NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 145

STAFFING CONSIDERATIONS IN CONSTRUCTION ENGINEERING MANAGEMENT

TRANSPORTATION RESEARCH BOARD
National Research Council

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ROBERT B. NEWMAN
Senior Vice President
Bergstralh-Shaw-Newman, Inc.

Topic Panel

JOSEPH A. FILIPPINO, *Pennsylvania Department of Transportation*
WILLIAM G. GUNDERMAN, *Transportation Research Board*
CHARLES S. HUGHES, *Virginia Transportation Research Council*
PETER A. KOPAC, *Federal Highway Administration*
PETER C. MARKLE, *Federal Highway Administration*
WILLIAM H. SHAW, *Missouri Highway and Transportation Department*
GARLAND W. STEELE, *West Virginia Department of Highways*
BOB H. WELCH, *Federal Highway Administration*

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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 the National Research Council is an assurance 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 National Research Council 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 the responsibilities of the National Research Council 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.

NOTE: The Transportation Research Board, the National Research Council, the Federal Highway Administration, the American Association of State Highway and Transportation Officials, and the individual states participating in the National Cooperative Highway Research Program do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the object of this report.

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PREFACE

A vast storehouse of information exists on nearly every subject of concern to highway administrators and engineers. Much of this information has resulted from both research and the successful application of solutions to the problems faced by practitioners in their daily work. Because previously there has been no systematic means for compiling such useful information and making it available to the entire highway community, 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 useful knowledge from all available sources and to prepare documented reports on current practices in the subject areas of concern.

This synthesis series reports on 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 these reports are useful will be tempered by the user's knowledge and experience in the particular problem area.

FOREWORD

By Staff
Transportation
Research Board

This synthesis will be of interest to construction engineers, contractors, administrators, and others interested in providing an adequate level of staffing on highway construction projects. Information is presented on determining the number of personnel needed, as well as the qualifications and training needed.

Administrators, engineers, and researchers are continually faced with highway problems on which much information exists, either in the form of reports or in terms of undocumented experience and practice. Unfortunately, this information often is scattered and unevaluated, and, as a consequence, in seeking solutions, full information on what has been learned about a problem frequently is not assembled. Costly research findings may go unused, valuable experience may be overlooked, and full consideration may not be given to available 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 reporting on common highway problems and synthesizing available information. The synthesis reports from this endeavor constitute an NCHRP publication series in which various forms of relevant information are assembled into single, concise documents pertaining to specific highway problems or sets of closely related problems.

Agency testing and inspection along with contractor staffing and quality control are important contributors to the quality of highway construction. This report of the Transportation Research Board discusses how agencies and contractors determine the

number of personnel needed on a highway construction project as well as the qualifications and training needed for those personnel.

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 researcher 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.

CONTENTS

ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Robert E. Skinner, Jr., Director for Special Projects. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. This synthesis was edited by Judith Klein.

Special appreciation is expressed to Robert B. Newman, Senior Vice President, Bergstrahl-Shaw-Newman, Inc., who was responsible for the collection of the data and the preparation of the report.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Joseph A. Filippino, Director, Bureau of Construction and Materials, Pennsylvania Department of Transportation; Charles S. Hughes, Senior Research Scientist, Virginia Transportation Research Council; Peter A. Kopac, Research Highway Engineer, Federal Highway Administration; Peter C. Markle, Highway Engineer, Program Management Branch, Federal Highway Administration; William H. Shaw, Assistant to the Chief Engineer, Missouri Highway and Transportation Department; Garland W. Steele, Engineering and Special Studies Advisor, West Virginia Department of Highways; and Bob H. Welch, Materials Engineer, Central Direct Federal Division, Federal Highway Administration.

William G. Gunderman, Engineer of Materials and Construction, Transportation Research Board, assisted the NCHRP Project 20-5 Staff and the Topic Panel.

Information on current practice was provided by many highway and transportation agencies. Their cooperation and assistance were most helpful.

STAFFING CONSIDERATIONS IN CONSTRUCTION ENGINEERING MANAGEMENT

SUMMARY

The overall objective of this synthesis was to explore the relationship between highway agency and contractor staffing of construction projects and the quality of construction attained. Subobjectives were to determine the state of the art in staffing highway construction projects, determine and analyze staffing practices of both the agencies and contractors, and provide guidance that can be used in the highway industry to properly staff construction projects.

CONCLUSIONS

Interviewed agency officials and contractors agreed that, given adequate design plans and specifications, the quality of highway construction depends on the quality of the individuals involved. Inspectors, engineers, craftsmen, foremen, and superintendents all must be well qualified and know their jobs to merit the respect of the other party. When there is mutual respect, quality is nearly assured.

Nearly all of the contractor personnel interviewed reported having sufficient numbers of qualified applicants in 1986. All of them have had problems in other years. Work in construction is not as attractive to those entering the work force as white-collar careers.

The fluctuations in the industry workload, with the uncertainties of continuing employment, discourage many from entering or remaining in construction. A stable program would improve the ability of both the agencies and contractors to properly plan and staff construction projects.

Most of the agencies reported difficulty in matching starting salaries offered to graduate engineers or two-year engineering-technology graduates. Recruiting efforts by the agencies need to be improved. Graduating engineers who worked for the agencies as seasonal employees are the most likely candidates for recruitment. Hiring freezes have limited agencies' ability to correct imbalances in their work forces.

The quality of inspection personnel—how well they are trained and motivated—is more important than the quantity of inspectors. It is better to have intermittent inspection by a qualified inspector than full-time inspection by one who does not know what to inspect or how to inspect it.

Clearly, many agency staffs are not adequate for the current workload without outside assistance. These agencies have supplemented their staffs by requiring contractors to provide more of the quality control and construction staking and through the use of consultants for construction engineering and inspection. There appear to be adequate numbers of personnel, but there is inadequate training provided for contractor and consultant staffs in many instances as well as for agency personnel.

Attrition of professionals in state highway and transportation agencies is expected

to be higher in the next several years than in the past. The expected loss of senior engineers will undoubtedly affect the construction functions in most states. Developing and implementing plans for replacing the lost skills should not be delayed.

Based on the data collected in the interviews, many states are requiring contractors to assume more of the quality control responsibilities. Although many of the agency personnel and contractors are not entirely comfortable with the change, the shifting of quality control responsibilities to the contractors is increasing. Contractor quality control was initiated in part to overcome shortages of inspection personnel. Another consideration was to improve quality by assigning that responsibility to the party who had control of the manufacturing process—the contractor or supplier.

RECOMMENDATIONS FOR HIGHWAY AGENCIES

Highway and transportation agencies that do not have staffing guidelines should develop them to guide supervisors in properly staffing construction projects—for both long- and short-term needs.

Guidelines should be used for staffing all construction projects, not just federal-aid projects.

Each agency should assess the effect that attrition will have on the staff available for construction engineering and inspection and develop plans for properly staffing projects. The staffing plans should include methodology for training staff members in the technical and administrative areas of project management.

The ratio of engineers to technicians (permanent employees) for construction engineering and inspection should be in the range of 1 to 5 and 1 to 6 for most agencies.

Unless one has been recently completed, each state highway and transportation agency should undertake an analysis to determine the training needs of the construction engineering and inspection personnel.

Highway and transportation agencies should develop or acquire formal training programs to meet any training needs identified.

Highway and transportation agencies should require construction technicians to become certified—either through in-house procedures or by NICET. This requirement should include technicians furnished by consultants, as well, when they perform this work for the agency.

RECOMMENDATIONS FOR CONTRACTORS

A study should be undertaken to catalogue available training suitable for contractor personnel.

Contractor personnel who perform quality control testing should be required to meet the same certification requirements as agency employees who perform similar work.

Highway and transportation contractors and contractors' associations need to promote construction as a career to attract capable employees into the industry.

CHAPTER ONE

INTRODUCTION

This synthesis was undertaken because of a concern that a lack of experienced, trained personnel assigned by the agencies or contractors is affecting the quality of highway construction.

OBJECTIVES

The objectives of the synthesis include:

- determining the state of the art in staffing highway construction projects;
- determining and analyzing staffing practices of both the agencies and contractors; and
- providing guidance that can be used in the highway industry to properly staff construction projects.

SCOPE

Agency testing and inspection along with contractor staffing and quality control activities are very important contributors to the quality of highway construction. The Federal Highway Administration's (FHWA) Highway Condition and Quality of Highway Construction Surveys of the past decade have shown that the size and quality of these assurance programs vary considerably. The experience, training levels, and productivity of the personnel assigned to these functions show great disparities.

The quality of highway construction is influenced by many factors. These may include:

- project and support staffing by agency and contractor (qualifications and numbers);
- project design and complexity (size and type);
- design, plans, specifications and standards;
- commitment to quality (by agency and contractor personnel);
- production versus quality; and
- outside factors and influences.

Agencies and contractors were surveyed relative to these factors and their impact on the quality of the finished work. The major emphasis was on staffing and staff qualifications. In this synthesis, the term "contractor" includes subcontractors, fabricators, and other suppliers.

DEFINITION OF THE PROBLEM

There is increasing concern expressed that quality of highway and bridge construction is not adequate for current traffic loadings let alone future loadings. This synthesis was undertaken to explore the relationship between staffing of construction projects and the quality attained.

Is the quality of highway construction suffering because of inexperienced or inept agency inspectors or contractor personnel? Are there enough capable individuals entering the industry? Are agency staffs large enough to ensure that quality construction is attained? Will attrition, especially retirements, compound the problem? Is assigning more quality control responsibilities to the contractors a feasible solution? Is adequate training available? Are there adequate rewards and incentives to attract quality personnel? Is the industry attractive to new recruits?

METHODOLOGY

The research was conducted in two phases: a literature search and structured interviews.

Very few recent publications dealing with staffing construction projects were found through the literature search. Several Transportation Research Board publications addressed these problems in the late 1960s and early 1970s.

Structured interviews were conducted with officials from selected state highway and transportation agencies and highway contracting firms. Copies of the interview guides are included in Appendix A. Interviews were conducted with 10 state agencies, one city, and five contractors. The 10 states represent six of the nine FHWA regions across the country. The contractors interviewed were from four different FHWA regions. In addition to the structured interviews, many contacts were made with other individuals to collect data from additional states and organizations or to clarify information from published reports. And panel members were helpful in supplying data for their states.

The contractors interviewed depend on highway contracts for much of their business. Their candid comments might jeopardize relationships with their clients. Consequently, they were promised anonymity in the synthesis.

CHAPTER TWO

CURRENT STAFFING PRACTICES

The current practices for staffing highway construction projects are discussed in this chapter. This includes discussions on the use of staffing guidelines, assignment of responsibilities for surveys and quality control, and other staffing practices.

DEFINITIONS

Terminology, position titles, and the like vary from one agency to another. In order to simplify interpretation of this synthesis, definitions of the following terms are provided:

District—a major subdivision or region of a state for administration of the construction program.

District construction engineer—the individual in charge of administering a district construction program. Other titles include district engineer, assistant district engineer for construction, district project coordinator, and regional construction engineer.

Resident engineer—the individual in charge of administering a construction program for a defined area, usually a portion of a district. Boundaries may be flexible. Another title is area engineer.

Project engineer—the individual in responsible charge for administering construction contracts for a project or projects. Other titles include project manager, chief inspector, resident engineer, and project coordinator.

Contractor—prime contractors, subcontractors, vendors, suppliers, and fabricators.

Quality control—all activities and considerations during the manufacture of the product that are necessary to ensure that the product has the desired quality characteristics, both levels and tolerances (*1*).

Acceptance sampling and testing—the collection and testing of samples of the product and/or the inspection of the manufacturing process as required to determine if the quality characteristics of the delivered product conform to the required levels and tolerances (*1*).

Quality assurance—the actions and considerations included in both "Quality control" and "Acceptance sampling and testing" (*1*).

Note: The individuals performing the functions described in the definitions for district construction engineer, resident engineer, and project engineer are not necessarily engineers. Most states do not use the engineer title unless the position is filled by a registered professional engineer, a graduate engineer, or an engineer in training (EIT). EITs are generally required to have passed the EIT portion of the professional engineer's examination. See Chapter Three for the discussion of qualifications of engineers and technicians.

AGENCY STAFFING

Manpower Guidelines

Slightly more than half of the state highway and transportation agencies have some form of manpower guidelines for determining construction engineering and inspection staffing needs. The guidelines vary considerably in form and complexity. Three basic types of manpower guidelines were identified. They are:

- staffing based on the dollar value of the contract;
- staffing based on type of improvement; and
- staffing based on activities and contract types.

Each type is discussed below. All of these guidelines are used more for estimating staffing needs for planning, recruiting, and training purposes than for making day-to-day or week-to-week assignments. Some states use a combination of the above methods for estimating manpower needs. A few agencies use guidelines for staffing federal-aid projects but not for state-funded projects.

Note: Many states use the term "manpower standard" instead of "manpower guideline." The term guideline is used in this report because essentially all states use judgment in applying the staffing values to more accurately predict the staffing needs.

Dollar Value

Typical dollar value guidelines equate staffing needs to the size and complexity of the project as reflected by the dollar value of the contract. Usually there are two sets of guidelines—one for bridge-only projects and another for all other types of projects. The latter guideline is used for projects that include both roadways and bridges.

One example of this type of guideline is used by the Vermont Agency of Transportation (*2*). The guidelines recommend staffing complements for up to six different project sizes for three project categories: roadway, bridge, and asphalt paving. (Vermont constructs very little portland cement concrete paving.) The Vermont guidelines are shown in Table 1. The number of engineers and/or technicians shown represents the typical num-

TABLE 1

VERMONT—PROJECT STAFFING CRITERIA—1986

Note: Engineer A and Technician A are entry-level positions in Vermont. Engineer C and Technician D are the senior field construction positions.

Size of Project	Manpower		
	ROADWAY PROJECTS	BRIDGE PROJECTS	ASPHALT PAVING PROJECTS
$ -- 150,000	Engineer A or Technician B	Engineer A or Technician B	Engineer B or Technician C Engineer A or Technician B
$ 150,000 -- 300,000	Engineer B or Technician C	Engineer B or Technician C	Engineer B or Technician C Engineer A or Technician B
$ 300,000 -- 500,000	Engineer B or Technician C Engineer A or Technician B	Engineer C or Technician D	Engineer B or Technician C Engineer A or Technician B
$ 500,000 -- 1,000,000	Engineer C or Technician D Engineer B or Technician C	Engineer C or Technician D Engineer B or Technician C	Engineer C or Technician D Engineer A or Technician B
$1,000,000 -- 2,000,000	Engineer C or Technician D Engineer B or Technician C Engineer A or Temporary	Engineer C or Technician D Engineer B or Technician C Plus men as needed	Engineer C or Technician D Engineer B or Technician C Plus men as needed
$2,000,000 and up	Engineer C or Technician D Engineer B or Technician C Engineer A or Technician B Technician A or Temporary Plus additional personnel as needed for structures, office & special features.	Engineer C or Technician D Engineer B or Technician C Plus men as needed	Engineer C or Technician D Engineer B or Technician C Plus men as needed Paving projects should have a minimum of two people

Adjustments will be made for complexities of projects, availability of personnel, and geographical distribution of projects and personnel.

ber of personnel and the skill levels to be assigned. Engineers and technicians are used interchangeably in making project assignments, as the table shows (*3*).

Another example of staffing guidelines based on contract amounts was developed in Maryland. Maryland uses 14 different contract sizes in its guideline manpower computations. The guidelines provide for estimating staffing needs for seven technician skill levels. The guidelines for roadways are shown in Table 2. The total estimated man-hours are computed by multiplying the available days times the average staff times nine hours per day. Table 3 shows the manpower guidelines for bridge projects. The guidelines are identical for roadway and bridge projects for contract amounts up to $2 million. Above that, the average staff for bridge projects is lower than for roadway projects. Summaries are prepared for each district to show the staffing needs for each employee classification, the number available from within the department and from current consultant contracts, and the deficiencies or excesses of personnel. Maryland's system was adapted from the Construction Engineering Manpower Management System (*4*). A description of the "Pooled Fund" system is included in Appendix B.

The staffing guidelines for Vermont and Maryland are compared in Figure 1 for roadways and Figure 2 for bridge projects. The staffing guidelines compare quite closely when the additional staff that Vermont assigns for projects above $2 million (the upper limit of Vermont's guidelines) is considered.

With dollar value guidelines, no other consideration is given to the variations in project characteristics that affect staffing needs.

Type of Improvement

Under this type of guideline, the average number of engineers and technicians typically required to staff a project is determined for each of the various types of improvements carried out by the agency. The guideline may show only the total number to be assigned or it may define the skill levels needed.

North Dakota developed staffing guidelines for 15 types of highway improvements in the late 1960s (*5*). These guidelines have been updated since then, and the number of guidelines has

TABLE 2

MARYLAND DOT—STAFFING GUIDELINES: ROADWAYS*

C.E.M.M. MANPOWER PLANNING TYPE "C"

Contract Amount $	Work Days	Avail Days	Cal. Days	Staff Mths.	Staff: Engineer VI	V	IV	Technicians III	II	I	TR	-Engr.- II	I	Hrs./ Days	Total Man-hrs.	Average Staff
0 - 100,000	30	42	60	2			0.5							9	189	0.5
100,000 - 200,000	55	78	112	4			1							9	702	1.0
200,000 - 350,000	80	113	162	5			1			0.5				9	1,526	1.5
350,000 - 700,000	100	141	203	7			1			1				9	2,538	2.0
700,000 - 1,250,000	140	196	283	9		1		1			0.5			9	4,410	2.5
1,250,000 - 2,000,000	170	240	345	11		1		1		1				9	6,480	3.0
2,000,000 - 3,000,000	200	283	406	14		1		1	1	0.5				9	8,915	3.5
3,000,000 - 4,000,000	240	339	487	16		1	1	1		0.5	0.5			9	12,204	4.0
4,000,000 - 5,500,000	290	409	588	20	1		1	1	1		0.5			9	16,565	4.5
5,500,000 - 7,000,000	340	479	689	23	1	0.5	1	1.5		0.5	0.5			9	21,555	5.0
7,000,000 - 8,500,000	380	537	771	25	1	1	1	1.5	0.5	0.5				9	26,582	5.5
8,500,000 - 11,000,000	420	593	852	28	1	1	1	1	1		1			9	32,022	6.0
11,000,000 - 14,000,000	470	663	953	32	1	1	1	1.5	1	0.5	0.5			9	38,786	6.5
14,000,000 & above	500	706	1,014	34	1	2	2	1.5	1	0.5	0.5			9	54,009	8.5

*Includes bridges when part of roadway contract.

Total Man-hours = Available days X Hours/day X Average staff

Staff Months = Total man-hours divided by (Hours/day X 21 Days/month X Average staff)

TABLE 3

MARYLAND DOT—STAFFING GUIDELINES: BRIDGES*

C.E.M.M. MANPOWER PLANNING TYPE "C"

Contract Amount $	Work Days	Avail Days	Cal. Days	Staff Mths.	Staff - E. T.: VI	V	IV	III	II	I	TR	Staff- --H.E.- II	I	Hrs. Days	Total Man-hrs.	Average Staff
0 - 100,000	30	42	60	2			0.5							9	189	0.5
100,000 - 200,000	55	78	112	4			1							9	702	1.0
200,000 - 350,000	80	113	162	5			1			0.5				9	1,526	1.5
350,000 - 700,000	100	141	203	7			1			1				9	2,538	2.0
700,000 - 1,250,000	140	196	283	9		1		1			0.5			9	4,410	2.5
1,250,000 - 2,000,000	170	240	345	11		1		1		1				9	6,480	3.0
2,000,000 - 3,000,000	200	283	406	14		1		1		1				9	7,641	3.0
3,000,000 - 4,000,000	240	339	487	16		1	1	1		0.5				9	10,679	3.5
4,000,000 - 5,500,000	290	409	588	20	1		1	1			0.5			9	12,884	3.5
5,500,000 - 7,000,000	340	479	689	23	1	0.5	1	1		0.5				9	17,244	4.0
7,000,000 - 8,500,000	380	537	771	25	1	1	1	1	0.5					9	21,749	4.5
8,500,000 - 11,000,000	420	593	852	28	1	1	1	1	1					9	26,685	5.0
11,000,000 - 14,000,000	470	663	953	32	1	1	1	1	1	0.5				9	32,819	5.5
14,000,000 & above	500	706	1,014	34	1	2	1	1	1	0.5				9	41,301	6.5

*For use when bridges are constructed independently.

See example computations on Table 2.

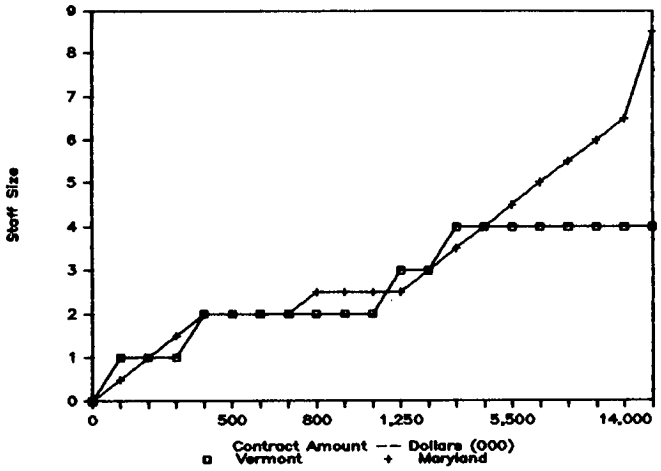

FIGURE 1 Comparison—staffing guides for roadway projects (Vermont and Maryland).

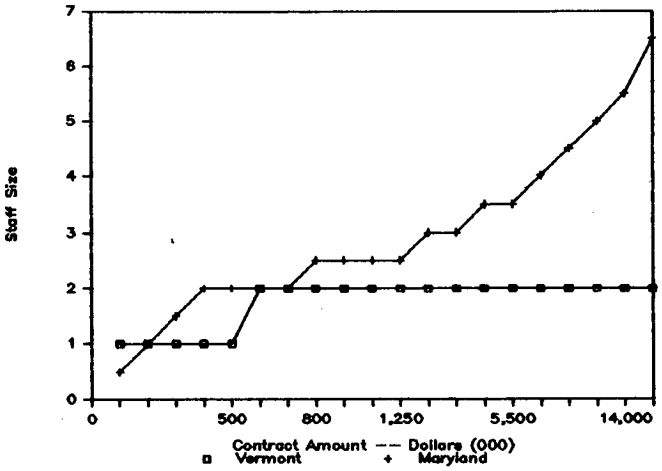

FIGURE 2 Comparison—staffing guides for bridge projects (Vermont and Maryland).

been increased to cover 23 improvement types plus the district lab (*6*). The types of improvements include:

- Grading and aggregate surfacing,
- Grade and bituminous base (selective widen and base),
- Bituminous surfacing,
- Milling bituminous surfacing,
- Seal,
- PCC surfacing or Econocrete,
- Recycled PCC pavement,
- Concrete repair,
- Box culverts,
- Bridges,
- Bridge deck overlays,
- Municipal items (grade, drain, surface, curb, and gutter),
- Signing and/or guardrail, and
- Rest area construction.

A typical North Dakota staffing guideline (grading and aggregate surfacing) is shown in Table 4 (*6*). Note that the guideline provides for assigning the survey crew, compaction and water inspector, scale person, and checker to the project as needed rather than on a full-time basis. The guideline shows the major activities of all personnel to be assigned and the classifications of those assigned permanently to the project.

Kansas developed and implemented manpower planning values based on types of improvement in 1973 (*7*, pp. 123–130). Guidelines were developed for 51 different types of project. Manpower projections based on these guidelines are developed as needed. Projections are not made on a regular basis.

Guidelines based on the type of improvement work best where most projects fit into one of the defined project types with little variation.

Activities and Contract Types

The combination of construction engineering activities and contract types provides an estimate of manpower needs based on the detailed characteristics of each project. Most states that use this type of guideline define about 30 major activities and 8 to 12 contract types. Modifiers may also be used to further relate staffing needs to project conditions. Not all activities and modifiers are used for any one project, of course.

Montana's guidelines are typical (*8*). Montana's system includes eight project types and up to 38 activities. The project types are:

- construction,
- reconstruction,
- rehabilitation,
- resurfacing,
- lighting and traffic signals,
- maintenance stockpiles,
- miscellaneous, and
- unique.

TABLE 4

NORTH DAKOTA MANPOWER PLANNING STAFFING STANDARD

CODE 10

Type of Improvement: Grading & Aggregate Surfacing

Major Activity	Number of Full-Time Personnel		
	Permanent	Temporary	Total
Supervisor	1	--	1
General Inspector	1	--	1
Survey Crew	1	4	5
Compaction & Water Inspector	--	1	1
Lab Person	1/2	--	1/2
Scale Person	--	1/2	1/2
Checker	--	1/2	1/2
Office Person	1/2	--	1/2
TOTAL	4	6	10

Permanent Personnel by Classification

Project Supervisor	1
Engineering Technician IV	1
Engineering Technician III	1

Vehicle Requirements

Automobile	1
Panels	3
Pickup	1

MONTANA DEPARTMENT OF HIGHWAYS
CONSTRUCTION MANAGEMENT
PLANNING--CONSTRUCTION ACTIVITIES--MAJOR PROJECTS

LETTING DATE March 8, 1982
DATE PREPARED Jan. 11, 1982
PROJECT MANAGER Alexander

TYPE CONSTRUCTION Construction AREA NO. 1130
MODIFIERS: TRAFFIC X URBAN ___ ROUGH TERRAIN ___ TIMBER ___ ISOLATED X

ACTIVITY CODE	ACTIVITY TITLE	PLAN. UNIT	NO. OF PLAN. UNITS	STD PLAN. VALUE (MH/UNIT)	M-HRS REQ.	M-HRS PER M-MONTH	EQUIV MAN MONTHS
001	Engineering Layout	R.M.	10.9	158	1722	173	10.0
002	Cross Sectioning and Slope Staking	R.M.	10.9	176	1918	173	11.1
	SUB-TOTAL - PRELIMINARY STAKING				3640		21.1
010	Bluetop-Subgrade	R.M.	-0-	76	-0-	173	-0-
011	Bluetop-Subgrade, Contractor Bid Item	R.M.	10.9	12	131	173	0.8
012	Grading Inspection	10 MCY	93.7	25	2343	195	12.0
013	Field Office - Grading	R.M.	10.9	56	610	173	3.5
	SUB-TOTAL - GRADING				3084		16.3
020	Culvert & Minor Drainage Structure Staking	100 L.F.	77.0	5	385	173	2.2
021	Culvert & Minor Drainage Structure Inspection	100 L.F.	77.0	13	1001	195	5.1
022	Field Office - Drainage	100 L.F.	77.0	4	308	173	1.8
	SUB-TOTAL - DRAINAGE				1694		9.1
030	Bluetop - Aggregate Construction	R.M.	-0-	63	-0-	173	-0-
031	Bluetop - Agg Const - Contractor Bid Item	R.M.	10.9	12	131	173	0.8
032	Aggregate Construction Inspection	MT	123.3	15	1850	195	9.5
033	Cement Treated Agg Construction Inspection	10 MSY	-0-	28	-0-	195	-0-
034	Field Office - Aggregate	M.T.	123.3	2	247	173	1.4
	SUB-TOTAL - AGGREGATE				2228		11.7
040	Line Control - Asphalt Paving	R.M.	10.9	23	251	173	1.5
041	Surface Preparation Inspection	R.M.	-0-	-0-	-0-	195	-0-
042	Asphalt Paving Inspection Base or Surf Course	M.T.	156.8	22	3450	195	17.7
043	Seal & Cover Inspection	R.M.	10.9	13	142	195	0.7
044	Field Office - Asphalt	M.T.	156.8	3	470	173	2.7
	SUB-TOTAL - ASPHALT PAVING				4313		22.6

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FIGURE 3 Example of Montana planning computations.

ACTIVITY CODE	ACTIVITY TITLE	PLAN UNIT	NO. OF PLAN. UNITS	STD PLAN VALUE (MH/UNIT)	M-HRS REQ.	M-HRS PER M-MONTH	EQUIV MAN MONTHS
050	Line/Grade Control - PCC Paving Staged Const	R.M.	-0-	105	-0-	173	-0-
051	PCC Paving Inspection	M.S.Y.	-0-	6	-0-	195	-0-
052	Field Office - PCC Paving	M.S.Y.	-0-	1	-0-	173	-0-
	SUB-TOTAL - PCC PAVING				-0-		-0-
060	Structure Staking - Conc	Bent	4	47	188	173	1.1
061	Structure Staking, Contractor Bid Item	Bent	-0-	9	-0-	173	-0-
062	Structure Staking, Timber	Bent	-0-	-0-	-0-	173	-0-
063	Structure Inspection, Concrete	Span	2	147	294	195	1.5
064	Structure Inspection, Timber	Span	-0-	-0-	-0-	195	-0-
065	Field Office, Structure	Span	2	23	46	173	0.3
	SUB-TOTAL - STRUCTURE				528		2.9
070	Staking Miscellaneous Items	R.M.	10.9	36	392	173	2.3
072	Inspection of Miscellaneous Items	R.M.	10.9	48	523	195	2.7
073	Field Office - Miscellaneous Items	R.M.	10.9	26	283	173	1.6
	SUB-TOTAL - MISCELLANEOUS				1198		6.6
080	Special Feature Staking	L.S.	-0-	-0-	-0-	173	-0-
081	Special Feature Inspection	L.S.	-0-	-0-	-0-	195	-0-
082	Field Office - Special Feature	L.S.	-0-	-0-	-0-	173	-0-
	SUB-TOTAL - SPECIAL FEATURE				-0-		-0-
090	General Field Office Work	I.M.H.	9603	0.15	1440	173	8.3
091	Project Supervision and Management	I.M.H.	18125	0.16	2900	173	16.8
092	Travel	S.M.H.	14721	0.15	2208	173	12.8
	SUB-TOTAL - GENERAL				6548		37.9
	TOTAL - ALL ACTIVITIES				23233		128.2

FIGURE 3 (*Continued*)

TABLE 5

MONTANA PLANNING STANDARDS—RECONSTRUCTION PROJECTS

Man-Hours per Planning Unit

CODE	DESCRIPTION	PLANNING UNIT	BASE PLANNING VALUE	MODIFIERS (Additives)				
				TRAFFIC	URBAN	ROUGH TERRAIN	TIMBER	ISOLATED
001	Engineering Layout	Roadway Mile	123	6		81	39	
002	Cross Sectioning & Slope Staking	Roadway Mile	150	33	92	93	17	
010	Bluetop - Subgrade	Roadway Mile	100	6	28	26		
011	Bluetop - Subgrade - Contractor Bid Item	Roadway Mile	8		4			
012	Grading Inspection	10,000 C.Y.	80		9			4
013	Field Office - Grading	Roadway Mile	100	1	8		4	
020	Culvert & Minor Drainage Structure Staking	100 L.F.	7	1		1		
021	Culvert & Minor Drainage Structure Inspect.	100 L.F.	12	2				1
022	Field Office - Drainage	100 L.F.	5		3			
030	Bluetop - Aggregate Construction	Course Mile	45	5	23	20		
031	Bluetop - Aggregate Construction - Contractor Bid Item	Course Mile	8		4			
032	Aggregate Construction Inspection	1,000 Tons	34		3			1
034	Field Office Aggregate	1,000 Tons	5		1			
040	Line Control - Asphalt Paving	Roadway Mile	21	2		4		
041	Milling	Roadway Mile	25					2
042	Asphalt Paving Inspection - Base or Surface Course	1,000 Tons	45		20			2
043	Seal and Cover Inspection	Roadway Mile	18		12			1
044	Field Office - Asphalt	1,000 Tons	5		2			
060	Structure Staking - Concrete	Bent	37	6	4	9		4
061	Structure Staking - Contractor Bid Item	Bent	7	1	1	2		1
062	Structure Staking - Timber	Bent	8					
063	Structure Inspection - Concrete	1,000 S.F.	76					8
064	Structure Inspection -Timber	Span	28	6				3
065	Field Office - Structure	1,000 S.F.	14			2		
070	Staking Miscellaneous Items	Roadway Mile	31		479	17		
071	Inspection of Miscellaneous Items	Roadway Mile	50	9	88	4		4
072	Field Office - Miscellaneous Items	Roadway Mile	34		26			
080	Special Feature Staking	Lump Sum	N/A					
081	Special Feature Inspection	Lump Sum	N/A					
082	Field Office - Special Feature	Lump Sum	N/A					
090	General Field Office Work	Insp. M-Hrs.	15 %					
091	Project Supervision and Management	Total M-Hrs.	12 %					
092	Travel	Surv./Insp. Man-Hours	See Table 6					

No guidelines were developed for the unique category. Staffing needs are estimated individually for each of these projects.

Because of the variations in terrain, ground cover, and project locations in Montana, the system also includes five modifiers that allow for increasing staffing estimates in response to special conditions on individual projects. The modifiers are applied to projects that involve construction:

- under traffic,
- in urban areas,
- in rough terrain or mountainous locations,
- where substantial timber or brush must be cleared, and
- in isolated locations where utilization of personnel between projects is not possible.

A copy of the activity planning guidelines for a reconstruction project is shown in Table 5 (*9*). This table does not include engineering and inspection activities for portland cement concrete paving. All of Montana's reconstruction projects have involved asphalt pavements, so guidelines for reconstruction of PCC paving were not developed.

The base planning values are expressed in man-hours per planning unit and are used for all projects where modifiers are not applicable. The planning value from Table 5 for cross sectioning and slope staking is 150 man-hours per roadway mile. If modifiers are appropriate, the modifier man-hours are added to the base planning value. For example, if the project were under traffic, the planning value is 183 man-hours per roadway mile—150 plus 33. If it were also in an urban area, an additional 92 man-hours is added, making the total planning value 275 man-hours.

Travel to project sites can be significant in Montana. Planning values for travel are expressed as percentages of the man-hours for field activities—staking and inspection—as shown in Table 6 (*9*).

The manpower requirements are computed for each project in man-hours by activity—the total planning value times the number of units. A sample computation is shown in Figure 3 (*8*). Man-hours are converted to man-months at rates based on nine hours per day for inspection activities and eight hours per day for all others. The man-months are summarized into 10 groups that generally correspond with contractor operations. The man-months for each activity group are spread over the months in which the operation is expected to be performed, as shown in Figure 4. When project time extends into more than one calendar year, separate forms are completed to estimate the needs for each year. The assigned project manager makes these estimates based on knowledge of the project, local working conditions, and, if the project has been awarded, the contractor's capabilities. The monthly staffing needs for all projects assigned to each project manager are summarized to determine personnel needs at each location. An allowance for leaves is added so a realistic comparison between needed and available manpower can be made. These allowances are expressed as percentages

TABLE 6

MONTANA PLANNING STANDARDS—TRAVEL

Planning Standard For Construction Activity 092--Travel

Activity Code	Description	Planning Unit	Travel Time from Project Office to Site (One-way)	Applicable Percent
092	Travel	Percent of total staking and inspection man-hours	0 to 30 minutes	0
			30 to 60 minutes	15
			More than 60 minutes	25

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MONTANA DEPARTMENT OF HIGHWAYS
CONSTRUCTION MANAGEMENT
ANNUAL STAFFING PLAN

Sheet 1 of 1

DISTRICT Missoula
PROJECT NUMBER I 90-2(7)83
PROJECT MANAGER Alexander
YEAR 1983
DATE PREPARED Jan. 10, 1983

ACTIVITY GROUP	MAN-MONTHS																
	TOTAL PLANNED	USED TO DATE	BALANCE	CURRENT YEAR													BALANCE TO COMPLETE
				JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	TOTAL	
PRELIMINARY STAKING	21.4	-0-	21.4		3.0	5.0	5.0	5.0	2.0	1.1						21.1	0.3
GRADING	19.2	-0-	19.2				0.3	1.5	2.0	2.0	2.0	2.0	2.0	1.5		13.3	5.9
DRAINAGE	9.1	-0-	9.1					0.5	1.0	1.0	1.0	1.0	1.0	1.0		6.5	2.6
AGGREGATE	11.7	-0-	11.7													-0-	11.7
ASPHALT PAVING	22.6	-0-	22.6													-0-	22.6
PCC PAVING	-0-	-0-	-0-													-0-	-0-
STRUCTURES	7.3	-0-	7.3							0.5	1.0	1.0	0.4			2.9	4.4
MISCELLANEOUS	13.1	-0-	13.1					0.5	0.5	0.5	0.5	0.5	0.5	0.5		3.5	9.6
SPECIAL FEATURE	-0-	-0-	-0-													-0-	-0-
GENERAL ACTIVITIES	44.1	-0-	44.1		1.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	1.0	28.0	16.1
TOTAL	148.5	-0-	148.5		4.0	8.0	8.3	10.5	8.5	8.1	7.5	7.5	6.9	5.0	1.0	75.3	73.2

Distribution: District Office
Originating Office

FIGURE 4 Example of Montana staffing plan.

and are based on actual experience in each district. Figure 5 shows an example summary for a project manager. These needs are then summarized for each district and statewide. Montana's system was also adapted from the Construction Engineering Manpower Management System (*4*).

The Montana system was first developed and implemented as a manual system. It has since been converted for use on microcomputers. The examples included here are from the manual system for ease in following the computations.

Staffing Practices

Estimating staffing needs for construction engineering and inspection personnel involves at least two steps. The first is the determination of annual needs on a month-by-month basis to cover the coming construction season. The second is the day-to-day and week-to-week assignments on individual projects in response to the contractor's operation. A third estimate, which is often neglected, is desirable for predicting trends in staffing needs for the next several years to improve recruiting and training efforts.

Annual Estimate

Staffing estimates are typically compiled in the winter months for the upcoming construction season. By making the estimates early, there is enough lead time to decide how best to utilize available staff, recruit permanent engineers and technicians, plan for temporary employees, and schedule and conduct any training needed. These staffing estimates are also used to determine which projects should be assigned to consultants for construction engineering and inspection. The staffing estimates may be made by staff members at any of four levels—headquarters, district, residency, or project. In general, staffing estimates are all based on individual projects that are currently under way or are expected to be under way during the construction season. Where projects are not yet well defined, staffing estimates must be based on programmed amounts or groups of projects. Estimates are made by month for each project.

Staffing summaries showing the manpower needed and available for each month are then prepared for each management level—project, residency, district, and statewide. Central-office construction engineers in several states hold periodic meetings with the district construction engineers to review staffing needs to balance staffing and workloads statewide. District construction engineers in turn hold similar meetings with the resident and project engineers to ensure that manpower is assigned where the need is the most critical within the districts.

Because of the uncertainties of contract lettings and contractors' schedules, estimating staffing needs is not an exact science.

Day-to-Day Assignments

To make the best use of available manpower, project engineers typically make short-term assignments in response to the contractor's operations actually under way. The assignments are based on the supervisor's judgment of the critical needs on projects and the capabilities of individual inspectors. A few agencies have staffing guidelines to assist project engineers in staffing project operations; most do not. New Jersey provides their project engineers with minimum inspection requirements for use in making day-to-day staffing assignments. Table 7 shows

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MONTANA DEPARTMENT OF HIGHWAYS
CONSTRUCTION MANAGEMENT
PROJECT MANAGER'S STAFFING SUMMARY

DISTRICT Missoula
PROJECT MANAGER Alexander
YEAR 1983
DATE PREPARED Jan 10, 1983

ASSIGNED CREW		PROJECT NUMBER	EST COMPL DATE	TOTAL PLANNED MAN-MTHS	BAL	ESTIMATED PROJECT STAFFING REQUIREMENTS BY MAN-MONTH												TOTAL THIS YEAR	BALANCE TO COMPLETE
CLASS	NAME					JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC		
EPM	Alexander	I 90-2(7)83	9-84	148.5	148.5		4.0	8.0	9.3	10.5	8.5	8.1	7.5	7.5	6.9	5.0	1.0	75.3	73.2
ET-3	Larson	S 0005(27)	11-83	92.7	43.6	2.8	2.8	3.2	3.7	4.5	5.1	6.2	6.2	4.4	2.7	2.0		43.6	-0-
ET-3	Thompson	HES 57-2(6)45	7-83	4.5	4.5				1.0	2.0	1.0	0.5						4.5	-0-
ET-3	Burns	SUB-TOTAL				2.8	6.8	11.2	13.0	17.0	14.6	14.8	13.7	11.9	9.6	7.0	1.0	123.4	73.2
ET-2	Saddler																		
ET-1	Shay	PRELIM SURVEY																	
ET-1	Walker	F43-2(3)86	3-84	40.2	12.9	3.0	3.0										3.0	9.0	3.9
SA-2	Edwards																		
SA-1	Spencer	MAN-MONTHS NEEDED (To District CMS-10)				5.8	9.8	11.2	13.0	17.0	14.6	14.8	13.7	11.9	9.6	7.0	4.0	132.4	
		LEAVE PERCENTAGE				22	29	11	8	14	9	14	12	15	19	32	29		
		LEAVE ALLOWANCE				1.3	2.8	1.2	1.0	2.4	1.3	2.1	1.6	1.8	1.8	2.2	1.2	20.7	
		TOTAL MANPOWER NEEDED				7.1	12.6	12.4	14.0	19.4	15.9	16.9	15.3	13.7	11.4	9.2	5.2	153.1	
		PERSONNEL ASSIGNED				10	10	10	10	10	10	10	10	10	10	10	10	120.0	
		EXCESS				2.9										0.8	4.8	8.5	
		DEFICIENCY					2.6	2.4	4.0	9.4	5.9	6.9	5.3	3.7	1.4			41.6	

Distribution: White - Construction Bureau (with budget submittal)
Yellow - District Office
Pink - Originating Office

FIGURE 5 Example of Montana project manager's staffing summary.

the minimum staffing requirements for asphalt paving (*10*). New Jersey's construction management system is also based on the Construction Engineering Manpower Management System (*4*).

The Pooled Fund Design Manual also provides guidance on establishing minimum and maximum staffing guidelines for making day-to-day assignments (*4*). The maximum staffing guidelines provide for contractor operations at two locations or shifts for major work items. [This type of guideline was first developed in Michigan (*11*).] Montana adapted these guidelines to its needs (*8*). An example of Montana's maximum staffing guidelines for selected activities is shown in Table 8.

Staffing Ratios

The number of permanent, full-time engineers and technicians assigned to field construction activities was compared for selected states. The results are shown in Table 9.

Temporary seasonal employees are used to supplement the permanent staff in most states. In Iowa, the Waterloo Residency staffing ratios would change to 12 percent engineers, 67 percent technicians, and 21 percent seasonal employees, if the peak summer employment is included. In Michigan, the ratios would be 10 percent engineers, 60 percent permanent technicians, 12

TABLE 7

NEW JERSEY MINIMUM INSPECTION REQUIREMENTS

ASPHALT PAVING

Inspection Element	Inspection		
	One-Time	Intermittent	Full-Time
Checking Equipment	X		
Placement & Temperature of Material (Collect Tickets)			X
Line & Grade Control		X	
Rolling		X	
Rolling Straight Edge	X		
Calculation for Payment	X		
Tack Coat	X		

TABLE 8

TABLE OF MAXIMUM STAFFING GUIDELINES PER MAJOR PROJECT—MONTANA

Active Contract Phase or Element	Number of Persons: One Contractor One Operation**	One Contractor Two Operations**
Survey Crew	3*	3*
Earthwork Inspection		
Grade Inspector	1	1
Density Inspector	1	2
Subtotal, Earthwork Inspection	2	3
Culvert and Minor Drainage Structure Inspection	1	1-2
Aggregate Construction Inspection		
Aggregate Road Inspector (Inc. Density)	1	1-2
Weighman	1	1
Ticket Taker	1	1-2
Gradation Tester	1	1
Subtotal, Aggregate Construction Inspection--ton basis	4	4-6
Cement Treated Aggregate Construction Inspection		
Road Inspector	1	2
Density Inspector	1	1
Plant Inspector	1	1
Subtotal, Treated Aggregate Construction Inspection	3	4

* Additional personnel may be added when traffic control, brush cutting, terrain, and contractor's operations require.

** Numbers are for single shift operations. Inspection personnel may be doubled for double shift operations as appropriate.

percent seasonal technicians, and 18 percent co-op students. Michigan's Co-op Student Program is discussed in Chapter Four.

The variations in staffing among states are significant. However, in reviewing these data, several items should be considered. Employees in Connecticut may enter the engineer classifications through experience without a formal engineering education or professional registration, so the ratio is not directly comparable to other states. It should also be noted that a high percentage of the field construction activities in Connecticut was performed by consultants in 1986. A higher percentage of agency engineers may be justified for overseeing the consultants.

Maryland relies nearly as much on consultants (65 percent in 1986), yet has no engineers in the field. Maryland normally provides a chief inspector and one or two other technicians for each project; consultants furnish the remaining technicians. The state's chief inspector is the authority on the project. (On selected projects—usually major undertakings—consultants provide all personnel, including chief inspectors and office personnel. A state employee oversees the consultants' work.) The department is limited to 400 employees for the construction function. They are trying to increase the number of engineers by replacing some of the retiring technicians with graduate engineers.

Utah has an in-house training and examination procedure for technicians to qualify as engineer associates. Engineer associates perform essentially the same duties as engineers but were counted as technicians for the above comparisons of ratios.

CONTRACTOR STAFFING

Responsibilities

The major staffing responsibility that contractors have traditionally faced is the provision of supervisors and craftsmen. Although they must continue that staffing, contractors are now required by some agencies to provide an increasing amount of services that were formerly provided by agency personnel. The two most common services assigned to contractors are construction staking and production quality control. Quality control for production of aggregates, asphaltic concrete, and portland cement concrete is often assigned to contractors. The requirements for these services vary from agency to agency and even from project to project within an agency. Quality-acceptance sampling and testing must be performed by agency representatives, of course.

No uniform reaction to this change was found among the contractors. Some contractors prefer to perform this work because they believe that neither state nor consultant personnel perform the work as quickly as their own personnel do. Contractors have experienced difficulty in retaining good technicians because the need for their services was inconsistent from project to project. Others were concerned with the honesty of their competitors in performing quality control on their own operations.

Staking

Of the states surveyed, 44 percent require contractors to provide construction staking on essentially all contracts and 33 percent require it on selected projects. The remaining agencies continue to provide all of the staking. The primary reason that more agencies now require contractors to provide construction staking is to overcome shortages of agency personnel—either locally or statewide. As more limitations on agency staffing have

TABLE 9

PERCENT OF PERMANENT FIELD CONSTRUCTION PERSONNEL

State	Engineers	Technicians
Connecticut	79	21
Iowa[a]	15	85
Maryland	0	100
Michigan	15	85
New Hampshire	65	35
North Dakota	15	85
Utah	6	94
Vermont	31	69
Virginia	0	100

[a]Based on the Waterloo Residency

been imposed, more agencies have required the contractors to perform the construction staking.

Job-Control Testing

About two-thirds of the agencies interviewed test aggregates for process quality control. The other third require the contractors or suppliers to perform these tests.

More than half of the agencies interviewed require the contractors or suppliers to perform all job control testing at the asphalt plants.

Almost half of the agencies require the contractors or suppliers to perform all job control testing at the concrete plants.

All agencies retain the responsibility for record/acceptance sampling and testing.

Use of Consultants

Contractors use consultants for all of the above services at times. As might be expected, the use of consultants varies from one contractor to another. In general, contractors that do not have a continuous need for these services are more likely to use consultants. It is more difficult for them to maintain a workload that enables them to retain skilled personnel in each area of expertise, especially when these services are performed by agency personnel on a significant number of the projects and by the contractor on the rest.

Selection and Payment

Where contractors hire consultants to perform work required by the contract, the contractors select the consultants using the same criteria as with other subcontractors. Selection is based on competency, availability, and cost, but not necessarily in that order. Most contractors work in a fairly specific area, and national contractors usually have regional offices. Consequently, contractors learn the reputations and capabilities of the consulting firms and testing labs in their areas and can select those that best meet the needs of each project.

The basis for payment for consultants' services used by contractors includes hourly rates, daily rates, rates per test, and lump sum. The method of payment depends on the scope of services. Lump-sum payments are used when the work can be well defined, time and materials rates when it cannot. Usually a maximum limit on the cost of services is established for time and materials payments. Consultants must comply with any minimum wage rates specified in contracts, the same as any other subcontractor.

Staffing Practices

The assignment of qualified craftsmen and supervisors in adequate numbers affects the quality of work attained. The interviews included questions on this subject.

Of the contractors interviewed, only one reported staffing guidelines, and those are kept confidential to retain any competitive advantage there may be. Contractors develop staffing schedules unique to each project during the bidding process. Some contractors have standard crew sizes for each operation, although the crew size may be increased or decreased for a particular project. The estimated number of crew days is priced out to develop unit bid prices.

The key to staffing construction projects for quality work is the ability of the firm to keep the same workers returning each season year after year. Contractors need to stay in the same general area to build up a reservoir of good workmen. A few craftsmen will travel to other states to work but most stay within a given geographical area. The better superintendents have a following of key foremen and craftsmen who work for them every year. Some firms maintain a computer listing of available personnel from throughout the company as well as applicants not currently employed by the firm.

Actual assignment of personnel is the responsibility of the field superintendents and foremen.

Staffing Projects of Different Sizes, Specialties, and Complexity

Paving work requires about the same size crew for all projects, at least on the mainline. Larger, more complex projects take longer or require more crews. The day-to-day activities and, consequently, the staffing on grading or bridge projects can vary depending on the amount of time available for project completion.

Method Specifications Versus End-Result or Statistical Specifications

Most contractors assign additional personnel, better-qualified personnel, or both to projects with end-result or statistical specifications because of the additional quality control required and possible price adjustments.

OTHER STAFFING

In addition to assigning selected construction engineering functions to the contractors, agencies supplement their staffs through the use of consulting engineers and testing laboratories.

Consulting Engineers

Data from the FHWA Fiscal Management Information System reports for a two-year period (1985 and 1986) show that, of 49 states and the District of Columbia, all but 3 contracted for some portion of their construction engineering on federal-aid projects. Contract expenditures accounted for less than 5 percent of the total construction engineering costs in 27 of these states. The use of A&E (architectural and engineering) firms in the remaining states ranged up to 81 percent, as shown in Figure 6. The consultants who performed this work were hired by the agencies. Any work by consultants employed by contractors is not included in Figure 6.

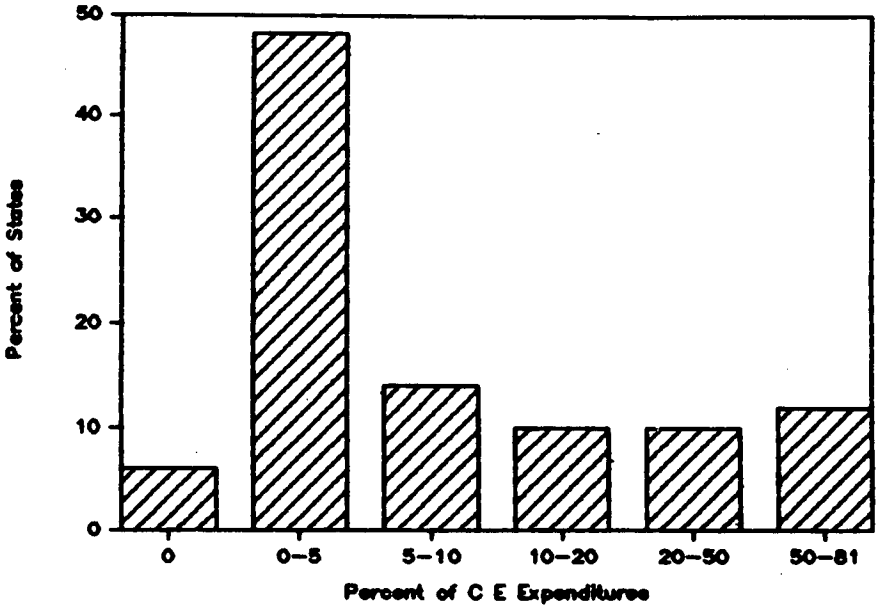

FIGURE 6 Construction engineering by consultants.

The federal-aid secondary program accounts for the use of consultants in some states. For example, the North Dakota State Highway Department does not hire consultants for construction engineering on contracts under its jurisdiction. However, the counties in North Dakota use consultants to supervise the construction of federal-aid secondary projects.

NCHRP Synthesis 146: Use of Consultants in Construction Engineering Management addresses this subject in greater detail.

Many agencies use consultants for inspection and testing of specialty items such as structural steel fabrication and precast and/or prestressed concrete beams, especially for out-of-state suppliers.

The use of consultants for construction engineering and inspection does not relieve the agency of the responsibility for satisfactory completion of the work. An agency employee must be assigned to administer the contract and oversee the work, at least on federal-aid projects (*12*).

CHAPTER THREE

QUALIFICATIONS OF CONSTRUCTION PERSONNEL

The minimum qualifications for entry into selected key positions by construction personnel in agencies and contracting firms are discussed in this chapter.

AGENCY PERSONNEL

Qualifications

Most states reserve the title "engineer" for registered professional engineers, graduate engineers, or engineers in training (EIT)—those who have passed the EIT portion of the professional engineer's examination.

In some states, however, no clear distinction was found between the duties for engineers and those for technicians in construction engineering. Technicians are performing duties in some states that are reserved for engineers in others. And technicians and engineers are used interchangeably in a few states. Consequently, a comparison of qualifications by function performed rather than by classification is thought to be of more value.

The minimum qualifications for entering the positions of project engineer, resident engineer, district construction engineer, entry-level technician, and second-level technician are presented in this section. The qualifications of higher-level technicians were collected, but the duties varied so much between states that it was not possible to make valid comparisons. In general, higher-level technicians are required to meet the minimum requirements for second-level technician but with progressively greater experience.

Project Engineer

A project engineer is in direct charge of the construction engineering and inspection of all aspects of a construction project or projects.

Graduate engineers with at least two years' experience or technicians with a minimum of five years' experience are typically assigned as project engineers. Some states assign personnel from up to three different personnel classifications, depending on the complexity of the project, the availability of personnel, and individual capabilities. Others have only one classification for project engineers. As shown in Table 10, only one of the states in the sample requires registration as a professional engineer. All of the other states will accept some combination of education and experience as equivalent to a degree in engineering.

Resident Engineer

A resident or area engineer has responsibility for administering all construction projects within a defined area, usually a portion of a district. Generally area boundaries have some flexibility to facilitate balancing workloads and staffing. Resident engineers typically supervise project engineers. This level of management is not used by all states—two-thirds of the states interviewed have this position.

Half of the states require individuals to be registered professional engineers to qualify for this position. The others will accept high school graduates, two-year technical graduates, or graduate engineers with suitable experience. The minimum requirements are summarized in Table 11.

District Construction Engineer

District construction engineers are in responsible charge of the construction program for a district and supervise assigned project engineers, either directly or through resident engineers.

Although most states use "engineer" in the title for this position, only two-thirds of the agencies interviewed require registration as a professional engineer when filling these positions. Few of the position descriptions referred to engineering degrees in the minimum requirements. It is difficult, and in some states impossible, to qualify for registration without a degree from an approved four-year engineering curriculum. So specifying registration will effectively also require a degree. A summary of minimum requirements for entering this position is presented in Table 12.

Entry-Level Technician

Essentially all agencies require entry-level technicians to be high school graduates or possess general education diplomas (GED). A few specify training or aptitude in mathematics or mechanical drawing. Because this is the entry level for inexperienced applicants, the requirements are minimal.

Second-Level Technician

Second-level technicians perform all rodding and chaining duties on survey crews; operate survey instruments for minor surveys; inspect contract items such as earthwork, guardrail

TABLE 10

QUALIFICATIONS—PROJECT ENGINEERS

State	Working Title	Classification	PE	Minimum Requirements: Engr. Degree	Minimum Requirements: High School	Minimum Requirements: Years Experience	Remarks
CT	Project Engineer	Transp. Sr. Engr.	No	Yes	Yes*	3	
			No	No	Yes*	7	Or equivalent training & experience
IA	Project Coord.	Const. Tech. II	No	No	Yes*	5	Or equivalent training & experience
KY	Project Engineer	Transp. Engr. II	Yes	Yes		2	In addition to that required for registr.
		Transp. Engr. I	Yes				
		Engr. in Train.	EIT			2	
MD	Chief Inspector	Engr. Tech. VI	No	No	Yes*	9	Plus written exam.
		Engr. Tech. V	No	No	Yes*	7	Plus written exam.
		Engr. Tech. IV	No	No	Yes*	5	Plus written exam.
ND	Proj. Mgr.	Engr. Tech. V	No	No		5	Plus equivalent of 2 years of college (engr.)
NH	Proj. Mgr.		No	Yes			All new hires must have BSCE.
OR	Proj. Mgr.		No				
UT	Proj. Engr.	Civil Engr. II	EIT	Yes		2	
		Engr. Assoc. III	No	Yes		4	Various substitutions may be made for educ.
VA	Proj. Engr.	Proj. Engr.	No	Yes		4	
			No	No		8	

*Or GED

TABLE 11

QUALIFICATIONS—RESIDENT ENGINEERS

State	Working Title	PE	Minimum Requirements: Engr. Degree	Minimum Requirements: Years Experience	Remarks
IA	Resident Engineer	Yes		1	
KY	Resident Engineer	Yes			
MD	Area Engineer	No	No		Experience as specified, plus written exam
ND	Resident Engineer	No	No	5	Plus equivalent of 2 years college engr.
UT	Resident Engineer	Yes			
VA	Resident Engineer A	No	Yes		Or equivalent training & experience

TABLE 12

QUALIFICATIONS—DISTRICT CONSTRUCTION ENGINEERS

State	Working Title	PE	Minimum Requirements: Engr. Degree	Minimum Requirements: Years Experience	Remarks
CT	District Engineer	Yes			
IA	District Construction Engineer	Yes Yes	Yes No	6 8	
KY	Asst. Dist. Engr./ Construction	Yes		4	In addition to that required for registration
MD	Asst. Dist. Engr./ Construction	No	No		Experience as specified plus written exam.
NH	Constr. District Engr.	Yes	Yes		BSCE now required for all promotions
ND	Dist. Proj. Coord.	No	No	7	Plus equivalent of 2 years of college (engr.)
OR	Reg. Constr. Engr.	Yes			
UT	Dist. Constr. Engr.	Yes			
VA	Assist. Dist. Engr.	No	Yes		Or equivalent training & experience

TABLE 13

QUALIFICATIONS—SECOND-LEVEL TECHNICIAN

State	Title	Minimum Requirements: High School	Minimum Requirements: Years Experience	Remarks
Conn.	Transp. EIT II	Yes[a]	1	
Iowa	Engr. Aide II Entry	Yes[a]	2	May substitute college for experience
	Promotion	Yes[a]	1	Experience as EA I
Ky.	Trp. Engr. Aide II	Yes	1	May substitute related technical training
Md.	Engr. Tech II	Yes[a]	1	Plus written exam. May substitute related education for experience.
N.D.	Engr. Tech. II	Yes[a]	2	
Utah	Engr. Tech. I	Yes	1	
Va.	Hwy. Const. Insp. A	Yes	3	Must have 1 year inspection experience

[a]Or GED

installation, and base course construction; and perform gradation and density tests.

All states require a high school or equivalency diploma for entry into this position. Experience requirements range from one to three years. The minimum requirements are summarized in Table 13.

All of the states in the interviews require technicians at all levels of expertise to be versatile. There are no separate categories for survey, testing, inspection, or office personnel. Those assigned to construction are expected to perform work in any of these areas. The specialization of technicians that occurred during construction of the major portions of the Interstate system is no longer prevalent.

Technician Certification

The capabilities of inspectors to ensure that quality construction is attained is a continuing concern to agency managers. Technician certification programs were instituted to ensure that assigned individuals were, in fact, qualified.

Three types of certifications applicable to construction technicians were identified. They are in-house, the National Institute for Certification in Engineering Technologies (NICET), and the American Concrete Institute (ACI). A few agencies take advantage of more than one type of certification.

In-House

Most in-house certification programs are limited to some testing procedures and plant inspection for asphalt and concrete production. Iowa, for example, certifies technicians in four areas: aggregate testing, nuclear density testing, asphalt plant inspection, and concrete plant inspection. Where any of these functions are the responsibility of the contractors, their personnel also must be certified.

In the mid-1970s, Michigan developed a complete certification program covering all construction technicians (*13*). Under the program, individual technicians are required to be certified in a number of key work elements to qualify for promotion. The criteria for promotion at each level require technicians to be certified in work elements in each of three areas—inspection, staking, and office procedures—to ensure that they are versatile. There are 37 key work elements and 67 non-key work elements currently in the certification plan. A typical work element, Inspect Bituminous Surfacing, is shown in Figure 7. The work element includes a description of the work, a listing of the tasks to be performed, documentation requirements, the requirements for applying for certification, and the certification procedures. Certification for most work elements includes a review of actual on-the-job performance of the work. The Work Elements Checklist (Figure 8) shows the minimum work element requirements for each technician level. Note that a Construction Aide I must be certified in one key work element in each of the major functions—inspection, staking, and office—plus any four non-key work elements to qualify for promotion to Transportation Construction Technician II. Qualifications for other technician levels are similar.

Work Element Number 54
Inspection
Journeyman Level of Difficulty

INSPECT BITUMINOUS SURFACING

Description. In charge of bituminous paving. Review plans and proposals to determine type of mixture and proper yield. Check specifications to determine proper operation of pavers and rollers, construction of joints, temperature of mixture, and selection of lane widths.

Check equipment for excessive wear and proper operation. Surface of the screed plates should be in good condition. Observe operation and see that necessary adjustments to ensure proper surface texture, crown, and uniform spreading of mix to proper line and grade.

Task List	Application Requirements
1. Review plans and proposals for: + Typical cross section + Depth and width for each course + Bituminous type + Penetration + Yield + Proper traffic control	Effective on-the-job performance of applicable tasks and approval by immediate supervisor and resident/project engineer. Work element #15 & #18 are prerequisites. Certification Procedure On-site observation, oral interview based on task list, review of required documentation.
2. Check aggregate base, existing surface, or stabilized base preparation + Raising drainage structures + Hand patching + Joint repair detail + Check base for readiness + Check prime application and yield + Check bond coat application	
3. Inspect paving equipment for: + Check distributor + Screed condition and extension + Crown of screed + Tamper bars + Condition of rollers + Paver automation + Approved grade referencing device + Properly working joint heater + General condition of paver and other miscellaneous equipment	
4. Issue permit to place mix, where applicable	
5. Inspect starting joint for grade and alignment (straight edge)	
6. Inspect placement of mix + Depth-grade + Condition of mix - Temperature - Moisture - Texture + Longitudinal joint + Alignment of mat + Surface distortion + Yield + Pick up and sign tickets + Paver speed consistent with plant production + Proper feed control	
7. Inspect rolling operation + Required number of rollers + Breakdown rolling + Intermediate rolling, where applicable + Finishing rolling + Density control	
8. Inspect end of day production joint for longitudinal grade (straight edge)	
9. Inspect shoulder safety conditions	
10. Prepare reports + Sign and date all documentation	

DOCUMENTATION

+ Inspector's Daily Report - Form 1122
+ Weight Tickets
+ Permit to Place

FIGURE 7 Typical work element—Michigan DOT.

NICET

NICET provides certification in highway construction inspection for three levels of technicians (*14*). (A more detailed

1192 (11/80)

WORK ELEMENTS CHECKLIST

INDIVIDUAL EVALUATION RECORD
MINIMUM ENTRANCE REQUIREMENTS

NAME Last	First	Initial	SENORITY DATE
PRESENT CLASSIFICATION			DISTRICT

CONSTRUCTION AIDE I - No work element requirements to enter.

TRANSPORTATION CONSTRUCTION TECHNICIAN - II* Date Promoted _____

KEY WORK ELEMENTS + ☐ Demonstrated Math Ability

Work Element No. Inspection	1
Work Element No. Staking	9
Work Element No. Office	10

NON-KEY WORK ELEMENTS

+ FOUR	2	3	4	5	7	8
	11	12				

TRANSPORTATION CONSTRUCTION TECHNICIAN - III* Date Promoted _____

KEY WORK ELEMENTS

Work Element No. Inspection	13	14	17	18
Work Element No. Staking	36			
Work Element No. Office	45			

NON-KEY WORK ELEMENTS

+ FOUR	35B	35A	35	34	33	32	31	30				
	19	20	21	22	23	24	25	26	27	28	29	29A
+ TWO	37	38	39	40	41	42	44					

TRANSPORTATION CONSTRUCTION TECHNICIAN - IV* Date Promoted _____

KEY WORK ELEMENTS + ☐ Demonstrated Math Ability

Work Element No. Inspection	15 or 16
Work Element No. Staking	43
Work Element No. Office	

NON-KEY WORK ELEMENTS

+ FIVE**	35B	35A	35	34	33	32	31	30				
	19	20	21	22	23	24	25	26	27	28	29	29A
+ THREE**	37	38	39	40	41	42	44					
+ TWO	46	47	48	49	50							

TRANSPORTATION CONSTRUCTION TECHNICIAN - V* Date Promoted _____

KEY WORK ELEMENTS

Work Element No. Inspection	51 or 52	53 or 55	54		
Work Element No. Staking	Any two 62 or (63, 64, 65)		66	67	68
Work Element No. Office	77	78			

NON-KEY WORK ELEMENTS

+ TWO	56	57	58	59	60	61	61A	
+ ONE	69	70	71	72	73	74	75	76

TRANSPORTATION CONSTRUCTION TECHNICIAN - VI* Date Promoted _____

KEY WORK ELEMENTS

Work Element No. Inspection	80	81	82
Work Element No. Staking	84	87	
Work Element No. Office	88	89	90
Work Element No. Supervision	92 or 93		94

NON-KEY WORK ELEMENTS

+ TWO	79	83		
	85	86		
	91			
+ TWO	91A	95	96	97
	98	99	100	

CHECKLIST UPDATE	
Work Elements	Date

* Minimum entrance requirements. Work Elements typically performed at the next lower level.
** Includes those required for the III level.

FIGURE 8 Work elements checklist—Michigan DOT.

description of the background of NICET and the certification procedures is in Appendix C.) There are no certification requirements for the entry level. Certification at each level is based on qualified experience and satisfactory completion of the examination (*15*). Several states—Pennsylvania and West Virginia, for example—require NICET certification as a prerequisite for promotion in the technician classifications. Other states—Arizona, Maryland, and New Jersey—have conducted NICET testing and are considering requiring this certification (*16*).

Pennsylvania requires consultant personnel engaged in construction engineering and inspection to be certified by NICET at the same levels as department personnel. Some other states and agencies specify various levels of NICET certification for services performed by either contractors or consultants.

As of November 1988, there are 4641 highway construction technicians certified in all levels by NICET. This represents an increase of 2981 technicians since October 1985 (*17, 18*). A breakdown of those currently certified in each state by certification level is shown in Table 14. These numbers represent all of the certified highway construction technicians in each state including employees of the states, contractors, and consultants.

TABLE 14

HIGHWAY CONSTRUCTION CERTIFICATIONS BY NICET

November 1988

State	Number of Certified Technicians Level II	Level III	Level IV	Total
Alaska	1	0	0	1
Alabama	0	2	0	2
Arizona	139	121	35	295
Arkansas	0	1	0	1
California	7	2	2	11
Colorado	70	5	3	78
Connecticut	68	42	24	134
District of Columbia	0	1	0	1
Delaware	11	4	3	18
Florida	10	8	7	25
Georgia	1	1	0	2
Iowa	1	4	2	7
Illinois	0	2	2	4
Kentucky	0	1	0	1
Louisiana	1	1	0	2
Massachusetts	2	1	0	3
Maryland	32	16	11	59
Michigan	2	1	1	4
Minnesota	0	1	2	3
Missouri	2	2	2	6
Mississippi	13	35	66	114
Montana	88	55	15	158
North Carolina	2	4	0	6
North Dakota	9	12	8	29
New Jersey	79	61	37	177
New Mexico	35	19	0	54
Nevada	2	0	0	2
New York	264	228	236	728
Ohio	8	5	2	15
Oregon	2	3	1	6
Pennsylvania	1004	785	345	2134
Texas	4	7	3	14
Utah	32	15	8	55
Vermont	1	0	0	1
Virginia	2	1	2	5
Washington	11	8	11	30
Wisconsin	0	3	7	10
West Virginia	144	154	148	446
Total	2047	1611	983	4641

ACI

The American Concrete Institute has certification programs for concrete finishers, concrete field testing technicians, concrete laboratory technicians, and concrete construction inspectors (*19, 20*). Applicants must pass both the written and performance examinations for certification.

None of those interviewed currently requires ACI certification.

Sources of Personnel

Engineers

Essentially all of the recruiting for engineers is conducted at the local universities and colleges within the state or in neighboring states. Recruiting efforts cover engineers for all divisions. No special recruiting is normally conducted by construction divisions. Nearly all of the states discontinued recruiting of engineers in the early 1980s and have only resumed recruiting in the last two years or so. The fluctuations in the construction programs and the limitations imposed on agency staff sizes has seriously affected recruitment programs for engineers. An unusually large number of transportation agency engineers are expected to retire during the next decade (*21,* p. 101). These retirements plus the limited recruiting in the last several years will leave many agencies severely short of qualified engineers for administration of construction programs.

Construction engineers reported that the most successful recruiting was accomplished through hiring civil engineering students during the summer months. These former employees have been more willing to return to the agency in full-time positions upon graduation.

Technicians

There are two-year technical schools in a number of states where agencies have been successful in recruiting technicians. The curricula at these schools provide the applicants with a good background for construction engineering. Most agencies start these graduates as second-level technicians rather than at the entry level. Where tech graduates are not available, applicants are recruited through the local job service or newspaper advertisements.

CONTRACTOR PERSONNEL

Qualifications

Craftsmen

Most contractors do not have written position descriptions or job qualifications for craftsmen. Union contractors recruit through the union hiring hall. The hall determines who will be sent to the project. The contractor does not have to keep those sent out but must go back to the hall for any replacements.

When a hiring hall is not used, applications are taken. The criterion for remaining on the job is the craftsman's ability to perform the work to the satisfaction of the supervisor.

Technicians

The need for technicians fluctuates from year to year depending on the requirements of the projects under way. This makes it more difficult for contractors to retain technicians. When the work is required, contractors either recruit technicians or subcontract the work to consulting engineering firms. Most of the contractors interviewed are using consulting services rather than recruiting technicians. In either case, technicians must meet the agencies' requirements for certification.

Foremen and Supervisors

Typically, contractors promote from within when there is a need for foremen or supervisors. Because these are key positions for completing the work productively, in accordance with the plans and specifications, and at a profit, the contractors usually promote only individuals who have proved that they have the necessary ability and experience.

Most foremen are high school graduates, and supervisors often have some college. Only the larger firms, where there is more opportunity for professional growth, typically hire engineers for supervisory positions at this level. College graduates, even those with two-year associate degrees, are not satisfied to be foremen for long. In some areas, it is difficult to entice craftsmen to accept supervisory positions.

CHAPTER FOUR

STAFFING PROBLEMS

Staffing problems of the state agencies as well as the contractors are discussed in this chapter.

AGENCIES

Authorization for Staff

All states where interviews were conducted have some type of limitation on the number of permanent employees for construction administration. Generally, the limitation was imposed by the state legislature or the governor. There are fewer limitations on seasonal or temporary employees. Maryland is limited to 400 permanent employees by the legislature, so staffing is supplemented by consultant personnel.

The number of construction employees in nearly all states has steadily declined during the past 15 years. Michigan's experience is typical (*22–24*). As shown in Figure 9, total employment, expressed in full-time equivalent positions (FTE), has been reduced from 1575 in 1968 to 733 in 1986. The construction work load during this same period, as represented by payments to contractors expressed in equivalent 1967 dollars for comparability, has increased about 8 percent—$120 million in 1968 to $130 million in 1986. Figure 10 shows the work load trend and the wide fluctuations from year to year. The department has made use of its manpower management system to plan and control project staffing; took advantage of improved technology by acquiring items such as electronic distance measuring devices (EDMs), electronic transits, and microcomputers for selected project offices; and staffed projects through a balance of permanent employees, co-op students, temporary technicians, and overtime.

Most other states have made similar reductions in staff. The full-time staff in Vermont is now 101, compared with 168 employees in 1970—a decrease of 40 percent (*3*). Iowa's peak staff of 700 construction employees has been reduced to about 500. At the same time, the work load in 1987 for these two states as expressed in 1977 dollars is equal to or greater than that for 1978.

Projects are also typically smaller in size now, with a larger number of projects under way than during the Interstate construction era, which makes staffing less efficient.

Availability of Staff

Despite the limitations on hiring and reductions in staff, most of those interviewed believed that they had an adequate number of employees so long as they could supplement that staff with overtime, temporary employees, and consultant personnel.

Overtime

Inspection personnel are required to match the contractors' hours of work. This entails inspectors working overtime during the construction season. Lower-level technicians typically receive cash payments for overtime, usually at one and one-half times the regular rate or compensatory time off at one and one-half hours for each hour earned. Mid-level employees are paid for overtime at regular rates or given compensatory time off on an hour-for-hour basis. Higher-level employees usually only receive compensatory time off. Some agencies allow employees to take either the cash or time off.

Excessive restrictions on either the earning of overtime or the method of compensating employees for overtime earned can hamper managers in properly staffing construction projects. Payment for overtime at one and one-half the regular rate is nearly always more cost-effective than increasing staff to eliminate the need for overtime. Although employees receive the extra compensation, actual costs of overtime to the agency usually are closer to one and one-fourth of regular pay rates because many of the fringe benefits do not increase for overtime. Requiring employees to take compensatory time off for overtime may interfere with completion of final estimates, winter construction, and other assignments.

Seasonal Employees

Many states give preference to civil engineering students for seasonal positions for construction inspection. These students have mathematical aptitude, are interested in the work, and are easily trained. The problem is availability. They are out of school only three months, leaving the projects short-handed in the spring and fall.

In the early 1970s, the Michigan DOT had a permanent staff of between 1000 and 1100 engineers and technicians, supplemented with 100 to 300 temporary employees assigned to field construction (*23*). In an effort to improve the efficiency of construction engineering and reduce engineering costs, a research project was undertaken. This effort enabled the department to determine its construction staffing needs by month for the assigned construction projects. These analyses showed the effect of the seasonality of the work and the desirability of reducing the number of permanent positions and finding productive work

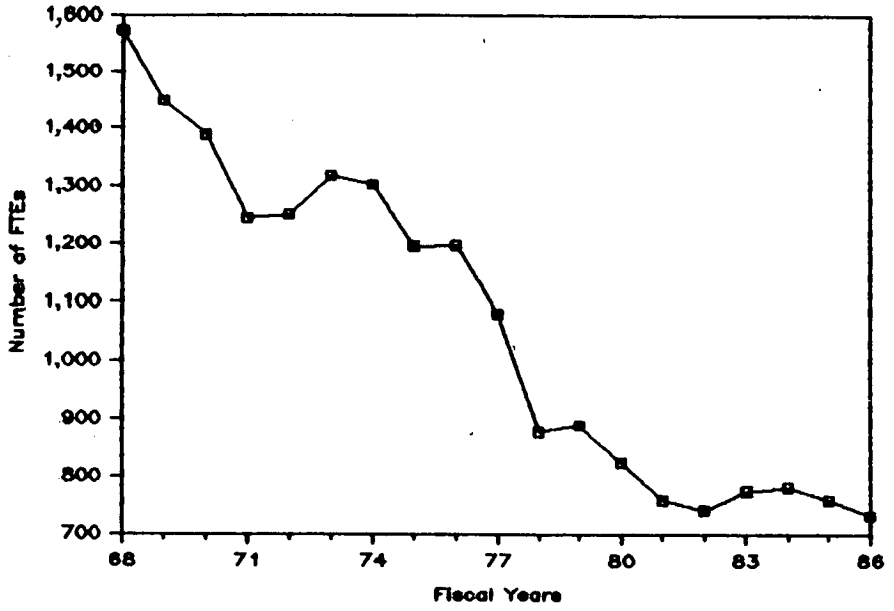

FIGURE 9 Employment trend—construction staff, Michigan DOT.

that could be performed in the winter months. A number of off-season work assignments were found to better utilize construction personnel, but there was still excess manpower in the winter months. Since that time, the total full-time permanent field work force has been reduced to the current level of 85 engineers and 500 technicians.

As full-time positions were eliminated, they were replaced with six-month positions and filled by civil engineering students from five engineering schools in Michigan (*7*, p. 170). The students work for the department during the construction season—May to mid-November—and attend school the other six months. They remain in the program only as long as they are students. No commitment of permanent employment is made. The engineering schools cooperated in implementing the Co-op Student Program by revising their curricula to meet the requirements of the construction season. In 1987, the department hired about 150 civil engineering students under this program. The program has worked well to provide skilled, interested, and easily trained inspection and survey personnel. Students have the advantage of having income to finance their education while

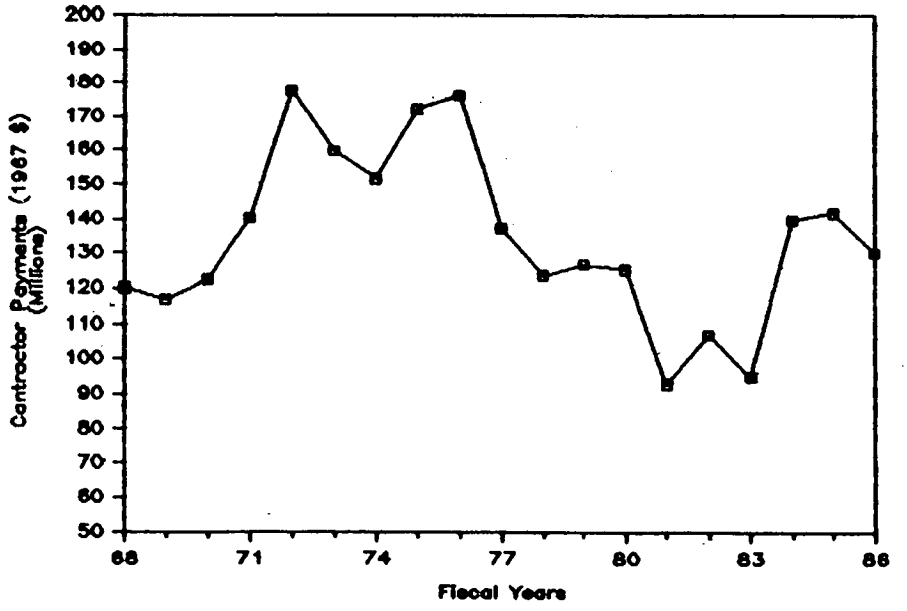

FIGURE 10 Construction work load trend—Michigan DOT.

gaining work-related experience. Most students require an extra year to complete their course work and qualify for bachelor's degrees.

Attitude and Morale

Most of those interviewed believe they have good people working for their agencies. The biggest problem is having the right number and caliber of people for the work load. The major contributor to this problem is the lack of a stable program. There is either too much work for the available staff or not enough; both demoralize employees. The work load fluctuation presents an even greater problem in the districts. It is difficult to transfer personnel between districts in response to varying work loads. Besides the expense, most employees do not like to work away from home.

In some states, pay scales are inadequate. Current starting salaries for graduate engineers or two-year technical school graduates are generally higher than these states can offer.

Attrition

A high percentage of the engineers employed by state highway and transportation agencies are now eligible or will be eligible for retirement in the near future. Transportation Research Board *Special Report 207* (*21*), which was published in 1985, explored this subject in depth. Although the report did not single out engineers assigned to construction, it is safe to apply the conclusions from the report to construction personnel.

Attrition is expected to be higher in the 10 years from 1985 to 1995 than in previous years. The professionals hired in the 1950s and early 1960s by state highway agencies become eligible for retirement in the late 1980s and early 1990s, creating an unusually high turnover of engineers. The significance of attrition varies from state to state. One of the conclusions from the report is (*21*, p. 99):

> Because the demands of the next 5 to 10 years are unique and substantially different from historic patterns in many cases, each state should carefully review its likely future attrition patterns. Simply applying some fixed percentages that have characterized earlier organizational history could make it more difficult to deal with future professional needs as they emerge.

CONTRACTORS

Availability of Staff

The state of the economy has a direct effect on the availability of the number of applicants for construction work. The contractors' response concerning the problem of hiring skilled personnel varied by the conditions in the particular area they are currently working. More than half reported having no problem finding competent craftsmen in the last year or two, but nearly all have had problems at some time.

One contractor has found that not enough younger people are interested in a career in construction crafts. They prefer to work with computers or in some other office job. The working conditions in construction are not attractive. One hundred fifty applicants responded to an advertisement for form setters. Of these, 3 had experience in setting forms and only 7 of the 150 would accept the job after they learned what it entailed.

As with the state agencies, contractors need stable work programs to attract employees to their firms and to the industry as a whole.

The American Road and Transportation Builders Association, whose members represent all aspects of transportation, recognized the problem of attracting people to the industry and published a brochure (*25*) to inform those seeking careers about the opportunities in the industry.

CHAPTER FIVE

TRAINING

Training programs in use by the agencies and contractors and training needs are discussed in this chapter. Training of technicians in the technology of highway construction has been identified as a need to ensure quality construction (*26*). Twenty-three of 44 states that responded to a questionnaire in 1985 reported that their training needs for construction personnel were not resolved. The Transportation Research Board has established Task Force A2D51 on Improving and Retaining the Technical Competence of Field Personnel in Flexible Pavement Construction to address the need in one phase of highway construction (*27*). The purpose of this task force is to explore ways to improve the technical and managerial competence of agencies, contractor, and consulting personnel employed in the construction of flexible pavements.

AGENCIES

In 1985, as a part of NCHRP Project 20-7, Task 26 (*26*), a survey of all state highway and transportation agencies was conducted to determine the availability of training programs and training materials and whether the available training had resolved the need for training. The results of that survey are presented in Table 15.

Eighty-six percent of the states that responded to that questionnaire had some training aids for construction personnel. The types of available training programs and materials varied from manuals to winter schools to complete curricula of courses consisting of lesson plans, instructors' guides, and videotapes. A description of the training aids available is included in Table 15. Only three or four states have training aids for all phases of contract administration. Training available in the other states covered selected phases of construction.

Fifty-seven percent of those responding reported that training, certification, and retention of technicians for quality assurance was a current problem.

Since 1985, several states have undertaken the development of additional training materials. These states include Alabama, Arizona, Georgia, Idaho, Iowa, Pennsylvania, and Washington. Nearly all of the training material being developed is in videotape format with lesson plans and instructor's guides.

CONTRACTORS

The major contractors have extensive training programs for nonmanagement personnel. These programs cover essentially every conceivable construction activity and craft. Smaller firms rely on union apprentice programs and on-the-job training.

All of the firms, no matter what size, conduct annual training for foremen and superintendents. These sessions typically run for a week and cover management skills, quality of workmanship, documentation, and the like.

Technicians are sent to state training courses whenever such courses are available.

OTHER SOURCES OF TRAINING

Training materials and services for agencies and contractors are available from several other sources. These include:

- the American Concrete Institute (ACI),
- the Asphalt Institute,
- the Associated Builders and Contractors, Inc. (ABC),
- the Associated General Contractors (AGC),
- the Institute of Transportation Engineers (ITE),
- the National Asphalt Pavement Association (NAPA),
- the National Highway Institute,
- the Portland Cement Association (PCA),
- local T^2 (Technology Transfer) Centers,
- the U. S. Bureau of Reclamation, and
- various construction equipment manufacturers.

American Concrete Institute (ACI)

ACI offers training and certification in field testing of concrete, concrete construction inspection, and concrete flatwork finishing (*19, 20*).

Asphalt Institute

The Asphalt Institute offers 15 audio-visual programs that would be appropriate for training construction personnel (*28*). Two are motion pictures. The others are color slides with cassettes. The subjects covered include:

- mix design,
- determination of asphalt content in paving mixtures,
- placing asphalt hot mix,
- testing asphalts,
- asphalt emulsion spray applications,
- recycling roads with asphalt emulsions,
- rolling and compaction of asphalt pavement,
- cracking and seating of PCC pavements before asphalt overlays, and
- asphalt overlays for rehabilitation.

TABLE 15

TRAINING SURVEY RESULTS

State	Training Available in 1985	Need Resolved	
		Yes	No
Ala.	Concrete and asphalt inspection manuals; plan reading and basic math courses.		X
Ariz.	Development in progress		X
Ark.	Self-help courses for inspectors		
Colo.	Certification in nuclear gauges and concrete testing		X
Conn.	Winter inspectors' schools		X
Del.	Asphalt stabilization film, slides on various subjects		X
Fla.	Self-study course, slide/lecture training, 10-week tech training - community colleges, special courses by outside experts	X	X
Hawaii	None	X	
Idaho	Started training program and are looking for training aids		X
Ill.	Task training courses: earthwork, drainage, subbase, pavements, structures, surveying, erosion, testing, and documentation	X	
Iowa	Developing videotapes		X
Kans.	Winter training sessions		X
Ky.	Series of film-strip audio-visual courses		X
La.	44 self-instructional and audio-visual courses	X	
Maine	A few lectures and slides		X
Md.	Construction manual, inspectors' job guide, winter school, NICET certification being developed		X
Mich.	15 workbook and audio-visual courses	X	
Minn.	Winter schools, pavement rehab slide/tape, certification programs	Partially	
Miss.	Asphalt paving manual, some slide/tape courses		X
Mo.	Winter schools	X	
Mont.	2 workbooks, 1 slide/tape, and 2 videos		X
Neb.	In the process		
Nev.	Classroom: testing, inspection, survey, and office	X	
N.H.	Annual schools	X	
N.J.	Videotapes: concrete cylinders and pavement smoothness testing. Others in development		X
N.M.	6 courses: testing, math, and basic inspection	X	
N.Y.	None		X
N.C.	Self-study courses: math, basic inspection, basic surveying, basic engineering, etc.		X
N.D.	Courses: scales, lab, asphalt and concrete plant, paving, pipe, etc.	X	X
Ohio	Concrete manual		X
Ore.	3 slide/tapes on bridge inspection		X
Pa.	Construction inspection videotapes	Helped	
R.I.	Winter schools		X
S.C.	Training aids for concrete, asphalt plants, asphalt paving, and grading	Partially	
S.D.	Manuals, videotapes, and classroom		
Utah	Materials and survey manuals, 4 testing films, flagging videotape		X
Vt.	Spring meeting	X	
Va.	In-house seminars	X	
Wash.	Videotapes: earthwork computation, asphalt plants, asphalt street inspection, bituminous surface treatment, cement factor, nuclear gauge		X
Wis.	Manuals and guides, workshops	Partially	
W.Va.	Self-instruction manuals: bituminous paving, earthwork, PCC paving, structures, etc.		
Wyo.	Annual classroom training: surveying and testing		X

Note: Results shown are from questionnaires submitted in 1985.

Associated Builders and Contractors, Inc. (ABC)

ABC provides training materials consisting of student workbooks and instructor's guides in a number of skills (*29*). Those of particular interest to highway and bridge contractors are:

- introduction to construction,
- carpentry,
- ironworking, and
- welding.

Associated General Contractors (AGC)

AGC offers instructional materials in a number of craft skills also (*30*). The subjects of interest to highway and bridge contractors include:

- carpentry,
- bricklaying,
- cement masonry,
- construction craftsman,
- heavy-equipment operator, and
- heavy-equipment mechanic.

The materials are available to both members and nonmembers.

Institute of Transportation Engineers (ITE)

ITE offers two series of training programs on traffic control through construction and maintenance work zones. The 200 Series courses explain how to plan, design, and monitor traffic control to minimize the impact of traffic flow on both short- and long-term construction and maintenance zones. The 1000 Series was designed specifically for field personnel. Both series include a course on work area flagging (*31*).

National Asphalt Pavement Association (NAPA)

NAPA has developed training materials covering several subjects for its members in its Training Aid Series. [Nonmembers may also rent or purchase this material (*32*).] Training materials include booklets, films, slides, tapes, instructor's manuals, and student workbooks, depending on the subject. This series includes:

- truck driving techniques,
- hot-mix raking techniques,
- rolling and compaction of asphalt pavement,
- placing hot-mix asphalt,
- duties of the technician,
- sampling and testing aggregates,
- job-mix formulas and blending aggregates,
- specific gravity of fine and coarse aggregates,
- controlling and setting up a cold feed,
- dryer techniques,
- testing for control of hot-mix quality,
- mix design techniques, and
- introduction to hot-mix asphalt production.

In addition, NAPA has a series of films on management for asphalt paving contractors; technical films on the asphalt finisher and techniques for asphalt paving; and films on safety.

National Highway Institute

The National Highway Institute, a staff office within FHWA, develops and administers, in cooperation with state highway agencies, training programs for FHWA and state and local highway agency employees (*33*). Courses developed or conducted by NHI in the area of construction include:

- bridge paint inspection,
- corrosion engineering/cathodic protection,
- techniques for pavement rehabilitation,
- highway materials engineering,
- rock blasting,
- geotextile engineering,
- value engineering,
- design and operation of work zone traffic control, and
- planning and scheduling work zone traffic control (*34*).

Courses under development that are expected to be available in the near future include these subjects:

- expert witness,
- construction contract claims, and
- conducting EEO contract compliance reviews (*34*).

Portland Cement Association (PCA)

PCA offers five 16-mm films and 33 videotapes on subjects appropriate for training construction personnel (*35*). Most are available for rental or purchase. The subjects covered include:

- portland cement basics,
- soil-cement inspection and field control,
- principles of quality concrete,
- transporting and placing quality concrete,
- finishing and curing quality concrete,
- field testing,
- laboratory testing,
- vibration of concrete,
- recycling,
- overlays, and
- traffic control.

A number of slide sets without audio cassettes are also offered. Some slide sets include notes or scripts for use in conducting training sessions.

T^2 Centers

Forty-two technology-transfer centers have been established in the United States—nearly one for each state (*36*). These centers were established initially to focus on rural roads, bridges, and transportation. One of the major functions of these centers is the transfer of technology to local transportation agencies. As a part of this technology transfer, the centers have acquired

FIGURE 11 Construction training available—U.S. Department of the Interior, Bureau of Reclamation.

publications and training programs that are available for loan. They also conduct or arrange for training workshops and seminars. Although T^2 centers were established primarily to assist local governmental agencies, state agency, consultant, and contractor personnel can take advantage of the training available from these centers.

Recently, a directory of available training and technology resources was compiled to assist T^2 centers (*37*). Subjects listed in the directory of interest to construction personnel include:

- construction mathematics,
- plan reading,
- surveying,
- inspection,
- quality control and testing,
- earthwork,
- erosion control,
- blasting,
- bridge construction,
- pipe placement,
- gabions,
- equipment operation,
- safety,
- recycling,
- stabilization,
- traffic control,
- project management, and
- final estimates.

Bureau of Reclamation

Another source of training material for construction inspectors is the U.S. Bureau of Reclamation. The Bureau is developing three series of construction inspector courses (*38*). The entire training package includes 4 orientation courses, 15 intermediate-level courses, and 22 advanced courses. The courses are listed in Figure 11. Thirteen of the courses have been completed, and most of the remainder are expected to be completed in 1989. The cost of the courses ranges from $125 to $1550.

Further information concerning these courses can be obtained by contacting the Employee Development Officer, U.S. Bureau of Reclamation, Denver, Colorado, at telephone number (303) 236-5389.

CHAPTER SIX

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

There were several questions raised in defining the problem that this synthesis was to address. Although most of these questions are too difficult to address conclusively within the scope of this synthesis, each is discussed in this section.

Is the quality of highway construction suffering because of inexperienced or inept agency inspectors or contractors' personnel?

Everyone agreed that, given adequate design plans and specifications, the quality of highway construction depends on the quality of the individuals involved. Inspectors, engineers, craftsmen, foremen, and superintendents all have their role to play. Both agency and contractor personnel must be well qualified and know their jobs to merit the respect of the other party. When there is mutual respect, quality is nearly assured. A good, technically sound set of contract documents and knowledgeable, fair-minded engineers and technicians to enforce the contract provisions are essential for attaining quality.

Certainly, on some projects quality does suffer because of poorly trained or unmotivated inspectors or inept workers. Inspectors must be trained to recognize materials and workmanship that do not conform with plans and specifications and, just as important, know what to do about them. Inspectors must ensure conformity with the plans and specifications. It is not enough to recognize a problem if no action is taken to correct it. Contractors and their supervisors do not always require their employees to produce quality work.

Are there enough capable individuals entering the industry?

The answer to this question depends on when and where it is asked and the state of the overall economy. Nearly all of the contractor personnel interviewed reported having sufficient numbers of qualified applicants in 1986. All of them have had problems in other years. Work in construction is not as attractive to those entering the work force as, say, the computer field or other white-collar careers.

The fluctuations in the industry workload, with the uncertainties of continuing employment, discourage many from entering or remaining in construction. A stable program would improve the ability of both the agencies and contractors to properly plan and staff construction projects.

Most of the agencies reported difficulty in matching starting salaries offered to graduate engineers or two-year engineering technology graduates. Recruiting efforts by the agencies need to be improved. Graduating engineers who worked for the agencies as seasonal employees are the most likely candidates for recruitment. Hiring freezes have limited agencies' ability to correct imbalances in their work forces.

Are agency staffs large enough to ensure that quality construction is attained?

No direct correlation between the number of inspectors and the quality of the work could be documented. The quality of inspection personnel—how well they are trained and motivated—is more important than the quantity of inspectors. It is better to have intermittent inspection by a qualified inspector than full-time inspection by one who does not know what to inspect or how to inspect it. If an inspector observes an operation that does not comply with the plans or specifications and does not stop the contractor, either through lack of training or timidity, enforcing corrective action later becomes very difficult. Intermittent inspection, where work can be inspected during the process or upon completion, puts more of the burden for quality control on the contractor. Still, there are only so many items that an inspector can check in a day, and some items—those that cannot be tested after completion—require full-time inspection.

Clearly, many agency staffs are not adequate for the current work load without outside assistance. These agencies have supplemented their staffs by requiring contractors to provide more of the quality control and construction staking and through the use of consultants for construction engineering and inspection. There appear to be adequate numbers of personnel, but there is inadequate training provided for contractor and consultant staffs in many instances as well as for agency personnel.

Will attrition, especially retirements, compound the problem?

Attrition of professionals in state highway and transportation agencies is expected to be higher in the next several years than in the past. The expected loss of senior engineers will undoubtedly affect the construction functions in most states. Attrition projections are not uniform from state to state. A few will experience little change in the rate of attrition. For most states, though, it will be a significant problem, and developing and implementing plans for replacing the lost skills should not be delayed.

Is assigning more quality control responsibilities to the contractors a viable solution?

The data collected in the interviews indicate that many states are requiring contractors to assume more of the quality control responsibilities. Although many of the agency personnel and contractors are not entirely comfortable with the change, the shifting of quality control responsibilities to the contractors is increasing. Contractor quality control was initiated in part to overcome shortages of inspection personnel. Another consideration was assigning that responsibility to the party who had control of the manufacturing process—the contractor or supplier. Quality is built in, not inspected in. If a contractor is inept or not conscientious, the chances of quality construction are poor no matter how many inspectors are assigned.

Contractors are influenced by costs. The costs of rework to correct deficiencies or price adjustments for specification tolerances quickly offset any possible gain from cutting corners, provided the risk of having to correct the deficiencies or accept a price adjustment is high enough.

Assigning quality control responsibilities to the contractors is feasible, providing:

- the agency's acceptance testing and inspection procedures include random spot checks to ensure that quality material is produced and incorporated into the project;
- a certification procedure is adopted to ensure that contractors' technicians are, in fact, qualified; and
- specifications are defensible with reasonable price adjustments.

RECOMMENDATIONS

The recommendations for improvements for agencies and contractors are presented in the following section.

Agencies

Guidelines

Recommendation: Highway and transportation agencies that do not have staffing guidelines should develop them to guide supervisors in properly staffing construction projects—for both long- and short-term needs.

About half of the agencies are using some type of staffing guideline for estimating personnel needs each year. Few agencies have guidelines to assist project engineers in making day-to-day staffing decisions. Guidelines do not substitute for good judgment, but their use will provide more uniform inspection to ensure quality construction and make the best use of available personnel. Construction inspection is not an assembly-line production. Supervisors need flexibility in making personnel assignments. Guidelines work best when technicians are versatile and can perform a variety of assignments. Guidelines can also be used to determine the need for construction engineering and inspection consultants.

Any staffing guidelines established must take assigned responsibilities into account. The assignment of construction staking or process-control testing to the contractors obviously changes the manpower needs for the agency.

The Construction Engineering Manpower Management Design Manual (the Pooled Fund system) is still a practical source of information for agencies in designing manpower management systems for construction personnel. With the current availability and capacity of microcomputers, the systems should be designed for use on microcomputers to simplify the calculations. (A description of the Pooled Fund system is included in Appendix B.)

Recommendation: Guidelines should be used for staffing all construction projects, not just federal-aid projects.

A few states use their guidelines only on federal-aid projects. The source of funding does not change the need for quality construction or adherence to the plans and specifications. Staffing guidelines should apply equally to all projects. Reducing staff on state-funded projects sends the wrong signal to inspection and contractor personnel—that quality is not important on state projects. And the public does not perceive any difference in federal-aid or state-funded construction projects. Quality construction is expected in either case.

Availability of Staff

Recommendation: Each agency should assess the effect that attrition will have on the staff available for construction engineering and inspection and develop plans for properly staffing projects. The staffing plans should include methodology for training staff members in the technical and administrative areas of project management.

Most states will lose a high percentage of their senior engineers and technicians in the next 10 years or so. The loss varies from state to state. Each state should assess its own situation and develop a plan for replacing the skills that will be lost as these individuals elect to retire. Supplementing agency staff by assigning more quality control responsibilities to contractors and through increased reliance on consultant construction engineering and inspection is feasible up to a point—as long as agencies retain the in-house construction expertise necessary to properly administer construction contracts. The most effective way to attain that expertise is through actual performance of the construction engineering and inspection tasks on construction projects. The portion of the construction program to be performed in-house should be at least large enough to accomplish this training, and this would normally be accomplished with a staff level that could handle the low point of projected work loads.

Recommendation: The ratio of engineers to technicians (permanent employees) for construction engineering and inspection should be at least 1 to 6 for most agencies.

Most state highway and transportation engineers have not recruited engineers consistently. In the years when revenues were low, few if any engineers were hired. Consequently, engineering staffs for most state highway and transportation agencies have significant age gaps. Some agencies have insufficient

numbers of engineers to staff the field construction function and rely heavily on technicians for supervision of construction projects. Considering the risks to the public both during construction and after projects are completed and the potential liability, agencies need to protect themselves by assigning project supervisors who have expertise and credibility. Engineers should be assigned to supervise all major projects and be readily available to assist with engineering problems on all projects.

Training

Recommendation: Unless one has been recently completed, each state highway and transportation agency should undertake an analysis to determine the training needs of the construction engineering and inspection personnel.

Recommendation: Highway and transportation agencies should develop or acquire formal training programs to meet any training needs identified.

Most of the construction training of engineers and technicians in the past has been on the job. An increasing number of agencies are developing training materials to assist the district, resident, and project engineers to train their staffs. Typically, the training materials include videotapes, lesson plans, and instructor's guides to assist those who conduct the training. Libraries of the training courses are available in each district and in a few agencies in each residency office. This has obvious advantages:

- all trainees receive the same core training on each subject;
- training can be conducted shortly before the particular operation is scheduled to begin;
- the material is available for training seasonal employees so they can be more effective; and
- training can be conducted on short notice to take advantage of rainy days.

Training complements on-the-job experience; it does not replace it. Rather, it shortens the time for individuals to become effective.

Certification

Recommendation: Highway and transportation agencies should require construction technicians to become certified—either through in-house procedures or by NICET. This requirement should include technicians furnished by consultants, as well, when they perform this work for the agency.

The use of in-house and NICET certifications is increasing. Personnel assigned to inspection and testing must be qualified whether they are employed by the agency, a consultant, or the contractor. Certifications provide benchmarks for evaluating the qualifications of these technicians. A technician certified at, say, Level II in Highway Construction by NICET can be expected to have specific capabilities. NICET certifications are recognized nationally, and in-house certifications ensure that those qualifying have specific knowledge of the certifying agency's procedures.

Implementation of a certification program must be phased in to allow time for technicians to qualify. Development of a training program to aid them in qualifying is essential in most agencies if implementation is to be successful. Classification plans should be revised to incorporate the certification requirements at each level and include provisions for promotions as appropriate to encourage becoming certified and maintaining certification.

NICET certification is more attractive to consultant personnel because of its national recognition and acceptance in transportation agencies in other states, as well as other types of agencies.

Contractors

Training

Recommendation: A study should be undertaken to catalogue available training suitable for contractor personnel.

The National Highway Institute serves as a clearing house for the exchange of information concerning training available for agency personnel. No similar source of training information for contractors was identified. Contractor associations have developed training materials in response to members' needs. Other material is available from equipment manufacturers. Contractors, particularly smaller ones and disadvantaged firms, need to be made aware of these resources. A catalogue entitled *State and Local Highway Training and Technology Resources* was prepared to assist T^2 centers provide services to local agencies (*37*). A similar catalogue is needed to identify training available for contractor personnel.

Essentially all of the contractors contacted have an annual training program for foremen and superintendents. Only the larger firms had any training available for craftsmen. The other firms relied on on-the-job training or union apprentice training.

Certifications

Recommendation: Contractor personnel who perform quality control testing should be required to meet the same certification requirements as agency employees who perform similar work.

As with agency or consultant personnel, contractor employees assigned the responsibility for quality control must be qualified. The easiest way to establish this qualification is through the same certification process the agency uses for its own personnel.

Staffing

Recommendation: Highway and transportation contractors and contractors' associations need to promote construction as a career to attract capable employees into the industry.

The highway construction program has fluctuated from year to year, depending on the collection of gas taxes and passage of the federal highway act. A stable program is needed to min-

imize the effect of peaks and valleys in the work load and to improve the reputation of highway construction as a career. Many craftsmen who were laid off during slack periods following energy crises did not return to construction when work increased.

The American Road and Transportation Builders Association has published a brochure on careers in transportation and road building (*25*). The brochure includes sections on career opportunities with contractors, but those sections are necessarily short. More effort is needed in construction.

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INTERVIEW GUIDE--AGENCIES

Name of Person(s) Interviewed_____

Position_____

Agency_____

Date__/__/86. Telephone_____ Visit_____ Conducted by_____

1. How are personnel assigned to projects?_____

Are staffing guidelines/standards available?_____

Copies available?_____

Describe standards

2. How do the guidelines/standards provide for staffing projects of different sizes, types and complexity?

3. How is inspection staffing related to contractors' level of productivity?

How is inspection staffing related to project quality?

4. What are the qualification requirements for construction engineers?

District Construction engineer

Resident engineer

Project engineers

Copies of classification plan?

5. What are the qualification requirements for construction technicians?

Surveyors

Testing

Inspection

Office

Is certification required?____ In-house_____ NICET___

6. Do you have the correct staff for your workload?

Staff balanced for workload by district?

Ratio of engineers to technicians?

Ratio of senior to junior technicians?

7. Are there any constraints on staffing?

Source of constraint?

8. Have studies been conducted to determine staffing needs?

Are copies available?

9. Are inspectors provided with adequate transportation?

10. How do you recruit engineers?

Technicians?

11. What training do you provide construction technicians?

Engineers?

What career development programs are available?

12. What construction engineering functions have been assigned to contractors?

Construction staking?

Process control?

Aggregate testing?

Asphalt plants?

Concrete plants?

Are plants automated?_____Does the contractor provide printouts?_____

13. Are private testing and inspection facilities used?

If yes, who selects the facility and who pays for the services?

What are the selection criteria?

14. Are your plans, specifications, and standards adequate?

15. What is your current experience and volume of contractor claims?

Change orders?

16. Do you use method, end-result, statistical specifications, or other? (Describe)

How much can specifications influence quality?

17. What influences attaining good quality construction?

How much can the inspector influence quality?

How much can the contractor's superintendent?

18. What interferes with attaining quality?

19. What problems do you have in staffing construction projects?

INTERVIEW GUIDE--CONTRACTORS

Name of Person(s) Interviewed_____

Position_____

Firm_____

Date___/___/86. Telephone_____ Visit____ Conducted by_____

1. How are personnel assigned to projects?

Are staffing guidelines/standards available?_____

Copies available?_____ Describe standards:

2. How do you determine staffing needs for:

   o Projects of different sizes, specialty types and complexity?

   o How does staffing differ for projects with methods specifications vs. those with statistical specifications?

3. What are the qualification requirements for contractor employees?

   o Craftsmen

   o Foremen and supervisors

   o Technicians

   Are technicians certified? _____Yes _____No. In-house_____
NICET____State____

4. How do you recruit staff?

5. Is there a problem in hiring skilled personnel in sufficient numbers?

6. What kind of training programs do you have?

7. What construction engineering functions are assigned to contractors with your specialties?

   o Construction staking

   o Process control

   o Aggregate testing

   o Asphalt plants

   o Concrete plants

   o Other

   Are plants automated?

8. Have you conducted any staffing studies?

9. Are plans, specifications and standards adequate to ensure quality?

10. What is the major item in attaining good quality construction?

    What is the role of the superintendent in quality attainment?

    The foremen?

    The craftsmen?

    The inspector?

11. What interferes with your attaining quality?

12. What problems do you have in staffing construction projects?

13. Does the assignment of a specific engineer affect your bid?

APPENDIX B

CONSTRUCTION ENGINEERING MANPOWER MANAGEMENT—SYSTEM DESIGN "POOLED FUND" PROJECT

During the 1970s, many state highway and transportation agencies recognized the need to improve the management of the construction engineering function to provide proper staffing—adequate but not excessive—to ensure quality while controlling construction engineering costs.

In 1976, 21 state agencies pooled their highway planning and research (HPR) funds to finance the development of a "model" construction engineering manpower management system (CEMMS) that could be adapted for the use of each state. The study produced a System Design Manual, designed to assist agencies in developing their own unique systems while taking advantage of research and developments completed by other states (*4*).

Construction engineering as covered in the System Design Manual includes staking, inspection, quality control and assurance, documentation, and related field activities performed by field construction personnel for all phases of construction—such as clearing and grubbing, grading, paving, and structures—and all types of projects—from construction of new roadways and bridges to widening and resurfacing.

The Manual provides for development of system components, including:

Planning and Staffing Procedures
- Selecting manpower planning methods
- Selecting contract types
- Selecting planning activities
- Selecting planning units of measure
- Developing contract staffing guidelines—minimum and maximum
- Adapting standard planning values
- Developing dollar conversion standards
- Developing manpower planning procedures
- Selecting a manpower staffing method
- Developing staffing activities
- Developing manpower distribution procedures
- Developing manpower balancing procedures
- Developing skill level guidelines
- Developing a procedure for determining skill level requirements

Budgeting Procedures
- Developing budgeting procedures
- Developing standard costs

Scheduling Procedures
- Selecting a scheduling method
- Developing scheduling procedures

Monitoring Procedures
- Selecting a work monitoring method
- Developing work reporting and monitoring procedures

System Updating Procedures
- Developing a contract type updating procedure
- Developing a planning activity and unit of measure updating procedure
- Developing a standard planning value updating procedure
- Developing a standard costs updating procedure
- Developing a skill level guideline updating procedure

The system was developed as a manual system because of the long turnaround times being encountered from mainframe computers at that time. The system lends itself to the use of microcomputers, and several states have adapted the system for use on computers.

At least eight states have based their construction engineering manpower management systems on the "Pooled Fund" System.

APPENDIX C

THE NATIONAL INSTITUTE FOR CERTIFICATION IN ENGINEERING TECHNOLOGIES

The National Institute for Certification in Engineering Technologies (NICET) is sponsored by the National Society of Professional Engineers (NSPE). It was formed in 1981 to replace the Institute for the Certification of Engineering Technicians (ICET) and the Engineering Technologist Certification Institute (ETCI) (*14*). ICET was founded in 1961 by NSPE to serve the career needs of technician members of the engineering team. ETCI was established in 1977 to provide a meaningful certification program for technologists that did not conflict with either the state-administered registration processes for engineers or the ICET certification programs for technicians. NICET's objective is to support a practical career path for engineering technicians and technologists, thereby improving the quality and quantity of engineering services deliverable per dollar of cost.

The Institute is an examining body whose function is to evaluate the qualifications of those who voluntarily apply for certification. Personal recommendations; written examinations; and verification of the applicant's work experience, competency, and knowledge are all part of the evaluation process. As evidence of satisfactory attainment of its criteria, the Institute grants and issues certificates and maintains a registry of holders of such certificates.

The NICET certification programs for technicians and technologists are being developed as a nationally applicable, individualized, job competency-based, nondiscriminatory certification system that can be interfaced with educational/training resources and a variety of personnel systems.

Special NICET certification programs of interest to highway and transportation construction personnel include:

CERTIFICATION PROGRAMS

Construction Materials Testing Engineering Technology

- Subfield—Asphalt
- Subfield—Concrete
- Subfield—Soils

This certification program was designed for technicians in private industry engaged specifically in construction inspection. Knowledge of engineering properties of construction materials used in buildings, roads, and pavements and knowledge of testing specifications, standards, methods, and materials evaluation is required.

Transportation Engineering Technology

- Subfield—Highway Construction

This certification program was designed for publicly employed highway construction technicians involved in the construction and inspection of highway projects. Areas covered are specifications and contract plan reading; record-keeping and reporting; construction surveying; field testing procedures, techniques, and equipment; and supervisory techniques.

- Subfield—Highway Materials

This certification program was designed for publicly employed highway materials technicians involved in laboratory and field testing of materials such as aggregates, asphalts, concrete, soils, paints, and metals. Included is knowledge of techniques and equipment, record-keeping and reporting procedures pertaining to material and quality control, and supervisory techniques.

- Subfield—Highway Surveys

This certification program was designed for publicly employed highway survey technicians involved in all aspects of surveying related to the roadways, structures, and right of way. Areas covered include use and care of equipment, field and office activities, plan reading, preparing topographic maps, and photogrammetry.

Other related subfields for certification are bridge safety inspection, highway design, highway maintenance, and highway traffic operations. Areas under development include certification programs in transportation for bridge design and right of way.

The certification requirements, the work element definitions, and the examinations for Transportation Engineering Technology were developed with the assistance of a panel of state highway and transportation agency experts to ensure that these certification programs met the needs of the agencies. The American Association of State Highway and Transportation Officials (AASHTO) sponsored this participation.

WORK ELEMENT LISTING—HIGHWAY CONSTRUCTION

The NICET certification programs are based on individual evaluation and qualification on tasks or work elements required to perform the work. The titles of the work elements for highway construction technicians are listed here to show the depth of

coverage. Consult the *Program Detail Manual* (*15*) for complete definitions of the work elements.

Level I—General Work Elements
- Basic sampling and field testing of materials
- Basic surveying
- Simple plans and specifications
- Topographic maps
- Basic mathematics
- Basic metric units and conversions

Level I—Special Work Elements
- Base and subbase materials
- Clearing and grubbing
- Backfilling
- Fencing
- Median barriers and guardrails
- Structural painting
- Protective treatment of concrete structures
- Protective treatment of concrete pavements
- Simple drainage structures
- Aggregate surfacing

Level II—General Work Elements
- Standard sampling and field testing of materials
- Standard construction surveying
- Standard plans and specifications
- Basic individual safety requirements
- Traffic controls
- First-aid procedures
- Computation and recording of areas, volumes, and cost extensions

Level II—Special Work Elements
- Rigid pavements
- Flexible pavements
- Detours and temporary roads
- Landscaping and slope protection
- Topsoil removal, demolition, and clearing final project cleanup
- Surface tolerances
- Small buildings
- Piles
- Guardrails and/or median barriers
- Structural materials and members
- Culverts
- Traffic control devices
- Final measurement—rigid pavements
- Final measurement—flexible pavements
- Final measurement—small buildings
- Final measurement—piles
- Final measurement—guardrails and/or median barriers
- Final measurement—landscaping and slope protection
- Final measurement—topsoil removal, demolition, and clearing
- Final measurement—culverts and/or minor drainage structures
- Final measurement—traffic control devices office checks of as-built plans
- Office checks of payrolls
- Office checks of post-tested materials and post-pay quantities

Level III—General Work Elements
- Materials testing in the field
- Construction surveys
- Complex plans and specifications
- OSHA and other safety requirements
- First-aid and emergency services
- Traffic controls and detours
- Compliance with federal, state, and local programs
- Activity coordination
- Basic erosion controls
- Quantities and costs of line items
- Steel and concrete structures
- Communication skills
- Materials and equipment accountability

Level III—Special Work Elements
- Construction of concrete structures
- Construction of steel structures
- Construction of composite structures
- Major paving project
- Major structural project
- Rest area with sanitary facilities
- Major grading and drainage project
- Major safety improvement project
- Basic cost analysis data for contract changes
- OJT training programs

Level IV—General Work Elements
- Major construction project
- External working relationships
- Regulatory requirements
- Equipment reports
- AC and PC concrete mix design
- Structural steel shop inspection
- Alterations to design
- Change orders
- Special training needs

HIGHWAY CONSTRUCTION EXAMINATION REQUIREMENTS

NICET recognized the need for versatile technicians. It was also recognized that few technicians would have the opportunity to gain experience in all of the work elements listed above. Consequently, individuals applying for certification are required to qualify in a selected number of work elements at each level. The requirements for a new applicant are summarized on the next page. Refer to the Program Detail Manual for additional information.

Application Level	Work Elements	Number Available	Number To Pass
Level II	Level I — General	6	4
(Associate Engineer Technician)	Level I — Special	10	6
	Level II — General	7	6
	Level II — Special	25	7
	Total	48	23

Application Level	Work Elements	Number Available	Number To Pass
Level III	Level I — General	6	4
(Engineer Technician)	Level I — Special	10	8
	Level II — General	7	6
	Level II — Special	25	14
	Level III — General	13	10
	Level III — Special	10	3
	Total	71	45
Level IV	Level I — General	6	2
(Senior Engineer Technician)	Level II — Special	25	11
	Level III — General	13	10
	Level III — Special	10	6
	Level IV — General	9	7
	Total	63	36

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TRANSPORTATION RESEARCH BOARD
National Research Council
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

ADDRESS CORRECTION REQUESTED

000015M006
ROBERT M SMITH
RESEARCH & ASST MATLS SUPVR

IDAHO DEPT OF TRANSPORTATION
P O BOX 7129
BOISE ID 83707