National Cooperative Highway Research Program

NCHRP Synthesis 215

Determination of Contract Time for Highway Construction Projects

A Synthesis of Highway Practice

Transportation Research Board
National Research Council

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Synthesis of Highway Practice 215

Determination of Contract Time for Highway Construction Projects

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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.

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The members of the technical committee selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and, while they have been accepted as appropriate by the technical committee, they are not necessarily those of the Transportation Research Board, the National Research Council, the American Association of State Highway and Transportation Officials, or the Federal Highway Administration of the U.S. Department of Transportation.

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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 highway administrators; design, construction, and specification engineers; project schedulers; and highway construction contractors. The synthesis describes the state of the practice with respect to procedures used throughout the United States and other countries to determine highway construction contract time, with emphasis on new methods in use.

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.

Transportation agencies must set reasonable times for completion of construction projects. Factors to be considered in determining contract time include materials, equipment, labor, cost, and constraints such as weather, traffic conditions, utilities location, and user convenience. This report of the Transportation Research Board covers the still pertinent procedures from *NCHRP Synthesis 79: Contract Time Determination,* (e.g., critical path methods, linear scheduling, bar charts) as well as new methods in use (e.g., A + B methods, lane rental, flexible time-to-start). In addition to information on various methods to determine contract time, information on issues related to implementing procedures for contract time determination, from both agency and contractor perspective, is included.

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.

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The Principal Investigators responsible for the conduct of this synthesis were Sally D. Liff, Manager, Synthesis Studies, and Stephen F. Maher, Senior Program Officer. This synthesis was edited by Linda S. Mason.

Scott A. Sabol, Senior Program Officer, National Cooperative Highway Research Program, Transporation Research Board, provided valuable assistance to the consultants, the topic panel and staff.

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

DETERMINATION OF CONTRACT TIME FOR HIGHWAY CONSTRUCTION PROJECTS

SUMMARY

"Contract time," a term with recognized legal as well as common-use meaning, is the maximum time allowed for completion of all work described in contract documents. The determination of contract time affects not only the actual duration of the construction project, but also such aspects of the construction process as costs, resource planning, selection of contractors, and traffic problems.

In recent years, the primary emphasis of the highway construction industry has shifted from building new transportation facilities toward resurfacing, restoration, and rehabilitation projects. Many of these projects are constructed in urban areas and must contend with heavy traffic conditions, creating major inconveniences to the public and adverse impacts on the local economy. Seeking to minimize these disruptions by reducing construction durations, state departments of transportation (DOTs) have developed a variety of standard written procedures for contract time estimation.

This synthesis report describes the results of a survey of these techniques. The survey included an extensive review of U.S. and foreign literature, interviews with practicing project schedulers and construction contractors, and analysis of responses to a detailed questionnaire from 43 state and provincial DOTs in the United States and Canada.

The survey showed that most agencies use similar processes for estimating contract time. The construction project is first described in terms of its constituent activities or controlling operations, the most reasonable sequence of these operations, and the likely duration of each operation. Many agencies use standard production rates to make these duration estimates. One of several standard project scheduling techniques is used to estimate reasonable total project duration, which is then taken as a preliminary estimate of contract time.

The most frequently used scheduling techniques are bar charts and the critical path method (CPM). Sometimes the two methods are used in combination. Some states apply a method based on statistical analysis of historical data, known as parametric time estimating. Other existing scheduling techniques, such as the program evaluation review technique (PERT) and linear scheduling, are rarely used by state DOTs, although a number of states are considering them for future use. Computers have become an integral part of the scheduling process and many states have developed customized applications.

The preliminary estimate of contract time typically is adjusted to reflect the special conditions under which the project will be constructed. The survey identified some 20 major factors on which adjustments are based, including weather and other seasonal factors, traffic conditions, and utilities relocation.

Some agencies have developed analytical tools to aid estimation of the quantitative effect of these factors on contract time. The weather conversion chart, representing the effect of climatic factors on contract time, is the most well-developed of these tools.

Many practitioners also consider such physical characteristics of a project as location, size, and project type to be very significant for adjusting contract time. Budget, legal and environmental problems are less frequently of concern. Allowances may be made for contractors' mobilization and component assembly time, as well as for steel fabrication and materials delivery. The adjusted preliminary contract time is reviewed by experienced agency staff. After review and approval, the estimated time is incorporated into the bid documents.

Many agencies are experimenting with contract methods intended to reduce construction time by motivating contractors to speed construction, using monetary rewards for early completion or penalties for late completion. Among these methods are incentive/disincentive, bidding on cost and time (commonly known as A+B), and lane rental. Such methods can influence contract time, although only the A+B method does so directly. Agency experience with these innovative methods for the most part has been positive. In most cases, the construction time has been reduced substantially, compared to contract time assigned to similar projects using conventional contracting methods.

Most agencies and practitioners reported satisfaction with the current methodology for contract time determination. However, improved tools and methods for handling procedural details are being sought. In the future, computer applications are expected to increase, enabling greater use of more sophisticated scheduling techniques. Development of knowledge based expert systems (KBES) for time estimation and scheduling also hold potential for improving estimates of contract time and reducing construction duration.

CHAPTER ONE

INTRODUCTION

Contract time, the maximum time allowed for completion of all work described in contract documents, influences not only construction project duration, but also budgeting, resource planning, a project's impacts on the local economy, and contract claims experience. This pervasive influence makes contract time estimation one of the most important tasks in construction contracting.

National Cooperative Highway Research Program (NCHRP) Synthesis 79: *Contract Time Determination* (*1*), published in 1981, documented the practices used by departments of transportation (DOTs) for this important task. Since that publication, major changes in the highway construction industry have created a need to update the information assembled in that earlier synthesis.

This synthesis report discusses the current practice of contract time determination among DOTs, within the context of ongoing changes in the highway construction industry. The synthesis is based on an extensive survey of U.S. and foreign literature, interviews with schedulers and contractors, and a review of procedures used by agencies. This latter review included analysis of the responses by 43 agencies to a detailed questionnaire sent to DOTs in the United States and Canada.

All of these several sources are referred to in this report as the "synthesis survey." The literature review is the basis for the reference list following the body of this report. Appendix A presents the questionnaire form, and Appendix B lists the states and provinces that responded to the questionnaire.

Organization of the Report

This report is organized in six parts. The first chapter deals with the general process of determining contract time as it is performed by various DOTs. The second chapter describes the details of the methods used by DOTs when dealing with various issues of determining contract time. The third chapter reviews the various factors that influence the determination of contract time. An important part of this chapter is the review of the relationship "weight" that practitioners give to each of the factors. The effects of innovative contracting methods on the determination of contract time are discussed in Chapter 4. Chapter 5 presents findings and recommendations. The eight appendices contain additional data related to various parts of this synthesis. Appendix A lists the survey questions that were sent to various DOTs in the United States and Canada. The results of this survey have played an integral part in the development of this report. Appendix B provides data on DOTs that responded to the questionnaire. Appendix C lists methods used by those DOTs to determine contract time. Appendix D is a detailed example of the contract time determination procedure used by the Florida DOT. Appendix E is a project classification list used by the California DOT. Appendices F, G, H are data related to the use of innovative contracting methods.

THE IMPORTANCE OF CONTRACT TIME

The term "contract time" has particular legal application and can be understood in court proceedings to mean the owner's "warranty of design." As such, contractors' claims based on unreasonable contract times are compensable if the time is found to be significantly at odds with conventional practice. Contract time must represent the time in which an average, competent contractor will be able to complete the project, and may be represented by working days, calendar days, or a completion date. In the case of completion date, the agency must give the bidder a starting date as well.

If the allowed contract time is too short, bid prices may be higher, quality may be reduced, and the number of legal disputes may increase. If the contract time is too long, the public will endure unnecessary inconvenience and the local business community may suffer excessively. DOTs seek to set the optimal contract time that will balance project cost against project quality and public costs. This depends on accurate estimates of construction time.

Accurate estimation of construction time is always important, but particularly so when a series of independent contracts (i.e., projects) planned in the same area may be contingent on one another. Contingency may include interference between operations of various projects to the extent that the start of one depends on the completion of another, for example, when large quantities of soil removed from one project must be used as fill material in another project.

THE CHANGING CONSTRUCTION MARKET

Contract time has become increasingly important as the market in highway construction has shifted from development of new transportation facilities projects to a preponderance of resurfacing, restoration, and rehabilitation (3R) projects. Many of these projects are constructed under heavy traffic conditions, causing delays to the traveling public and adversely affecting the local economy. The overall cost of such disruptions, estimated as components of road user costs (RUC) (see Chapter 4), has increased sharply in recent years and, for projects constructed in major metropolitan areas, may be very high, placing a greater premium on controlling construction project duration.

This premium is likely to increase. High and growing traffic volumes on many highways are creating the need for added lanes, roadway widening, and bridge upgrading. Night and weekend work is increasingly the only way to reduce adverse impacts of these 3R-type projects. Highway design and construction professionals will need better procedures for determining contract time, to optimize project cost with regard for public inconvenience.

In 1991, the Federal Highway Administration (FHWA) issued a final rule under Title 23, *Code of Federal Regulations,* Part 635, which required every state DOT to have adequate written

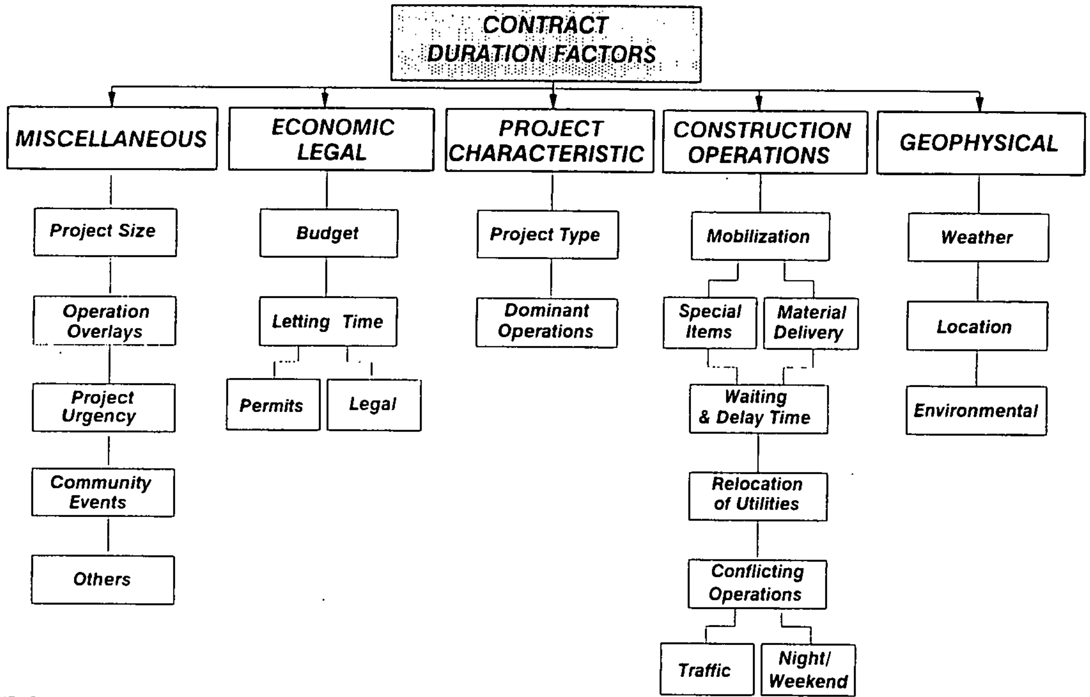

FIGURE 1 Major factors affecting contract time.

procedures for contract time determination. The FHWA also published Technical Advisory T5080.15 "Construction Contract Time Determination Procedures" (*2*) to assist the agencies in developing their own procedures for contract time determination.

Concurrent with the growth of these needs, the rapid advance of computer applications in the construction scheduling process has made possible the use of more detailed and sophisticated contract time estimation methods. Personal computers have become an integral part of most agencies' operations. User-friendly scheduling software packages have become available, enabling their use by larger numbers of agency schedulers.

Added incentives for making better estimates of contract time stem from the evolution and increasing use of contracting methods developed to reduce construction time. Such methods, which provide financial incentives to contractors to speed construction, are the subject of a 1991 Transportation Research Board (TRB) report, "Innovative Contracting Practices," which recommended increased experimentation with these innovative methods by state agencies. (*3*)

FACTORS INFLUENCING CONTRACT TIME

A key task in determining contract time is estimating the necessary and reasonable amount of time required to do the work described in contract drawings and specifications. The duration of any particular project is ultimately determined by a wide range of factors, such as the complexity of the project, the likelihood that such conditions as climate and terrain will facilitate or impede construction operations, and whether other projects being constructed at the same time will cause shortages of labor or materials. Only some of these factors are under the control of the construction contractor or the DOT.

Figure 1 summarizes the factors typically influencing contract time, as identified by preliminary input from DOT practitioners while preparing the questionnaire for this study. Simply estimating project duration requires knowledge of and experience with construction, understanding of the inherent uncertainties in a project, and insight into the construction market, but DOT decisions, policies, and regulations influence duration as well. Determination of contract time thus depends not only on estimates of project duration, but also on the agency's objectives and constraints. High traffic volumes subject to construction disruptions may require that construction proceed with nighttime work and other more costly procedures, to reduce project duration. Budget limitations, on the other hand, may preclude specifying a short project duration that might require such additional cost. The process of contract time determination thus involves elements of both forecasting and decision making.

THE CONTRACT TIME DETERMINATION PROCESS

The synthesis survey found that most DOTs use a similar seven-step process to determine contract time. Procedural details and analysis methods in individual agencies' practices vary, as discussed in Chapter 2. DOTs typically document their procedures in guidance manuals, such as those from Florida, presented in Appendix D.

The DOT typically designates a unit within its organization to be in charge of the contract time determination process. This unit acts as the DOT's scheduler. The actual scheduling function can be performed by various departments in the DOT organization, such as design, production, construction, or other departments, but responsibility for determining contract time rests with the scheduling unit.

TABLE 1
EXAMPLE LISTING OF PRODUCTION RATES FOR CONTRACT TIME DETERMINATION (4)

SECTION	ITEM	CONTRACT TIME
201	Clearing and Grubbing	1.5 Acres/Day
202	Removal of Timber Bridge	2 Spans/Day
202	Removal of PCC Pavement	500 Yd^2/Day
202	Removal of Concrete Box Culverts	1/Day
202	Removal of Asphaltic Concrete Surfacing	1 Mile/Day 2 Lane Miles/Day
203	Excavation or Embankment (figure highest quantity only)	3,000 Yds^3/Day (Rural) 1,000 Yds^3/Day (Urban)
203	Borrow or Truck Hauled Embankment	500 Yds^3/Day (Truck Hauled)
203	Mucking Ditches (consider section)	1,000 Ft./–0.5 Mile/Day
203	Mucking (very large quantity)	3,500 Yds^3/Day
203	Shaping Roadbed	1 Mile/Day
203	Shaping Roadway, Ditches & Slopes	0.5 Mile/Day
203	Shell Embankment	2,500 Yds^3/Day
301	Base Course (Non-Stabilized)	1,500 Yds^3/Day
301	Base Course (Class I)	1,000 Yds^3/Day
302	Scarifying and Compacting Roadbed	1 Mile/Day 2 Lane Miles/Day
303	In-Place Cement Stabilized Base Course	6,000 Yds^2/Day (Roadway) 4,000 Yds^2/Day (Shoulders)
304	Lime Treatment (24 Ft. Width) (20 Ft. Width)	6,000 Yds^2/Day 5,000 Yds^2/Day
305	Subgrade Treatment (Working Table)	8,000 Yds^2
401	Aggregate Surface Course	300 Yds^3/Day
501	Asphaltic Concrete (less than 20 tons or broken construction)	500–1,000 Tons/Day
501	Asphaltic Concrete (typical overlay or construction)	1,000 Tons/Day

Phase 1: the Input Data

The DOT scheduler gathers and reviews all the data necessary for estimating construction time, generally including design drawings, specifications, special provisions, bills of quantities, correspondence, and any other relevant data.

Phase 2: List of Activities

After reviewing the input data, the scheduler prepares a list of activities representing the major tasks to be accomplished in the project's construction. In a number of DOTs this list consists only of major activities, known also as controlling operations. In most cases, the list of activities includes the activity's name or description, its standard code (if the DOT has a standard state coding system), and its work quantity and unit price. Some DOTs have created lists of standard activities for several types of projects, to assist the scheduler in determining the necessary activities for projects of that type. Appendix E is California's classification system.

Phase 3: The Use of Production Rate for Determining Activity Duration

The DOT scheduler determines the duration for each activity in the list using production rates and work quantities. "Production rate" is a quantity of production accomplished over a specific time period (e.g., cubic meters of concrete placed per day). Realistic production rates are the key in determining reasonable contract times.

Most DOTs have developed a list of standard production rates to assist the scheduler. (See Table 1, for example, from Louisiana.) These rates are based on statistical analysis of historical data on construction in the state, and are based on the amount of work that a typical crew can be expected to accomplish in a working day.

Production rates can be presented in the form of a chart as well as a table, or even a computerized database. Figure 2 shows the production rate function for pavement placement, used by Maryland (5). This example illustrates greater degrees of sophistication that can be introduced into the basic estimation process.

Some states have developed production rates expressed in monetary terms (i.e., dollars of construction put in place per day), but more typically, physical rates are used. In any case, these average production rates reflect past experience, and so depend on an implicit assumption that construction methods, equipment, environmental controls, and prices for the project being analyzed are generally similar to those on which the production rates were based.

Using the standard production rates and the work quantities, the scheduler can estimate the duration of each activity, using the following general equation:

$$T^i = \frac{Q^i}{P^i}$$

where

T = The duration of activity i (e.g., days)
Q = work quantity for activity i
P = production rate for activity i.

For example, referring to Table 1, Louisiana's estimate for the time for placing 13,000 yd^3 of aggregate surface course would be computed as follows:

$$T = \frac{13{,}000}{300} = 43 \text{ days}$$

i = placing of aggregate surface course (section 401)
Q = 13,000 yd^3
P = 300 yd^3/day

Actual production rates in the field depend on many factors such as weather, topography, project size, and characteristics of the specific crews performing the work. Some of these factors, e.g., weather or topography, are to some extent foreseeable, and some states have developed different standard production rates for various zones within their states or project types. Other agencies suggest a range or more than one rate for each activity (e.g., low, medium, and high productivity). Alaska has developed a unique approach for determining production rates, reflecting a statistical basis and assumptions about how a project is undertaken. The responsible scheduler must determine what rates to use and whether the standard rates should be modified for estimating duration of a particular project.

Phase 4: Sequence of Construction

Based on experience, and with the aid of the list of activities and their durations, the scheduler describes the logical sequence of activities needed to construct the project. The sequence of activities shows the sequence of individual steps in the construction process, which activities depend on or must follow completion of others, and which activities can be carried out concurrently. The sequence is generally shown as a precedence diagram suitable for scheduling, such as a bar chart (also known as the Gantt chart) and the critical path method (CPM) typically is used to compute the total project duration. This computation then gives the scheduler a preliminary contract time estimate.

Computations may be made by hand, but a variety of computerized packages are available to make the computation. A detailed discussion of scheduling techniques follows in Chapter 2.

Figure 3 is an example of a bar chart used by California (*6*) showing the sequence of activities and the total time for a project involving construction of a bridge. Figure 4 is an example of a CPM diagram for a freeway construction project, as used by Michigan.

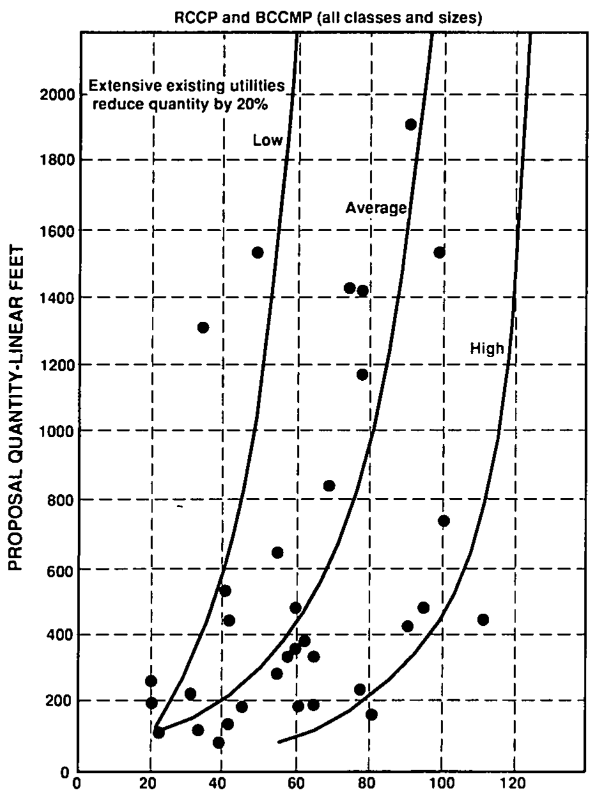

FIGURE 2 Production rate chart, Maryland (*2*).

Phase 5: Adjusting

The DOT scheduler next adjusts the preliminary contract time, as calculated in phase 4, to reflect the particular conditions under which the project will be constructed. The scheduler considers the effect of specific factors such as location, weather, and traffic, as summarized in Figure 1. The practices and judgment of various agencies, regarding the relative importance of these various factors, is the topic of Chapter 3.

After identifying the factors that are likely to affect a specific project and their impact on the contract time, the scheduler adjusts the preliminary contract time. This adjusted contract time, in working days units, is converted to calendar days or completion dates in those states that represent contract time in these terms.

Phase 6: Review

The adjusted contract time, as estimated in phase 5, is reviewed by experienced agency practitioners. Some factors that reviewers consider are state budget, agency work load, contractors' availability, and current labor market. Some states (e.g., New Mexico, Delaware) are developing standard procedures based on statistical analysis of historical data to assist the reviewers.

Phase 7: Final Contract Time

The review may lead to additional adjustments of the earlier estimate of contract time. Following these adjustments and final agency approval, the final contract time is incorporated into the bid documents and subsequently becomes part of the contract between the construction contractor and the agency.

PARAMETRIC TIME ESTIMATING (HISTORICAL DATA ANALYSIS)

Parametric time estimating, sometimes referred to as historical data analysis, is a major variation of the basic process of contract time determination that does not require a breakdown of tasks to be accomplished in the construction project. Instead, statistical regression analysis of historical data is used to estimate directly the

PRELIMINARY PROGRESS SCHEDULE

SALIENT FEATURE	QUANTITY	UNIT	ESTIMATED DAILY PRODUCTION RATE	NO OF DAYS
CLEAR & GRUB				5
EARTHWORK	125,000	CY	5,000	25
BASE & SUBBASE	10,650	CY	900	12
ASPHALT CONC.	9,200	TON	1,200	8
BRIDGE				130
ELECTRICAL				120
DRAINAGE				20
EROSION CONTROL				30
STRIPING & MARKERS				15
PLANTING, IRRIG. & PLANT ESTB.				160

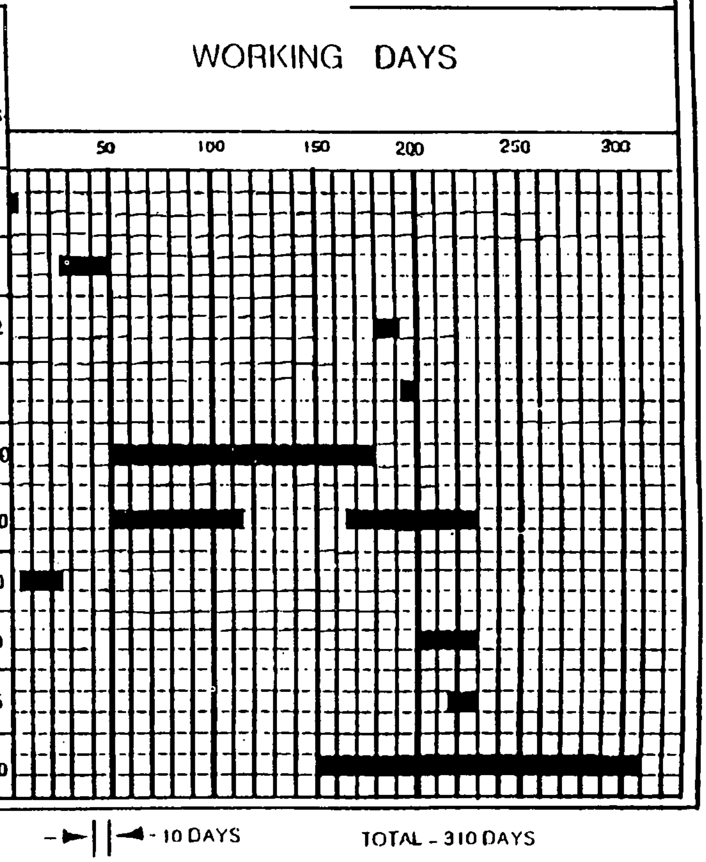

FIGURE 3 Bar chart, California (*3*).

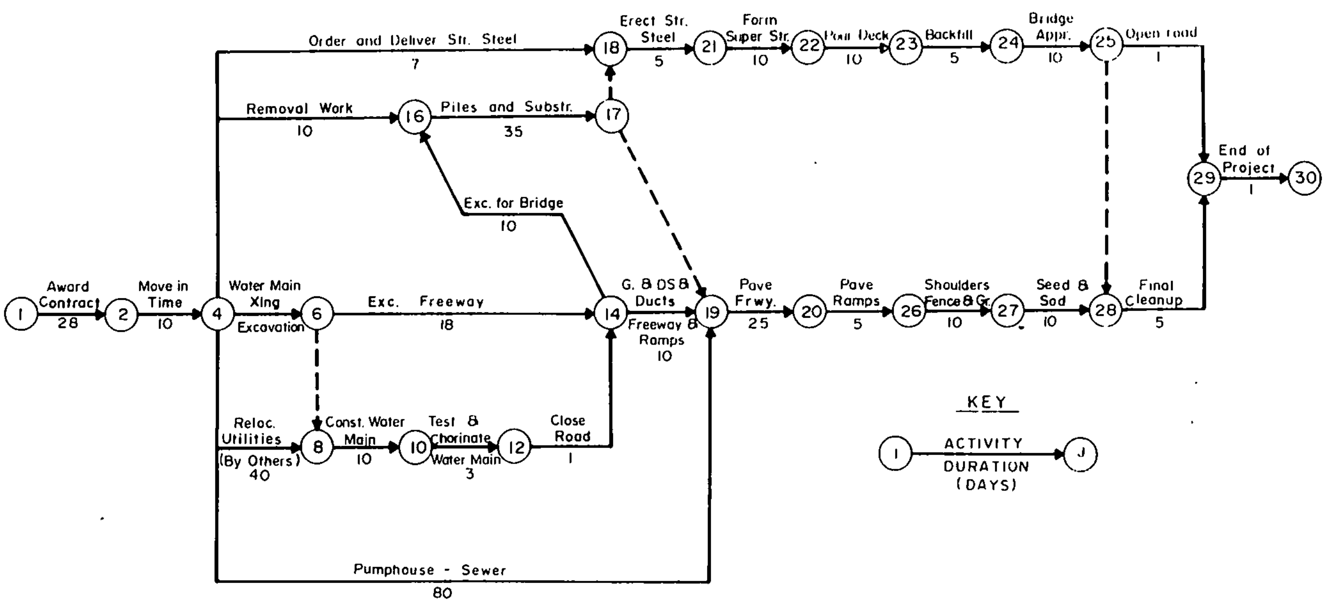

FIGURE 4 CPM using the arrow diagram, Michigan (*7*).

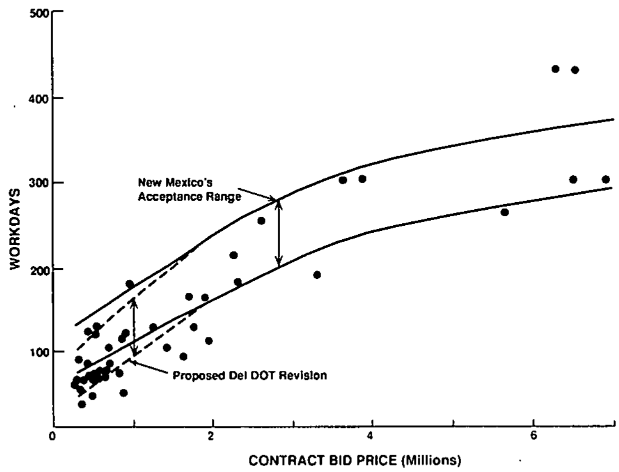

FIGURE 5 Parametric time estimate, Delaware, New Mexico (*8*).

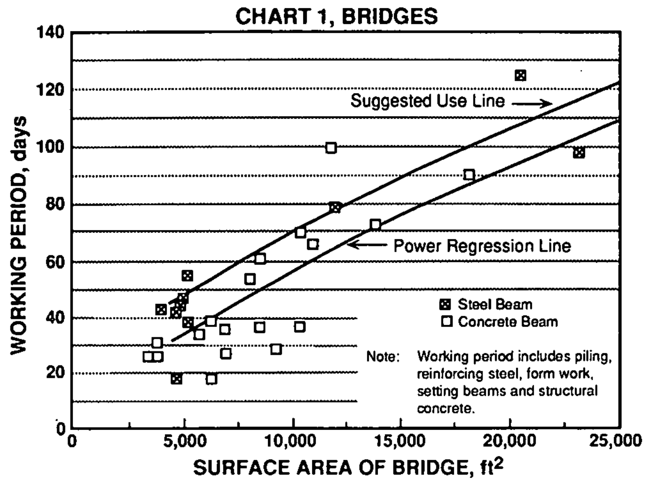

FIGURE 6 Parametric time estimated, Iowa (*9*).

relationships between construction time and parameters indicating project scale or magnitude. The most commonly used parameter is the project's cost, but physical measurements such as length, area, and volume often are used as well.

If the agency has sufficient data on a specific type of project, the regression analysis will give the DOT scheduler a very reliable indication of the reasonable contract time to be assigned to a new project of that type. Parametric time estimating is an alternative to phases 2–4 in the basic process discussed previously.

Figures 5 and 6 are examples of parametric time estimating charts resulting from regression analysis, as used by Delaware and New Mexico (*8*) and Iowa (*9*), respectively. Contract bid price and bridge surface area are used as independent variables for estimating preliminary contract time in the figures.

A more sophisticated version of parametric time estimating uses multiple regression on more than one project parameter. For example, the construction duration for a highway segment may be estimated as a function of cost, length, and number of lanes. The availability of easy to use statistical analysis software packages enables even a scheduler without extensive knowledge of statistics to develop these regression charts.

Proponents of parametric time estimating prefer its simplicity, compared with developing construction sequences and time schedules, and argue that with sufficient historical data the results can be quite accurate, especially when dealing with simple, short-duration projects. Those favoring the method suggest that its adoption by more DOTs would increase the base of data and lead to increasing accuracy in the analyses.

Others hesitate to use this method because it is very sensitive to the accuracy and size of the input database. Some practitioners argue that it is simply wrong, because there is no necessary logical relationship between the cost of the project and its construction time, and that the correlations shown through statistical analysis are, therefore, misleading. For example, a complex project with a small budget may require more time than a simple project with a large budget. Similarly, a highway of 2000 meters (6,560 lf) does not require twice the time to construct as a project of 1000 meters (3,280 lf).

CHAPTER TWO

CONTRACT TIME DETERMINATION PRACTICES

This chapter describes various DOTs' procedures for determining contract time and dealing with the major issues arising in the estimation of contract time. The synthesis survey found that almost all participating DOTs follow the basic process described in Chapter 1.

TIME UNITS

DOTs measure contract time in several different ways:

- Working days (e.g., 280 working days), time the contractor will be working on the project, excluding weekends or Sundays and holidays.
- Calendar days (e.g., 250 calendar days), elapsed time without regard to the contractor's necessarily being on the job.
- Completion dates (e.g., December 15, 1995), a specific date in the calendar year by which the project is to be completed; must refer to a starting date by which the contractor will be able to commence work.

Hinze and Coleman (*10*) reviewed the practices of 50 state DOTs, finding that most agencies use a combination of time units in their procedures. The decision as to which time unit to use depends on the project size, length of time, urgency, and other considerations. Table 2, taken from that study, shows the frequency with which states reported using various combinations of time units.

SCHEDULING TECHNIQUES

Considerable variation is found among agency choices of scheduling techniques used in estimating contract time. The synthesis survey, as well as studies done by Iowa (*11*) and Rowings and Rahbar (*12*) found bar charts, networks (CPM and its variants), parametric time estimating (historical data), and simplified methods to be the principle types of techniques in use.

Most states combine techniques in their procedures. Appendix C lists the various methods used by state DOTs in their scheduling procedures.

Bar Charts

Bar charts are by far the most popular scheduling technique, used by some 60 percent of DOTs. Many states have developed their own customized bar chart methods, using a predesigned list of activities for standard projects of several types.

In recent years, many states have used computers to generate bar charts. Figure 7 is an example of a computerized bar chart. The computerized computation and drawing of a bar chart eliminates time-consuming manual graphic work, enables the scheduler to enhance the schedule presentations, and enables easy modification to accommodate project change.

Many agencies consider bar charts useful because they have strong visual impact and are easy to understand. The major disadvantages of bar charts are that they do not show clearly the interrelationships among activities and do not define which activities are more critical to project completion. These shortcomings may be a handicap to effective contract time estimation, especially when dealing with complex projects.

Preparing a bar chart using most commercially available scheduling software packages requires input data in a format and with a level of detail suitable for CPM analysis, although a few simple software packages can generate bar charts without conducting a complete CPM computation.

Critical Path Methods

Network scheduling techniques were developed in the late 1950s to meet demands for more effective management of complex military and civilian projects for which bar charts proved inadequate. Using the same underlying principles, two techniques were developed, the critical path method (CPM), which has gained widespread use in construction, and the program evaluation review technique (PERT, discussed in a later section). A substantial literature exists describing the basic principles of network analysis.

Many DOTs use CPM to describe the sequence of construction operations and to calculate contract time. Some agencies use the technique only for complex projects, while others (e.g., Iowa) use CPM for most of their projects.

The core of these techniques is the activity network showing sequence and dependencies among individual work activities the project comprises (see Figure 4). "Dependency" refers to the requirement, for example, that an activity not be started before another activity, on which the first is dependent, is finished. There are several types of dependency that may be considered in project scheduling.

In the past, most DOTs' schedulers used only one type of dependency, commonly known as normal dependency (N–Normal), which means that one activity can start only after a previous one has been completed. Although this type of dependency is the most common in construction practice, it does not cover all possible situations. In recent years, many DOT schedulers have started to use advanced types of dependency:

Start-to-start dependency indicates that activity B must start a few days after activity A has started. This is described in the symbol $S_AS_B = E$ where S represents a start and E is the time interval between the two starts. A similar dependency is *finish-to-finish*, symbolized as $F_AF_B = E$, meaning that activity B must be

TABLE 2
TIME UNITS USED BY DOTS TO SPECIFY CONTRACT TIME (*10*)

Time Unit	States Using Units No.	Names
Working Days Only	5	CA, MN, NE, TX, WA
Calendar Day Only	2	NC, NY
Completion Date Only	0	--
Working Days or Calendar Days	6	CO, ME, MI, MO, MT, NJ
Working Days or Completion Date	3	NH, WV, WY
Calendar Days or Completion Date	10	AK, CT, MA, NV, OH, OR, PA, SC, VT, WI
All Three Units (W.Days/C.Days/Comp.Date)	24	All the rest.
TOTAL	50	

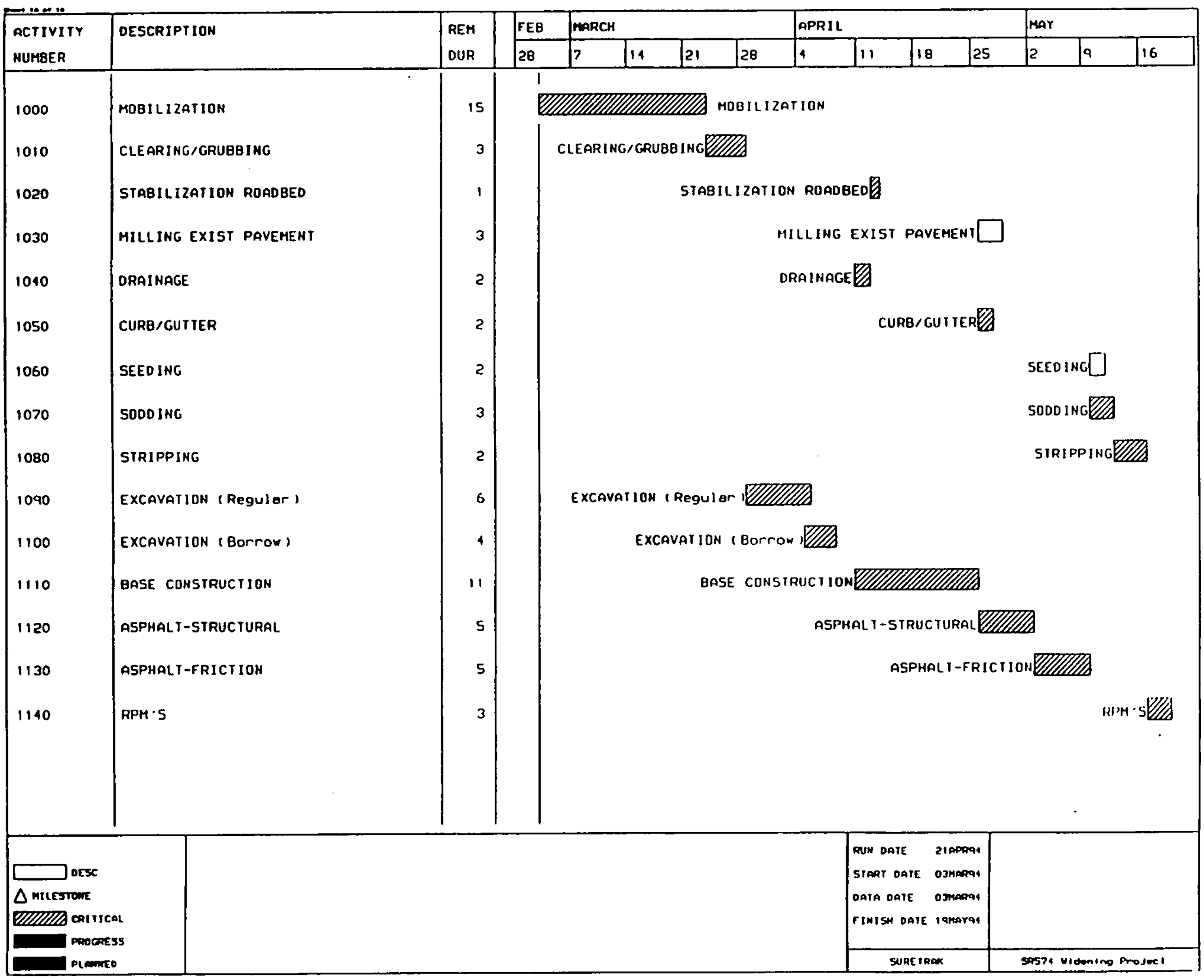

FIGURE 7 Example of a computerized bar chart.

completed a few days (E) after completion of activity A. *Finish-to-start* dependency ($F_AS_B = E$) means that after finishing activity A, a delay of E (e.g., 7 days for curing concrete) has to occur before activity B is started.

The use of these advanced dependencies enables a DOT scheduler to prepare a list of activities that follows in a more realistic way the sequence of construction operations. Table 3 is an example of a list of activities indicating these advanced dependencies.

TABLE 3
EXAMPLE OF INPUT DATA FOR CPM ANALYSIS WITH ADVANCED DEPENDENCIES

ACTIVITY #	TASK DESCRIPTION	DURATION (in weeks)	DEPENDENCY	TYPE*
1	Preliminary Planning	10	-	N
2	Structural Design	6	1	N
3	Mechanical Design	10	1	N
4	Purchase Mechanical System	12	3, 5	N, N
5	Obtain Building Permits	16	2	SS = 3
6	Clearing Land	2	5	N
7	Foundation Excavation	2	6	N
8	Electrical Installation	3	6	N
9	Water Connections	3	6	N
10	Foundation	2	7	SS = 1
11	Install Mechanical Equipment	3	4, 12	N
12	Structure Construction	8	8, 9, 10	FS–1,SS=2,N
13	Electrical Wiring	2	11	N
14	Plumbing	2	11	N
15	Check Equipment	1	13, 14	N, N
16	Office and Services	6	6	N
17	Trial Operation	4	15, 16	N, N

(Data for design and construction of small pumping station)

*Key: N = Normal Dependency
FS = 1 Finish to Start with an Interval of 1
SS = 3 Start to Start with an Interval of 3

The network itself may be constructed according to either of two conventions:

- The *arrow diagram*, also called Activity On the Arrow (AOA), and
- The *precedence diagram*, also called Activity On the Node (AON).

The main differences between these two versions of the method are in the ways activities and their sequences are graphically displayed (as their names explain), their ability to accommodate various types of dependencies, and their ability to support manual schedule computations. The results of the CPM calculations are the same with both methods, and debate continues among professionals regarding the relative merits of the two approaches. It seems, however, that increasing numbers of practitioners prefer the precedence diagram format.

An important factor underlying the growing popularity of CPM is the increasing availability of computers and software to perform the extensive computations the method entails. The advent of the personal computer, in particular, and of off-the-shelf "user-friendly" scheduling software packages have enabled many DOT schedulers to use CPM more efficiently and effectively. Rowings and Rahbar (*12*) found that 46 percent of DOTs are using computers in their scheduling process. Dozens of commercial scheduling software packages currently are available for CPM calculations. An evaluation by Herbsman (*13*) of the most popular commercial packages showed them to be based on the same principles and very similar in operation. The major differences among packages are degree of sophistication, number of available options (e.g., their ability to deal with resources management or cost loading), graphical presentation capabilities, and purchase price.

Time-Scale Diagrams

A feature of bar charts that appeals to many scheduling practitioners is the readily apparent representation of time duration for activities in the project schedule. The length and relative relationship of bars on the chart reveal activity duration and when in the project schedule each activity is to begin and end. However, the traditional bar chart shows no functional relationships or dependencies among activities. The CPM diagram, in comparison, shows dependencies and logical sequences very well, but does not necessarily display activity durations and schedules.

Time-scale diagrams represent a combination of the two techniques. Activities are represented as bars, arrows, or blocks proportional in length to the activity's duration, as is done in a bar chart. The relationship of activities is shown by placing these time-proportioned activities in a CPM diagram. Figure 8 is an example of a time-scale diagram using the AON technique.

While producing a time-scale diagram once required time-consuming manual drafting, particularly daunting when the number of activities was large, today the availability of scheduling software packages and affordable printers and plotters makes the task relatively simple and easy to perform. This format may be expected to gain popularity as a result.

Program Evaluation Review Technique (PERT)

The PERT method, like CPM, developed in the late 1950s, is used most commonly for large industrial and weapons system design-and-development applications. While CPM treats the duration of each activity as a single, determined value, in PERT appli-

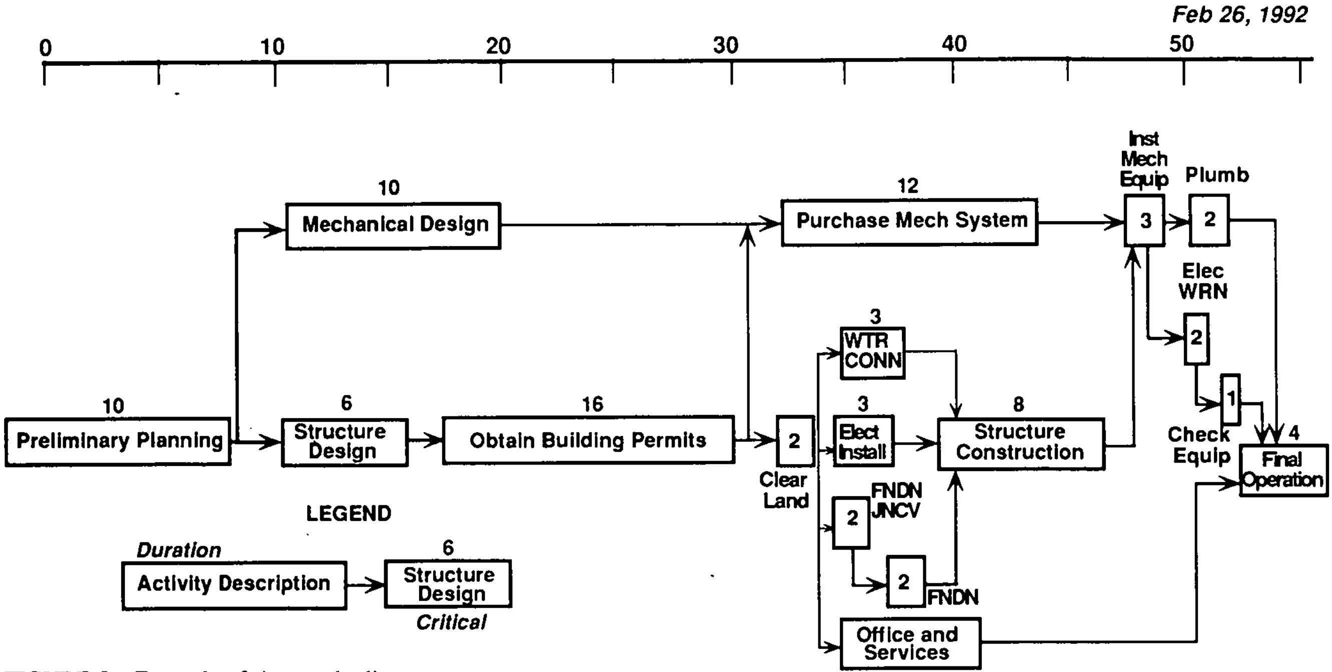

FIGURE 8 Example of time scale diagram.

cations the value can vary to reflect uncertainty. Typically, each activity is assigned three possible values:

a = the optimistic estimate or shortest reasonable time
m = the average estimate or most likely reasonable time
b = the pessimistic estimate or longest reasonable time.

Using the same basic network analysis principles as CPM, the PERT user performs multiple computations to develop a probabilistic distribution of estimated project duration. The typical output of a PERT calculation will be a set of preliminary contract times and the estimated probability that the project will be completed within that time period, e.g., 20 percent probability that the project can be completed in 210 days or fewer, 40 percent probability that the project can be completed in 240 days or fewer, and so on.

Schedulers can decide which level of probability their agencies can accept and thereby determine the appropriate contract time. For example, the 90 percent probability level might be chosen for a very sensitive project that must be completed by a specific date, while the 70 percent level may be acceptable for a routine project.

Use of PERT in DOTs currently is rare, although its greater complexity (compared to CPM) may be warranted when scheduling research and development projects. Such projects, e.g., involving use of new construction techniques or new materials, pilot or demonstration projects, have greater uncertainties that make scheduling more challenging.

Simplified Methods

A few DOTs have developed simplified procedures for rapid estimation of contract time for short-duration, routine or standard projects, or for use when regular procedures otherwise cannot be followed. In most cases, the agency uses predesigned lists of controlling operations for various types of standard projects.

In the most basic method, the DOT scheduler determines from the design documents the work quantity needed for each operation and, using the state list of standard production rates, calculates the time needed for each operation. The total time for all operations represents the contract time in working days. Figure 9 shows an example of the use of such a method by Iowa.

For states that use calendar days or completion dates, the scheduler converts the time unit by using a simple conversion factor (e.g., Florida estimates 1.46 calendar days for each working day). The scheduler may adjust the estimated contract time using judgment and experience. The technique is simple and quick, but likely to be less accurate than bar chart or network procedures.

A more simplified estimating technique resulting, nevertheless, in more sophisticated results is linear scheduling, also termed line of balance (LOB) (*14*) or linear scheduling method (LSM) (*15*). Linear scheduling is useful for projects that consist of a number of similar sections, each one constructed by the same repetitive construction operations. Highway and road projects, pipelines, and tunnels often are the linear type and well-suited to the linear scheduling process.

When using the linear scheduling technique, the scheduler develops the list of major operations needed for construction of the project. Quantities of work and standard production rates are used at aggregate levels to estimate the rate of progress for each operation, e.g., one km/day (or one mile/day) in a road construction project, or 100 m/day (330 ft/day) in a pipeline project. The scheduler plots each operation on a two-dimensional graph that shows time versus the length of the project. The final graph shows a series of lines, each representing the progress of an operation. Each new line is drawn to start when the scheduler judges that the preceding work will have progressed sufficiently for the operation

IOWA
DEPARTMENT
OF
TRANSPORTATION

LETTING 2-21-92

PROJECT DATA SHEET	34
DISTRICT	2
COUNTY	HOWARD
PROJ. NO.	BRF-272-1(6)- - 38-45
WORK TYPE	BRIDGE (new

ESTIMATE OF TIME REQUIRED

ITEM	UNIT	QUANTITY	RATE PER DAY	DAYS	DAYS NOT AFFECTING TIME LIMIT	TOTAL DAYS REQUIRED
Excavation Class	Cu. Yds.					
P.C.C Pavement	Sq. Yds.					
A.C.C. Binder and Surface Course	Tons					
Gravel or Crushed Stone Shoulder	Tons					
Seeding	Acres					
Guardrail	Lin. Ft.					
Remove Existing Structure	L.S.			10	7	3
147'x32' PPCB 3 span over creek	Sq.Ft	4704	Chart	34		34
Concrete Barrier Rail	1 in. Ft	328	50	7		7
Clean Up						1
Total Working Days Required						45

TWF 8-20-91

Prepared By: DRT

Date: 12-18-91

Comments: Road closed by ACC contractor.
No winter Free Time
Approx. Start 4-27-92
Use 55 working days since RCB project needs 55.

FIGURE 9 Simplified time estimate form, Iowa (*9*).

to be initiated. The completion time of the last operation then determines the contract time.

Linear scheduling is used extensively in highway construction scheduling abroad. In the United States, its use is very limited and most applications have been part of research projects, for example in North Carolina (*15*). Practitioners familiar with linear scheduling believe that it is a powerful tool that may be used in scheduling in the highway construction industry.

BIDDING ON COST AND TIME—THE A+B METHOD

Bidding on cost and time, also termed the A+B method, relies on the contractor to prepare a cost and project time proposal. The method differs from the scheduling techniques previously discussed in the sense that the agency scheduler does not specify the contract time in the bid documents, although a maximum time

TABLE 4
EXAMPLE OF TABULATION OF BIDS SUBMITTED UNDER THE A+B METHOD

Bidder	A[a]	Bid Tabulation Days Bid*	B[b]	A+B[c]
1	$15,636,000	450	$2,250,000	$17,886,000
2	$16,070,000	426	$2,130,000	$18,200,000
3	$15,628,000	523	$2,615,000	$18,243,000
4	$16,231,000	646	$3,230,000	$19,461,000
5	$15,835,000	780	$3,900,000	$19,735,000

Notes:
[a] The estimated cost of each bidder
[b] The time value calculated by multiplying the bid days by the time unit cost of $5,000 per day
[c] The combined cost
* The DOT's original estimate was 729 days.

may be specified. The agency receives bid offerings of time and cost, and determines the contract time by selecting one of the bids.

The selection generally is made by determining which bid represents the lowest total cost, combining construction cost (A) and estimated costs to the public for construction delays and disruptions (B). These latter costs, sometimes termed road user costs (RUC), are incorporated into the contract document. Appendix G presents a summary of agencies reporting use of the A+B bidding method. Appendix H shows example calculations of RUC as done by the Kansas DOT.

The lowest combined cost (A+B), rather than construction cost alone, determines the successful bidder. In most cases, the contract contains a disincentive clause to discourage the contractor from overrunning the contract time bid. The FHWA's *Technical Advisory T 5080.10* (*17*) discusses the following formula for determining the low bidder:

$$TCC = A + B$$

where
TCC = total combined cost
A = the bidder's proposed construction cost
B = the estimated time (road user) cost

B is to be calculated as

$$B = ET \times RUC$$

where
ET = the bidder's proposed contract time
RUC = road user cost per unit time

Table 4 is an example from a bid tabulation using the A+B method on a highway project in Kentucky (*18*).

Herbsman and Ellis (*19*) evaluated 20 projects that were contracted using the A+B method and concluded that the use of this method may reduce the contract time substantially, as compared to the DOTs original time estimates (also the "engineer's time estimate"). This reduction in contract time has been achieved with little or no additional cost to the public. The FHWA came to a similar conclusion: "This method has been effective in getting projects completed sooner than would have been the case if normal contracting procedures had been utilized" (*17*). Contractors who participated in A+B contracts said that in most cases they did not raise their unit prices, compared to similar projects that were bid in conventional contracts. They were able to bid on reduced contract time by better planning of their resources, better project organization, and paying more attention to the scheduling process.

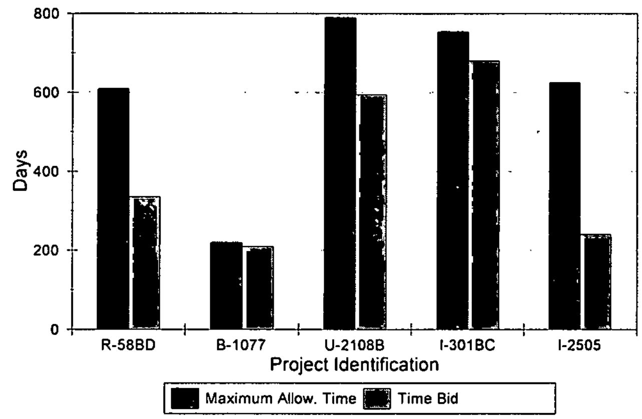

FIGURE 10 Comparison of contract time, North Carolina (*20*).

The synthesis survey found that 40 percent of the responding states have used or considered using the A+B method. (see Appendix C) Figure 10 shows data gathered from five projects in North Carolina (*20*), which were contracted using the A+B method. Analysis of these data reveal significant differences in construction time bid as compared with the engineers' estimates of maximum allowable time in most of these projects.

States that experimented with the A+B method generally found the experience to be positive, although respondents emphasized that the method should be used with care and applied only to appropriate projects. Among the advantages attributed to the the method are a potential for earlier completion of projects, a better overall product value (considering both cost and time), better project planning and preparation by contractors, and more realistic estimation of contract time.

Some of the agency personnel interviewed cite disadvantages for this method. Small contractors are said to be placed at a disadvantage or precluded from participating in this type of bidding because they may not have the resources to assign multiple crews to projects. Competition is thereby restricted and prices possibly increased. Also, a contractor may bid an unreasonably low contract time, and when awarded the contract may take shortcuts that can affect the quality of work, or increase the number of claims.

These purported advantages and disadvantages have not been well-documented, and represent some of the aspects of the A+B method that warrant research. Other research topics include development of standard procedures for calculating time value, appropriate procedures for dealing with contract time extensions, and appropriate response if the contractor completes the project ahead of schedule.

NEW METHODS

Expert systems are interactive computer programs incorporating judgment, experience, rules of thumb, intuition, and other expertise to provide knowledge and advice about a given subject.

The development of such programs to aid decision making has gained momentum in the past decade, and applications to construction operations in general and scheduling in particular have received considerable attention (*21*). However, until recently, these applications required sophisticated computer programming skills, knowledge of advanced techniques in the field of artificial intelligence, and powerful and costly computer hardware. The appearance of commercially available standard software packages, known as expert systems shells (ESS), has enhanced the appeal of expert systems applications.

Estimating contract time is well-suited for expert system development. In the future, expert system software is likely to be developed to provide the inexperienced scheduler access to expertise gained by experienced practitioners. The most useful application may be in establishing the logical sequence of construction operations. Some work in this area has been done in academic institutions by several researchers, including De La Garza and Ibbs (*22*) and Echeverry et al.(*23*). *NCHRP Synthesis 183: Knowledge Based Expert Systems in Transportation,* by Cohn and Harris (*24*) discusses several aspects of these new planning and decision-making tools.

ASSESSMENT OF TIME ESTIMATING ACCURACY

Most of the practitioners interviewed at DOTs expressed satisfaction with their current contract time determination procedures, although most also indicated a desire to find ways to improve these procedures. However, the synthesis survey found limited evidence of objective assessments of experience with contract time estimation.

New Hampshire (*25*), for example, tried to assess its procedures by comparing original contract times (i.e., engineer's estimates) to the actual time to project completion, for 92 projects representing 20 percent of the projects completed by the agency between 1985 and 1991. The study yielded the following statistics:

- Six percent of the projects had overrun the original contract time or the approved extended time by an average of 17 calendar days (approximately a 7 percent increase over the original schedule).
- 27 percent of the projects were completed on the original contract completion date or the approved extended one.
- 63 percent of the projects underran the original contract time or the approved extension by an average of 15 calendar days (a five percent reduction from the original time schedule).
- Four percent of the projects underran the original contract time by more than 100 calendar days with an average of 232 days (approximately a 30 percent reduction from the original time schedule).

Underruns typically were in the range of 17 percent of contract time or less, but one project initially estimated to require 2 years underran the contract time by 50 percent, because very mild winters enabled the contractor to work all year long instead of a typical 3–8 month construction season.

CHAPTER THREE

FACTORS USED IN DETERMINING CONTRACT TIME

In estimating contract time, a scheduler must consider a wide range of factors likely to influence project duration. Based on preliminary input from DOT practitioners, a list of major factors that are considered in contract time estimation was compiled. The participants in the synthesis survey were asked which of these factors they consider significant when estimating contract time, and to add other factors they consider important, based on their own experience. Figure 11 lists these factors in order of the frequency with which respondents cited their importance, along with the percentage of respondents citing each.

The survey indicated that respondents find it difficult to isolate the importance of any single factor. Most practitioners recognize that in many cases factors such as location, traffic, and night operations have overlapping and interactive impacts on project duration. The following paragraphs review how practitioners consider these various factors in estimating contract time.

WEATHER AND SEASONAL EFFECTS

Weather and seasonal effects are considered by almost all states as the major factor affecting contract time. *NCHRP Synthesis 47: Effect of Weather on Highway Construction* (*26*) concluded that "all highway construction is affected to some degree by adverse weather," and estimated that 45 percent of all construction is "weather-sensitive" and especially susceptible to significant weather related impacts. Table 5 shows that study's summary of the effect of weather conditions on various construction operations.

Weather conditions are likely to influence contract time estimation in three principal ways:

1. Conversion of Time Units — Many states have established conversion charts, based on historical weather data, that enable conversion of estimated contract time, calculated in average working days without regard to time of year, to calendar days or completion dates in particular months. These charts show how many working days are likely to be available for construction in a specific month, e.g., 12 working days in December in Wyoming. Table 6 is an example of such a conversion chart used by Maryland. Some states have different charts for various weather zones. Iowa, for example, has three zones, California and Arizona each have four zones.
2. Winter Exclusion Period — In many cold-climate regions, there is a period during which weather conditions are likely to be sufficiently severe to prevent construction work. During this shut-down period, construction time is suspended. Some states try to schedule their projects to achieve completion before the shut-down period. Table 7 describes the shut-down periods used by various DOTs, as found by Hinze and Coleman (*10*).
3. Additional Time for Adverse Weather Conditions — The practice in most states is to grant the contractor time extensions when controlling construction operations were delayed by harsh weather conditions. However, only four states were found to have defined adverse conditions in their contract documents. The other agencies base this decision on engineering judgment and experience (*10*). For example, Montana awards time extensions only if the contractor cannot perform to at least 60 percent of his normal schedule. Florida does not allow time extensions for adverse weather except in very extreme conditions, such as hurricanes.

LOCATION OF THE PROJECT

The effect of project location is considered in conjunction with other factors such as traffic, project type, and utilities relocation requirements. In most cases, a project located in an urban area will be estimated to take more time than a similar project in a rural area. However, in some situations, projects in rural areas may require more time because of longer mobilization times and greater distances for material delivery. Some states define locational characteristics as an element of project type.

TRAFFIC IMPACT

Practitioners surveyed agreed that construction in high-volume traffic areas will add substantially to project duration, and contract time allowed for projects in high-volume traffic is longer than in similar projects in low-volume traffic areas. Some states, e.g., California and Illinois, restrict work on urban freeways to nights and weekends (adding time, as described below). Other states estimate contract time using production rates reduced to account for disruptions; Nevada, for example, reduces estimated production rates to 75 to 80 percent of normal levels when traffic is heavy.

RELOCATION OF UTILITIES

The impact of time required to relocate utilities depends on how responsibility for relocations is assigned. When included in contract time, utilities relocation is simply one of the several tasks to be accomplished during the project, albeit a particularly complex item.

In some states, including Delaware, utilities relocation is the DOT's responsibility and relocation time is not included in the contract time. Indiana, California and Wyoming are among the states that relocate utilities 2 to 3 months prior to the letting of the primary construction project and do not include it in the contract time. Other states not including utilities relocation time in

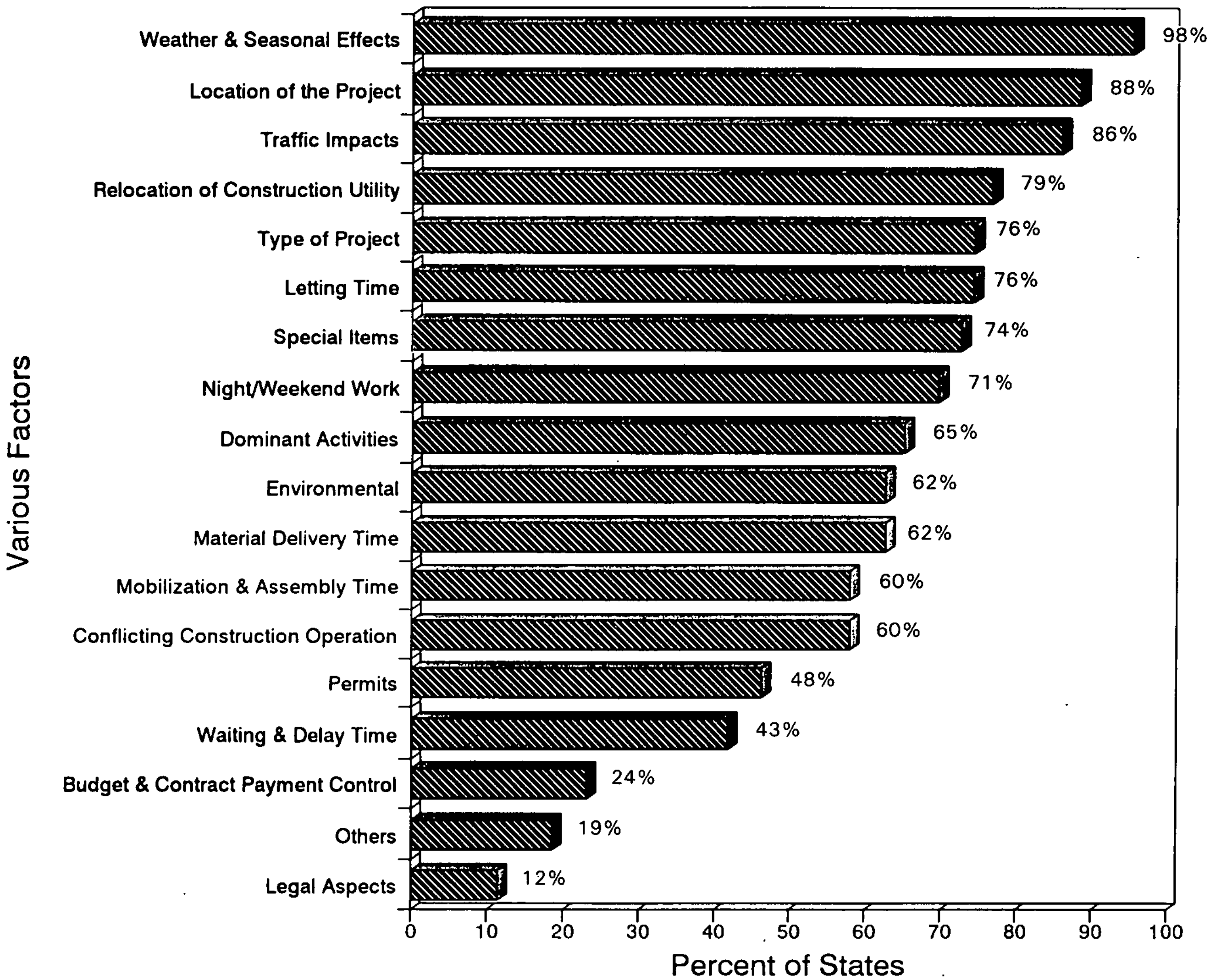

FIGURE 11 Major factors that affect contract time as reported in survey.

the contract time allow for justified delays caused by utilities relocation by approving a shut-down time.

Regardless of the approach, most of the practitioners interviewed admitted that the treatment of relocation time is one of the weakest areas in contract time determination. Some of those interviewed estimated that relocation can add as much as 40 percent to contract time, as compared to similar projects without a utilities relocation item.

TYPE OF PROJECT

Many states have developed project classification systems and, using historical data, have estimated the broad relationships between project type and contract time. The most common project types that state agencies consider to have a consistent effect on contract time are (a) urban versus rural projects, (b) flat terrain versus mountain projects, (c) bridge projects, (d) bridge repair, (e) pavements, (f) overlays (roadway and bridge), (g) sidewalks, (h) cut-and-fill projects, and (i) drainage projects. Appendix F shows a complex project classification system used by California (*6*).

LETTING TIME

Most schedulers feel that if a large number of projects are contracted at the same time in a region (city, county, district), the contract times should be extended to account for likely constraints on the availability of local resources (labor, materials, equipment). In cold-climate states, the calendar date of letting time is significant, as has been discussed. A similar effect is felt in some environmentally sensitive projects that may have impact on seasonal events, such as fish spawning. There are no definite figures on this factor, but some practitioners estimated that letting time can vary project duration and contract time by 10 to 20 percent.

SPECIAL ITEMS

The special item most often considered by DOTs when estimating contract time is fabrication and delivery of steel structures.

TABLE 5
EFFECTS OF WEATHER CONDITIONS ON HIGHWAY CONSTRUCTION (26)

CONSTRUCTION OPERATION	Low Temperature	Severity of Effect*					
		Rain	Sleet	Snow	Ice	Frozen Ground	Wind
Traffic Handling	L	M	S	S	S	L	L
Layout and Staking	M	S	S	S	S	M	M
Clearing and Grubbing	L	M	M	M	M	L-M	L
Material Delivery & Storage	L-S	S	S	S	S	L-M	L
Excavation	L	S	M	M	M	M	L
Embankment Construction	M-S	S	S	S	M	M-S	L
Structure Site Grading	M-S	S	S	S	M	M-S	L
Pile Driving	L	M	M	M	M	M	L
Dredging	M-S	L	L	L	S	L	M
Erection of Coffer Dams	M-S	M	M	M	S	L	L-M
Form Work	M	S	S	M	S	L	L-M
Steel Erection	M	S	S	M-S	S	L	M-S
Placing of Reinforcing Steel	M	S	S	S	M-S	L	L
Mixing and Placing Concrete	S	S	S	M	M	L	L
Curing Concrete	S	M	M	M	S	L	M
Stripping Forms	L	M	M	L	M	L	L-M
Backfill	S	S	S	M	M	M-S	L
Base Placement	S-M	S	M	M	M	M-S	L
Paving	S	S	S	S	S	M	L
Landscaping and Seeding	S	S	S	S	S	S	L
Painting	S	S	S	S	S	-	M
Fencing	L	M	M	M	M	M-S	L
Lighting	M	M	M	M	M	L	L
Signs	L	M	M	M	M	M	M

* Key: S - Severe, M - Moderate, L - Little

TABLE 6
EXAMPLE OF CONVERSION CHART FOR WEATHER EFFECT ON PROJECT DURATION (5)

AREA	Average Number of Working Days on Construction Contracts: SOUTH/EASTERN MARYLAND		CENTRAL MARYLAND		WESTERN MARYLAND	
Month	Bridges	Roads	Bridges	Roads	Bridges	Roads
Jan	10	5	8	8	4	3
Feb	10	7	8	8	4	3
Mar	14	11	12	13	10	10
Apr	16	15	15	17	15	15
May	18	14	18	17	16	15
June	20	19	19	18	18	18
July	20	17	19	17	19	18
Aug	20	18	20	19	19	18
Sept	18	18	18	20	18	18
Oct	19	18	19	17	18	18
Nov	17	13	16	13	10	10
Dec	10	9	11	10	6	6
Total	192	164	183	177	157	143

Other items are traffic signals and electro-mechanical systems, pre-stressed I beams and box beams, and sheet piling. There are no standard bases for estimating how much time to add for these special items, and it is primarily based on judgment and experience.

NIGHT AND WEEKEND WORK

Most practitioners surveyed felt that projects involving night or weekend work require longer durations (i.e., measured in working

TABLE 7
WINTER EXCLUSION PERIODS USED BY DOTS (*10*)

No. of DOTs	Dates	State
1	1 Nov - 31 Mar	NY
1	1 Nov - 30 Apr	AK
1	15 Nov - 15 Mar	ME
1	15 Nov - 31 Mar	IA
3	15 Nov - 15 Apr	MI, MN, ND
1	16 Nov - 15 Apr	MT
3	1 Dec - 1 Mar	ID, OR, UT
9	1 Dec - 31 Mar	CO, CT, IN, KY, NH, SD, VA, WV, WY
1	1 Dec - 15 Apr	VT
1	1 Dec - 30 Apr	OH
2	15 Dec - 15 Mar	MO, NC
1	15 Dec - 15 Apr	RI
1	16 Dec - 15 Mar	DE
1	16 Dec - 30 Apr	IL
27	Total	

days), as compared to projects completed during normal daytimes, because production rates at these times are lower and greater fractions of the shift are spent on safety procedures. However, under high-volume traffic conditions, experienced practitioners assert that night work actually increases production rates because interference is reduced.

DOMINANT ACTIVITIES

In most complex projects, one dominant activity, phase, or controlling operation has substantial influence on the contract time. The types of phases or operations that practitioners consider dominant include bridges, roads, resurfacing, and traffic operations. Many of the practitioners interviewed cited their experience in complex projects as evidence that the structures phases will most often be dominant in determining total contract time.

ENVIRONMENTAL FACTORS

When dealing with environmentally sensitive projects, the scheduler must add contract time to allow for mitigation of adverse impacts of construction. Examples of environmentally sensitive projects from various states and provinces include Alberta, where excavation of backfill in certain areas is environmentally sensitive; and California, which considers projects near fish-spawning areas likely to require extra care and time. Many DOTs consider projects that deal with hazardous materials to be environmentally sensitive. There are no commonly accepted rules for the time allowance required for environmentally sensitive projects, and each such case must be considered separately.

MATERIAL ACQUISITION AND DELIVERY

Delivery of special items, such as fabricated steel and overhead signs, is generally recognized to influence contract time (see above), but otherwise material acquisition and delivery time are considered part of the construction operation, warranting no extra time. In some states, California and Washington, for example, if material acquisition and delivery time cause delays beyond the contractor's control, the contractor will be granted time extensions.

MOBILIZATION AND ASSEMBLY TIME

The most common practice among DOTs is to add mobilization time into the estimated contract time. Time allowed for mobilization differs from state to state, for example, 5 days in Nevada, Wisconsin, and Kansas, 15 days in Maine and California, up to 40 days for mobilization of complex projects in Arizona. Some states determine the mobilization time based on such factors as project size, complexity, and distance to material resources.

CONFLICTING CONSTRUCTION OPERATIONS

Conflicting construction operations include conflicts within a project, caused by various contractors or trades working in one location at the same time, as well as conflicts between projects constructed at the same time in adjacent areas. Practitioners interviewed agreed that when there is potential for any sort of conflicting construction operations, the DOT scheduler should adjust schedules if possible to avoid these conflicts and possibly increase contract time to compensate for likely delays. Similar response may be required when conflicts between construction activities and nearby community and business activities are likely.

PERMITS

Most states consider permits to be the contractor's responsibility. However, many of the practitioners surveyed asserted that permits must be arranged prior to the letting time, and therefore do not effect contract time. Environmental permits are among those that may require special attention when determining contract time.

WAITING AND DELAY TIME

There are a number of types of delays to be considered when determining contract time, including those with technical bases, such as time needed for curing concrete or for embankment settlement. Another source of delay is waiting periods or public hearings required in environmental permitting processes. Most schedulers add these delay times to the contract time.

BUDGET

Budget affects the scheduling and planning of construction on the state level and has less effect on contract time of a specific project. In some situations, funds have to be spent in a given time, such as before the end of the fiscal year, and in such cases the contract time will be determined according to the budget constraints. Budgets may influence contract time on multi-year projects by limiting progress on each phase.

LEGAL ASPECTS

Few DOTs consider legal factors to have a significant effect on the contract time. Projects to be constructed in environmentally sensitive areas, requiring special permits, are cited as exceptional but significant cases.

OTHER FACTORS

A number of other factors influencing estimated contract time were mentioned in the survey, although most are related to those already discussed:

- Commitment by other departments or outside agencies to complete the contract by a certain date (Indiana),
- Effect of community institutions and events, like schools, business, farms, festivals, parades, fairs, and races, (Indiana, Washington, California),
- Availability of access roads for emergency situations (Maryland),
- Cash flow of the agency (Maryland, Alabama, Virginia),
- Review time needed for shop drawings, constructability analyses, post tensioning design, concrete mix design and related activities (Washington, New Jersey),
- Marine and railroad traffic, and
- Contract time set for similar projects in the past.

CHAPTER FOUR

THE EFFECT OF INNOVATIVE CONTRACTING PRACTICES ON CONTRACT TIME

In recent years some DOTs have begun to employ "innovative" contracting methods, designed primarily to reduce construction time of projects. These methods, not so much innovative as new to government procurement practice, rely generally on motivating the contractor to complete work quickly and with minimal disruption to ongoing activities of the community. Four methods were reviewed in this synthesis survey: incentive/disincentive (I/D); bidding on cost and time combined with I/D; lane rental; and flex time.

Those contracting methods do not have a direct effect on the determination of contract time, and only the second method (involving A+B bidding, discussed in Chapter 2) has any direct impact on the contract time itself. However, practitioners agreed that such methods may indirectly influence estimates of contract time, particularly when substantial financial incentives or disincentives are involved, because many schedulers will exert more effort in determining contract time. A similar innovative practice that may have indirect benefits on contract time is the concept of project "partnering." The U.S. Army Corps of Engineers has successfully implemented this practice on several of its projects. This particular practice was not investigated as part of this synthesis study; however, the reader is referred to *NCHRP Synthesis 214: Resolution of Disputes to Avoid Construction Claims* for further information.

INCENTIVE/DISINCENTIVE

Under an incentive/disincentive (I/D) agreement, a construction contractor will receive additional payments, above the agreed contract price, if construction is completed prior to the DOT-specified contract time. If the construction is completed late, a contractor is penalized by reductions in payment. Typically, the I/D fee is agreed on as an amount per day to be paid or withheld. A cap may be placed on the incentive amount.

The I/D fee generally is set by the DOT to reflect the estimated economic cost of delays to the public, using some form of the road user cost computations described in Chapter 2 and illustrated in Appendix H.

Most states follow the same basic principles in developing I/D contracts, though there are a number of variations in the procedural details of how they apply the method. A 1991 survey conducted by Iowa (*5*) on the use of the I/D method by various DOTs found that 35 of the 39 states participating in the survey were using I/D contracts. Most states used a combination of scheduling methods when determining contract time (see Table 8), and set the I/D rates in the range of $1,000 to $5,000 per day (see Table 9). In nearly 80 percent of these states, the incentive and disincentive rates were set at the same amount. The survey found that in most cases contractors received some incentive payment, and in 40 percent of the cases they received the maximum incentive payment allowed in the contract's provisions.

Opinions of the I/D method's value vary, with some practitioners convinced that the method reduces construction time and effectively recovers incentive fee payments in savings from reduced inconvenience to the public. Others believe that contract times have been set too high, enabling contractors to receive unjustifiably large payments for construction work by completing the project early using multiple crews and overtime. Practitioners agree that accurate estimates of contract time are a key to success when using the I/D method. Some states have effectively used computer software to estimate contract time to minimize the possibility of contractors gaining windfall profits because time estimates are too high.

BIDDING ON COST AND TIME COMBINED WITH I/D

Combining the I/D contracting method with the A+B bidding method (described in Chapter 2) is suggested as a way to reduce the likelihood of setting contract time at too high a level. The contractor bids on the contract time, and so has an early incentive

TABLE 8
METHODS USED BY DOTS FOR CONTRACT TIME ESTIMATION ON I/D CONTRACTS (*9*)

Method	DOTs Reporting Use (%)
Historical data	36
CPM	25
Production rates	52
Engineering judgment	58
Contractor bid (A+B)	14

TABLE 9
INCENTIVE/DISINCENTIVE RATES USED BY DOTS (*5*)

I/D Rates ($/day)	DOTs Reporting Use (%)
0–2,500	11.4
2,501–5,000	54.4
5,001–10,000	25.7
10,001–25,000	5.7
>25,000	2.8
Total	100.0

TABLE 10
BID RESULTS FROM PROJECTS USING A+B WITH AN I/D CLAUSE BY THE VARIOUS DOTS

Work Type	ADT	Contract Value ($)	RUC ($/Unit)	Time Bid	Time Used	I or D
Lane Reduction	128,000	5,479,852	4,000/Day	150 Days	120 Days	120,000 (I)
Bridge Deck Rehabilitation	115,000	5,845,490	1,370/Hr	1416 Hr	989 Hr	584,549 *(I)
Bridge Widening	39,000	7,162,765	3,530/Day	65 Days	39 Days	91, 780 (I)
Interchange Bridge Replacement	28,000	1,270,840	8,440/Hr	136 Hr	111 Hr	127,084 *(I)
Pavement Removal & Replacement	18,000	1,267,080	1,270/Hr	96 Hr	37 Hr	74,930 (I)
New Interchange Bridge	5,000	614,987	3,000/Day	90 Days	70 Days	60,000 (I)
Bridge Replacement	4,900	664,101	2,900/Day	90 Days	72 Days	52,200 (I)
2 Bridge Replacements	2,800	1,480,219	3,500/Day	120 Days	78 Days	147,000 (I)
Bridge Replacement	1,900	457,575	1,320/Day	57 Days	50 Days	9,240 (I)
Box Culvert Replacement	630	76,747	1,010/Day	10 Days	5 Days	5,050 (I)

* Data from presentation by G. Chullino, Missouri Highway and Transportation Department. Actual incentive lower than calculated incentive due to cap, i.e., maximum incentive allowed.

to set that time at low, yet realistic, levels. The successful low bidder (based on total of construction cost and road user cost) then has added incentive, in the form of the I/D fees, to complete construction within a shorter period than the agreed contract time.

Table 10 reviews experience of the Missouri DOT, on ten projects that were bid using A+B methods linked with incentive or disincentive payments for construction completion. In every case, construction was completed ahead of schedule.

LANE RENTAL

Lane rental provides "financial incentive to contractors and others to shorten the period during which they occupy part of the highway for doing construction and maintenance," (*29*) by charging a fee for the closure of traffic lanes, based on the time those lanes are taken out of service. The method, developed and put into practice in 1983 by the British Department of Transport (BDTp), was introduced into the United States at the 1990 annual meeting of the American Concrete Pavement Association (ACPA) (*28*).

The DOT determines the lane rental fee using principles similar to those for road user cost. For example, a group of practitioners that participated in the 1990 ACPA meeting estimated the cost of lane-closing in a hypothetical project on 1.5 miles of a four-lane urban highway to be

Cost during weekdays:
working 9 a.m. to 3 p.m.—$6,000/day for 1 closed lane
working 6 p.m. to 6 a.m.—$1,000/day for 1 closed lane
Cost during weekends:
working Friday 6 p.m. to Monday 6 a.m.—$10,000 for 1 closed lane
working Friday 6 p.m. to Monday 6 a.m.—$50,000 for the whole project while using detour.

The contract time (estimated using the agency's normal procedures) and the lane closure rates determined by the DOT become part of the bid document. Each bidder, when preparing a cost estimate, must determine the length of time and the period (e.g., day, night, weekend) during which lane closures will be needed. Using the rental fees set by the DOT, the contractor includes the cost of anticipated lane closures in the bid for the work items. However, some agencies are evaluating having the contractor bid the lane closure time (similar to the A+B procedure). In order to be competitive, the contractor must minimize the time of lane closures. During construction, the contractor is assessed by the agency for the time that lanes are obstructed. The rental fees assessed are deducted from the progress payments.

Maggs (*30*) reports on British experience that "lane-rental contracts for motorway reconstruction have been successful in demonstrating the scope for reducing the time needed for completion." Bondar (*31*) writes that "lane rental favors the more efficient firms who are able to give careful thought to planning the work," and reports that savings in avoided delays realized during the first 3 years in which the lane rental method was used were estimated by the BDTp to be 21.3 million British pounds. Contractors reported that the method provided effective motivation to be better organized, use innovative construction techniques, and improve scheduling procedures, particularly when rental fees were high (equivalent to $3,000/day or more). Agency officials found that the quality of work with lane rental was equal or superior to that achieved under conventional methods.

The technique does have costs. BDTp experience also shows that agency staff workload (e.g., for resident engineer, inspectors, and others) is much heavier when using lane rental, as compared with similar projects using conventional methods. Much effort must be given to choosing the right personnel, shift selection, and good communication with the contractor's staff. Experience with lane rental in this country is limited. The synthesis survey found 20 percent of participating agencies are considering the method, and some states (e.g., Colorado, Indiana, Oklahoma, Oregon, and Washington) are evaluating lane rental on projects. Appendix H presents examples of lane rental specifications that have been prepared by the FHWA.

FLEX-TIME

As a contracting method, flex-time permits the contractor to begin work at any time after receiving the notice to proceed, within a predetermined period of time, called the "window." For example, a window of 30 calendar days might be given on a project with contract time of 300 calendar days, allowing the contractor to start work any time within 30 days from the date of the notice to proceed (e.g., from April 1 to no later than May 1). Once the contractor begins, work must be completed within the 300 days.

The primary advantage of flex-time is the increased freedom it gives contractors to manage resources and material delivery. Some DOTs report that their contract time estimates with flex-time contracts are based on higher production rates and no time allowances for material acquisition and delivery, as compared to contract time for conventional contracts. The contract time reduction balances the additional schedule time that might be added by the "window." Florida, for example, reported very positive reactions from contractors, and Maine has used the method successfully for overlay projects to be completed before the onset of winter weather.

CHAPTER FIVE

FINDINGS AND CONCLUSIONS

FINDINGS

The research conducted for this synthesis investigated contract time estimation and management practices used by state and provincial departments of transportation (DOTs) in the United States and Canada. The following principal findings are supported by this work:

- Contract time is the maximum time allowed in contract documents for construction of a project. Estimates of construction project duration used by DOT staff to establish the contract time, which then is included in project plans, bid documents, and contracts, have an indirect but nevertheless important impact on construction cost, traffic congestion, and local economies.
- Most DOTs follow a similar basic process for determining contract time, based on the engineer's estimates of construction duration. However, there is a wide range of variations in procedural detail, particularly with regard to computer applications and databases.
- Most practitioners emphasize that engineering experience and judgment are crucial to effective contract time estimation. In many cases this judgment is subjectively applied and generally is not recorded in a systematic way that can be transferred to inexperienced schedulers.
- Increasingly, agencies are applying lists of standard activities, production rates, and other tools to assist schedulers and to improve their performance in estimating contract time.
- Twenty major factors are widely recognized as influencing contract time, but the quantitative impact of these factors generally is estimated based on judgment. Quantitative data have been collected and analyzed for only a few factors, such as seasonal factors and traffic levels.
- The most popular scheduling technique for contract time estimation (in both computerized and manual applications) is the bar chart (GANTT chart). The use of CPM is increasing rapidly, especially in complex projects. PERT and line of balance methods are rarely used.
- Parametric time estimating (also known as "historical data"), which does not require specification of tasks within a project, is used by only a few states.
- Computers have become an integral part of many DOTs' contract time estimation procedures, and their use is becoming increasingly pervasive. Many different commercial software products are in use by various DOTs.
- New contracting procedures aimed at controlling or reducing construction duration (lane rental, flex time, incentive/disincentive, bidding on time and cost) have potential impact on contract times and their estimation. Bidding on time and cost (A+B), in which the contractor's bid determines contract time, actually replaces engineers' estimates of contract time. Experience to date, while limited, indicates that these methods lead to reductions in project duration, as compared to contract times estimated for conventional projects.
- Knowledge based expert systems for project scheduling and time estimation, currently the subject of academic research, may in the future be developed as practical tools to assist agencies making contract time determinations.

CONCLUSIONS

While practitioners in state and provincial DOTs generally expressed satisfaction with their procedures for determining contract time, the experience reviewed in the synthesis survey indicates that DOT engineers' estimates of construction duration may be consistently biased toward longer times than are likely to be required for actual construction. The use of bidding and contracting methods that place greater responsibility on the contractor for determining contract time have been successful in reducing contract times, but they are not yet widely used. If the seeming bias toward longer time estimates in fact exists, DOTs may have tolerated unnecessarily long public delays and economic losses due to construction related traffic disruptions that are significantly higher than necessary. However, DOTs seeking to reduce contract times risk claims and litigation if contractors can demonstrate that contract times are unreasonably short.

The potential savings that reduced construction times will bring to the road-using public and the opportunities to reduce the financial risks of underestimating contract time represent substantial benefits to be gained if construction durations can be more accurately estimated. Transportation agencies should collect and pool data on construction project durations and the factors likely to effect duration, and analyze these data to produce new and accurate predictive models. Work to date on the parametric estimation method is a valuable start on such models, but must be extended substantially before results will be accepted within the scheduling profession.

While a stronger statistical base is badly needed for contract time estimation, the value of experience and need for professional judgment are substantial and inescapable. Computer applications that make such experience more widely available to practitioners have great potential to improve the accuracy of contract time estimation. Agency-sponsored research and development efforts aimed at laying the groundwork for commercial development of such applications can yield substantial returns on the public's investment. Such efforts should be actively supported.

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APPENDIX A

SURVEY QUESTIONNAIRE

National Cooperative Highway Research Program Project 20-5, Topic 24-04

DETERMINATION OF CONTRACT TIME FOR HIGHWAY CONSTRUCTION PROJECTS

Please have this questionnaire completed by the department, unit, or division responsible for determination of contract time (duration) for highway construction projects. Any background material such as documents or reports will be appreciated and, if requested, will be returned.

RESPONDENT INFORMATION:

Name: ____________________ Agency: ____________________

Title: ____________________ Address: ____________________

Division or Unit: ____________________ ____________________

Phone: ____________________

Date: ____________________

A. How does your agency determine contract duration?

- ☐ production rates
- ☐ bar charts
- ☐ critical path method (CPM)
- ☐ combination method (e.g., reduction rate and bar chart)
- ☐ parametric time estimate (e.g., cost-time)
- ☐ other (please specify) ____________________

Describe below the method that your agency uses, including any comments regarding the method's advantages, disadvantages, accuracy, etc. (Please send any written data, including procedures, examples, past research, etc.)

NCHRP Project 20-5, Topic 24-04 Agency: ____________________

"Determination of Contract Time for Highway Construction Projects"

B. Does your agency use or consider using any of the "innovative" ideas below for determining contract time?

- ☐ bidding on cost and time ("A+B system")
- ☐ lane rental
- ☐ completion day
- ☐ special incentive/disincentive system (please describe)

____

____

____

- ☐ other ideas from your experience or from others' experience in the United States or abroad (please describe)?

____

____

____

Comments:

Person completing Part B (if different from Part A):

Name: ____________________

Phone: ____________________

C. **There are many factors that may affect the determination of contract time. Please check the factors below that your agency considers when determining highway construction project contract time. After each item that you check, please briefly describe the relationship of that factor to the determination of contract time for a project. If you have any published data, please send it or describe it below.**

Factors (not in order):

☐ weather and seasonal effects -

☐ mobilization and assembly time -

☐ calendar day and/or working days -

☐ special items (e.g., fabricated structural members, electromechanical devices) -

☐ traffic impacts -

☐ type of project -

☐ budget and contract payment concerns -

☐ effect of letting time -

☐ legal aspects -

☐ use of "flex time" -

☐ effect of curves or computer programs on contract time determination -

☐ effect of critical path methods (CPM) -

☐ computer usage -

☐ relocation of utilities for construction -

Part C. (continued)

☐ dominant project type (structures vs. roadway) -

☐ location of the project (urban, rural, metropolitan area) -

☐ material delivery time -

☐ waiting and delay times -

☐ conflicting construction operations -

☐ permits -

☐ night work and weekend work -

☐ environmental issues -

☐ others (please specify) -

Comments (use an additional sheet if necessary):

Person completing Part C (if different from Part A):

Name: ____________________
Phone: ____________________

NCHRP Project 20-5, Topic 24-04 Agency: ____________________
"Determination of Contract Time for Highway Construction Projects"

D. We would also like to know contractors' opinions on the subject of determination of contract duration. Will you please identify 1-2 contractors in your state that might be willing to answer a similar questionnaire?

Contractor: ____________________
Contact person to call: ____________________
Address: ____________________
____

Phone: ____________________

Contractor: ____________________
Contact person to call: ____________________
Address: ____________________
____

Phone: ____________________

E. Please identify other personnel within your agency (but in different divisions, units, or departments) who may contribute to highway construction contract time determination.

Name: ____________________
Division: ____________________
Phone: ____________________

Name: ____________________
Division: ____________________
Phone: ____________________

Thank you for your cooperation. Please return the completed questionnaire to:

Dr. Zohar J. Herbsman
University of Florida
Department of Civil Engineering
345 Weil Hall
Gainesville, FL 32611

Phone: (904) 392-0935
FAX: (904) 392-3394

APPENDIX B

LIST OF DOTS PARTICIPATING IN THE SURVEY

No.	STATES	DIVISION OR UNIT	TITLE	ADDRESS
1	ALABAMA	Construction Bureau	Construction Engineer	1409 Coliseum Blvd., Montgomery, AL 36130
2	ALASKA	Headquarters	Design Std. Engineer	3132 Channel Dr., Juneau, AK 99801-7898
3	ARIZONA	Construction Operation Services	Construction Manager	206 S 17th Ave. 175A, Phoenix, AZ 85007
4	ARKANSAS	Program & Contracts Division	Programs & Contracts Engineer	PO Box 2261, Little Rock, AR 72209
5	CALIFORNIA	Construction-Claims Resolution	Senior Transportation Engineer	1120 N St., Sacramento, CA 95814
6	COLORADO	Staff Construction	Assistant Area Engineer	4201 East Arkansas Ave., Denver, CO 80222
7	DIST. OF COLUMBIA	Design & Engineering Division	Acting Chief	2000 14th St., NW, Washington, DC 20009
8	DELAWARE	Division of Preconstruction	P S & Coordinator	PO Box 778, Dover, DE 19903
9	FLORIDA	Office of Construction	State Scheduling Engineer	605 Suwannee St., MS-31, Tallahassee, FL 32399-0450
10	GEORGIA	Construction	Assistant State Construction Engineer	No. 2 Capitol Square, Atlanta, GA 30334
11	HAWAII	Highways Division	State Construction Engineer	869 Punchbowl St., Honolulu, HI 96813
12	IDAHO	Contract Administration	PS&E Supervisor	PO Box 7129, Boise, ID 83707
13	ILLINOIS	Design & Environment	Bureau Chief	2300 S Dirksen Parkway, Springfield, IL 62764
14	INDIANA	Operations Support	Chief of Operations Support Division	100 N Senate Ave., Rm 1314, Indianapolis, IN 46204-2249
15	IOWA	Office of Contracts	Proposal Coordinator	800 Lincoln Way, Ames, IA 50010
16	KANSAS	Construction & Maint.	Estimating Engineer	Docking State Office Building, Topeka, KS 66612
17	KENTUCKY	Design	Chief Draftsman	State Office Building, Frankfort, KY 40622
18	LOUISIANA	Contracts & Specifications Section	Contracts Engineer	PO Box 94245, Baton Rouge, LA 70804-9245
19	MAINE	Design Division	Contracts Engineer	State House Sta. 16, Augusta, NE 04333
20	MARYLAND	MD S.H.A.	Deputy Chief Engineer-Const.	707 N Calvert St., Baltimore, MD 21202
21	MICHIGAN	Construction	Structures Engineer	PO Box 30050, Lansing, MI 48909
22	MISSISSIPPI	Construction	State Construction Engineer	PO Box 1850, Jackson, MS 39215-1850
23	MISSOURI	Construction	Division Engineer	PO Box 270, Jefferson City, MO 65102
24	MONTANA	Construction	Assistant Construction Engineer	2701 Prospect Avenue, Helena, MT 59620
25	NEBRASKA	Construction Lettings & Facilities	Final Review Engineer	PO Box 94759, Lincoln, NE 68509-4759
26	NEVADA	Construction Division	Assistant Construction Engineer	123 S Stewart St., Carson City, NV
27	NEW HAMPSHIRE	Bureau of Construction	District Construction Engineer	Rm 119 J.O.M. Building, Hazen Dr., Concord, NH 03301
28	NEW JERSEY	Roadway, Plans & Specifications	Manager	1035 Parkway Ave. CN 600, Trenton, NJ 08625
29	NORTH CAROLINA	Construction	State Roadway Construction Engineer	PO Box 25201, Raleigh, NC 27611
30	OHIO	Construction	Deputy Director	25 S Front St., Columbus, OH 43212
31	OREGON	Office of Operations	Scheduling Specialist	2950 State St., Salem, OR 97310
32	PENNSYLVANIA	Contract Management Division	Construction Services Engineer	Rm 1212 T&S Building, Harrisburg, PA 17120
33	RHODE ISLAND	Public Works	Construction Operations	Rm 229, 2 Capitol Hill, Providence, RI 02903
34	SOUTH CAROLINA	Engineering-Construction	State Road Construction Engineering	PO Box 191, Columbia, SC
35	TEXAS	Construction & Contract Administration	Claims Engineer	125 E 11th St., Austin, TX 78701-2483
36	WASHINGTON	Program Development	State Design Engineer	Transportation Building, Olympia, WA 98504-5201
37	WISCONSIN	Construction	Chief Contracts Engineer	4802 Sheboygan Ave., Madison, WI 53707
38	WYOMING	Construction & Maintenance Branch	Construction Staff Engineer	PO Box 1708, Cheyenne, WY 82002-9019
39	ALBERTA	Regional Transportation	Director	4999 - 98 Avenue, Edmonton, Alberta T6B 2X3, Canada
40	MANITOBA	Construction & Maintenance	Contract Engineer	16th Floor - 215 Garry St., Winnipeg, M.B. R3C 3Z1, Canada
41	NEW BRUNSWICK	Construction	Director	PO Box 6000, Fredericton, N.B. E3BSH1
42	NOVA SCOTIA	Construction/Operations	Director of Construction	PO Box 186, Halifax, N.S. B3J 2N2
43	SASKATCHEWAN	Infrastructure Division	Senior Construction Engineer	1855 Victoria Avenue, Regina, Saskatchewan S4P 3V5

APPENDIX C

METHODS USED BY DOTS IN DETERMINING CONTRACT TIME

States	Production Rates	CPM Method	Bar Chart	Historical Data	Other Methods	Comments
Alabama					X	Not clear for CT estimating
Alaska					X	No formal method but depend on past experience or unofficial production rates
Arizona			X	X		Production rates/barchart for high traffic volume area
Arkansas	X		X			
California	X	X		X		Using computer software based on past performance
Colorado	X	X(l)	X(m)			CPM for large complex projects only
Delaware	X*			X#		*Projects < 1 $ million #Projects > 1 $ million
District of Columbia	X†			X‡		†CT > 12 months ‡CT < 12 months & routine projects
Florida	X	X	X			
Georgia	X	X	X			
Hawaii	X		X			
Idaho	X		X			
Illinois	X		X			
Indiana	X		X			
Iowa	X	X				
Kansas	X		X			
Kentucky	X		X			Use computer-generated bar graph
Louisiana	X				X	Use simplified form
Maine	X		X			
Maryland	X		X			
Michigan	X	X				Small projects use production rates; Large projects use CPM
Mississippi	X		X			
Missouri	X		X			
Montana	X				X	Use simplified form for CT estimating
Nebraska	X				X	Use simplified form for CT estimating
Nevada	X	X	X(m)			
New Hampshire	X					
New Jersey	X		X			
North Carolina	X		X			
Ohio	X(c)	X		X(m)		
Oregon	X	X				Use Super Project Expert & CPM
Pennsylvania	X		X			Large projects use CPM
Rhode Island	X	X		X		
South Carolina	X		X			
Texas					X	CT determined by area engineers based on experience; Dallas District uses CPM partially
Washington	X	X	X			
Wisconsin	X		X			
Wyoming	X	X				
Alberta	X	X	X			
Manitoba	X					
New Brunswick	X					
Nova Scotia					X	Use season limited method, mainly concerned with weather, seasonal variation, and budget
Saskatchewan	X					

X(l)=limited use　X(c)=critical projects only
X(m)=for most projects　CT=contract time

APPENDIX D

EXAMPLE OF CONTRACT TIME DETERMINATION PROCEDURES (FLORIDA)

PROCEDURE:

(1) **General Considerations**

The department establishes a contract duration on each construction contract. Several factors must be considered when establishing contract duration, such as:

- Provide a time for the Contractor to complete the project consistent with historical records o Contractor performance on similar work,
- Importance of the project to the implementation or Department Work Program,
- Emergency conditions,
- Minimize annoyances in residential areas,
- Minimize traffic disruption and delay in high-traffic areas,
- Coordination with other activities,
- Political sensitivity and public awareness, and
- Minimize cost of CEI activities.

Many of these factors can conflict with others and not all of them will have the same importance for each project.

The contract duration shall be established in conjunction with design's 90% review. If there are quantity changes following the Phase III review, the contract duration may require revision. It must, in any case, be firmly established in sufficient time for the Design Project Manager to calculate the quantities for the maintenance of traffic pay items before the 100% review.

To assist the Engineer establishing the contract duration, the Department has established guidelines for production rates. These guidelines will be periodically revised and improved. Questions regarding the setting of contract duration should be directed to the District Scheduling Engineer.

(2) **Specifications**

The first step in setting a duration for a contract is to determine if any *Special Provisions* apply. The person establishing the contract duration must be familiar with the project's specifications and may initiate the addition of others as needed. Examples of these are:

- Flex Time
- Compressed Time or Time Priority
- Incentive/Disincentive
- Special Working Hours
- CPM Schedule

(3) **Establishing Contract Duration**

The "Guidelines for Establishing Contract Duration" contains a set of production rates for many or the activities that occur in highway/bridge construction projects. Production rates for all possible activities are not included nor are all production rates used in each construction job. The production rates may have to be supplemented with information from other sources and should be tempered with good engineering judgement and past experience with similar work.

(a) Establishing Activity Durations

Establishing a project's duration will be accomplished with the following steps:

1. Review the project plans and specifications with special emphasis on maintenance of traffic. If the project has more than one phase, determine what work can be done in each of the phases.

2. List the required activities for each phase. These are listed on the form for contract durations. This list does not need to be exhaustive but does need to include all controlling items of work or activities on the critical path.

3. List each quantity of the unit of work that will be used as a basis for estimating the duration of that activity, e.g., for storm sewers this would be the number of linear feet of pipe, etc.

   On a project with more than one phase use only that quantity associated with that phase. If the list of pay items shows, for example, 10,000 cubic yards of excavation for a project that has two phases with approximately the same amount on each phase, put 5,000 cubic yards as the unit of work for excavation in phase 1 and 5,000 cubic yards as the unit of work for excavation in phase 2. Extreme accuracy is not required. It is only necessary that the parts of a quantity of a pay item sum to the whole, but a percent or two of error on any phase will not affect the results. For a project with two phases this may be a 50%-50% split for a particular pay item. This is just as accurate as using a 45%-55% split.

4. Use the production rates and charts to convert the units of work into work days. Do this for each activity in each phase.

5. Multiply each of the work days by a factor or 1.6 to convert them to contract days.
   a. The factor of 1.46 is based on 250 working days per year, that is, the contractor not working on 52 Saturdays, 52 Sundays, and 11 other days. Implicit in this factor is the assumption that the contractor will use "normal" work hours.

   b. If the time requirements of the project are modified by special provisions, it may be appropriate to use another factor, either larger or smaller. For a project with Incentive/Disincentive a factor of 1.0 or less could be used. This would be based on the assumption that the contractor would work 7 days per week with extended work hours. On the other hand, if the special provisions curtail the number of hours per day the contractor may work, the factor used may be larger than 1.46.

   c. When using a computerized scheduling software package, work days can be converted to calendar days using the calendar function in the program. Holidays, vacation time and other non-work days are entered into the project calendar. Depending on the time of year this may or may not replicate the 1.46 factor normally used for converting work days to calendar days.

(b) Drawing a Bar Chart

1. Select a scale to draw the bar chart, i.e., if the project is about 200 days and fits on one form, make each block 10 days. More than one page may be used for long projects. Succeeding pages may be for later time periods.

2. Put the first activity bar on the bar chart, beginning at day 1 and extending the line for

the duration of that activity.

3. Determine how many days after the beginning activity has started until the second can start. Use that contract day as the starting date of the second activity and extend the bar for the duration of the second activity.

   For each succeeding activity, the scheduler must decide if its start is dependent or partially dependent on a preceding activity. If so, then the beginning of the activity is placed to reflect this dependence.

4. Repeat until all activities are completed on the chart. Use more than one form sheet if necessary.

5. When all activities are on the chart, 15 days general time is normally added. Do not multiply the 15 days by a factor. The contract time is now established.

6. Computerized scheduling programs may be used to establish contact times. The input into the computer is developed in the same manner as that used for the manual method. If using a computerized scheduling program, substitute a report from that program in place of the manual bar chart form. The report(s) from the scheduling software and/or noncomputerized form should show, as a minimum, for each activity name, units of work production rate, duration, beginning contract day and ending contract day.

7. Review utility agreements. If a time set in a utility agreement for making the utility adjustments is greater than the project duration established in the steps above the time in the utility agreement will prevail.

(4) **Documentation**

(a) On each form used, complete the Federal-Aid Participation (FAP) number, lead project number, county name, the contract time, and the name and phone number of the person who established the contract duration.

(b) Schedules are considered a part of the "plans to Tallahassee package." Instructions for submitting the complete "plans to Tallahassee package" are included in the Roadway Plans Preparation ManuaL

(5) **Prosecution**

The contract duration is not final until the project is bid. Up to this point in time the project duration can be influenced by changes in design or by external intervention. The designer (Project Manager) and the District Scheduling Engineer shall coordinate all changes that would affect the contract duration.

FLORIDA DEPARTMENT OF TRANSPORTATION
PRODUCTION RATE FOR ESTIMATING WORKING DAYS

ACTIVITY:		PRODUCTION RATE - WORKING DAYS
1.	CLEARING AND GRUBBING (.000023 Ac/Sq Ft)	1 to 10 Acres per day, depending on nature not to exceed 20 days
2.	EXCAVATION (Regular Lateral Ditch, Subsoil, Convert grading Roadway to cubic yards for this purpose.	See chart for production rate Shoulder Grading (Resurfacing) 1 mi/day
3.	EXCAVATION (Truck Haul) Less Than 100,000 cy 100,000-300,000 cy Greater Than 300,000 cy	900 Cy/D; 3,800 Cy/D. 7,500 Cy/D;
4.	STABILIZED ROADBED	5,000 Sq Yd/Day (Maximum 10 Days)
5.	BASES	See Chart for Production Rate
6.	CEMENT CONCRETE	5,000 Sq. Yd/Day
7.	MILLING EXISTING PAVEMENT	8,000 Sq.Yd/Day (20 days maximum) Maximum days may be limited by specifications
8.	PLANT MIXED SURFACES (in tons see conversion factors below)	See Chart for Production Rate
9.	STORM SEWERS (include pipe, inlets, manholes, etc.)	100 to 400 LF/Day
10.	CURB AND GUTTER VALLEY GUTTER	400 to 800 LF/Day
11.	BARRIER WALL - PERMANENT	200 LF/Day
12.	SIDEWALK	300 Sq Yd/Day
13.	SODDING	1,500 Sq Yd/Day (10 days maximum)
14.	SEEDING	23,500 Sq Yd/Day (5 days maximum)
15.	REFLECTIVE PAVEMENT MARKERS	0 - 5,000 Use 500/Day 5,001 + Use 1,000/Day
16.	THERMOPLASTIC STRIPING	6.7 Mi/Day
17.	SURFACE TREATMENT	200 Cy/Day
18.	GUARDRAIL (When a significant part of Contract)	1,500 LF/Day
19.	BREAKING AND COMPACTING EXISTING CONCRETE PAVEMENT (Re-seat Conc. Pave.)	5,000 Sq Yd/Day
20.	COMPRESSION SEAL REPLACEMENT	100 LF/Day

APPENDIX E

EXAMPLE OF PROJECTS CLASSIFICATION SYSTEM (CALIFORNIA)

'A' SERIES — BUILDINGS AND MISCELLANEOUS MODIFICATIONS

'AA' HAZARDOUS WASTE REMOVAL
'AB' REPAIR OR IMPROVE BUILDINGS
'AC' CONSTRUCT MAINTENANCE STATION
'AD' CONSTRUCT ROADSIDE REST
'AE' CONSTRUCT WEIGH STATION
'AF' CONSTRUCT OR MODIFY PORTABLE TRUCK SCALE OR WEIGH-IN-MOTION SYSTEM
'AG' CONSTRUCT, MODIFY OR RELOCATE AGRICULTURAL INSPECTION STATION
'AH' CONSTRUCT TOLL PLAZA FACILITY
'AI' MODIFY ROADSIDE REST
'AJ' MODIFY OR INSTALL GAS, DIESEL OR EMULSION TANKS
'AK' MODIFY OR INSTALL ELECTRICAL
'AL' CONSTRUCT OR MODIFY SAND, SALT, MATERIAL OR EQUIPMENT STORAGE BUILDING
'AM' ENERGY CONSERVATION MODIFICATIONS
'AN' MODIFY OR INSTALL AUTO HOIST, TRUCK HOIST, LUBE SYSTEMS OR AIR REELS
'AO' MODIFY WEIGH/MAINTENANCE STATIONS
'AP' MODIFY, INSTALL OR REPAIR ROOF
'AQ' MODIFY OR INSTALL DOORS
'AR' CONSTRUCT OR MODIFY REST ROOMS
'AS' CONSTRUCT OR MODIFY BUS SHELTERS
'AT' PAINT BUILDING
'AU' MODIFY TOLL PLAZA
'AV' MODIFY OR INSTALL VENTILATION SYSTEMS
'AW' MODIFY OR INSTALL SEWER, WATER, LPG OR PUMPS
'AX' MODIFY OR INSTALL FIRE SYSTEM
'AY' MODIFY OR INSTALL ELEVATOR
'AZ' MODIFY EMPLOYEE HOUSINGS

'B' SERIES — STRUCTURES

'BA' MODIFY OR INSTALL BRIDGE RAILING
'BB' BRIDGE RESTRAINERS
'BC' REHABILITATE BRIDGE DECK
'BD' BRIDGE PAINTING (HM-Program)
'BE' SEISMIC RETROFIT-PHASE 2/SINGLE-COLUMN
'BF' REHABILITATE STRUCTURE
'BG' BRIDGE REPLACEMENT
'BH' CONSTRUCT NEW TOLL BRIDGE
'BJ' WIDEN BRIDGE
'BK' REMOVE BRIDGE
'BM' TOLL BRIDGE IMPROVEMENTS
'BN' CONSTRUCT NEW BRIDGE 'BE'
'BP' SEISMIC RETROFIT-PHASE 3/MULTI-COLUMN

'C' SERIES — RESURFACING

'CA' RESURFACE HIGHWAY
'CB' RESURFACE OR PAVE PARKING AREAS
'CC' RESURFACING PROJECTS WITH STRUCTURES $$
'CD' SEAL COAT (HM-Program)
'CE' RESURFACE & DRAINAGE
'CH' RESURFACE, SIGNALS & LIGHTING
'CK' RESURFACE & CHANNELIZE
'CM' THICK BLANKET

'D' SERIES — REALIGNMENT

'DA' REALIGN HIGHWAY OR ROADWAY

'DB' CURVE CORRECTION
'DC' CURVE CORRECTION & WIDEN
'DD' REALIGN HIGHWAY & WIDEN
'DE' REALIGNMENT PROJECTS WITH STRUCTURES $$
'DF' VERTICAL ALIGNMENT CORRECTIONS
'DH' REALIGN & CHANNELIZE

'E' SERIES — CHANNELIZATION

'EA' CHANNELIZATION
'EC' CHANNELIZE, SIGNALS & LIGHTING

'F' SERIES — NEW CONSTRUCTION

'FA' CONSTRUCT CONVENTIONAL HIGHWAY OR EXPRESSWAY-PROJECTS W/O STRUCTURE
'FB' CONSTRUCT CONVENTIONAL HIGHWAY OR EXPRESSWAY-PROJECTS W/ STRUCTURES
'FC' CONSTRUCT FREEWAY
'FD' CONSTRUCT INTERCHANGE, OVER-CROSSING, GRADE SEPARATION, OVERHEAD OR UNDER-CROSSING
'FG' CONVERT HIGHWAY OR EXPRESSWAY TO FREEWAY
'FH' CONSTRUCT FREEWAY TO FREEWAY INTERCHANGE
'FJ' RECONSTRUCT STREET OR CUL-DE-SAC (Projects Related to Fwy Construction)
'FK' STAGED FREEWAY CONSTRUCTION-WITHOUT STRUCTURES $$
'FL' OVERALL ROUTE DESIGN
'FM' STAGED FREEWAY CONSTRUCTION-WITH STRUCTURES $$

'G' SERIES — STORM/EARTHQUAKE DAMAGE

'GA' SLIDE OR SLIPOUT CORRECTION
'GB' REPLACE HIGHWAY
'GD' STORM OR EARTHQUAKE DAMAGE PROJECTS WITH STRUCTURES $$
'GE' DRAINAGE CORRECTIONS
'GF' RE-VEGETATION
'GG' REPLACE OR REPAIR GUARDRAIL, BRIDGE RAIL OR FENCE
'GK' REPLACE OR REPAIR PUMPS, WELLS OR ELECTRICAL

'H' SERIES — OPERATIONAL IMPROVEMENTS SYSTEMS

'HA' RAMP METERING SYSTEMS
'HB' RAMP METERING PROJECTS WITH STRUCTURES $$
'HC' MODIFY OR INSTALL TRAFFIC SURVEILLANCE SYSTEMS

'J' SERIES — ROADWAY SAFETY

'JA' PAVEMENT MARKERS
'JC' GRIND OR GROOVE PAVEMENT

'K' SERIES — ROADSIDE SAFETY

'KA' CONSTRUCT CONCRETE BARRIER
'KB' MODIFY OR INSTALL SIGNS
'KC' MODIFY OR INSTALL LIGHTING
'KD' MODIFY OR INSTALL CRASH CUSHIONS
'KE' MODIFY OR INSTALL SIGNALS & TRAFFIC COUNT
'KG' MODIFY OR INSTALL SIGNS, SIGNALS & LIGHTING
'KH' MODIFY OR INSTALL GUARDRAIL OR BRIDGE APPROACH RAIL
'KL' MODIFY OR INSTALL FENCE
'KP' MODIFY OR INSTALL SIGNS & LIGHTING
'KV' MODIFY OR INSTALL CRASH CUSHIONS & SIGNS

'L' SERIES — LANDSCAPING

'LA' HIGHWAY PLANTING
'LB' IRRIGATION SYSTEM

'LC' RESTORE LANDSCAPING
'LD' PLANT ESTABLISHMENT CONTRACTS (HM-Program)

'M' SERIES — PROTECTIVE BETTERMENTS

'MA' DRAINAGE PROJECTS WITH STRUCTURES $$
'MB' SLOPE PROTECTION OR STABILIZATION
'MD' INSTALL, REPAIR OR IMPROVE DRAINAGE FACILITY

'N' SERIES — NOISE ATTENUATION

'NA' MODIFY OR INSTALL SOUNDWALL
'NC' SCHOOL NOISE ATTENUATION

'P' SERIES — ROADWAY REHABILITATION

'PA' REHABILITATE CONVENTIONAL HIGHWAY (AC)
'PB' REHABILITATE EXPRESSWAY OR FREEWAY (AC)
'PC' REHABILITATE INTERSECTION, RAMPS AND INTERCHANGES
'PD' REHABILITATE PCC PAVEMENT
'PE' REHABILITATE PROJECTS WITH STRUCTURES $$
'PG' RECYCLE AC PAVEMENT

'Q' SERIES — WIDENING

'QA' WIDEN HIGHWAY OR EXPRESSWAY-PROJECTS WITHOUT STRUCTURES $$
'QB' WIDEN HIGHWAY OR EXPRESSWAY-PROJECTS WITH STRUCTURES $$
'QC' WIDEN SHOULDER OR LAND-PROJECT WITHOUT STRUCTURES $$
'QD' WIDEN FREEWAY-PROJECTS WITHOUT STRUCTURES
'QE' WIDEN FREEWAY-PROJECTS WITH STRUCTURES $$
'QF' MODIFY RAMPS OR INTERCHANGES-PROJECTS WITHOUT STRUCTURES $$
'QG' WIDEN & CHANNELIZATION
'QH' MODIFY RAMPS OR INTERCHANGES-PROJECTS WITH STRUCTURES $$
'QI' WIDEN SHOULDER OR LANE-PROJECTS WITH STRUCTURES $$
'QJ' CONSTRUCT PASS LANES (HWY OR EXPWY)-PROJECTS WITHOUT STRUCTURES $$
'QK' CONSTRUCT PASSING LANES (HWY OR EXPWY)-PROJECTS WITH STRUCTURES $$
'QL' WIDEN, SIGNALS & LIGHTING
'QQ' CONSTRUCT OR MODIFY CURBS, SIDEWALKS OR WHEELCHAIR RAMPS

SPECIAL PYPSCAN CODING

'RW' RIGHT OF WAY INVOLVEMENT ONLY
'SS' LUMP SUM MINOR ONLY
'ZZ' PROJECTS NOT COVERED BY ABOVE DESCRIPTIONS

APPENDIX F

LIST OF DOTS USING THE A+B METHOD (FHWA)

DOTS USING THE A+B BIDDING METHOD (FHWA)

Practice	State	Remarks
Cost plus Time Bidding (A+B)	Arkansas	One project, favorable results
	California	Three projects, no results reported. Also used on 10 critical Northridge earthquake projects awarded totalling $87,833,713 (a portion only). As of August 3rd, $25,675,000 in incentives had been paid for early completion.
	Colorado	One project, no results reported
	Delaware	Three projects, first two had favorable results. Third had problem unrelated to A+B bidding
	District of Columbia	Two projects, favorable results
	Georgia	One project, no results reported
	Idaho	One project, no results reported
	Iowa	One project, no results reported
	Kentucky	One project, favorable results
	Maryland	Several projects, favorable results
	Michigan	Two projects, I-69 concrete barrier installation had excellent results
	Minnesota	One project, no results reported
	Mississippi	Two projects, favorable results
	Missouri	Numerous projects with favorable results
	Nebraska	One project, favorable results
	New York	Eleven projects (inc. 4 FAP) let 2/94 & 3/94
	North Carolina	Ten projects, generally favorable results
	North Dakota	One project, University Avenue in Fargo, let 3/25/94
	Pennsylvania	Two projects, favorable results
	South Carolina	One project, no results reported
	Texas	Two projects, unfavorable results. A+B created friction between the state and the contractor.
	Utah	Three projects, favorable results
	Virginia	One project, no results reported

APPENDIX G

EXAMPLES OF ROAD USER COST COMPUTATION (KANSAS)

Determine User Cost by the use of *Quewz*: Kansas

Quewz is a PC-based computer program developed by the Texas Department of Highways and Public Transportation for economic analysis of work zones.

The program considers such factors as whether a crossover will be used, the number of traffic lanes available in both directions before and during construction, the normal speed limit, the percentage of truck traffic, the traffic count, and the hours of work. The program will calculate any possible traffic delay along with other related costs.

Quewz will not calculate the cost when the number of lanes remaining open to traffic before and during construction remain the same. In this case calculate the reduced service flow rate using factors provided by the Bureau of Traffic Engineering. Multiply the factor by the dollar value given for a *Quewz* run having the number of available lanes increased by one lane in each direction would be increased to 3 lanes and the program considering the 3 lanes before and 2 lanes during construction.

User cost for detour projects. The extra miles traveled on a detour are determined by measuring the difference in the distance to be traveled in miles using the detour and the distance in miles through the project that is affected by the detour. The user costs are then calculated with the mileage difference being multiplied by \$.22 per mile for cars and \$.71 per mile for trucks (or the latest cost per mile as published by the Internal Revenue Service for business tax purposes). In addition to the direct cost for the mileage difference, the cost of labor for the truck drivers must also be added. To find the added cost of labor for truck drivers, first calculate the length of time in hours required to travel through the project at the normal speed limit. Second, calculate the length of time in hours required to travel through the detour at the normal speed limit. Additional time may need to be added to each of the above for delays caused by turning movements, stop signs, traffic signals, etc. The differential in hours is then multiplied by the number of trucks and the wage rate plus fringe shown in the proposal. For example:

AADT - 20,000
Trucks 8% = 1 600 trucks per day, 18,400 cars per day
Truckers wages plus fringe = \$10.50
Length of project affected by detour = 10 miles; speed limit 55 mph
Length of detour 21 miles, speed limit 55 mph - the detour has 2 additional stops, one controlled by traffic signal
Length differential 21 - 10 = 11 miles
Calculated User Cost: car - 11 x 18,400 x .22 = \$44,528
truck - 11 x 1600 x .71 = \$12,496

Hour difference:
10 miles divided by 55 = 0.1818 hours
21 miles divided by 55 = 0.3812 hours
stop sign 2 minute delay + 2 minutes delay to arrive at full speed = 0.0666 hour

Time differential 0.3812 + 0.033 + 0.066 - 0.1818 = 0.2984 hours
Cost = 0.2984 x 1600 x 10.50 = \$5,013.12
Total User Cost Per Day = 44,528 + 12,496 + 5,013.12 = \$62,037.12

The cost for construction engineering as shown in the current edition of the Standard Specifications Section 108.08 may be added to the above calculated user cost.

APPENDIX H

EXAMPLE OF LANE RENTAL SPECIFICATION (FHWA)

Sample Special Provision
Project No.

LANE RENTAL FOR CONSTRUCTION - DAILY BASIS

A. GENERAL

Monetary assessments will be made against the contractor for each calendar day there are restrictions or a reduction in the number of available travel lanes or shoulder width.

B. DEFINITION OF TERMS

For this contract the following definitions apply:

(a) *Calendar Day*—Any day or portion of a day on the calendar including Saturdays, Sundays and legal holidays, beginning and ending at midnight.

(b) *Rental Charge*—The amount, as shown in the proposal, which represents the average daily cost of interference and inconvenience to the road user for each lane and/or shoulder closure or obstruction.

(c) *Obstruction*—When the contractor's operations have resulted in the useable lane width of the travelway or shoulder to be less than that specified in the plan documents.

C. LANE RENTAL

This contract includes a lane rental procedure under which the contractor is assessed a rental charge for each lane and/or shoulder closure or obstruction from the time of Notice to Proceed until such time that the project is complete.

One lane of the roadway shall remain open for each direction of traffic at all times. The rental charge to be assessed for each lane or shoulder closure or obstruction per direction of traffic per calendar day is as follows:

Closure and/or obstruction	Daily[1] Rental Charge
one lane	$ 20,000
one shoulder	$ 5,000
one lane and shoulder	$ 25,500
two lanes	$ 45,000
two lanes and shoulder	$ 50,000

The applicable lane rental charges will be deducted from any monies due the contractor for work performed. The deduction will be made based on the applicable rate for any and all closures or obstructions whether work is being performed or not. This deduction will be done on each progress payment.

D. FAILURE TO COMPLETE WORK ON TIME

All contract work shall be completed by ____ [2]. For each calendar day that any contract work remains uncompleted after the contract time prescribed for the completion of all work, $___ [3] will be deducted from any money due the Contractor, not as a penalty, but as liquidated damages.

On those days when the contractor is to be charged the liquidated damages fee, but the contractor has closed or obstructed a lane and/or shoulder, the contractor will be charged the greater amount, either the appropriate lane rent or the liquidated damages fee indicated.

This assessment will be deducted from any monies due or to become due the contractor.

Notes:

[1] This sample specification has been written in a manner such that rent is to be charged for every calendar day which a lane and/or shoulder is closed or obstructed, with any portion of a calendar day treated as a whole calendar day. The rental rates included in this example are included only for example purposes. Rental rates need to be determined for each project based on actual user costs for that project. As an option, portions of a calendar day could be handled as fractional periods (e.g., 6 hrs or 12 hrs) and the daily rental charge applied proportionally.

[2] A maximum number of calendar days should be specified to encourage the contractor to complete the project as early as possible.

[3] The liquidated damages rate should be based on construction engineering inspection costs and in cases where there is a public need may also include road user costs. Because construction engineering inspection costs and road user costs may be included in setting lane rental rates, in the administration of contracts that include both lane rental and liquidated damages, the contracting agency must be sure that the contractor is not charged twice (both as rent of a lane or shoulder and also as a liquidated damage) for the same cost being incurred, be it construction engineering inspection or road user costs.

Sample Special Provision
Project No.

LANE RENTAL FOR CONSTRUCTION - HOURLY BASIS

A. GENERAL

Monetary assessments will be made against the contractor for each hour there are restrictions or a reduction in the number of available travel lanes or shoulder width.

B. DEFINITION OF TERMS

For this contract the following definitions apply:

(a) *Calendar Day*—Any day on the calendar including Saturdays, Sundays and legal holidays, beginning and ending at midnight.

(b) *Hour*—Any continuous 60-minute period or portion of a continuous 60-minute period beginning at that point when a lane and/or shoulder is closed or obstructed by the contractor's operation.

(c) *Rental Charge*—The amount, as shown in the proposal, that represents the average hourly cost of interference and inconvenience to the road user for each lane and/or shoulder closure or obstruction.

(d) *Obstruction*—When the contractor's operations have resulted in the useable lane width of the travelway or shoulder to be less than that specified in the plan documents.

C. LANE RENTAL

This contract includes a lane rental procedure under which the contractor is assessed a rental charge for each lane and/or shoulder closure or obstruction from the time of Notice to Proceed until such time that the project is complete.

One lane of the roadway shall remain open for each direction of traffic at all times. The rental charge to be assessed for each lane and/or shoulder closure or obstruction per direction of traffic per hour [1] is as follows:

Closure and or obstruction	Hourly [2] Rental Charge	Hourly [2] Rental Charge
	6:30 - 9:00 AM 3:00 - 6:00 PM	All other hours of the day
one lane	$ 2,000	$ 500
one shoulder	$ 500	$ 125
one lane and shoulder	$ 2,500	$ 625
two lanes	$ 4,500	$ 1,250
two lanes and shoulder	$ 5,000	$ 1,375

The applicable lane rental charges will be deducted from any monies due the contractor for work performed. The deduction will be made based on the applicable rate for any and all closures whether or not work is being performed. This deduction will be done on each progress payment.

D. FAILURE TO COMPLETE WORK ON TIME

All contract work shall be completed by ___ [3]. For each calendar day that any contract work remains uncompleted after the contract time prescribed for the completion of all work, $___ [4] will be deducted from any money due the contractor, not as a penalty, but as liquidated damages.

On those days when the contractor is to be charged the liquidated damages fee, but the contractor has closed or obstructed a lane and/or shoulder, the contractor will be charged the greater amount, either the appropriate lane rent or the liquidated damages fee indicated.

This assessment will be deducted from any monies due or to become due the contractor.

Notes:

[1] In some unusual situations, where opening the roadway to traffic is extremely critical, having rental rates for portions of an hour, such as 15-minute increments may be considered.

[2] This sample specification has been written in a manner such that rent is to be charged for every hour a lane and/or shoulder is closed or obstructed, with any portion of an hour treated as a whole hour. The rental rates are included as examples only. Rental rates need to be determined for each project based on actual user costs for that project.

[3] A maximum number of calendar days should be specified to encourage the contractor to complete the project as early as possible.

[4] The liquidated damages rate should be based on construction engineering inspection costs and, in cases where there is a public need, may also include road user costs. Because construction engineering inspection costs and road user costs are also included in setting lane rental rates, in the administration of contracts that include both lane rental and liquidated damages, the contracting agency must be sure that the contractor is not charged twice (both as rent of a lane or shoulder and also as a liquidated damage) for the same cost being incurred, be it construction engineering inspection or road user costs.

FHA/HNG-22/S.J.GAJ
November 15, 1991

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