shown in Figure 14 indicates an estimate of 8.5 man-months of effort in March, 11.4 man-months of effort in April, and so on. These figures may be viewed as target levels around which the project engineer must make day-to-day scheduling decisions. The project engineer schedules the work by preparing a detailed weekly written schedule (Fig. 17) on Thursday of each week for the coming week. Project personnel are assigned to specific tasks, locations, and times for the following workweek. The schedule is based on the contractor's work schedule and established productivity standards. Flexibility is built into the scheduling system by the notation of primary assignments (those covering work that will occur if construction operations proceed

ANNUAL STAFFING PLAN

CONSTRUCTION MANAGEMENT SYSTEM

Project Engineer Vander Weide

1109 A (Rev. 4-76)

C.S. ID.	63051
JOB NO.	08520A
LETTING DATE	March 1976
EST. COMP. DATE	November 1977
DATE PREPARED	1-28-76
YEAR	1976

MAN-MONTHS

	CODE	ACTIVITY	PLANNED TOTAL PROJECT	USED TO DATE	BALANCE	JAN	FEB	MAR	APR	MAY	JUNE	JULY	AUG	SEPT	OCT	NOV	DEC	TOTAL	BALANCE TO COMPLETE
												CURRENT YEAR							
STAKING	01	Roadway Layout	6.3	0	6.3			2	3	1.3								6.3	0
STAKING	02	Utility Layout	3.5	0	3.5			2	1.5									3.5	0
STAKING	05	Cross-Section and Slope	9.7	0	9.7				1	1	1	1	0.5	0.5	0.5	0.5		6.0	3.7
STAKING	06	Grade	4.9	0	4.9					0.4	0.4	0.4	0.4	0.4	0.4	0.4		2.8	2.1
STAKING	09	Other Roadway Earthwork	1.4	0	1.4				0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1		0.8	0.6
STAKING	11	Surfacing	3.9	0	3.9							0.3	0.4	0.4	0.4	0.4		1.9	2.0
STAKING	14	Structure																	
STAKING	15	Minor Structure and Drainage	7.1	0	7.1				1.5	1.5	0.5	0.5	0.5	0.5				5.0	2.1
STAKING	17	Curb, Gutter and Guardrail	5.9	0	5.9							0.6	0.6	0.6	0.6	0.6		3.0	2.9
STAKING	18	Special Feature																	
STAKING	19	Other	1.1	0	1.1							0.1	0.1	0.1				0.3	0.8
		TOTAL STAKING ACTIVITIES	43.8	0	43.8			4.0	7.1	4.3	2.0	3.0	2.6	2.6	2.0	2.0		29.6	14.2
INSPECTION	21	Removal and Relocation	5.1	0	5.1			0.5	1.0	1	1	0.5						4.0	1.1
INSPECTION	22	Traffic Control during Construction	2.2	0	2.2				0.4	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	1.2	1.0
INSPECTION	24	Earthwork	5.6	0	5.6				0.4	0.4	0.4	0.4	0.4	0.4	0.4			2.8	2.8
INSPECTION	25	Earthwork Density Control																	
INSPECTION	31	Aggregate Placement																	
INSPECTION	32	Aggregate Construction Density Control																	
INSPECTION	33	Weigh Aggregate																	
INSPECTION	41	Bituminous Paving	2.3	0	2.3								0.4	0.4	0.4			1.2	1.1
INSPECTION	42	Bituminous Plant	1.9	0	1.9								0.3	0.4	0.3			1.0	0.9
INSPECTION	43	Weigh Bituminous Material	1.9	0	1.9								0.3	0.4	0.3			1.0	0.9
INSPECTION	45	Joint Repair	6.1	0	6.1						0.5	1	1	0.5	0.1			3.1	3.0
INSPECTION	46	Concrete Paving																	
INSPECTION	47	Curb, Gutter, Sidewalk and Miscellaneous Concrete	3.2	0	3.2							0.3	0.3	0.3	0.3	0.3		1.5	1.7
INSPECTION	48	Concrete Surfacing Plant																	
INSPECTION	51	Structures																	
INSPECTION	52	Minor Structures and Drainage	6.3	0	6.3				0.5	1	1	0.6	0.1	0.1				3.3	3.0
INSPECTION	53	Concrete Plant for Structures																	
INSPECTION	62	Special Feature																	
INSPECTION	69	Miscellaneous	5.6	0	5.6								0.4	0.4	0.4	0.4		1.6	4.0
		TOTAL INSPECTION ACTIVITIES	40.2	0	40.2			0.5	2.3	2.5	3.0	2.9	3.3	3.0	2.3	0.8	0.1	20.7	19.5
		TOTAL OFFICE WORK ACTIVITIES	30.5	0	30.5			3	1	0.5	0.5	0.5	0.5	0.5	0.5	1	2	10.0	20.5
		TOTAL PROJECT MANAGEMENT AND MISCELLANEOUS ACTIVITIES	11.9	0	11.9			1	1	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	6.0	5.9
		TOTAL, ALL ACTIVITIES	126.4	0	126.4			8.5	11.4	7.8	6.0	6.9	6.9	6.6	5.3	4.3	2.6	66.3	60.1

Figure 14. Project engineer's annual staffing plan (Michigan) (1).

DISTRICT STAFFING SUMMARY

1180 (M 11/74)

DATE PREPARED JAN. 12, 1973
YEAR 1973

CONTROL SECTION ID.	JOB NO.	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.
		MAN-MONTHS											
I41029	00574A	3.0	3.0	1.7	2.7	4.0	5.5	5.2	4.4	6.1	5.8	3.5	3.0
I70024	00986A	3.0	3.0	1.7	1.7	3.0	4.0	7.2	6.4	6.2	5.4	4.4	3.0
I70024	00985A	5.0	5.1	5.9	7.0	8.5	9.1	9.1	9.6	9.6	9.6	8.3	5.9
I70024	00983A	3.8	4.2	3.5	7.0	10.2	10.1	10.6	10.9	9.9	9.3	6.1	3.8
I70024	00984A	3.9	4.1	4.1	4.1	5.2	9.9	9.5	10.5	11.5	9.3	6.1	2.8
I03035	00024A	3.0	3.0	3.4	3.9	4.9	9.5	11.8	10.5	9.5	9.8	5.2	3.2
I03035	00023A	3.0	3.0	4.5	8.0	9.0	9.0	6.5	7.5	8.0	6.0	4.2	3.0
TOTAL DIRECT MAN-MONTHS		24.7	25.4	24.8	34.4	44.8	57.1	59.9	59.8	60.8	55.2	37.8	24.7
AVG PERCENT OF DIR. MAN-MOS.		27	24	16	10	9	6	11	7	8	8	24	37
INDIRECT MAN-MONTHS		6.7	6.1	4.0	3.4	4.0	3.4	6.6	4.2	4.9	4.4	9.1	9.1
TOTAL MAN-MONTHS		31.4	31.5	28.8	37.8	48.8	60.5	66.5	64.0	65.7	59.6	46.9	33.8
MEN AVAILABLE		35	35	35	35	35	35	35	35	35	35	35	35
DEFICIENCY OR EXCESS		+3.6	+3.5	+6.2	-2.8	-13.8	-25.5	-31.5	-29.0	-30.7	-24.6	-11.9	+1.2

Figure 15. District staffing summary (Michigan) (7).

as expected) and secondary assignments (those to be accomplished when a construction operation changes or does not proceed as expected).

A project schedule of this type requires (a) an estimate of the contractor's operations plan for the coming week, (b) a selection of the primary highway agency assignments that correspond to the operations that have been identified, (c) the number of days and man-hours required for the primary assignments (based on established productivity rates), (d) the number and names of the personnel required, and (e) the secondary assignments that will be made. This schedule can be posted in the project office so employees can check their assignments for the following week. Schedules of this type never reach the district level, because they are discarded at the end of each week. Office engineering assignments are handled in a similar fashion. If excesses or deficiencies are found at this level during scheduling, the project engineer contacts the district so that reassignment of personnel among projects can be made.

To encourage statewide uniformity in the decisions regarding the maximum number of personnel required, guidelines such as those given in Table 13 (which applies to rural freeway projects) have been prepared.

Controlling

Controlling is simply a reporting activity. Each employee records his or her hours by activity and project on a daily basis, and the totals for each week are submitted to the division office for computer processing. A computer printout for each project compares the hours used per activity with planned hours (Fig. 18); this is mailed biweekly to the project engineer.

A controlling system such as the one used in Michigan has two important benefits. First, it provides project engineers with information about their projects, enabling them to evaluate their performance. Project engineers control the entire management system to some extent. They provide the input for staffing and scheduling, and they use a base they can control: man-hours. It is thus important that project engineers know how well they have staffed, scheduled, and controlled man-hours so that they can improve their decision-making and their control.

Second, this controlling system supplies data that can be used to update or revise the planning values used by the construction staff engineer for the management system. Data obtained from the controlling system will be used to check planning values and to determine if the values are correct and reasonable.

The control function is accomplished when the percent of the planned manpower that was used on a particular activity (e.g., roadway layout), on a group of activities (e.g., staking), or on the total project is compared with the progress that the contractor has made at the same summary level. Contractor progress can be expressed in terms of percent of contract time used, percent of contract work completed, or some similar indicator.

Modifications to the Original System

Michigan has collected enough data from the system to allow an evaluation to be made. With regard to staffing, Casey (1, p. 142) notes:

"The staffing function as designed does not work. The intent had been that the District would compute man-hour needs based on the planning standards and individual project quantities and characteristics for all projects to be let during the calendar year. To be useful, this had to be done in February or March of the year. However, detailed information on most projects is just not available that far in advance. The only definite information the District has early in the year is the number, type, and estimated contract costs for the projects on their program."

To account for this problem, Michigan analyzed the data it had acquired in terms of man-hours per $1,000 of contract cost for each of the 12 types of projects built in Michigan. Standards were then set up according to project type and provided to the districts for the staffing phase. This approach provides a relatively easy and quick way to predict staffing needs and to evaluate staffing during the construction season. This analysis also permits identification of field engineering costs as a percentage of contract costs by type and by district.

With regard to scheduling, Casey (p. 144) notes:

"Scheduling as designed has not worked. It is too detailed and too dependent upon accurate prediction of the contractor's operation for the coming week. Contractors' operations are highly unpredictable, as are weather and other conditions. Therefore, detailed schedules were usually useless. The scheduling of secondary assignments proved somewhat more successful. Consequently, alternate methods of primary scheduling are still being tried experimentally, but on an optional basis. Secondary scheduling will continue."

With regard to controlling, Casey (pp. 144, 149) notes:

"Reporting has been modified to provide only the useful and necessary data and to eliminate some of the detail which was causing confusion and inaccuracy. Each individual employee continues to report his work hours on a daily basis for each project. The activities for reporting purposes have been reduced to the five main categories of staking, inspection, office, supervision and miscellaneous. Thus, the individual reports only a maximum of five categories rather than a possible forty-

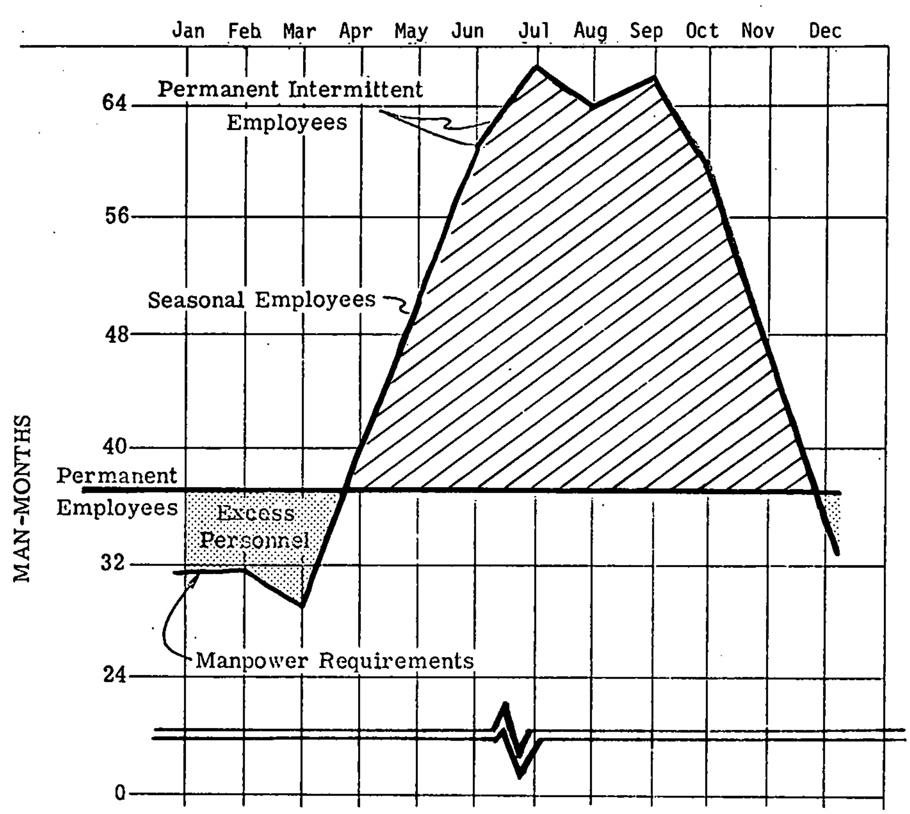


Figure 16. District manpower profile (Michigan) (7).

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. I 70026			2 2 2	8 8 8	8 8 8			See Schedule, Project I 70026

Figure 17. Typical weekly project schedule (Michigan) (1).

TABLE 13

SUMMARY OF MAXIMUM STAFFING STANDARDS PER PROJECT—RURAL FREEWAYS CONSTRUCTION, MAY 1974

Active Project Phase or Element	NUMBER OF PERSONS	
	One Contractor Spread	Two Contractor Spreads
Project management	3	3
Survey crew	3	3
Clearing, grubbing, and other preparations inspection	1	1
Earthwork inspection	2	3
Aggregate construction inspection -- square-yard basis	1	2
Aggregate construction inspection -- ton basis	3	5 - 6
Bituminous surfacing inspection	3	4
PCC surfacing inspection	4	7
Major structure inspection	2	3
Drainage structure inspection	1	1 - 2
Miscellaneous	1	1
Maximum during winter when no construction work is under way	5	--

DISTRICT 5
CONTROL SECT 41012
JOB NUMBER 09281A
PROJECT TYPE 06 URBAN BIT

BI-WEEKLY MANPOWER REPORT
CONSTRUCTION MANPOWER MANAGEMENT SYSTEM

DATE PROCESSED 02/04/77
PERIOD ENDING 01/29/77F
MOSHT REPORT 358
PAGE 1

PROJECT ENGINEER WILLIAM OCONNOR

ACTIVITY		PLANNING UNIT	MAN-HOURS			
ACT CODE	ACTIVITY TITLE		PLANNED	USED TO-DATE	BALANCE	PERCENT USED
	STAKING:					
01	ROADWAY LAYOUT	ROADWAY MILES	180	188	8-	104 %
11	SURFACING	ROADWAY MILES	25	11	14	44 %
15	MINOR STRUCTURE AND DRAINAGE	ROADWAY MILES	60	42	18	70 %
19	OTHER	ROADWAY MILES	30	65	35-	217 %
	TOTAL STAKING ACTIVITIES		295	306	11-	104 %**
	INSPECTION:					
21	REMOVAL AND RELOCATION	ROADWAY MILES	80	30	50	38 %
22	TRAFFIC CONTROL DURING CONSTR	ROADWAY MILES	5		5	0 %
31	AGGREGRATE PLACEMENT	ROADWAY MILES	50	74	24-	148 %
32	AGGREGRATE CONST DENSITY CONT	ROADWAY MILES	50	48	2	96 %
33	WEIGH AGGREGATE	ROADWAY MILES	50		50	0 %
41	BITUMINOUS PAVING	1,000 TONS	1,048	656	392	63 %
42	BITUMINOUS PLANT	1,000 TONS	367	253	114	69 %
43	WEIGH BITUMINOUS MATERIAL	1,000 TONS	341	3	338	1 %
45	JOINT REPAIR	100 LNFT	462	363	99	79 %
52	MINOR STRUCTURE AND DRAINAGE	ROADWAY MILES	75	62	13	83 %
69	MISCELLANEOUS	ROADWAY MILES	40	31	9	78 %
	TOTAL INSPECTION ACTIVITIES		2,568	1,520	1,048	59 %**
	OFFICE WORK:					
71	IN PREPARATION FOR CONSTRUCT	ROADWAY MILES	10	40	30-	400 %
73	AGGREGATE CONSTRUCTION	ROADWAY MILES	10	12	2-	120 %
74	BITUMINOUS SURFACING	1,000 TONS	79	68	11	86 %
77	MINOR STRUCTURE AND DRAINAGE	ROADWAY MILES	30	6	24	20 %
79	MISCELLANEOUS	ROADWAY MILES	100	192	92-	192 %
	TOTAL OFFICE ACTIVITIES		229	318	89-	139 %**
	PROJECT MANAGEMENT AND MISC:					
81	PROJ SUPERVISION AND MANAGEMT	LUMP SUM	300	130	170	43 %
82	STANDBY	% HOURS 1-81	339	156	183	46 %
89	MISCELLANEOUS	% HOURS 1-81	68	76	8-	112 %
	TOTAL PROJ MGMT AND MISC		707	362	345	51 %**
	PROJECT TOTAL		3,799	2,506	1,293	66 %***

Figure 18. Michigan's biweekly manpower report (1).

two. This is expected to result in more accurate and reliable data, with improved system acceptance and operation."

With regard to the total system, Casey (p. 149) notes:

"This then is the basic system as it has evolved and is now operating. It is believed that in this form it has become a useful management tool to determine real staffing needs at the Division, District, and Project Office levels and to evaluate staffing practices on an ongoing basis. However, once having determined the needs it is up to management to take necessary actions to staff according to needs, and this is the difficult part."

ARKANSAS' MANPOWER MANAGEMENT SYSTEM

The basic construction management system developed by the Arkansas State Highway and Transportation Department began its test phase on four highway "laboratory projects" in January 1977 (3, 4, 16, 20, 21). Several unique features of the scheduling phase of the system are highlighted in the following paragraphs. A flow chart that describes the entire system is shown in Figure 19. The manpower planning phase projects manpower for surveying, construction, and office and administrative activities for each project, and it totals the results for each project to make a residency forecast.

An examination of the special requirement for contractor scheduling information for each project indicates how the system allows a resident engineer to (a) forecast personnel needs far enough in advance to ensure that there will be adequate personnel to handle the assigned work and (b) schedule these personnel on a short-term (two-week) basis.

Contractor Scheduling Requirement

A project engineer is in charge of an organization that reacts to the activities of the contractor, and the project engineer therefore must possess an accurate contractor schedule. Because it usually is very difficult to obtain such information from the contractor, the Arkansas system has included the following special contractual provisions in its "laboratory projects" (20, p. 15).

"The contractor shall submit an 'Activity Work Schedule' for a twelve (12) week period showing the anticipated beginning and ending dates of all major work items during the period, in accordance with the form and instructions provided by the Engineer. This 'Activity Work Schedule' shall be updated every four weeks, and submitted to the Resident Engineer.

"In addition, the contractor on the job shall submit at two-week intervals on the Thursday before the beginning of the schedule period, on a form provided by the Engineer, a scheduled estimate of the work that the contractor plans to perform during the following two weeks, and meet with the Resident Engineer or his representative at this interval to discuss the scheduled work. This Two-Week Work Schedule shall contain dates,

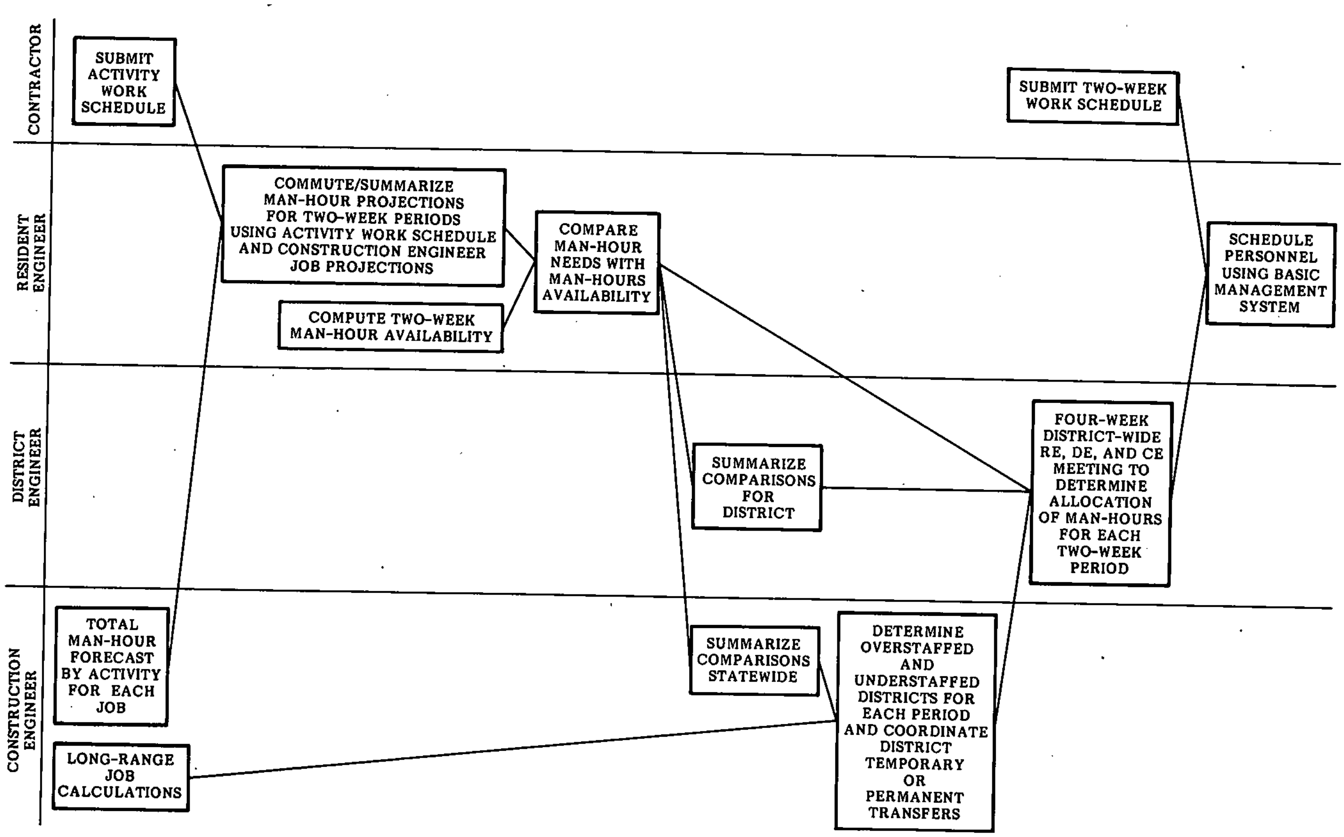


Figure 19. Arkansas' basic construction management system.

station limits of operations, and sequence of operations on an activity basis. The contractor shall notify the Engineer two (2) work days prior to beginning a major activity not scheduled in this Two-Week Work Schedule, if significant inspection and/or survey work is required.

"Changes in the contractor's operations contrary to the 'Two-Week Work Schedule' due to changing weather conditions and other factors beyond his control are considered unavoidable, and it is not the intent of these requirements to unduly delay the contractor when this occurs. The intent of these requirements is to allow the Engineer to accurately schedule his work in the most productive and economical manner while providing the necessary stakeout, inspection and documentation."

The activity work schedule, which allows the project engineer to make long-term plans, is divided into six two-week periods and indicates the time frame for each activity as well as the estimated percentage of the planned quantity that will be completed for each two-week period. This schedule is updated every four weeks.

The biweekly schedule is a more detailed prediction of the contractor's proposed work. It shows the station limits for each contractor work activity, the predicted amount of persons to be used, and the estimated pay quantity. The project engineer and the contractor jointly complete the form every two weeks. If the contractor decides to change the plans after the schedule is prepared (because of weather conditions, contractor error, etc.), the project engineer has the right to delay the change for three days if people can not be rescheduled accordingly.

Department Construction Scheduling

As can be seen in Figure 19, the system develops a two-week schedule of manpower needs. The project engineer uses the information obtained from the contractor's biweekly schedule, along with the work accomplishment planning units (see Table 11), to prepare manually a specific short-term manpower schedule. The same procedure can be used with the contractor's 12-week activity work schedule to develop a long-range manpower schedule similar to the annual staffing plan shown in Figure 14.

As noted earlier in this chapter, the scheduling phase of the Michigan system did not work because it was difficult to obtain an accurate prediction of the contractor's operations. The Arkansas system has a contractual requirement for a 2-week and a 12-week contractor schedule in an attempt to alleviate this problem.

LOUISIANA'S MANPOWER MANAGEMENT SYSTEM

The basic manpower management system that is used by the Louisiana Department of Transportation was discussed in Chapter Two (2, 8). The system components of staffing, scheduling, and controlling in Louisiana are fairly similar to those in Michigan and Arkansas.

In the Louisiana system, contractors are required to submit two-week, four-week, and total-project schedules. As a result of this input and the actual performance on the project, project engineers must prepare (a) a detailed manpower schedule for each project and a summary of manpower needs for all projects assigned to them, (b) an update of the work schedule bar chart originally prepared by headquarters, (c) a project status report that compares planned and actual manpower use for each project and a summary for all projects assigned to them, and (d) a project office manpower schedule report that summarizes, by function, the manpower needs for all projects in a project engineer's office.

When project engineers develop their construction-personnel schedule, they must list both primary and secondary assignments. Some project engineers also use third-level assignments. These nearly always involve office work, and they are posted in the field offices. If both primary and secondary assignments fail, personnel still know the work that is expected of them.

Project engineers also are being encouraged to schedule on a multiple-project basis, because the day-to-day variations in contractor operations can be reduced when a work base larger than one project is used.

WASHINGTON'S MMIS

As noted in Chapter Three, the automated Manpower Management and Information System (MMIS) is used in Washington to forecast manpower requirements and schedule project progress (5, 17, 18). However, the need for day-to-day scheduling of manpower to accomplish the work and the need for the control of manpower to assure that the work is being accomplished in the most efficient manner are not met by the automated MMIS.

CHAPTER FIVE

ANALYSIS OF EXISTING PRACTICES

THE HIGHWAY CONSTRUCTION ENVIRONMENT

Effective day-to-day management of highway construction projects in most state highway agencies presents a formidable challenge for management personnel. The current environment has created a number of problem areas for these managers. In addition, a number of significant changes that have necessitated modifications of current practice have occurred in the last few years. Some of these are mentioned in the following paragraphs so that some insight might be gained into present-day conditions.

Management Concerns

One of the most important areas of management concern is the uncertainty of predicting the construction program work schedule. It was noted in a number of states that it is difficult to predict accurately which projects will be let and which will be delayed. This uncertainty makes it difficult to determine what average staff level should be maintained, thus making it essential to have multiqualified people who can adapt to changing circumstances on short notice.

Perhaps the most difficult scheduling problem faced by management is the need to adjust work assignments because of a change in the contractor's work schedule. The shift to or from overtime, the use of multiple work shifts, and the initiation or completion of concurrent activities create a dynamic environment that challenges the flexibility of even the best scheduling system.

Another problem faced by many state highway agencies is the changing public attitude toward highway programs. In some states there has been legislative pressure on agencies to do more than simply spend all the dollars in the budget; agencies must now show where and how the dollars were spent and the results that were obtained. Pressures arising from environmental concerns have also intensified, causing a serious impact on the project-letting schedule and subsequently the workload within districts. Much of the planning and scheduling effort may be nullified when a project is thwarted by the judicial system. Likewise, much planning and scheduling is invalidated when one or more projects are cleared for construction by a single court decision.

Changing Conditions

The number and types of projects under construction have a dramatic effect on construction manpower management. Nearly all states have experienced a reduction of the total miles under construction. With this has come a corresponding shift from a limited number of major Interstate projects representing total highway construction (i.e., the complete spectrum from clearing and grubbing to finished pavement) to many smaller rehabilitation and maintenance projects, such as overlays, bridge deck repair, guardrail installation, and safety work. This shift presents an entirely different staffing and scheduling situation. Because of the number and variety of projects being administered, all state agencies are experiencing a demand for multiqualified personnel rather than specialists.

The emphasis on multiqualification has made training another important management concern. To meet this challenge a number of states have instituted either formal or self-study training programs (see Chapter Six).

Some states have faced a reduction in real dollars because of inflation, even though their budgets have remained steady or have increased. This fact, coupled with the fact that fewer miles of road are under construction because of a shift in program emphasis, has led to freezes on salaries and new hiring and, in some cases, layoffs of personnel. In Michigan, upper-level management has decided to use temporary employees as the means for achieving staff scheduling flexibility.

Technological Changes

More sophisticated equipment now is being used by both the contractor and the state highway agency. The use of automated and electronic equipment has had a significant effect on construction contract staffing requirements. For example, inspection equipment such as the nuclear density gauge has reduced drastically the time required for soil-density tests, therefore increasing the number of tests that can be performed by an inspector. State highway agencies' extensive use of computers has further increased the productive capability of employees. Laser surveying equipment and electronic distance-measuring devices have reduced surveying time, but in a number of states the use of this improved surveying equipment generally has been limited to centralized or floating parties. Also in the area of surveying, photogrammetry and aerial photography have increased productive capacity greatly. Automated construction equipment, such as the autograder, also has reduced construction time and staffing requirements.

OPPORTUNITIES FOR CHANGE

The highway construction situation is definitely dynamic, and it is with this in mind that the area of changes that can be made to existing practices is presented here. The discussion is by no means comprehensive, because there are 50 state highway agencies. The examples given here, however, should provide some guidance to those states intent on performing their construction engineering and contract administration in the most effective and efficient manner.

Organizational Practices

The efficiency of a state highway agency is often a function of the size of the organization. In addition, the various equipment and personnel policies and the effectiveness of the communication system within the agency play a significant role in the success of a well-managed construction program.

The organizational chart for a typical highway agency is shown in Figures 20 and 21. As noted in Chapter Two, most state highway agencies are set up on a district basis. The basic features shown in Figures 20 and 21 are characteristic of centralized and decentralized organizations. The construction division typically falls under the control of an engineer for operations, who may be responsible for contract administration, estimation, and program coordination. Guidance also is provided to the district offices. The district offices are responsible for the detailed planning and scheduling, inspecting, and testing.

Communications

The effectiveness of a state highway agency depends at least partly on the establishment and maintenance of good lines of communication within the organization. Arkansas (22), as part of its management study, examined the interdivisional and intradivisional communication situation to identify areas where improvements could be made.

With regard to interdivisional communication, it was found that the construction division, in the course of performing its appointed duties, does not operate in isolation. It continually exchanges advice and inputs with all the divisions of the department. Effective interaction and communication with other divisions is vital.

In Arkansas, communication and coordination between the construction division and the other divisions are accomplished by formal means, such as committee meetings and correspondence. It was noted that these modes of communication should be used as frequently and effectively as possible. The divisions responsible for planning would benefit greatly from incorporating construction division inputs into their program planning. The construction division has a statewide perspective on construction activities, which benefits the program planning process in both the planning and programming divisions. Similarly, the construction division can benefit greatly from improved communication with these two divisions. The construction engineer has only limited information about jobs to be let in the next three months and even less information about future probable construction.

If informal communication links among divisions are strong, there may be almost no need for formal arrangements. These communication ties are enhanced if only a few parties (division heads) are involved. In Arkansas it was found that these ties were further strengthened because most of the division heads had been with the department for a substantial period of time, had common educational and cultural backgrounds, and knew one another quite well. Also, it was noted that communications are improved if division heads are located in the same building, because the probability for chance contact is greater. During such encounters a division head may discuss an item of concern that is not a major problem at the time and thus does not warrant a phone call or special meeting; this discussion decreases the probability that the concern will become a major problem. Similarly, if parties are in the same building, they do not feel hesitant to call another division or arrange a meeting with another division when they have an item of potential concern, whereas they might hesitate to do so when the more laborious effort of obtaining a WATS line or driving to another location is involved.

With regard to intradivisional communication, it is

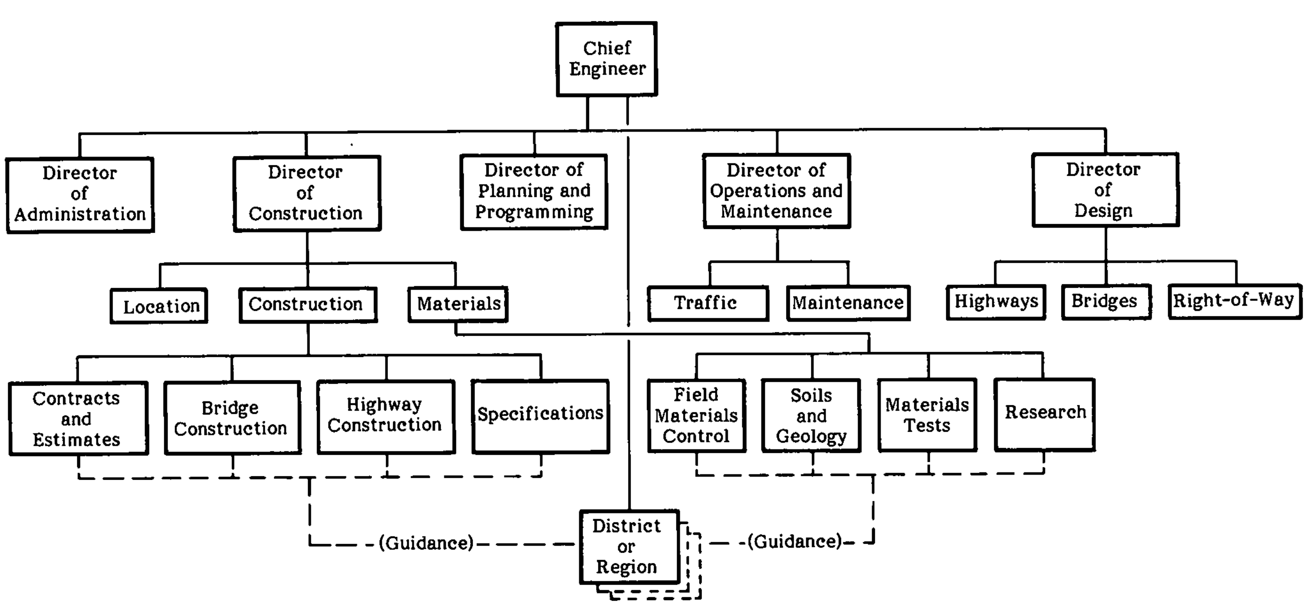


Figure 20. Typical headquarters-level organization chart.

equally important that proper communication exist within the construction division itself. This is often not easy in a decentralized construction operation, where there are numerous district centers of operations. However, structures and procedures can be designed to facilitate adequate communication and maximize departmental efficiency.

One problem area that exists in many states is the limited transfer of information among districts. The districts operate in relative isolation from one another. Each district engineer manages a district in the manner best suited to his or her personality and to the district's personnel, characteristics, and needs. Although this is a desirable feature of the district organizational concept, this independence should not preclude either the broader exchange of information among districts or a district's adoption of work methods and management techniques that have worked well in other districts.

For example, the Arkansas study found that a very limited number of districts employed aerial photogrammetric techniques, made available by the surveying division, for cross sections used in computing earthwork quantities. However, the districts that did use the services employed them frequently. A similar situation existed with regard to the use of the traffic division in the design of temporary traffic-flow patterns through construction areas. Similarly, the extent and type of alternate work assignments given to district personnel during the off-season varied greatly among districts. Also, management tools (scheduling techniques, data analysis, and cost-benefit analysis) were used to widely varying degrees by different districts.

Some of these inconsistencies were attributed to the preferences of individual district engineers and to unique conditions in each district. However, many were due to district engineers' lack of knowledge about the availability and value of these services and tools. It was felt that improved communication among districts (and among districts and divisions) was needed to facilitate the more efficient selection and use of work methods and management tools.

One of the conclusions of the Arkansas study was that the present organizational structure was appropriate for the task at hand. The decentralized structure, with strong local authority (the district engineer), was considered important to the success of the highway program, because district needs could be best assessed, district priorities best established, community inputs best realized, and control of work best directed with this type of arrangement. The results of the communication study undoubtedly will assist in making this structure more effective in the future.

Duties and Responsibilities

Whether there is decentralized or strong central control, it is important that the duties and responsibilities of each position be well defined. This helps prevent overlapping of responsibilities and allows for more efficient working conditions. Most states have civil service classifications that provide job descriptions and skill requirements. In addition, functional descriptions of positions, along with duties and responsibilities, frequently are included in construction manuals. It is important that all personnel know their duties and responsibilities so that maximum efficiency can be

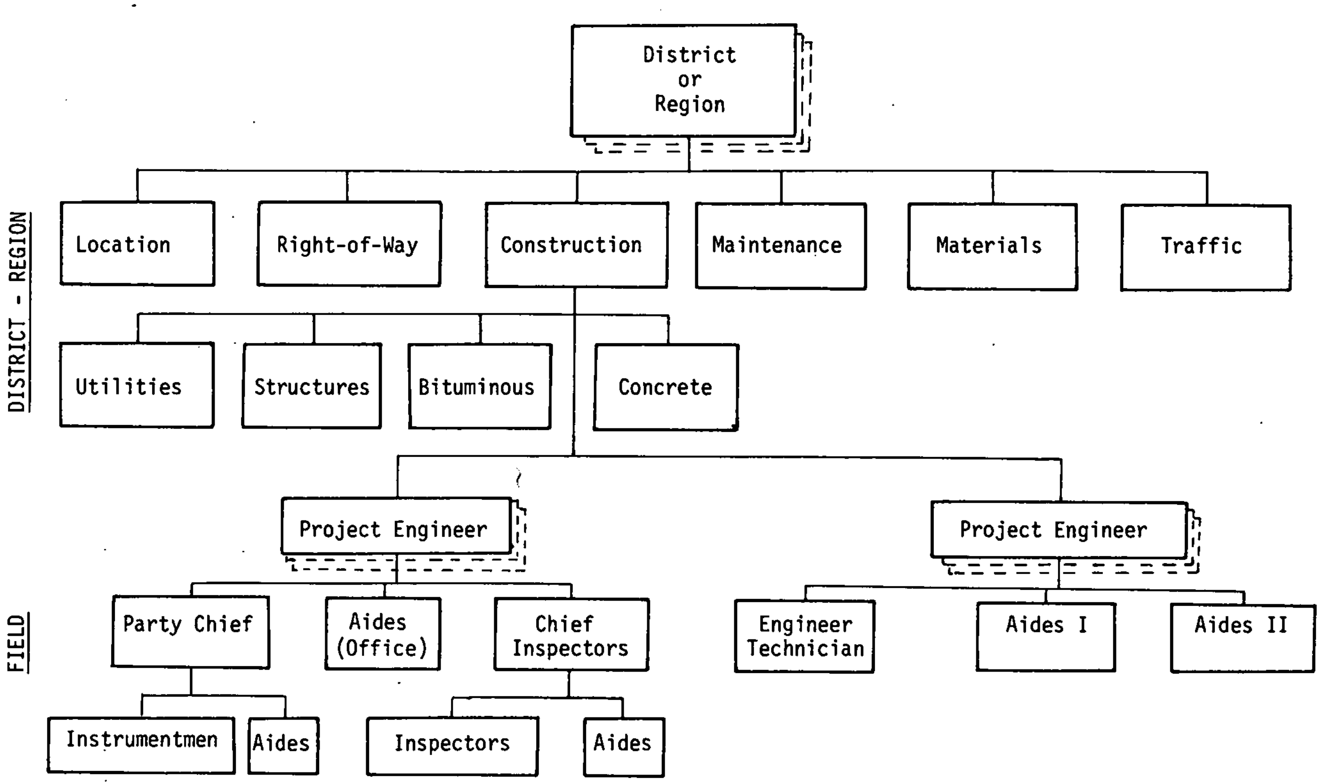


Figure 21. Typical district- and field-level organization chart.

obtained with a minimum of conflict. It appears that a number of states have some form of statement of responsibilities and duties. Figure 22 shows a statement of job responsibility for some of the positions in the Michigan highway agency (23); a logical starting point for improving the organizational aspects of construction manpower management might involve the development of statements such as those shown in this figure.

Only the headquarters and district levels are addressed in Figure 22. A more detailed explanation of some of the job responsibilities at the project level is covered in Chapter Six.

Construction Engineering Practices

A program that is geared toward making improvements in existing construction methods and practices offers the possibility of relieving some of the problems cited at the beginning of this chapter by indicating how the work can be done more efficiently with the available manpower.

A work improvement program can be divided into two levels of application. The primary level involves a macroanalysis of current practices to identify the obvious improvements that will increase productivity and efficiency. One can critically analyze existing practices by asking six basic questions about them (24). What is their purpose? Why are they necessary? When is the best time to do them? What is the best way to do them? Where is the best place to do them? Who is best qualified to do them? This type of analysis can lead to such improvements as replacing one method with another and establishing revised crew sizes or equipment complements.

The secondary level, the microanalysis approach, can be as effective as macroanalysis. This approach (24), which often involves time-and-motion studies, work-sampling techniques, time-lapse photography, crew balance charts, and process charts, can be applied either in conjunction with or after the completion of the obvious improvements. Because very few state highway agencies have established a need for microanalysis, it is not discussed in this chapter. This secondary level should not be ignored completely, however, because it does represent a second logical step in methods improvement.

Definition of Construction Engineering

As noted in Chapter Three, studies in Michigan (14), Louisiana (8), and other states have shown that all highway agency construction engineering activities can be classified into three major categories: surveying, inspection, and project office work. Studies in these states also have indicated that, although many potential activities exist, approximately 80 percent of the work effort is devoted to between 30 and 40 activities and that it is therefore appropriate to concentrate work improvement studies on these key activities.

Although there is great potential for improving productivity through work improvement methods, experience has shown that no single item dramatically reduces the man-hours required. Rather, many seemingly insignificant factors, when combined, result in measurable savings for a state highway agency. A number of these areas of potential improvement have been identified in the Michigan, Louisiana, and Arkansas management studies, and other states have made similar improvements. The more obvious improvements are discussed in the following paragraphs.

Surveying

Surveying is an essential activity on all highway construction projects. The uniqueness of each highway agency, however, causes large variations in surveying manpower requirements. The first basic work improvement question that might be asked, then, is: "Which organization should do the surveying work?"

Most states meet all their surveying needs with in-house personnel and thus need to maintain a large number of qualified survey parties. West Virginia, however, allows contractors to do much of their own surveying. On some larger contracts, surveying may be included as a separate bid item. Currently West Virginia stakes out the centerline and right-of-way and surveys final cross sections. All other surveying functions are the responsibility of the contractor. There is even some thought of allowing the contractor's survey party to do the final cross sections with a representative of the highway department present. Both approaches have advantages and disadvantages, and the trade-offs must be recognized clearly.

By doing all surveying in-house, a state highway agency has more control over the work and thus more assurance that the job is done properly. For this peace of mind, however, the state must pay the price for the higher manpower requirements. Also, in-house surveying means that the contractor does not have to bear the entire burden of responsibility for surveying. The number of survey parties required is a function of the type of work activity being performed by the contractor, and it may be argued that the most cost-effective way to meet the demand for fluctuating manpower requirements is with a state highway agency surveying force. In addition, it may not be efficient for the contractor to have a survey party on small projects, because the requirements for surveying work may be minimal and intermittent. Contractors who bid on these smaller projects or who work infrequently for the state highway agency may be unfamiliar with the required procedures or staffing methods, sometimes making it necessary for the state to pay a premium price for surveying services it could have provided more effectively itself.

If the state highway agency allows contractors to perform their own surveying, the state must rely heavily on the contractors' competence. With qualified contractors and adequate state supervision, very little is given up for the reduced staffing requirements that are gained. An added advantage is the reduced chance that a contractor work activity will be delayed because of the unavailability of surveying personnel.

An obvious compromise is for the highway agency to do all the surveying when the manpower resources are available and to allow contractors to do some of their own surveying when the state's manpower is insufficient.

This question of who should do the surveying is only one of the possible work improvement areas that can be considered. Following is a discussion of some of the other survey improvements that have been investigated.

Crew Sizes. Many state highway agencies have found that there are optimum crew sizes for surveying as well as for such maintenance activities as asphalt patching, leveling and sealing, mowing, ditch-cleaning, and snow and ice control. Data collected in Michigan showed that an experienced three-person survey crew was superior to both an inexperienced and an experienced four-person crew (14). It was found that when one employee was added to a three-person crew the quantity of work done per man-hour dropped by as much as one-third, even though the same amount of total work might be done.

CONSTRUCTION DIVISION

Administrative Section (Lansing)	Authority and Responsibility
Engineer of Construction	Authority for directing and controlling division functions in administering statewide highway construction and related activities on trunk lines and other Federal-aided systems. Reviews and approves plans, proposals and specification application or interpretation. Coordinate construction activity with activities of other divisions and other agencies. Consider and/or resolve construction-oriented disputes or claims. Exercise control of division budget. Establish and revise operating procedures. Assign subordinate supervisory personnel. Approves construction-oriented authorizations and pay documents. Authorize in-service training. Report to Deputy Director – Highways through the Assistant Deputy Director.
Construction Engineer Region I	Administer highway construction and related activities in 6 Districts (3, 4, 5, 6, 7 and 8) of the State. Assist the Engineer of Construction in directing and controlling division functions. Authorize progress and final payments to contractors and recommend changes in and extras to contracts. Determine construction progress schedules. Staff Engineers assist the Construction Engineer in handling administrative duties for the region and specialize in grading, drainage, finishing or structures for the region.
Construction Engineer Region II	Administer highway construction and related activities in 3 Districts (1, 2 and Metro) of the State. Assist the Engineer of Construction in directing and controlling divisional functions. Authorize progress and final payments to contractors and recommended changes in and extras to contracts. Determine construction progress schedules. Staff Engineers assist the Construction Engineer in handling administrative duties for the region and specialize in grading, drainage, finishing or structures for the region.
Construction Staff Engineers	Serve as assistants to the Engineer of Construction specializing in a specific type(s) of construction. Insure that plans and specifications are uniformly adhered to throughout the state. Act for Engineer of Construction, recommending or authorizing contract changes or extras, in a particular specialty.
	Automation and Attorney General Liaison. Supervise inspection of automatic controls and printout equipment on concrete plants, asphalt plants, platform scales and surge bin scales and interpret applicable specifications. Prepare correspondence with Attorney General's office regarding extra work authorizations. Coordinate Construction Division data processing applications.
	Bituminous. Specializes in bituminous equipment, asphalt mix and pavement construction, specifications and interpretation thereof.
	Concrete. Specializes in concrete mix, pavement, bridge deck, curb and gutter, sidewalk, etc., construction specifications and interpretations thereof.
	Gravel and Seal. Specializes in aggregate production methods and materials, aggregate base construction and seal coat construction; evaluates scales used for proportioning and determining of pay quantities.
	Operations Review. Provide general supervision over documentation of the quality and quantity of construction contracts. Assure that state and federal regulations, contract forms and documentation procedures are in compliance. Expedites recovery of funds and close out of contracts. Supervise Construction Manual revisions.
	Management Systems. In cooperation with consultant, implement construction manpower management system. Review and update construction work methods.
Office Engineer	Process engineering and technical data used to support changes and extras to contracts. Prepare technical correspondence and reports. Approve some pay documents.
Personnel and Office Manager	Determine field personnel needs, transfers between districts and new hiring. Prepare and control Division budget. Control equipment and supply purchasing and distribution. Approve office and equipment rentals. Review personnel time records and subsistence payments. Supervise clerical and file room personnel. Approve some pay vouchers. Liaison with Department Personnel Division.

TYPICAL DISTRICT ORGANIZATION

Organizational Unit or Title	Authority and Responsibility
Senior District Engineer	Authority for coordinating major programs within the District involving planning, engineering, construction, traffic and maintenance of the highway system in the eleven county west Michigan area. Makes recommenda-

Figure 22. Statement of job responsibilities (Michigan) (23).

tions on highway needs and acts as liaison between the District and all divisions in the Lansing office. Performs other related work involving public relations contacts with the general public and local governmental units. Responsible for maximum utilization of all District personnel and for the attendance, general conduct and decorum of all employees in the District. Exercises control of the budget. Performs additional work as required by the Highway Commission, Highway Director and Deputy Director – Highways.

Office Manager	Handles District personnel hiring and needs, approves and controls equipment and supply requests. Supervises clerical personnel, janitors, maintenance of files, and the District radio operation.
Finance Account Executive	Responsible for maintaining Stores Control of State-owned materials in eleven counties and four District maintenance units. Represent the Bureau of Finance in the District to give advice in financial matters and aid in the processing of financial documents. Responsible to the District Engineer for District administration and inter-division coordination as it relates to Finance. Responsible directly to the Bureau of Finance in Lansing for technical and financial policy matters.
Utilities-Permits Engineer	Authority for checking and processing permit applications for right of way use and occupancy, private utility facilities relocation or adjustments, and implementation of the Billboard Control Program in the District. Exercises control of the budget. Responsible to the District Engineer for District administration and interdivision coordination as it relates to utilities-permits. Responsible directly to the Maintenance Division in Lansing for technical and utilities-permits policy matters.
District Construction Engineer	Authority for providing technical and supervisory direction to construction operations in the district. Assigns construction personnel within the district. Recommends changes and extras necessary on existing construction projects. Exercises control of the budget. Reviews preliminary plans and progress schedules. Conducts preconstruction meetings. Coordinates utility relocations, reviews contractors' EEO programs and is responsible for coordination of construction safety. Investigates complaints and disputed claims and recommends solutions. Conducts some in-service training. Responsible to the district engineer for district administration and interdivision coordination as it relates to construction. Responsible directly to the Construction Division in Lansing for technical and construction policy matters.
Assistant or Assistant to District Construction Engineer	Assists district construction engineer in performing the above functions. Acts for the district construction engineer in his absence. May also perform office engineer functions. Process engineering and technical data used to support extras and changes to construction contracts. Prepare technical correspondence and reports for district construction engineer. Perform final review of project records to support quantity and quality of of work. Train State and County personnel in proper documentation procedures.
District Office Engineer	Conducts and/or supervises final reviews of project records. Trains State and County personnel in documentation procedures. Reviews data for change and extra authorizations. Assists in conducting preconstruction meetings. Assists above supervisors in their duties.
Project Engineer and Crews	Sufficient project engineers and crews are assigned as workload demands.
Maintenance Engineer	Authority for the control of maintenance of trunk lines within the district. Exercises control of budget, quality, quantity, and level of service of maintenance work. Directs and coordinates the work of contract agencies and State maintenance forces within the district. Responsible to the district engineer for district administration and interdivision coordination as it relates to maintenance. Responsible directly to the Maintenance Division in Lansing for technical and maintenance policy matters.
Testing and Research Engineer	Authority for the testing and investigation of soils necessary to supply highway design and construction information. Tests and investigates aggregates and provides for testing and control of materials for construction projects. Serves as consultant to the project engineer on soils problems during construction. Exercises control of the budget. Responsible to the district engineer for district administration and interdivision coordination as it relates to testing and research. Responsible directly to the Testing and Research Division in Lansing for technical and testing and research policy matters.
Right of Way Manager	Authority for property acquisition, relocation assistance, property management and appraisal activities, along with excess property disposal within the district. Exercises control of the budget. Responsible to the district engineer for district administration and interdivision coordination as it relates to right of way. Responsible directly to the Right of Way Division in Lansing for technical and right of way policy matters.
Traffic and Safety Engineer	Authority for the control of traffic engineering, signs, signals and accident studies within the district. Exercises control of the budget. Works with local governmental units on traffic matters. Responsible to the district engineer for district administration and interdivision coordination as it relates to traffic and safety. Responsible directly to the Traffic and Safety Division in Lansing for technical and traffic policy matters.

Similar results were reported in Louisiana, where it was concluded that there are probably instances in which a four- or five-person crew is slightly more productive than a three-person crew but that high levels of productivity could be achieved by standardizing the survey crew at three people (8).

Staking Services. Louisiana discovered another inconsistency with regard to surveying: levels of surveying services being provided to contractors on different projects varied widely (8). It was recommended that the services and number of stakes provided be standardized statewide.

Slope-Staking and Grade Book. Field personnel frequently generate slope-stake information that requires many calculations and considerable time to develop and record. This information usually is generated during the project design phase also. This fact was recognized in Louisiana, and steps are being taken to modify the computer output reports so that this design information can be supplied directly to construction field personnel (8).

Inspection

A basic work improvement question that a state highway agency may ask with regard to the inspection of construction materials is: "What type of material specification will be employed?" The traditional approach, which is used in most states, requires a large contingent of inspectors. This approach assumes that the state highway agency is responsible for all inspection and control of the process that produces the material, whether it is during the production, delivery, or placement phase.

The alternative to this approach is the adoption of statistically based end-result specifications. *NCHRP Synthesis 38*, which covers these specifications in detail, indicates that 33 states have tried, are planning to try, or are using some form of statistical specification (25).

When such programs are implemented, the highway agency's role in inspection and testing should diminish greatly. There is tremendous potential for reducing manpower requirements and reassignments to other activities, because a statistical specification puts the highway agency inspector at both the plant and the job site in an "acceptance-testing" capacity. Also, it puts the responsibility for the extensive, day-to-day "process-control" testing squarely on the shoulders of the material supplier at the plant and the contractor at the job site.

Statistically based end-result specifications should, if properly implemented, provide considerable savings in construction engineering costs, even though inspectors that are more highly qualified may be required.

There is some disagreement among state highway agencies about the merit of statistically based specifications as well as about their potential for providing savings, because very few studies have compared the quality obtained by these specifications with that obtained by conventional inspection practices. Also, statistical specifications are too new to have caused enough of a shift of inspection personnel from highway agencies to contractors and material suppliers to indicate a reduction of personnel. The theoretical savings will become real only as more experience is obtained. Statistically based specifications do, however, present an attractive work improvement alternative.

Following is a discussion of other work improvement areas associated with inspection.

Intermittent (or Spot) Inspection. Many state highway agencies have recognized the manpower waste that occurs when continuous inspection is performed. One example is the inspection of reinforcement. Competent inspectors should be able to evaluate the acceptability of a mat of reinforcement after it is completed with the same level of assurance as if they had watched each bar tied in place. In Michigan it was noted that a spot inspection program of this type has a potential savings of $200,000 per year (26).

In Virginia a construction division memorandum formalized this procedure (27). The following excerpt from the memorandum explains the steps involved.

"The above recommendation, which has received FHWA and administrative approval, is aimed at reducing the number of inspectors to the minimum necessary to assure the Department that our construction work is being performed in reasonably close conformity with the plans and specifications. The stated recommendation is to be implemented as rapidly as possible.

"I suggest the following procedure be used to implement the new inspection policy.

"(a) The project engineer or head inspector, with the assistance of a member of the district or residency staff, and after a review of the Contractor's work schedule, is to prepare an inspection activity priority list for each item listed on the proposal. This list should be influenced to a large extent by the number and experience of the inspectors presently assigned to the project or available for assignment to the project.

"(b) Utilizing whatever assistance is required, the head project inspector is to develop a schedule of critical stages of activity at which time an inspection must be performed prior to further advancement of the work. This schedule is to be communicated, preferably in writing, to the contractor's superintendent and job foreman before the work is begun.

"(c) Inspectors who have been used predominantly in specialized areas are to be assigned to various construction activities during the upcoming construction season in order to broaden their experience in the highway construction field."

An example for the construction of a box culvert is cited. The critical operations might be:

1. Determination of excavation quantities and inspection of the foundation.
2. Inspection of pile-driving operations.
3. Checking of grades established for form work.
4. Checking of form dimensions and condition.
5. Inspection of steel placement.
6. Testing of concrete and viewing of concrete placement operations.
7. Inspection of the application of the cure and of the temperature control during the initial curing period.
8. Inspection of the product after stripping of forms.
9. Inspection of backfill operations.

As the memorandum notes:

"It can be seen that all of these operations, with the exceptions of items 2 and 6, lend themselves to spot or random visits to the site. Operations 2 and 6 require continuous inspection for the duration of those activities. It is also apparent that the inspector must have a clear understanding with the foreman in charge of the box culvert construction that work is not to proceed to the next operation until the preceding operation has been checked by the inspector.

"It will be recognized that stage inspection places the burden of quality control squarely upon the shoulders of the contractor; however, it will also place a burden upon our inspectors to perform prompt and competent evaluations of each stage of construction."

Excessive Sampling. It has been found that construction inspection crews frequently take too many samples and run too many tests. In some cases this can be traced to phrases in the inspection or testing procedures that instruct the employee to take a certain number of tests or as many as possible. In Michigan, spot checks showed that in many cases excessive sampling and testing prevailed and that 100 to 150 percent over requirements was common (14). *Excessive testing not only reduces field productivity, it also increases the workload of the project engineering office, the material-testing laboratories, the project auditors, and so on.* In Michigan, steps are being taken to eliminate these excesses.

Density Tests. Many state highway agencies have reported improved productivity through the use of nuclear density gauges instead of such time-consuming methods as the sand-cone technique. Michigan initiated a program of certifying certain density inspectors, and the reduced record-checking of these inspectors is expected to save $9,800 per year (26).

Acceptance of Certified Scale Checks. Also in Michigan, a savings of $4,200 per year is expected to be achieved by the acceptance of Department of Agriculture "scale checks" of private scales used by the highway department (26).

Project Office Work

A number of state highway agencies also have investigated the improvement of current practices in the area of project office work. Following is a discussion of some of the areas that have a potential for improvement.

The Use of Plan Quantities for Contractor Payment. Traditionally, contractor payments for excavation and embankment have been based on the results of two cross section surveys, one conducted prior to construction and the other after the work was completed. In Michigan (26) and Louisiana (2) it was recognized that these steps required large amounts of manpower and money. It was felt that this duplication of effort was needless, because the original ground line and final grade information was provided on the plans. Both states have modified this approach to use plan (contract) quantities subject to adjustment for known changes and limited spot-checking of the completed project. A Michigan program designed to eliminate all recomputation efforts will lead to an annual savings of about $1,145,000 in manpower costs (26).

Partial Contractor Payments. In Louisiana the procedures used to prepare and document partial or progress payments to contractors were found to be very time-consuming (8). There was a duplication of records and computations, thus creating excessive paperwork. As the result of a work methods analysis, several recommendations and subsequent changes were made. These changes include (a) staggering the due dates of the payment estimates to level the workload, (b) making payments based on plan quantities, (c) making the project engineer responsible for determining the amount of partial payment and maintaining adequate documentation, and (d) reducing the amount of documentation required and thereby reducing the checking effort needed at the central office. Before these changes were made, the documentation required for partial payments was roughly equivalent to that required for final payments. In addition to these modifications, it was also recommended that the partial payment system be computerized and that it be designed to reject a payment request for any item that exceeded the plan quantities unless a change had been submitted.

Excessive Documentation. The Michigan study (26) pointed out that there was excessive reporting on concrete items. Much of the information was not serving any useful purpose, and many reports were being sent to people who rarely used them. Usually the needed information could be obtained with a call to the project office. Much of the duplication of information, reports, and data has been eliminated, at a potential savings of $120,000 annually.

Duplicated Documentation. In Louisiana it was found that inspection information was being recorded on a daily work report and then transcribed into a bound project diary (2). The daily work report was found to be unnecessary and was subsequently eliminated. Arkansas identified a number of reports that required numerous copies (22). Because ball-point pens could not produce legible copies if four or more sheets were included, these reports had to be typed, thus increasing the potential for error. The value of these extra copies was questioned, and in many cases the extras were eliminated.

CHAPTER SIX

PERSONNEL ADMINISTRATION

The need for improved construction manpower management may be recognized widely within a state highway agency; however, as reported in manpower management studies (4, 8, 14, 16), a sophisticated system of planning and scheduling is only a partial solution to the problem. Indeed, policies regarding personnel classification, training, temporary employees, off-season assignments, overtime, and travel play important roles in determining the success of the highway agency's efforts.

PERSONNEL CLASSIFICATION

Management has a number of uses for a properly administered classification plan. Such a plan provides the basic structure for dealing with personnel matters, particularly in recruitment, selection, and placement. It should permit pay policies to be considered in relation to the duties and responsibilities of positions. If the classification plan facilitates a job analysis, the results of this job analysis provide a basis for the assessment of training needs and training course development. Perhaps more important, however, a well-designed and well-maintained personnel classification plan provides an inventory of the state highway agency's available manpower resources. This knowledge is essential to effective manpower management.

Position Classification Approach

According to Bergstralh (28), the traditional approach used by most civil service agencies classifies employee positions on the basis of job descriptions. In other words, what is classified is the work that is to be done rather than the individual who is to do it. The underlying theory behind this approach is that each position is independent of the individual occupying the position. The individual employee is rewarded for having the ability to perform more difficult tasks without regard to his or her productivity rate. The integrity of the position classification plan—that is, the degree to which an existing class accurately represents work patterns, duties, and responsibilities of the individual employees within that class—may vary considerably.

This lack of consistency in classification, which was identified in the Arkansas manpower management research project (4, 16), influences the construction division in two major respects. First, because it usually lacks the structural basis of an equitable pay plan (which should normally be provided by a classification plan), it is virtually impossible to assure that similar work is compensated for by the same general level of pay. Second, the position structure does not delineate clearly the duties, responsibilities, and implied capabilities of the division's personnel, factors that are essential to effective manpower planning.

Another detrimental characteristic of the position classification system is that it encourages specialization. Typically, two career paths exist—one for surveyors and one for inspectors—and they do not meet until they reach the supervisory level.

For managerial control purposes, there is a need for titles that describe employee capabilities and responsibilities, and this need underlines the basic inadequacy of most existing classification plans. In an attempt to solve this problem, several states have redesigned their classification systems according to a functional approach.

Employee Classification (or Functional) Approach

In any manpower management system, workloads must be converted into manpower needs. In the process, manpower performance capabilities, as represented by both productivity and versatility, become a major component. These features are not considered in the position classification approach, because the work to be done is classified. An employee classification system categorizes individuals according to the work they perform and the contribution they make to the state highway agency's efforts in terms of versatility and productivity.

For example, an analysis of the work done by most construction inspection personnel indicates that few single tasks are particularly difficult (28). Learning to run slump tests is about as easy as learning to inspect pipe placements. The same situation is true for many surveying activities and office functions. The employee who can complete a wide variety of these tasks is worth much more to a highway agency than is the individual who can perform only a few of them. The productivity of the total force is increased if such an individual is employed, because standby time is reduced.

Michigan uses an employee classification system that bases classification on both performance difficulty and performance variety (14, 28, 29). Recognition is given to the fact that it takes a great deal more time and effort to master a series of tasks than it does to master a few tasks, even when the tasks vary only slightly in difficulty.

Michigan's Personnel Classification System

In Michigan, personnel classification is based on two major factors: employee ability and task difficulty.

Employee Ability

Capabilities required for a task must be identified and classified. Michigan's process of identifying performance requirements led to the classification of 33 activity statements. Each then was analyzed so that a task-by-task description of the work required for that activity could be developed. The analysis identified 99 tasks, or work elements. The tasks were then analyzed, and an inventory was compiled of the knowledge and abilities required to perform all construction surveys, inspections, and documentation. This inventory was set forth in a series of 78 ability, or performance, statements, which were cross-referenced to the tasks. Figure 23 shows the ability statement for bituminous paving inspection (14).

The importance of the ability statement is twofold. First, it ensures that the project engineer has access to the performance requirements for each work assignment. Second, it provides the employee with a detailed description of the abilities required for promotion.

Task Difficulty

An analysis of the 99 tasks revealed that they could be categorized into four definable levels of difficulty: basic, intermediate, journeyman, and senior. Examples of the distribution are shown in Figure 24 (14). The analysis of the tasks revealed the following significant points:

1. Tasks that can be mastered quickly, in half a day or so with effective training materials, were found in all four major work categories: surveying, road inspection, bridge inspection, and office engineering.
2. Instrumentman tasks, often lumped into one group, readily break down into different levels, indicating that inspectors can be trained to do much of the work that survey crews are called back to do.
3. Office tasks range from the basic to the senior level of difficulty, permitting greatly increased in-season shifts between office and field assignments for improved manpower use.
4. Experience on any task eases the training problems on the next task, regardless of shifts among specialties.

Basis for New Classification Plan

The new classification plan consists of five classes (14). Advancement to a higher class is based on the accumulation of abilities on a task-by-task basis. Figure 25 (14) shows the minimum qualifications and requirements for promotion to Transportation Construction Technician III. This particular class is the journeyman level, but the individual may be required to perform work requiring basic and intermediate skills. As can be seen, the employee must be able to perform certain essential

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.

Figure 23. Michigan's bituminous paving inspection ability statement (14).

key tasks. The non-key tasks are divided into inspection, survey, and office activities. The employee must demonstrate proficiency in each area. Considerable flexibility is provided, however, inasmuch as the individual has a choice of which areas to pursue. Promotions to Technicians II and III can be made as rapidly as individuals become qualified, although advancements to Technicians IV or V can be made only when positions become available.

Changes in Objectives

As a result of the implementation of the manpower management system, the Michigan Department of State Highways and Transportation has revised its staffing objectives, as shown in Figure 26. The pyramid in the figure represents the traditional concept, in which the number of employees in each classification decreases as status (reflected by task difficulty, responsibility, and salary) increases. The pentagon represents the department's revised concept. The Transportation Construction Technician III (journeyman level) is recognized as the key classification position. The larger the percentage of the total force that can be advanced to that classification, within limits, the smaller the total force can be. This is because fewer, more skilled employees usually are more productive than a larger number of unskilled employees. Therefore, Technicians III should outnumber Technicians I and II.

Under the new plan, employees rarely work outside their classifications. They can, however, 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. An individual's classification is based primarily on the percentage of all tasks that fall within the employee's capabilities, as distinguished from tasks included in a position description. This concept is shown in Figure 27.

Arkansas' Personnel Classification System

Several other state highway agencies have recognized the inconsistencies in their position classification plans as well as the difficulties associated with the effective administration and maintenance of those plans. Arkansas and Washington have taken the initial steps toward a revision of their classification systems by preparing an inventory of work activities and translating the tasks required into knowledge and ability statements.

In Arkansas (16) it has been recommended that the department's position classification plan be modified by the assignment of functional title descriptions rather than class title descriptions (see Table 14). The need for functional titles underlines the inadequacy of the current classification plan. The existing pay relationships suggest a wide variation in compensation for similar work, and there exists an overlapping of duties and responsibilities among existing classifications.

It is anticipated that logical clusters of classifications will be developed and that this inventory will serve as the basis for the assignment of personnel and manpower planning. It will also provide an informal structure of classifications that can be used for subsequent classifications and personnel decisions.

As can be seen from Figure 28, the knowledge and ability statements prepared in the Arkansas study (30) differ somewhat from Michigan's. For quick and easy reference, these statements list the tasks required to perform the work activity. These tasks are also keyed to the pilot reporting system, which is being used to record accomplishments. Knowledge, abilities, and skills required are also shown in the Arkansas statement.

TRAINING PRACTICES

In a comprehensive program of personnel management, training is an essential element. Increasing the level of requisite skills (including multiqualification) among employees can be expected to produce parallel increases in productivity, quality of work, and employee satisfaction.

The effectiveness of any training program depends largely on the support it gets from top-level management, and the training program should be coordinated at central headquarters to ensure that there is uniformity throughout the state. The trend toward multiqualified personnel increases the importance of the training program.

Most states have a formal in-service training program coordinated by a designated staff officer in charge of all division training activities. Training in most construction divisions has been delegated to the district level, where courses are scheduled at the discretion of the district engineer, usually during the off-season. It is

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

Figure 24. Michigan's ranking of task difficulty (14).

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.

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.

Figure 25. Excerpts from Michigan's qualifications and requirements for a Transportation Construction Technician III (14).

important that the division training officer do the coordinating, because the district engineer easily can get caught up in the day-to-day pressures of administering the projects and relegate training to a position of secondary importance.

As noted in the Arkansas study (15), the mere fact that training courses are offered, even though they may be beneficial and contain excellent technical content, does not ensure that the training program is well developed and well balanced. Such shortcomings as insufficient gradations in course content, infrequency of courses, and undefined organizational responsibility for training can hinder the training effort.

Selection of course participants usually is made by the employee's supervisor, the designated training officer, or the employee. Equal employee participation must be ensured so that the selection process will not be viewed as a reward mechanism.

To complement its manpower management system and employee classification system, Michigan is expanding its training program for all construction technicians (14). With assistance from FHWA, the department is conducting new and varied courses by using departmental and college facilities. The program is designed to provide training to seasonal as well as permanent employees. Seasonal employees are trained primarily through short courses. Personnel are assigned to training tasks by project supervisors in the same way they are assigned to work activities. Employees teach themselves the material, and they are subject to periodic checks on progress and performance. Permanent employees are expected to take essentially all the short courses, and advanced training for them is being contemplated. Under consideration are advanced workshops in decision-making, public relations, environmental consideration, safety factors, and project management.

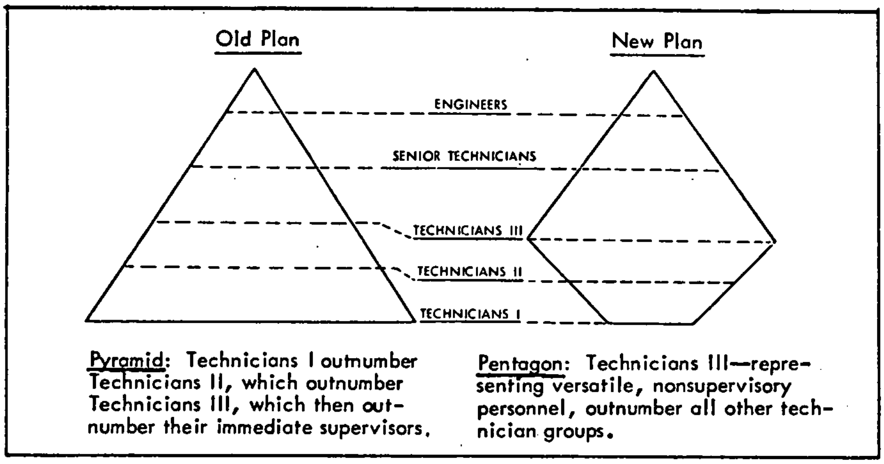


Figure 26. Michigan's modified staffing plan (14).

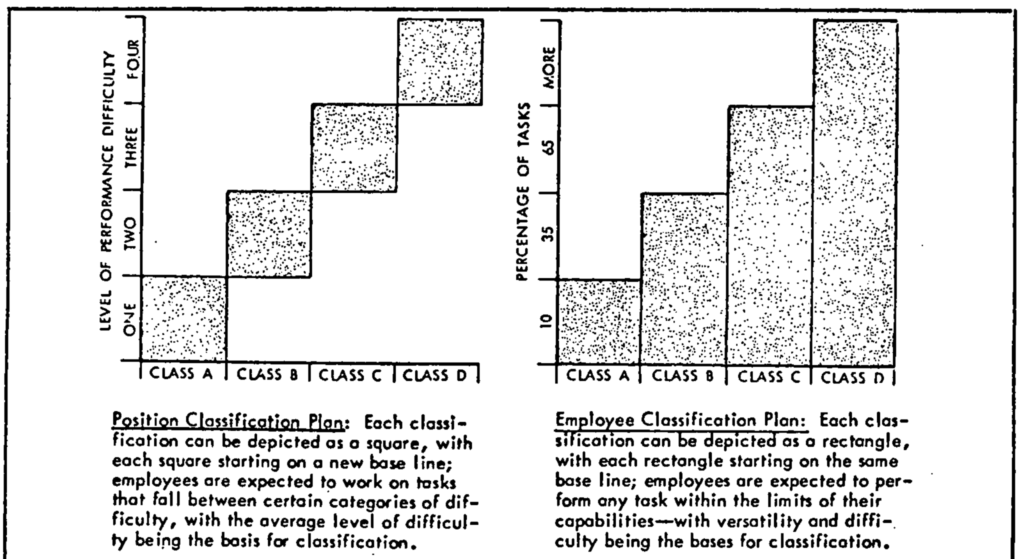


Figure 27. Comparison of two personnel classification plans (14).

TEMPORARY AND SEASONAL EMPLOYEES

The largest expenditure of man-hours usually occurs during the peak construction season—the summer months, in most states. In the more temperate climates the construction season may be all year, but this does not assure lesser fluctuations in workloads; with unpredictable letting schedules and budget fluctuations, workload peaks and valleys occur even in temperate climates.

The manner in which states choose to meet these peak manpower demands varies considerably. California, for instance, is unique in that it has two widely different geographical regions. The temperate southern region has a year-round construction season, whereas the northern region has a considerably shorter one. This situation allows California to meet peak demands with in-house personnel by lending or transferring personnel as needed. Pennsylvania's policy, on the other hand, is to not transfer or lend personnel between districts. Also, the use of temporary help is very limited in Pennsylvania, so extensive off-season reassignments must be made. Most states, however, depend on seasonal employment to supplement the work force.

Unfortunately, hiring seasonal employees does not always produce the desired results. Indeed, critics argue that such employees do very little productive work because usually they work three months or less and have very little opportunity to develop many of the basic skills. The practice does, however, work quite well in some states, Michigan among them.

In 1973-74 the Michigan Department of State Highways and Transportation was confronted with a serious shortage of skilled manpower (29). Despite rising workloads, the department reduced the size of the staff through the conventional approaches of eliminating positions, redistributing work, and leaving vacated positions unfilled. In addition, the construction division converted many full-time positions into seasonal, or part-time, positions. Both trends can be seen in Figure 29.

After studying several alternatives, Michigan adopted a plan based on the following steps (29):

1. Continue to reduce the number of full-time field positions through attrition at a rate of 40 to 50 per year, until approximately 650 are left.
2. For each full-time position eliminated, provide a replacement by employing civil engineering students on a six-month cooperative work-study basis, whereby they would work during the construction season and attend school in the winter.
3. Continue to employ seasonal employees to augment the full-time work force and provide flexibility on a seasonal basis.
4. Expand a part-time intermittent-employee program to eliminate understaffing at peak work periods and to provide short-term flexibility.
5. Provide an improved classification, training, and certification program to upgrade all employees.
6. Increase assignments of full-time employees to alternate work assignments in other divisons during off-season periods.

Providing a seasonal employee with the skills necessary to replace the departed full-time employee was a problem. The expanded training program and the selection of regular seasonal employees helped somewhat, but the best solution was the development of a cooperative work-study program for civil engineering students. These students were found to be the most interested, capable, and trainable group. Furthermore, when they returned for several seasons, their skill levels became equivalent to those of the average full-time employee. During the 1976-77 fiscal year approximately 100 of the 230 temporary employees hired were participants in the cooperative work-study program, and indications are that the program has been very successful.

TABLE 14

FUNCTIONAL VERSUS CLASS TITLE DESCRIPTIONS PROPOSED IN ARKANSAS (16)

Functional Title	Class Title
Instrumentman	Engineering Aide IV, V
Engineering Helper II	Engineering Aide II, III
Engineering Helper I	Engineering Aide I, II
Senior Inspector	Engineering Aide IV, V, and Engineering Assistant I
Inspector	Engineering Aide II, III, IV

OFF-SEASON ASSIGNMENTS

Fluctuations in workloads create an additional problem during the off-season. When construction is progressing slowly or when winter weather causes projects to be shut down, the construction division is faced with the problem of overstaffing. For management, full employee use is advantageous for accountability purposes as well as for promotion of morale. Achieving full employment, however, requires considerable planning and coordination with other divisions within the state highway agency. The off-season opportunities fall into two categories: construction assignments and nonconstruction assignments.

Records and documents that do not get the proper attention during the busy construction season have to be brought up to date or completed. Project office winter assignments occupy a significant portion of the division's manpower reserves. Typical assignments include computing final estimates, drawing as-built plans, preparing authorizations, setting up field books for new projects, and checking plans and quantities. Some fieldwork also can be done, particularly in those states where a limited number of projects remain active throughout the off-season. Location and preliminary survey work also can be done.

Full employee use within the construction division during the off-season often is not possible, thus necessitating the reassignment of employees to nonconstruction activities. Reassignment to other divisions, however, usually is complicated by the fact that few, if any, other divisions experience peak workloads during the winter months. For the reassignment approach to work, the divisions that would use construction division personnel would have to plan their work schedules and budgets for a winter peak load. These divisions could therefore reduce their total year-round permanent work force. In some cases their personnel could be reassigned to construction during the summer. This policy requires changes and definite actions by the other divisons to solve what is sometimes regarded as a construction division problem.

Many capital-outlay jobs can be done by construction personnel, and many states take advantage of these opportunities to reassign personnel to the maintenance division for such work as fencing, guardrail installation,

TASK STATEMENTS

226.01 Inspects surface for proper preparation.

226.02 Orders surface swept, cleaned, and surface of all exposed structures protected as necessary to ensure proper condition.

226.03 Establishes station limits of application, and stringline area.

226.04 Determines rate of application from plans.

226.05 Checks the availability of equipment and inspects pressure distributor, spreading equipment, and rollers for conformance with specifications, proper operating condition, and calibration.

226.06 Checks delivery tickets to ensure quantity and certification of materials.

226.07 Records temperature of asphalt at time of application.

226.08 Records distributor gauge readings at the beginning and end of each application or takes and records tank levels with a calibrated metal measuring stick.

226.09 Observes procedures used in materials placement, rolling, sweeping and drag broom operations to ensure conformance with specifications.

226.10 Orders corrective action for deficiencies in materials or work as necessary.

226.11 Prepares and submits daily report forms for bituminous surface treatment including air temperature and weather conditions; location, length, and width of each application; description or sketches of irregular areas of application; and other required information.

226.12 Maintains daily diary reports of operations.

KNOWLEDGES, ABILITIES, AND SKILLS

Knowledge of applicable standard specifications.

Knowledge of construction equipment and methods used in bituminous surface treatment operations.

Knowledge of the use of survey stakes for control purposes.

Knowledge of corrective measures for deficiencies in materials or work.

Knowledge of basic mathematics including mixed calculations involving addition, subtraction, multiplication, and division of whole numbers and decimals.

Knowledge of standard reporting formats and requirements.

Ability to read and interpret plans, specifications, and special provisions.

Ability to read and interpret field notes.

Ability to make accurate measurements of tank levels with a calibrated measuring stick.

Ability to make accurate field measurements.

Ability to detect obvious deficiencies in materials or work.

Ability to communicate effectively, orally and in writing.

Ability to establish and maintain effective working relationships with supervisors, contractors, co-workers, and the general public.

Ability to prepare required reports and records.

Skill in taking measurements of tank levels with a calibrated metal measuring stick.

Figure 28. Construction Inspection Activity 226: Bituminous Surface Treatment Inspection (30).

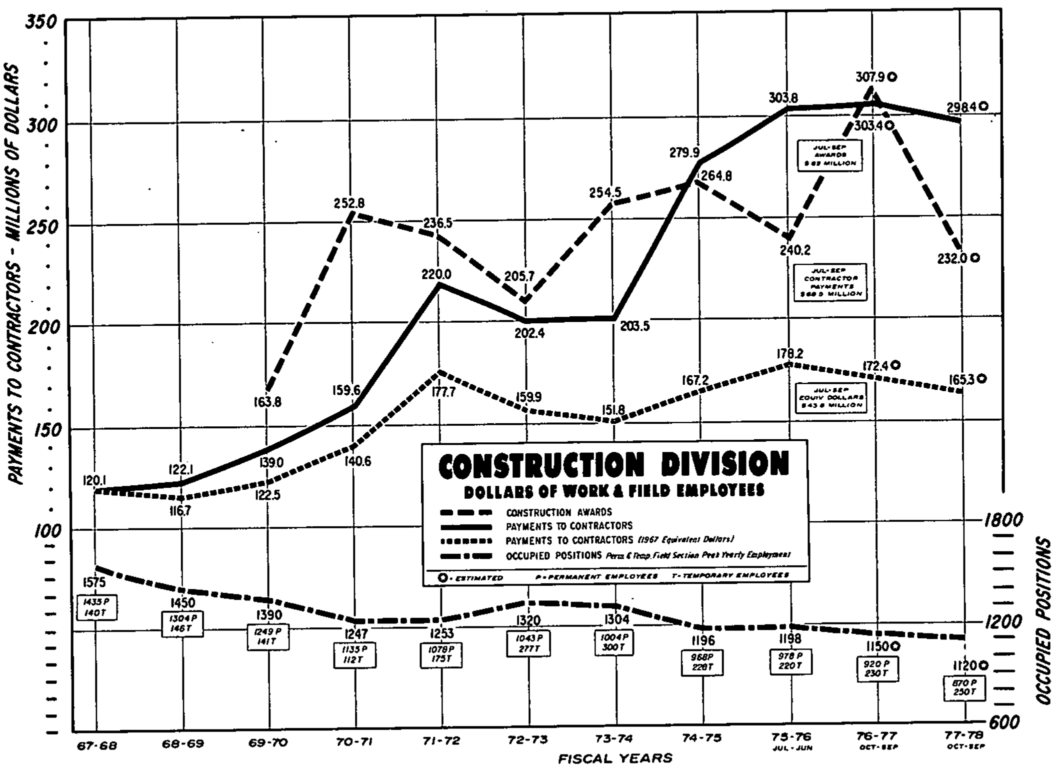


Figure 29. Trends in contract dollars and construction division employees in Michigan (23).

and selective clearing. These capital-outlay jobs present no budgeting problems but do require planning.

As Figure 30 shows, there is potential for reassignment in many other areas. One approach that has been tried in Michigan and several other states involves the creation of special design squads at the district level. Each of these squads has been staffed with three or four experienced design personnel and supplemented by eight to ten construction personnel. One of the design specialists will be transferred to construction during the summer. In Arkansas the construction division coordinates with the survey, maintenance, planning, and research divisions and with the final-estimates section. By performing such activities as location and preliminary surveys, road inventory surveys, traffic counts, preparation of final estimates, inspection of drainage flows, bridge maintenance inspections, soil surveys, and roadway designs, the division can use its personnel more fully and at the same time reduce the backlog of work that the other divisons have accumulated.

OVERTIME AND COMPENSATORY TIME

Several approaches can be taken to meet short-term peak man-hour requirements. One, already mentioned, is the use of part-time intermittent employees. Another approach involves the use of overtime. Using overtime can reduce the number of persons employed, particularly on an eight-hour work schedule. Overtime is particularly important in a state such as Connecticut, which has a standard workweek of 35 hours.

Most states pay nonexempt employees time and a half for overtime work (16). However, as shown in a study done in conjunction with Michigan's construction manpower management research project, overtime actually costs the department only 20 percent more than straight time; the remaining 30 percent represents leave time, holidays, and insurance premiums earned during straight-time hours. For this reason, states that use overtime consider it a bargain.

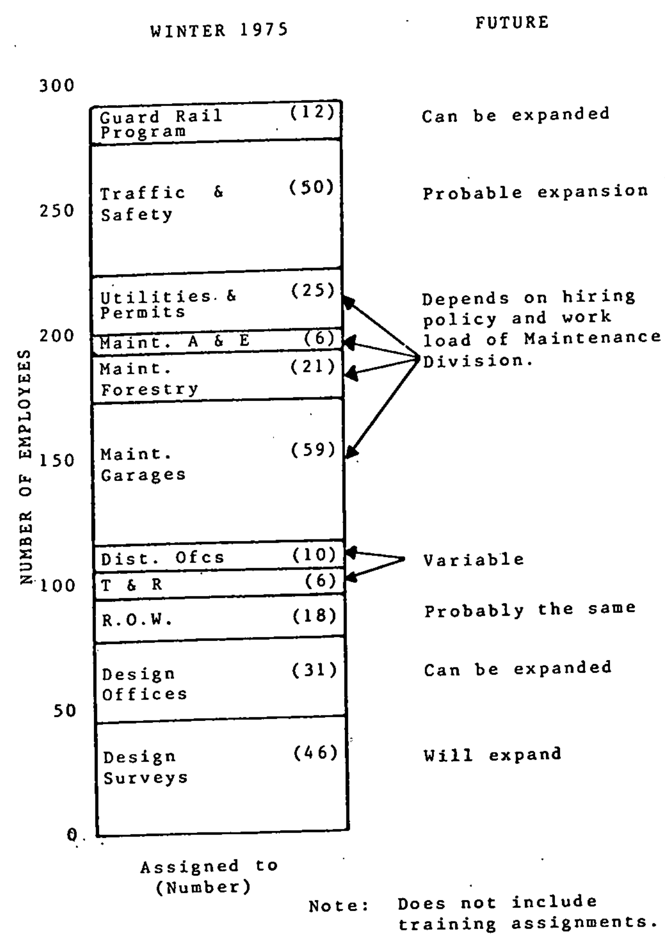


Figure 30. Michigan's 1975 construction division temporary winter assignments and future assignment trends (23).

Overtime has other advantages over the hiring of additional personnel. The percentage of personnel use typically decreases as the number of employees increases, thereby reducing productivity. Also, additional employees add to the problem of off-season use. And continuity of inspection is important on many activities.

Administration of overtime can create problems, however, as was found during the Arkansas construction management study (16). A number of inconsistencies in the payment for overtime work were found; specifically, payments had been made to certain classifications generally regarded as exempt. Part of the problem comes from the position classification plan, which was used as the basis for determining and defining eligibility for overtime pay. This practice is defensible only if work assignments within a classification are reasonably similar and are reflected adequately in the class description. Clearly, an equitable overtime policy is not independent and must be administered in a nondiscriminatory manner to minimize the potential for employee morale problems.

The Arkansas study (16) indicated that there is no uniform pattern among state highway agencies with respect to using overtime versus awarding compensatory time; both methods are used widely. Several states, in fact, allow the employee the option of either.

TRAVEL AND TRANSFER POLICY

Practices related to transfers or loans between districts can provide a valuable key to determining the flexibility of a state's personnel policy. Transferring personnel from one district to another is one method of meeting a peak workload. However, to induce interdistrict transfer, it is necessary to pay employees adequate compensation for moving expenses. States that use interdistrict transfer usually do so on a voluntary basis. It is more common for one district to borrow personnel from another. Unfortunately, in most cases the economic compensation provided to the individual is inadequate. Many states have indicated that the future may bring mandatory transfers.

In California, where the use of temporary and summer employment has ceased, the use of transfers and loans is becoming more frequent. On the other hand, in Michigan, where use of temporary employees is increasing, the use of transfers or loans is decreasing. This indicates that both techniques—hiring temporary help and making transfers—are effective in meeting peak work demands.

Other states do not use transfers often. Pennsylvania, for instance, seldom uses long-distance transfer, and then only with the consent of the individual. Transfers made between districts usually are restricted to commuting-distance transfers. Several states indicated that it is more difficult to transfer personnel between union bargaining units.

To avoid problems of permanent transfer, several states have moved the administrative responsibilities for a project from one district to another. This temporary redefinition of district jurisdiction is particularly effective when adjacent districts have uneven workloads. It then becomes possible to transfer responsibility for a project in the overloaded district to the district that has the light workload. This technique has been employed extensively in West Virginia and to various extents in other states. The approach carries the concept of interdistrict loans to a much greater extent by transferring not only personnel but total project administrative responsibility.

CHAPTER SEVEN

CONCLUSIONS AND RECOMMENDATIONS

Effective manpower management within the construction division of a typical state highway agency is a formidable task that requires the full use of existing methodologies as well as the willingness to adopt some of the newer, more sophisticated approaches that have been developed and are being implemented. This synthesis, therefore, has presented some of the current practices within a context of change, because the dynamic environment that is highway construction demands a constant reappraisal of present conditions in terms of the innovative attitude that assumes: "There must be a better way."

MANPOWER MANAGEMENT SYSTEMS

There are two approaches to establishing a framework of management: the functional approach and the systems approach. The functional approach defines the four primary functions of management as planning, organizing, leading, and controlling and indicates how construction manpower management fits into this structure. Although this approach is satisfactory in certain situations, a complete analysis of existing practices has led a number of state highway agencies to develop a management systems approach, which overlays these functions on the organizational structure of the agency. The systems approach contains the elements of planning, staffing, scheduling, and controlling.

Recommendations

Effective construction manpower management begins with a management systems approach. The development of a model similar to the one presented in Chapter Two, either to reflect current practice or to propose changes, is recommended as a first step for many of the state highway agencies that are beginning an investigation into this area.

MANPOWER PLANNING

The first step in any construction manpower management system is planning, or predicting manpower needs. State highway agencies can not adequately staff projects and schedule manpower unless reasonably accurate predictions of manpower needs related to a defined highway program are made. Planning generally involves analyzing the projects in the program and using some method of converting project characteristics into manpower needs.

Planning systems recently have been developed in Michigan, Louisiana, Arkansas, and Washington. Although each of these states has adopted a slightly different approach, as a group they probably offer the best example of what can be done to improve current planning practices. Following is a list of the key elements in these approaches.

1. A system of classification of projects by important characteristics.
2. A definition of the basic contractor activities and, for a specific project being analyzed, the development of the quantities of work required in terms of agreed-on work measurement units for each contractor activity.
3. A definition of the key highway agency construction engineering activities that relate to the contractor activities. For each of the key construction engineering activities a productivity standard has been developed based on an extensive analysis of data on past completed projects.
4. A conversion process that essentially determines man-hours required for each activity by using this simple equation:

Man-hours = No. of work units x productivity standard

5. An idealized construction arrow diagram or bar chart that can be applied for those projects that have not yet been let to contract.

The most important element in each of the systems is a data file that provides realistic productivity standards for departmental activities. The appropriate use of these standards allows for both long-range planning at the district level and short-range planning at the project level. Although experience in Michigan indicates that more reliable planning occurs if several projects are considered as a group, it is reasonable to assume that this problem will be overcome as these planning procedures are further refined.

Recommendations

The planning approaches that have been taken in the four states mentioned, despite the growing pains, should be considered and perhaps adopted by other state highway agencies that feel the need to revise their planning procedures. Many areas within the planning process, however, need further exploration. The proper choice of project characteristics, the methods that should be used to develop productivity standards so they can be employed for both long-range and short-range project planning, and the relationship between departmental activities and an idealized project schedule are areas where an interchange of information is needed. A state-of-the-art seminar or workshop that allowed some of these points to surface not only would provide guidance for people in the states already using these approaches but also would provide the opportunity for other state highway agencies to be exposed to these practices.

MANPOWER STAFFING, SCHEDULING, AND CONTROLLING

Manpower planning results in the determination of the total man-hour requirements at the project, district, and headquarters level. Staffing converts these requirements into monthly manpower needs. Both planning and staffing can be applied to projects that are either under construction or in the preconstruction stage. Ultimately, however, a project is let to contract, and the scheduling phase (which involves the assignment of specific individuals to work activities) as well as the controlling phase (which compares the actual and planned man-hours) of manpower management are applied.

With respect to staffing, scheduling, and controlling, it is important to understand that the highway agency project engineer is managing a reactive field organization; that is, it must respond to the actions of an outside party—the contractor. This makes the project engineer's job extremely difficult. The key to successful staffing and scheduling, therefore, is a knowledge of the contractor's schedule of operations, from both a short-range (one- to two-week) and a long-range (one-year) viewpoint. Michigan has problems in the scheduling phase because this knowledge is hard to obtain. Arkansas has a special contract provision requiring that the contractor periodically supply the project engineer with updated versions of the short- and long-range schedules; this provision may provide the solution to the problem.

An important aspect of the scheduling element is that flexibility should be built into the system (to allow for changes in the contractor's operations, etc.), with a list of primary and alternate (or secondary) assignments for all employees on the one- or two-week schedule that is used. This practice is an extremely important aspect of the scheduling phase and should be considered seriously for adoption.

Recommendations

Even in the four states cited, the general consensus is that short-term project scheduling (as well as project staffing) is most efficiently done manually by the project engineer. It also appears, from states' responses to the questionnaire, that few states, if any, use an automated manpower scheduling system for the construction phase of a project.

Computerized scheduling systems are readily available, and most large contractors now use them as a matter of standard operating practice. Further study into this area is justified, therefore, to determine (a) whether automated manpower scheduling systems are used for only the project development stage or for both the project development and construction stages and (b) what problems, if any, are impeding the use of these systems for the construction phase. Once these facts have been determined, the next logical step would be the development of a system that overcomes the problems.

Controlling consists of comparing the expended man-hours with the planned man-hours that were determined by using the productivity standards in the data file. Generally, effective management of manpower resources is assumed if the percentage of manpower use agrees with the percentage of contract completion. It still could be asked, however, whether or not that type of control determines how *effectively* the personnel are being used on the project, because planned man-hour targets often can be met easily even with ineffective management if the productivity standards by which they were determined are unrealistic. The "control loop" can be closed effectively only if these productivity standards are updated periodically and if they reflect the most efficient way to perform a task. Too many factors can be hidden within a productivity standard, and the next logical step of control that might be considered by some state highway agencies is the development of a realistic work-sampling program that more accurately reflects the optimum use of manpower resources on a project.

ANALYSIS OF EXISTING PRACTICES

From both an organizational and a construction engineering viewpoint, there are opportunities for change in construction manpower management practices. An Arkansas study indicated that management effectiveness within a highway agency can be improved if the existing system of interdivisional and intradivisional communication is examined critically. A clear definition of duties and responsibilities is an important step toward effective management.

Each state highway agency has its own set of construction engineering practices. However, there are some basic areas where change is possible.

With regard to surveying, attitudes about the use of in-house surveying capability indicate that possibilities exist for change in the basic surveying approach. Several states have effected changes in crew sizes, the standardization of staking services, and the use of design slope-staking information by field forces.

In the area of inspection, the use of statistically based end-result specifications is a possible means of reducing state highway agency manpower requirements. Still to be resolved is the definition of quality, the effect of staffing practices on quality, and whether or not statistical specifications do in fact reduce staffing requirements. The personal interview and survey results indicate that studies of this type are not being given the attention they deserve by many state highway agencies.

A number of states have modified their inspection practices, thus saving cost and manpower; this indicates that immediate changes can be made. Similarly, several state highway agencies have made a number of changes in their project office work practices.

Recommendations

Because of the pressure in many states to reduce the number of personnel involved in office engineering, surveying, and inspection, it is of primary importance to determine how the present assignment practices in a particular state affect the quality of the end product. The first approach might be an attempt to determine if current practices really are needed to achieve the quality desired. Experimental projects that use entirely new practices might provide the answer.

The second approach might involve an analysis of projects that have been built under statistically based end-result specifications to determine if these specifications have achieved the results desired at a reasonable cost and have greatly reduced the need for the same number of state inspectors. If they have not, reasons should be found. It is disturbing to note that 22 of the states that responded to the questionnaire have not even considered such a study. Such a study, either on the state or federal level, is extremely important at this time.

With regard to existing practices in general, even though a state highway agency might not feel the need for a completely revised construction manpower system, it still can achieve a more effective and efficient operation if it institutes a program that critically analyzes existing practices with the objective of improving them wherever possible.

PERSONNEL PRACTICES

The various aspects of personnel administration play an extremely important role in the day-to-day operations within any type of construction manpower management system. Different types of personnel classification systems can be developed, either in conjunction with or in addition to the civil service systems that most states operate within.

One of the most critical needs, as expressed in the interviews, is the need for multiqualified rather than specialized personnel. Michigan's efforts to redesign its employee classification system with this orientation should provide guidance for the state highway agencies that expressed this need.

One of the critical areas in personnel administration is the meshing of highway personnel's activities and tasks with the knowledge, abilities, and skills required. Several states have made excellent attempts to satisfy this objective, and their practices are recommended for consideration.

Recommendations

State highway agencies that are faced with the need for change should observe Michigan's classification procedures closely. Regarding other aspects of personnel administration, state highway agencies that are evaluating their practices should be guided by the practices cited in Chapter Seven.

REFERENCES

1. CASEY, G. J., "Construction Staffing in Michigan." Proc., Quality Assurance and Construction Manpower Management Conf. (June 1977) pp. 119-153.
2. BOAGNI, J., "Construction Manpower Management in Louisiana." Proc., Quality Assurance and Construction Manpower Management Conf. (June 1977) pp. 166-183.
3. TIPPIN, W., "Systems Management in the Arkansas Highway Department Construction Program." Paper presented at the Arkansas Hwy. Dept., Div. of Construction, Resident Eng. Conf. (Mar. 1976).
4. "The Arkansas Highway Department Construction Management Research Project." Res. proposal (Sept. 1975).
5. ANDERSON, D. R., and GOETZ, G. E., "Engineering Resource Planning and Use in the State of Washington." Transp. Res. Record 585 (1976) pp. 68-77.
6. ALLEN, L. A., The Management Profession. McGraw-Hill, 1964.
7. "Implementation Manual for the Construction Management System." Roy Jorgensen Associates, Inc., rep. to the Michigan Dept. of State Hwys. and Transp. (Mar. 1975).
8. "Construction Manpower Management." Roy Jorgensen Assoc., Inc., draft of final rep. to the Louisiana Dept. of Transp. and Dev. (Apr. 1977).
9. PHALEN, J. R., Construction Eng., State of Vermont Dept. of Hwys. Personal correspondence (July 23, 1976).
10. SCYOC, E. R., Dir. of Construction Div., West Virginia Dept. of Hwys. Personal correspondence (July 29, 1976).
11. GRANT, J. R., Dist. Construction Eng., Ohio DOT. Personal correspondence (Aug. 11, 1976).
12. SPIER, E. G., and BELL, G. L., "Determining Manpower Needs for Construction Inspection." Hwy. Res. Record No. 266 (1969), pp. 18-27.
13. HENDRICKSON, E., Construction Eng., North Dakota State Hwy. Dept. Personal correspondence (July 2, 1976).
14. "Highway Construction Management." Roy Jorgensen Assoc., Inc., final rep. on a res. proj. conducted jointly with the Michigan Dept. of State Hwys. and Transp. (June 1976).
15. "Highway Construction Management Implementation." Roy Jorgensen Assoc., Inc., rep. to the Michigan Dept. of State Hwys. and Transp. (Sept. 1976).
16. "Annual Report for Arkansas Highway Department Construction Management Research Project." Pub. Admin. Serv. (Dec. 1976).
17. Manpower Management Information System—Vol. 1: Procedures. Washington State Dept. of Hwys. (Oct. 1975).
18. Manpower Management Information System—Vol. 2: Standards. Washington State Dept. of Hwys. (Oct. 1975).
19. MARESCA, F. A., "Planning for Preconstruction and Construction." Proc., Quality Assurance and Construction Manpower Management Conf. (June 1977) pp. 101-118.
20. "Construction Management System—Vol. V: Implementation Manual." Pub. Admin. Serv., rep. to the Arkansas State Hwy. Dept. (Jan. 1978).
21. "Construction Management Laboratory Project Instruction Manual." Pub. Admin. Serv., rep. to the Arkansas State Hwy. Dept. (Oct. 1976).
22. "Construction Division Organization and Management." Pub. Admin. Serv., rep. to the Arkansas State Hwy. Dept. (Jan. 1977).
23. CASEY, G. J., Construction Staff Eng., Michigan Dept. of State Hwys. and Transp. Personal interview (Sept. 1976).
24. PARKER, H. W., and OGLESBY, C. H., Methods Improvement for Construction Managers. McGraw-Hill, 1972.
25. "Statistically Oriented End-Result Specifications." NCHRP Synthesis 38 (1976) 40 pp.
26. "Report of Work Method Changes Recommended as a Result of the Construction Management Study." Michigan Dept. of State Hwys. and Transp. (Supplied in personal correspondence with G. J. Casey, Construction Staff Eng., June 17, 1977.)
27. RUNKLE, S., Res. Analyst, Virginia Dept. of Hwys. Personal correspondence (Apr. 28, 1977).
28. BERGSTRALH, K. L., "Fighting Reduced Revenues With Increased Productivity." Paper presented at the TRB ann. meet., Washington, D.C. (Jan. 1977).
29. CASEY, G. J., "Reduction of Permanent Construction Field Positions to Eliminate Winter Overstaffing." Unpub. paper, Michigan Dept. of State Hwys. and Transp. (Dec. 15, 1975).
30. "Arkansas Highway Department Construction Division Knowledge, Ability and Skills Statements." Pub. Admin. Serv. (July 1976).

APPENDIX A

A COMPILATION OF DATA GATHERED BY PERSONAL INTERVIEW

During the data-collection phase of the synthesis study, personal interviews were conducted in selected states. The primary interviews were in California, Louisiana, Michigan, Pennsylvania, Washington, and West Virginia. In addition, information was obtained from interviews conducted by TRB staff members and others in various states, among them Connecticut, Georgia, Illinois, Kansas, North Dakota, Tennessee, Utah, and Virginia. The information obtained from the latter group is not as extensive as that gained in the primary interviews. A standard series of questions was asked in the primary interviews. Following are the questions and a summary of the answers obtained.

A. THE STAFFING FUNCTION

I. What Is Construction Engineering?

1. What activities are included in construction engineering?
2. Is surveying ever a separate bid item?
3. To what depth does the inspection activity go?
4. What type of office work is included in construction engineering?

Most states indicated that construction engineering could be divided into three major categories: surveying, inspection, and office work.

Surveying. All states interviewed except Louisiana and West Virginia performed all surveying in-house and said surveying is never a separate bid item. Louisiana tries to do all surveying; the contractor may do some layout, however, depending on the availability of state personnel. In West Virginia, surveying may be a separate bid item on major projects. The state will stake centerline and R.O.W., but the contractor is responsible for all the work.

Inspection. California, Michigan, and Washington indicated that state personnel do inspection in all phases of operations, including production, delivery, and placement. Louisiana, Pennsylvania, and West Virginia use statistically based end-result specifications, which eliminates some inspection functions. In West Virginia, for example, in most cases the contractor is responsible for process control and the state performs only acceptance sampling. Many of the states use some form of plant certification program, which eliminates the need for an inspector at the production site.

Office Functions. Most states have the same types of office functions, including payroll, records, quantity computations, and progress payments. Approximately 30 percent of Michigan's field engineering costs result from office work.

II. Definition of the Over-All State DOT Organization

1. How is the DOT organized (regions, districts, etc.)?

All the states contacted are organized on a district basis. The primary difference among them is in the amount of control exercised by the central office. Most states have a high degree of centralized control, but in Washington the districts are nearly autonomous.

2. Are the duties and responsibilities at each level well defined?

Almost every state indicated that there is good definition of the duties, skills, and authority for all classifications and jobs. This definition takes two forms, the first involving the civil service classification system and the second involving job descriptions in various departmental manuals. In West Virginia, civil service is limited to engineers and a few other professional levels, but this lack of civil service classification status has not led to a large turnover of inspectors.

III. Contract Staffing Background

1. What are some of the more significant changes in highway construction that have occurred in the past ten years (organizational, technological, level of workload, specifications, etc.)?

Because the responses to this question were quite detailed, the results are summarized on a state-by-state basis.

California

a. Massive increase in paperwork.
b. Use of sophisticated equipment (autograder) by contractor.
c. Use of laser surveying equipment.
d. Extensive use of computer.
e. Greatly increased individual workload.
f. Reduced number of roadway miles under construction.
g. Personnel layoffs.
h. Shift from large projects to more numerous small projects.
i. Necessary enforcement of social and environmental laws as a contract requirement.

Louisiana

a. Have changed to end-result specifications.
b. More sophisticated surveying equipment.
c. Extensive use of computers and programmable calculators.

d. Work emphasis is shifting to:
—safety programs
—upgrading with overlays
—bridge replacement
—guardrail replacement

Michigan

a. Workload has shifted from rural to urban and back to rural.

b. More and more projects but smaller in size.

c. Personnel emphasis has shifted from specialists to generalists (promotion now based on multiple skills).

d. Beginning to use nuclear density-testing equipment.

e. Going to more spot-testing (specs. reflect this shift).

f. For above reasons as well as improved work methods there is a need for fewer people.

g. Shift has been from permanent to temporary employees.

h. Fewer people are needed because of:
—spot-checking
—multiqualified people
—improved work methods
—uniformity of work and job descriptions

Tennessee

a. Lower workloads.
b. Increased paperwork.
c. Improved training.

Washington

a. Drop in workload.
b. Lack of promotional opportunities.
c. Detailed cost accounting.
d. Budgeting by work standards.
e. Implementation of manpower control system.
f. Increased use of computer.
g. Use of photogrammetry and aerial photography.
h. Shift to reconstruction from new construction.

West Virginia

a. Use of statistically based end-result specifications has reduced required number of inspectors.

b. Training and certification of material inspectors.

c. Loss of personnel.

d. Shift to many small projects, particularly overlay work.

e. Increased necessity for multiqualified personnel.

2. What are your chief concerns as a manager (productivity, quality, dwindling resources, etc.)?

Some concerns voiced by more than one state are as follows: the necessity to hire and train multiqualified, multiskilled employees; unreliable letting schedules that make it difficult to determine which jobs will be let and which delayed; inability to transfer employees; inability to retain experienced personnel due to salary or promotion structure; maintaining a quality product.

3. Is any of your staff unionized?
4. If so, have your labor costs been increased?
5. Has unionization taken away your ability to manage?

Michigan, Pennsylvania, and Washington have unions. In Michigan there exists only a quasi-union that has no right to strike or bargain. In Washington some personnel are members of the AFL-CIO. The union in Washington has collective bargaining power, a grievance committee, and limited striking power. It is not very strong, however, and staffing costs have not risen.

IV. Related Areas

1. How do the following factors influence the staffing level on a project: type of project, geographical location, personnel capabilities, contractor's past performance, others?

The major contributor to staffing levels was stated to be the scope and complexity of the project. Items such as interchanges, bridges, complex layouts, and so on, can increase staffing requirements. Also, the construction operation can influence the staff levels required. The construction sequence and the number of shifts worked by the contractor dictate the number of personnel required on the project. Further, the shift to smaller projects has led to dealings with inexperienced contractors, which may require the highway agency to provide tighter inspection and surveillance.

2. Who determines the budget and how it is spent?

In all states interviewed, the budget is prepared at the central office but specific decisions on how the money will be spent are made at the district level.

B. PERSONNEL PRACTICES

I. Personnel Inventory

1. Do you keep an inventory of personnel to determine the number of people with certain qualifications?

The only type of personnel inventory in the states interviewed is based on the number of employees in each civil service classification. In most cases the inventory is maintained at the district level.

2. How are qualifications evaluated with respect to knowledge, skill, and ability?

The most common evaluation technique is the use of civil service tests. Some states (e.g., Utah) have statewide testing programs to indicate training needs. Michigan plans to implement an on-the-job performance testing program.

II. Job Standards

1. Are there any job standards established by which to measure productivity?
2. What is the origin of these standards?
3. Has there been any resistance from personnel in the field?
4. How does actual field productivity compare with these standards?

Michigan and Washington use job standards, and California and Louisiana currently are developing standards.

Michigan. The job standards in effect in Michigan originated from a study made by a consultant. This study was based on rural projects only; urban standards are still under development. The comparison between job standards and actual field productivity has been good with respect to rural projects, but on other jobs individual variance is sometimes quite significant.

Washington. Washington uses standards for budgeting purposes. These standards are based on cycle time studies, work sampling, specially designed studies (in which individuals keep their own records), and historical data. There has been some resistance to the use of standards. There seems to be good correlation between the standards and actual field productivity on the whole, but individual projects vary greatly.

III. Temporary Employee Policy

1. What is the employment policy with regard to hiring temporary help?

2. What is the source of this temporary help?

Few states interviewed make extensive use of temporary employees. California, Georgia, Pennsylvania, and Tennessee report little use of temporary help. Louisiana, Washington, and West Virginia use summer employees, but the number varies significantly. Michigan, however, has adopted a policy of meeting peak work demands with a fairly large temporary work force. The primary source of temporary employees in most states is civil engineering co-op students and other college students. Michigan in particular uses a large number of civil engineering co-op students and has found them easy to train and eager to learn.

IV. Overtime/Comp-Time Policy

1. What is the policy with regard to overtime and comp time?

2. Does the policy change with the level of organization?

The policies regarding overtime and comp time vary greatly among the states interviewed. In Washington, comp time can not be used under the union contract. Overtime is used, but five days' notice must be given to the employee. The same situation applies in Michigan: overtime is used, but comp time is not allowed. West Virginia has a uniform statewide policy regarding overtime and comp time: comp time is given for District Engineers, Division Engineers, and the Chief Engineer's offices; others receive straight time or overtime for workweeks in excess of 40 hours.

V. Travel and Transfer Policy

1. What are your travel regulations or restrictions?

2. What is your employee transfer policy?

3. Has this policy changed as less work has developed?

The subject of transfer received much response during the interviews. Transfers are being used more frequently, and there is a general trend toward a mandatory transfer policy in many states. Following are the responses of each of the states interviewed.

California. The state attempts to make transfers and loans voluntary. This generally works well, because adequate monetary compensation is made for travel expenses. Transfers and loans are made more frequently now than they once were, because summer and temporary employment has ceased.

Louisiana. Travel time or pay usually is not given. Only in isolated cases are transfers made outside of a district.

Michigan. Transfers and loans are made frequently, but their use is decreasing. Travel expenses are approximately 1 percent of contract costs. The state considers transfers and loans to be a key to successful flexibility, and the economic compensation for moving expenses reflects this belief.

Pennsylvania. Interdistrict transfer is somewhat rigid and generally is restricted to commuting distances. Long-distance transfer seldom is used, and then only with the consent of the individual.

Washington. Transfer is not mandatory at present, and compensation for moving expenses is inadequate. The trend is toward making transfers mandatory. A per diem allowance is provided when employees are away from their duty stations for more than 11 hours. The maximum commuting distance is 45 miles (70 km).

West Virginia. Loans between districts are made extensively. Transfers are currently voluntary, but there is a strong trend toward a mandatory policy. Only under specific circumstances are moving expenses paid for transfers.

VI. Off-Season Assignments

1. Is construction activity halted during the winter months?

2. What is done with permanent personnel during extended periods of construction inactivity?

Most states interviewed curtail construction activities during the winter. Louisiana, Tennessee, and southern California have year-round construction seasons, and Kansas uses about 60 percent of its construction force on construction activities during winter months.

Assignments in states that have off-seasons are quite similar. Some of the most frequent types of assignments for construction personnel during periods of low construction activity are design, office work, maintenance, training, snow and ice control, traffic counts, drafting, and inventories.

Several states have extensive training programs for employees during winter months.

VII. Training Practices and Certification

1. Is there a formal training program in effect?

2. Is there a certification requirement for each of the different functions?

3. Is there a continuing education program?

4. Are employees trained to perform multiple functions?

The one thing that stands out from all the interviews is the continual emphasis on the need for multiqualified and multiskilled personnel. Every state stressed the fact that the trend is toward generalization and multiple qualification rather than specialization. Following are comments from some states.

California. There is a formal training program only for new employees. All training is handled at the district level. Written and oral tests are slanted toward generalization, and employees are encouraged to perform multiple functions. There is no formal continuing education program. Certification is required only for testing and for some structure inspectors. Yearly updating of certificates is required.

Louisiana. Training is required for promotion, but personnel are mostly self-taught. The trend is toward generalization rather than specialization. Several areas have a certification program that requires testing over and above civil service tests. Certificates are updated every four years.

Michigan. Top management is fully convinced of the value of a good training program, and the current program is due to expand. Also, a continuing education program will be emphasized more in the future. Employees are trained to perform multiple functions, and promotions are tied into this ability. Certification is required, and a more extensive certification system is under development.

Washington. The training program has been directed more toward management training than technical training. Employees are not trained formally to perform multiple functions, but there is a trend in that direction. Certification exists only in certain isolated cases.

West Virginia. Formal guidelines for training are developed at the central office and given to the districts, where the training is done. Self-study opportunities also are available. Multiple qualification is encouraged, and many employees have multiple certification. Inspectors are certified in asphaltic concrete, portland cement concrete, compaction, aggregate testing, and welding.

C. STAFFING ESTIMATES

I. The Staffing Estimating Procedure

1. How far in advance and to what level of detail (state, regional, district are staffing requirements estimated?

2. Specifically, what is the step-by-step procedure for predicting staffing levels?

Systems for predicting staffing levels vary from simple "engineering judgment" to very complex computerized systems (several of which are discussed in the body of this synthesis). A brief summary of some of the responses is presented here.

California. Staffing estimates are prepared at the district level with the aid of a computer program. The estimate is based on certain identifiable factors for each project. From these factors a base value for man-hours required is determined. This base value is adjusted by by the use of a combination of factors, including the following:

a. Bridge work. The base value is adjusted by the percentage of the total project value that is bridge work.

b. Zone. The project zone is based on the weather and terrain of the project. The state is broken into five weather-terrain zones.

c. Location. There are different adjustments, depending on whether the project is in a rural, village, suburban, urban, or metropolitan location.

d. Alignment. This factor is based on whether the project is on new, mixed, or existing alignment or is a widening project.

e. Judgment factor. This factor is based on a knowledge of the project. A plus or minus factor may be applied for conditions not covered in the previous factors.

Louisiana. Estimates are prepared at the central office. A base number of man-hours is determined first, based on project quantities and productivity standards. This base value then is adjusted upward, based on the judgment of a group of engineers; there is no set procedure for making this adjustment. Then the total number of man-hours is forwarded to the district engineer for review. At present the number of man-hours does not differentiate among the different job classifications.

Michigan. The central construction division prepares estimates two years in advance. In the past the estimates were based on best engineering judgment, but now they are based on job standards for rural projects. Man-hour estimates are determined by a comparison of these job standards with the estimated quantities on the project. The estimate, which has the number of man-hours for each skill level, then is sent to the district engineer for review and concurrence. (The Michigan system is discussed at length in Chapter Three.)

Washington. Estimates are computer-generated. Information is entered on a computer form that includes a breakdown by project type and a series of factors dealing with the particular project in question. The program has the capability of printing out a number of different manpower-related reports on a project-by-project basis or on an activity basis for an individual project. (The Washington system is discussed in detail in Chapter Three.)

West Virginia. Estimates are prepared one and a half to two years in advance. Monetary limitations and priority changes have made prediction of project starting dates extremely unreliable, so it is difficult to predict staffing requirements accurately. A computer program is available for making the predictions, but currently it is not being used because of monetary restrictions.

II. Evaluation of System

1. Has any attempt been made to evaluate the accuracy of the estimate?

In most cases either no formal evaluation has been attempted, the program is too new to have been evaluated, or an evaluation is taking place now. There are as yet no findings to report.

III. Future Trends

1. What are the future trends with respect to predicting staffing requirements?

There were very few responses to this question. Most of the responses center around future staffing requirements rather than the prediction of these requirements. California and Pennsylvania are moving toward end-result specifications in an effort to reduce staffing needs. West Virginia will be updating staffing standards in its construction manual to reflect the reduced staffing needs resulting from its statistically based specifications. Washington indicated the further implementation of their Manpower Management Information System and the use of work-methods evaluation. Louisiana will implement a computer management system in the future.

D. STAFF-LEVELING TECHNIQUES

I. Available Options

1. Given a need for more people than available, what do you do?

2. How influential are these factors: multiqualification, temporary employees, interdistrict transfers, floating parties, transfer of administrative responsibilities between districts, contractor engineering, consultant field engineering, consultant field inspection?

3. What are the future trends in the area of staff leveling?

The states employ many different staff-leveling techniques. A summary of some of them is presented in the following paragraphs.

California. Staff leveling primarily takes the form of overtime and the use of multiqualified personnel. Future trends include the increased use of interdistrict loans and transfers and the shifting of personnel from design to construction in the summer and back to design in the winter.

Louisiana. Staff-leveling techniques include the use of multiqualified personnel and much overtime. Transfer of administrative responsibility has been tried, but not as a matter of policy. Consultant engineering is used only on bridge design, but consultant field engineering may be used, especially in preliminary layout. Consultant field inspection also is used.

Michigan. Multiskilled people and temporary employees create flexibility, and both are used extensively. Their use will expand in the future. Interdistrict transfers also are used.

Washington. The state feels that the use of multiqualified personnel creates flexibility. Overtime and restricted vacations are used, and there is limited use of floating parties for bridge inspection. Administrative responsibility occasionally is transferred across district lines. Future trends include the use of multiqualified personnel, floating parties, and mandatory transfers. The ratio of technicians to engineers will increase.

West Virginia. Temporary employees and interdistrict loans are used frequently, as are floating survey parties. Administrative responsibility is transferred between districts quite often. Contractor engineering also is used often. Consultant field inspection is done on special projects only. In the future the state will experiment with having the contractor perform final-payment surveying with a state representative present.

APPENDIX B.

A COMPILATION OF DATA GATHERED FROM QUESTIONNAIRES SENT TO STATE HIGHWAY AGENCIES

In addition to personal interviews (see Appendix A), a brief questionnaire was mailed to all 50 state highway agencies so that additional information could be gathered. Forty-one states responded to the questionnaire. The compilation of the responses provides additional insight into the various construction contract staffing practices that exist throughout most of the country.

Question 1(a): What procedure, method, or formula is used to predict staff and resource requirements?

Of the states that responded, most have no formal procedure; in other words, they predict staffing requirements on a number of judgmental factors. These factors include the number of projects to be let, the types of projects, past experience, and engineering judgment. However, several states use a system based on the number of people per contract dollar. For instance, such a factor might take the form of X inspectors per million dollars.

Another approach used in several states is the development of staffing standards for various types of projects. In New Jersey a manning table indicates the number of personnel of each classification required for each of six project types (Fig. B-1). Illinois uses a spread sheet that breaks future projects into seven general types, with an average manpower requirement known for each type. Florida carries this staffing standard approach a bit further by using the manpower utilization development approach. Projects are classified into 14 categories, with manpower requirements given for various contract times. This includes a one-month period for preconstruction activities.

Four states use the computer in predicting staffing requirements. Idaho uses a multiple regression program to develop a manpower estimating formula for construction manpower needs from physical aspects of individual projects and regional characteristics. The dependent variable is man-hours per roadway mile, and likely independent variables are structure area per roadway mile, type of project (rural or urban), number of overwinter periods, length of project in roadway miles, climate zone, and topography. After this phase is completed, the distribution of manpower over the life of the project is investigated.

California has developed a computer program to prepare a budget for field man-hours. The budget is prepared at the district level and is designed to consider such variables as project length; contract amount; amount of bridge work; weather and terrain; location of the project; whether the project is on new, mixed, or existing alignment; and a judgment factor based on knowledge of the project.

A base requirement for man-hours first is determined as a function of the cost of the project adjusted to 1973 dollars. This figure then is adjusted by the use of correction factors based on the variables listed in the previous paragraph. These correction factors, determined from historical data by the use of a multiple regression analysis, vary with each district.

The key feature of California's computer program is the fact that it considers many variables that easily can be overlooked in simpler methods. Development of such a program requires a thorough examination of historical data to determine which variables have a significant effect on manpower requirements.

The Michigan and Washington programs are discussed in Chapter Three.

Question 1(b): Is this done at the state or district level?

Prediction of staff and resource requirements is done at the state level in 13 states, at the district level in 16 states, and at both levels in 6 states. In 4 states predictions are made at the district level and reviewed at the state level.

Question 1(c): Has any use of the computer been made to develop this prediction?

Twenty-five states have not used the computer, and 12 have. Its relative use has varied widely in these 12 states, ranging from a consideration of historical data to the sophisticated systems discussed in response to Question 1(a).

Question 1(d): Do you have an automated manpower scheduling system?

Thirty-four states do not, one (Washington) does, and two (Idaho and Utah) have a system under development.

Question 2(a): Has any recent attempt been made to evaluate present assignment practices and their effect on quality?

Question 2(b): Has such a study been documented?

Twenty-eight states answered no; following are responses from states that answered yes.

Arizona. Study of transfer policy has been made.

Arkansas. Construction management research program is under way.

Colorado. Formal reports have indicated good quality control.

Illinois. An attempt has been made to establish review procedures for major construction items.

Indiana. Cost analysis has been made regarding "construction engineering."

Kansas. Supervisors perform continual evaluation.

Kentucky. Examines problems only as they arise.

Michigan. Highway construction management study has found no ill effects on quality due to assignment practices.

Missouri. Quality is continously monitored by staff personnel.

North Carolina. Statewide audits indicate quality is acceptable.

Pennsylvania. Review group evaluates job and reports to the secretary of transportation.

South Carolina. Assignments themselves, not assignment practices, are reviewed.

Virginia. Reviews are performed by a monitoring team within the department.

Question 3: How do your methods of quality control, type of contract, specifications, etc., that are used to evaluate construction and materials affect requirements for resources and staffing?

Three states indicated that contract scope and size are the major influences on staffing. Eleven states indicated that the method of quality control significantly influences staffing. Another eleven indicated that all the factors in the question affect staffing, and a few states indicated that the factors in the question have little or no effect on staffing requirements.

Utah indicated that statistical quality control requires higher staffing levels, whereas Kentucky, Pennsylvania, and West Virginia indicated just the opposite.

Some specific responses from three states are given in the following paragraphs.

Delaware. Construction engineering forces are drawn from completed or partially completed contracts. Staffing of each job is influenced by (a) size of contract in dollars; (b) size of contract in miles; (c) type of contract (rural, urban, bridge structures, asphalt, PCC, etc.); (d) experience of available people; (e) season of year and progress rate anticipated; (f) contractor's formal construction schedule; (g) contractor's past experience in the proposed work; (h) state's experience with the contractor on similar previous work; (i) surveying requirements as indicated by the specifications; and (j) amount of laboratory work (field and central) required because of the type of work and special specification requirements (in rare cases the contractor does part).

Illinois. The basic contract variations used are documentation of pay items, contractor or state staking, and end-result or method specifications. Each of these has an effect on the staffing required. The use of fewer pay items, plan quantity agreements, and volume or surface measurement units in lieu of tons appears to reduce staffing needs only slightly. The amount of staking provided by the contractor or by the state can produce a more significant change in staffing, but probably not greater than 10 to 15 percent. End-result specifications and a reduced frequency of sampling give the appearance of saving staffing requirements, but at present this effect is not measurable.

New Mexico. The state feels that the factors in the question are the major influences on staffing requirements. About 15 percent of the field personnel are needed to meet OSHA, EEO, auditing, and other nonconstruction requirements.

Question 4(a): What procedures are in use to evaluate the technical qualifications of the various staff personnel?

Question 4(b): Is this information used in making staff assignments?

The most common procedure is the use of supervisor evaluations; 18 states use this type of evaluation, 6 on a yearly basis. Four states use civil service exams, and several states use testing programs other than civil service. Management's personal knowledge and judgment is an evaluation technique in 6 states. Six other states use certification. Four states use a merit system for evaluation, and Delaware stated: "The personnel function of the Department of Transportation is governed by the Merit System of the State of Delaware. Under the Merit System, every Transportation position has a written classification specifying educational or experience requirements."

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