NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 79

CONTRACT TIME DETERMINATION

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM
SYNTHESIS OF HIGHWAY PRACTICE 79

CONTRACT TIME DETERMINATION

Topic Panel

LEONARD BELLANCA, *G. A. & F. C. Wagman, Inc.*
KENNETH J. GOTTULA, *Nebraska Department of Roads*
WILLIAM G. GUNDERMAN, *Transportation Research Board*
ROBERT HOLLIMON, *Mississippi State Highway Department*
D. P. O'DONNELL, *District of Columbia Department of Transportation*
R. D. SHUMWAY, *Alaska Department of Highways*
JACK STERNBACH, *New York State Department of Transportation*
DALE VANDENBERG, *Wyoming State Highway Department*
K. L. ZIEMS, *Federal Highway Administration*

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

AREAS OF INTEREST
CONSTRUCTION
(HIGHWAY TRANSPORTATION)

TRANSPORTATION RESEARCH BOARD
NATIONAL RESEARCH COUNCIL
WASHINGTON, D.C. OCTOBER 1981

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

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

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

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

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

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

NCHRP SYNTHESIS 79

Project 20-5 FY 1979 (Topic 11-10)
ISSN 0547-5570
ISBN 0-309-03166-4
Library of Congress Catalog Card No. 81-84294

Price: $7.20

NOTICE

The project that is the subject of this report was a part of the National Cooperative Highway Research Program conducted by the Transportation Research Board with the approval of the Governing Board of the National Research Council, acting in behalf of the National Academy of Sciences. Such approval reflects the Governing Board's judgment that the program concerned is of national importance and appropriate with respect to both the purposes and resources of the National Research Council.

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 National Academy of Sciences, or the program sponsors.

Each report is reviewed and processed according to procedures established and monitored by the Report Review Committee of the National Academy of Sciences. Distribution of the report is approved by the President of the Academy upon satisfactory completion of the review process.

The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine. The National Academy of Engineering and the Institute of Medicine were established in 1964 and 1970, respectively, under the charter of the National Academy of Sciences.

The Transportation Research Board evolved from the 54-year-old Highway Research Board. The TRB incorporates all former HRB activities and also performs additional functions under a broader scope involving all modes of transportation and the interactions of transportation with society.

Published reports of the

NATIONAL COOPERATIVE HIGHWAY RESEARCH PROGRAM

are available from:

Transportation Research Board
National Academy of Sciences
2101 Constitution Avenue, N.W.
Washington, D.C. 20418

Printed in the United States of America.

PREFACE

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

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

FOREWORD

By Staff
Transportation Research Board

This synthesis will be of special interest to construction engineers and others concerned with contract administration. Guidelines are presented for the consideration of relevant factors in determining contract time.

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

Transportation agencies must set reasonable times for completion of construction projects. Factors to be considered in determining contract time include materials, equipment, manpower, cost, and constraints such as weather, regulations, traffic, utilities, and user convenience. This report of the Transportation Research Board presents guidelines and recommendations for the establishment and enforcement of contract times.

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

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

CONTENTS

ACKNOWLEDGMENTS

This synthesis was completed by the Transportation Research Board under the supervision of Paul E. Irick, Assistant Director for Special Technical Activities Division. The Principal Investigators responsible for conduct of the synthesis were Thomas L. Copas and Herbert A. Pennock, Special Projects Engineers. This synthesis was edited by Nancy A. Ackerman.

Valuable assistance in the preparation of this synthesis was provided by the Topic Panel, consisting of Leonard Bellanca, Manager, Bridge Operations, G. A. & F. C. Wagman, Inc.; Kenneth J. Gottula, Construction Engineer, Nebraska Department of Roads; Robert Hollimon, Assistant Chief Engineer, Operations, Mississippi State Highway Department; D. P. O'Donnell, Engineer of Bridge Construction and Maintenance, District of Columbia Department of Transportation; R. D. Shumway, Deputy Commissioner, Alaska Department of Highways; Jack Sternbach, Director, Construction Subdivision, New York State Department of Transportation; Dale Vandenberg, Construction and Maintenance Engineer, Wyoming State Highway Department; and K. L. Ziems, Chief, Contract Administration and Safety Branch, Office of Highway Operations, Federal Highway Administration.

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

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

CONTRACT TIME DETERMINATION

SUMMARY

State transportation agencies devote considerable time and effort in attempting to set a reasonable time for completion of a construction project, as each day of work beyond the predetermined completion date generates costs for the agency, the road user, and the general public. Contract time is based on the estimated number of working days or calendar days or on a specific completion date.

Contracts providing more time than is actually needed for a project may discourage innovative management or construction techniques, encourage contractors to bid more work than can be handled, and increase agency costs. However, additional time may also result in lower bid prices and permit low-productivity contractors to bid.

Contracts specifying less time than necessary for completion of a project can result in higher bid prices and eliminate qualified contractors. However, they can also encourage good management, high productivity, and lower administrative and engineering costs.

Transportation agencies usually determine contract time based on (a) construction season limits, (b) quantity or production rates, (c) work-flow techniques, (d) estimated costs, and (e) external factors, such as coordination with utilities and railroads, need for industrial access, and other commitments.

With working-day contracts, the ability of an agency to have a project completed in a reasonable time depends on the policy for making time charges. Most agencies charge a full day if more than one-half of a normal shift is suitable for work. Several agencies account for time charges to the nearest one-fourth of a day. Among the items that will affect the charge of working days are adverse weather conditions, materials shortages, delivery delays, labor problems, and agency delays.

Incentive payments (or bonuses) are used by some agencies where there is a compelling need for early completion of a project. All agencies have some provision for liquidated damages for late completion of a project; the daily charge is usually related to the total contract amount.

The conclusions reached in this synthesis include the following:

- When establishing or modifying a time-estimation procedure, the performance of the procedure should be monitored, the effects of site conditions and terrain should be considered, and information should be obtained from state contractor associations.
- In determining contract time, a construction data file that covers the previous 3 to 5 yr should be used. The schedule should be reviewed and adjusted to reflect other factors, such as project size, availability of materials, and commitments of the agency engineering and inspection forces.

• Except for certain projects that must be completed within narrow time limits, there does not appear to be a need for highly restrictive contract duration times.

• The working-day and calendar-day methods have an advantage over the completion-date method in that the contractor is not liable for circumstances beyond his control; however, the agency must be careful to document each day that is charged.

Suggested guidelines include:

• Agencies should be flexible in establishing contract time. Construction season time limits have merit for some work, particularly for paving and resurfacing projects.

• Once specified, contract time becomes a contractual condition and should be enforced. Time charges on working-day contracts should be administered uniformly and fairly.

• It appears desirable and equitable to prescribe liquidated damages for (a) the time that traffic and the public are inconvenienced and (b) supervision costs incurred by the agency.

• A formal, rational approach should be developed to determine contract time; it should be based on past experience and updated frequently.

CHAPTER ONE

INTRODUCTION

There is a consensus among state transportation agencies on the need to specify the time limitations of contracts and to assess charges for failure to complete a project within the specified time. Many state agencies devote considerable time and effort in attempting to set a reasonable time for completion of each project, because each day of work beyond the predetermined time period of the contract generates proportional costs for the agency, the road user, and the general public.

Responsible contractors have sufficient motivation to complete a project at the earliest possible date. Early completion of a project results in lower overhead costs, lower interest costs for borrowed dollars, less exposure to damage by the elements (repairs must be made at the contractor's expense), avoidance of increased costs of labor and materials, and freedom to bid on other work. Nevertheless, some projects are delayed by contractors for various reasons, such as incompetence and financial problems. As there can be no advance indication of which project will encounter difficulties in progress because of contractor problems and/or external conditions, it is necessary to impose on all projects a disincentive for failure to meet the prescribed time.

The state transportation agency is responsible for establishing the time period for completion of a construction project. For over 50 yr, it has been common practice for agencies to estimate the number of working or calendar days required to complete work or to set a specific calendar date for completion. Procedures for assessing damages against the contractor were established by all 48 states in 1929 (*1*).

Different procedures are used to estimate the number of working days or calendar days needed to complete construction projects. Some of these techniques are simple and depend on the individual judgment. Others are more complicated, drawing heavily on past data accumulated by the agency and possibly using a computer system for storage and to develop time schedules.

The contract time as determined by a transportation agency generally is not used by contractors in preparing bids. Many contractors prepare their own estimates of time requirements based on personnel, equipment production rates, and work methods. The agreement or lack of agreement between the agency and the individual contractors often will be reflected in the bidding on the project. This does not mean that one estimate is more correct than the other, but that the agency may use an average time and the contractor may use more specific production rates.

ESTIMATING CONTRACT TIME

A review of AASHTO and transportation agency procedures for estimating contract time reveals some differences.

Contract time is based on the estimated number of working days or calendar days or on a specific completion date (fixed date). The completion date may be established by computing working days or determined by external influences.

The following definitions are relevant to a discussion on estimating contract time:

Calendar day. Any day shown on the calendar beginning and ending at midnight (*2*).

Working day. A calendar day during which normal construction operations could proceed for a major part of a shift (Saturdays, Sundays, and holidays are usually excluded) (*2*).

Controlling item(s). Contract work item that (a) is large in volume, (b) requires a lengthy period for completion, or (c) is on the critical path of a precedence diagram.

Saturdays, Sundays, and legal holidays are not counted as working days by most agencies (some agencies permit the contractor to work on these days). The controlling items are usually the basis for charging a work day. Several agencies permit the engineer to charge a fraction of a day. Time may or may not be charged on a working-day contract during the 3 or 4 winter months with adverse weather.This is intended to encourage the contractor to work during this period; however, in some cases, this allows the contractor to stop all work.

A calendar-day contract may or may not be the same as a fixed- or completion-date time period. Both contracts may include guaranteed work days or a specified number of days for each month. The completion-date contract, with or without a guaranteed number of working days, is widely used by state agencies. Specifications for completion-date contracts are not consistent among the states. The following specifications were derived from several states.

Completion date (specific). The contractor must have all (essential) work completed by a specific date without regard for working days.

Completion date (guaranteed working days). The contract completion date can be extended if the contractor has not had available the number of working days as stated in the contract. Either the number of working days for each month or the total number of days for the contract period may be stipulated.

If a project *must* be completed on or before a specific date, the contract should have a specific completion date. In other cases, contract time can be determined by means of working days, calendar days, or a completion date with guaranteed days.

RESPONSIBILITY FOR SETTING TIME LIMITS

The responsibility for setting contract time limits generally is assigned to the design and/or construction personnel within a transportation department. If the critical path method (CPM) or a similar planning method is used, the design team

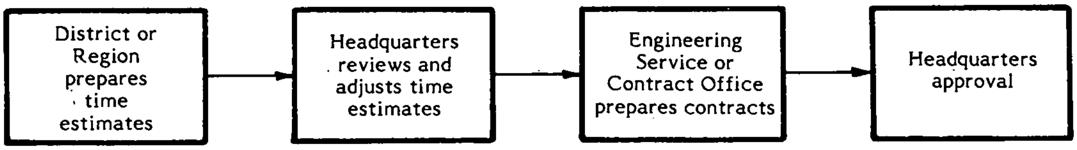


FIGURE 1 Contract time determination and review originating at the district level.

will usually prepare the first estimate to be reviewed by the construction division. If the determination of contract time is based on experience or construction seasons, the construction unit will usually have the responsibility for setting the time limits.

In some agencies, the district office sets the time subject to review approval by the headquarters' design or construction section (Figure 1). In other agencies, the time is set at the headquarters level with the district passing judgment on major or critical projects. Minor projects may go directly to the contract office (Figure 2). The flow chart used by one agency to determine contract time is shown in Figure 3.

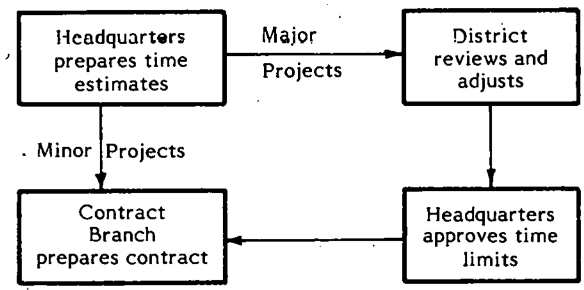


FIGURE 2 Contract time determination and review originating at the headquarters level.

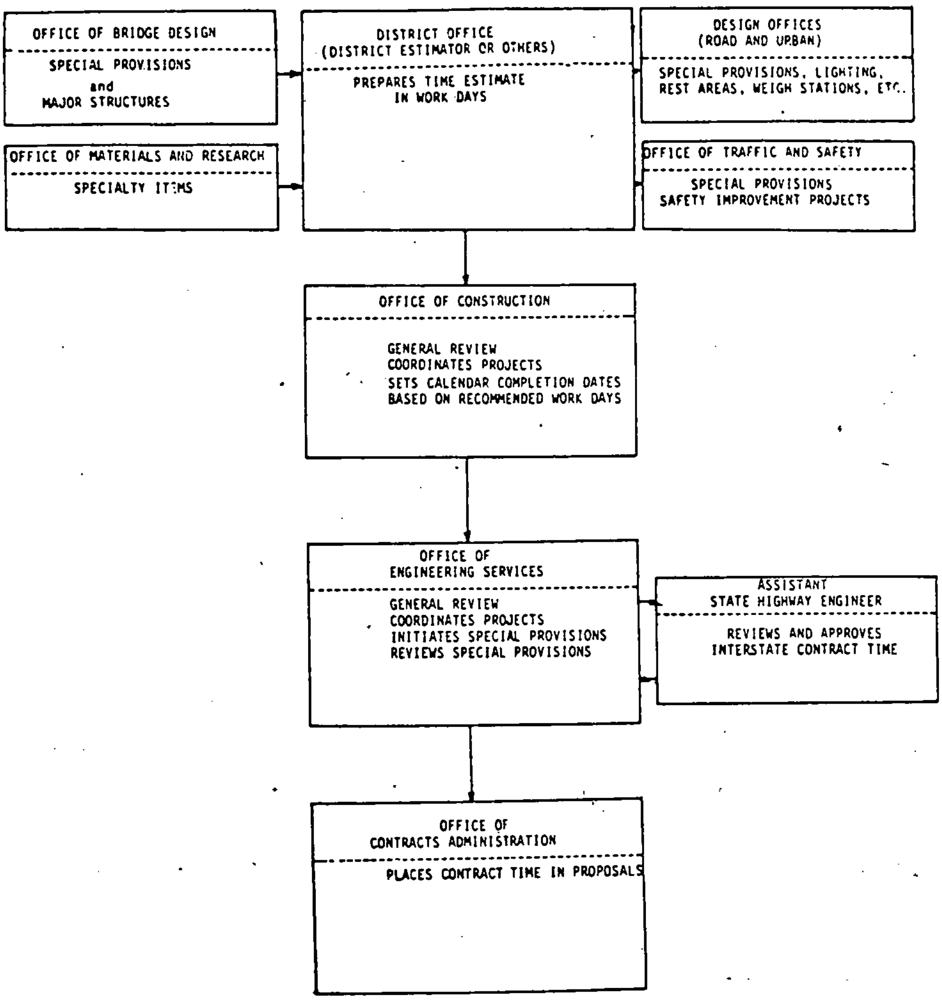


FIGURE 3 Procedure for determining contract time (Georgia).

Policies and practices are determined by the size of a project. Although most agencies can list projects in which political necessity played a part in setting the completion date, these cases are few when compared to the total program.

CONTRACT PERIOD

Strong arguments can be made by contractors for both long and short contract periods. One objective in the determination of a time period by agencies is to encourage a reasonable number of contractors to bid on the project. Knowledge of the capabilities and work loads of the contractors that normally bid each type of work is required. In some cases, projects are delayed in order to obtain more favorable prices during a period of reduced work loads.

Contracts that specify an excessive number of working days or a long time period may:

- Discourage innovative management or construction techniques.
- Encourage contractors to bid more work than can be handled in a timely manner.
- Require increased agency administration and engineering costs.
- Encourage lower bid prices.
- Permit both high- and low-production contractors to bid on project.
- Reduce the bonding capacity of contractors.

Contracts that specify too few working days or a short time period may:

- Encourage higher bids.
- Increase bond costs for contractors.
- Eliminate some qualified contractors.
- Encourage good management and thus high production.
- Cause the contractor to question each work-day charge (on working-day contracts).
- Lower administration and engineering costs.

CHAPTER TWO

CURRENT PRACTICE

BASIS FOR DETERMINING CONTRACT TIME

The determination of contract time by transportation agencies is primarily based on:

- Construction season limits,
- Quantity or production rates,
- Work-flow techniques, and
- Estimated costs.

In many cases, a the above practices is used—even for a single project (Table 1). Other methods that have been used by several agencies include time units and completion date specified by the contractor at the time of the bid.

Construction Season Limits

Perhaps the most common practice for determining contract time for surfacing and paving projects is to set the time limits at or shortly after the end of the construction season. This method is satisfactory when: (a) the projects are awarded early in the season; (b) a large number of projects are not awarded to a single contractor; (c) materials are readily available; and (d) the contractor is held responsible for the expense of maintaining the project over the winter or paying liquidated damages.

Consideration should be given to the latest feasible starting date for critical items on seasonal projects. For example, concrete bridge decks should not be placed late in the fall if chemicals might be used for ice control during the winter.

Quantity or Production Rates

The quantity approach involves the determination of a daily production rate for each controlling item in the contract. The agency may compute the daily rate for all items or only the controlling items that could significantly affect the project time.

The Construction Daily Production Table used in Illinois to compute increments of time, along with the supporting figures, is presented in Appendix A. The production table for work items is usually based on experience and past data from completed projects. This information is tempered with judgment, with the controlling items used as the primary basis for specifying contract time.

TABLE 1 CURRENT PRACTICES FOR DETERMINING CONTRACT TIME

STATE	Contract Time Determined by: Working Days (%)	Calendar Days (%)	Fixed Date (%)	Have Bids Ever Been Based on Different Numbers of Days?	Techniques or Procedures Used to Determine Contract Time: Work Season (%)	Production Rates (%)	CPM (%)	Cost Est. (%)	Liquidated Damages Range/Day ($)	Bonus Range/Day ($)
ALABAMA	97	1	2	No	X			X	45 - 980	
ALASKA		X	X	No	X	X			50 - 500	
ARIZONA	X			No		X			42 - 420	
ARKANSAS	X			No		X			42 - 420	
CALIFORNIA	X			No	20	60	20		50 - 1500	
DELAWARE	X	X	X	No	10	30		60	30 - 420	
DIST. OF COL.				Yes				X	30 - 150	
FLORIDA		X		No		X			(1) - 300	
GEORGIA	60	5	35	No	30	70			30 - 420	
HAWAII	X			No	10	30	30	30	42 - 420	
IDAHO	95	1	4	Yes	X				75 - 1300	
ILLINOIS	99.5		0.5	No		X			30 - 5600	1500 - 10 000
INDIANA	5.2	1	48	No	X	X			30 - 1000	(2) 50 - 1000 day
IOWA	X			Yes (3)		X			42 - 200	
KANSAS	X			No		X			75 - 1500	(11) 750 -
KENTUCKY	35		65	No	65	35			60 - 600	
LOUISIANA	80	20		No		X		X	42 - 420	
MAINE	80		20	No		X			30 - 420	
MARYLAND	75	25		No	X	X		X	(4)	
MASSACHUSETTS			X	No	X			X	30 - 500	
MICHIGAN	70		30	No	20		80		20 - 1000	(5)
MINNESOTA	90		10	No					150 - 900	(6)1000 - 3500
MISSISSIPPI			X			X			0 - 560	
MISSOURI	95		X	No	50	50			50 - 1500	
MONTANA	X			No	X	X			28 - 420	
NEBRASKA	98	2		No		X			42 - 420	(7)
NEVADA	X			No			X		300 - 1000	
NEW HAMPSHIRE	2		98	No	X				30 - 300	(8) 100 - 500
NEW YORK			X	No	X				50 - 1000	
NORTH DAKOTA	20		80	No	75	15		10	50 - 700	(9) - 500
OHIO	X			No	X	X			30 - 600	
OKLAHOMA	75	15	10	No	25	75			30 - 1000	
OREGON (10)	1	50	20	No	X	X		X	40 - 840	
PENNSYLVANIA		X	(12)		X		(13)		300	
RHODE ISLAND		X		Yes	X	X			30 - 300	
SOUTH CAROLINA			X	No	X			X	20 - 420	
SOUTH DAKOTA	X		X	No	X				50 - 600	
TENNESSEE	90		10	No	X	X		X	30 - 420	
UTAH	X	X	X	No	X			X	42 - 420	
VERMONT			X	No	X				42 - 420	
VIRGINIA		X	X	No	X	X			50 - 500	
WASHINGTON	X		0.5	No	X		X		42 - 2000	0 - 2000
WISCONSIN	30	40	30	No		90	10		50 - 595	
WYOMING			X	No	X	X	X		50 - 600	

NOTES: (1) 1/4% of contract amount per day. (2) Used on less than 1% of contracts with "not to exceed limit." (3) Only on selected projects with normal versus round-the-clock day. (4) Based on engineering, administration, and other costs of time overrun. (5) Used in special cases. (6) Bonus set by special provision. (7) Same as penalty, but rarely used. (8) Only for special projects. (9) Recent use on selected projects with $400-500 range. (10) Calendar work days - 29%. (11) One project only. (12) Only under special circumstances. (13) Bar chart for most projects; CPM only on large, complex projects.

Several agencies require that the contractor review the production rates and the time provided and then prepare a bar chart, a precedence CPM diagram, or other acceptable work-flow chart to indicate scheduling and work-control efforts. The chart is used to measure progress on the project and to aid the agency and contractor in addressing the proper items if the work lags.

Work-Flow Techniques

Large, complicated projects requiring extensive coordination of materials, equipment, personnel, and administrative support can best be handled by means of work-flow techniques. Such techniques include the critical path method (CPM) (*3, 4*), project engineering control (PROJECT) (*5*), and program evaluation and review technique (PERT) (*6*). Heuristic concepts have been suggested as a replacement for CPM in the planning of the construction process (*7*). A 1980 research report (*8*) recommended CPM to the Indiana State Highway Commission for planning construction projects.

A number of texts and manuals offer specific instructions on CPM and its use for construction projects. Information on the basic elements of CPM is given in Appendix B. Only seven state agencies use CPM routinely; however, other agencies prepare CPM charts for major projects. In some cases, each work item is accounted for, but for most projects only the major or controlling items are charted.

The accuracy of any work-flow diagram or chart is dependent on the experience, judgment, and data sources available. In general, agencies have indicated that key personnel possess both experience and judgment and have an intimate knowledge of construction conditions and contractors in their areas. However, concern has been expressed that much of this experience and judgment is concentrated in a few senior individuals and that it is not possible to transfer this knowledge in a short period of time.

There is also some concern about the time period for data accumulation on production rates. Some agencies claim that the time set for specific work items should be based on recent data to reflect advances in technology. Other agencies suggest that applying present-day production rates in estimating time could eliminate some contractors who have a good performance record but are using older equipment.

In a few cases, agency methods for the collection of production-rate data have been questioned. For example, in projects where production was restricted or intermittent, the data have been biased to some extent.

Although CPM is widely used by highway agencies and contractors, many agencies use the conventional bar or progress chart, either alone or with a CPM network. Some agencies have suggested that the progress or bar chart (Figure 4) can be explained more easily than an elaborate CPM network to property owners, members of the press, inspectors, and contractors' foremen. It is also less complicated to present in court if the agency is involved in litigation.

An example of contract time determination in Wyoming is presented in Appendix C. The steps taken and the selection of a completion date for a project involving grading, paving, structure, highway, and miscellaneous work are described.

Estimated Costs

Projects costs are related to the time or working days required to complete a construction project. Several agencies use the estimated costs of a project as a basis for determining time requirements.

The procedure used by the New Mexico Highway Department is one method of using project costs to estimate work time (see Appendix D). This procedure was developed from a study of the current practices for estimating time in New Mexico and seven other states.

Some agencies use estimated costs to set the number of working days; other agencies indicate that this procedure is usually used for smaller or less complicated projects. The experience in Washington, D.C. (structure) and in New Mexico (grading, paving) with cost versus completion time is shown in Figure 5. The need for each agency to develop its cost data based on location and type of work is clearly demonstrated. (Separate curves for urban and rural work may be necessary.)

Time Units

A research effort in Mississippi developed a computer-generated procedure for estimating work time and for reporting and monitoring contractor progress (*9*). CPM is used to generate bar-graph progress schedules. Time units are used as the measure of work; each month has an assigned number of time units that varies with the type of work. The use of time units for days enables the project engineer to make time charges based on the actual work performed on the controlling items. A brief description of the Mississippi procedure is given in Appendix E.

Completion Date Set by Contractor

Projects in Washington, D.C., and Mississippi provide examples of contracts where the contractors were given a role in the selection of the completion date. In the Washington, D.C., project, contractors could choose between two completion dates presented by the agency and submit a bid for completion of work by either date. The agency accepted the lowest valid bid. The Mississippi project involved shifting traffic from two divided lanes in each direction to single lanes in each direction, with an increase in user cost of $7,000 per day. Each contractor entered a bid and a completion date. The agency added an adjustment to the bid, which was the product of the number of days and the $7,000 per day increased cost. The four lowest bids are shown below. The combination of $4,721,599.82 for work items and $1,057,000 for user costs ($7,000 × 151) produced the low bid. The $7,000 per day cost was also added to the amount usually charged for liquidated damages.

Bidder	Direct Work Total Items($)	No. Days @ $7,000	Total Work and Days Comparison($)
1	4,721,599.82	151	5,778,599.82
2	4,544,930.41	250	6,294,930.41
3	5,271,196.81	212	6,755,196.81
4	5,215,617.29	266	7,077,617.24

INDIANA STATE HIGHWAY COMMISSION

CONTRACT Bridge Project - Sheet 1
PROJECT
DISTRICT

LETTING DATE
START DATE May 1, 1980
COMPLETION DATE

MADE BY
CHECKED BY
APPROVAL BY

CALENDAR DAYS →
WORK DAYS →

NO.	WORK ITEMS	QUANTITY	DAILY PRODUCTIVITY	Preceding items (shown at bar)
1	Move In	-	-	
2	Remove Existing Structure	-	-	1
3	Order and Deliver Piling	-	-	
4	Construct Fill	8,000 cyd	500 cyd/day	2
5	Bent 1 Cofferdam	1 ea.		4
6	Bent 1 Piling	1500 lft	500 lft/day	3, 5
7	Bent 1 Form & Pour Footing	10 cyd	10 cyd/day	6
8	Bent 1 Cure Footing	-	-	7
9	Dewater, Form & Pour Bent 1 Stem	20 cyd	10 cyd/day	8
10	Bent 1 Cap	10 cyd	10 cyd/day	9
11	Bent 2 Cofferdam	1 ea.		5
12	Bent 2 Piling	1500 lft	500 lft/day	6, 11
13	Bent 2 Form & Pour Footing	10 cyd	10 cyd/day	7,9,12
14	Bent 2 Cure Footing	-	-	13
15	Dewater, Form & Pour Bent 2 Stem	20 cyd	10 cyd/day	9, 14
16	Bent 2 Cap	10 cyd	10 cyd/day	15
17	North End Bent Drive Piling	1000 lft	500 lft/day	12
18	North End Bent Form & Pour	30 cyd	10 cyd/day	15, 17
19	North End Bent Cure	-	-	18
20	South End Bent Drive Piling	100 lft	500 lft/day	17
21	South End Bent Form & Pour	30 cyd	10 cyd/day	18, 20
22	South End Bent Cure	-	-	21
23	Order & Deliver Beams	-	-	
24	Set Beams	-	-	10,16,19,22,23
25	Form & Pour Diaphragms	15 cyd	5 cyd/day	24
26	Cure Diaphrams	-	-	25
27	Form Deck And Coping	-	-	26 (3)
28	Rebar	60,000 lbs	20,000 lbs/day	27 (2)
29	Pour Deck W/) Support Cuttouts	150 cyd	150 cyd/day	28
30	Remove Bulkheads & Place Concrete	20 cyd	10 cyd/day	29
31	Cure Deck	-	-	30
32	Form & Pour Top Wall	30 cyd	15 cyd/day	31 (1)
33	Cure Top Wall	-	-	32
34	Reinforced Concrete Approaches	180 cyd	30 cyd/day	32
35	Cure Approaches	-	-	34
36	Place Compacted Aggregate	450 tons	2000 tons/day	35
37	Place Bituminous Mix	250 tons	1300 tons/day	36
38	Bridge Rail	800 lft	600 lft/day	33,35,37
39	Guard Rail	1200 lft	600 lft/day	37
40	Seeding & Sodding	5000 syd	2500 syd/day	37
41	Clean-up	-	-	38,39,40

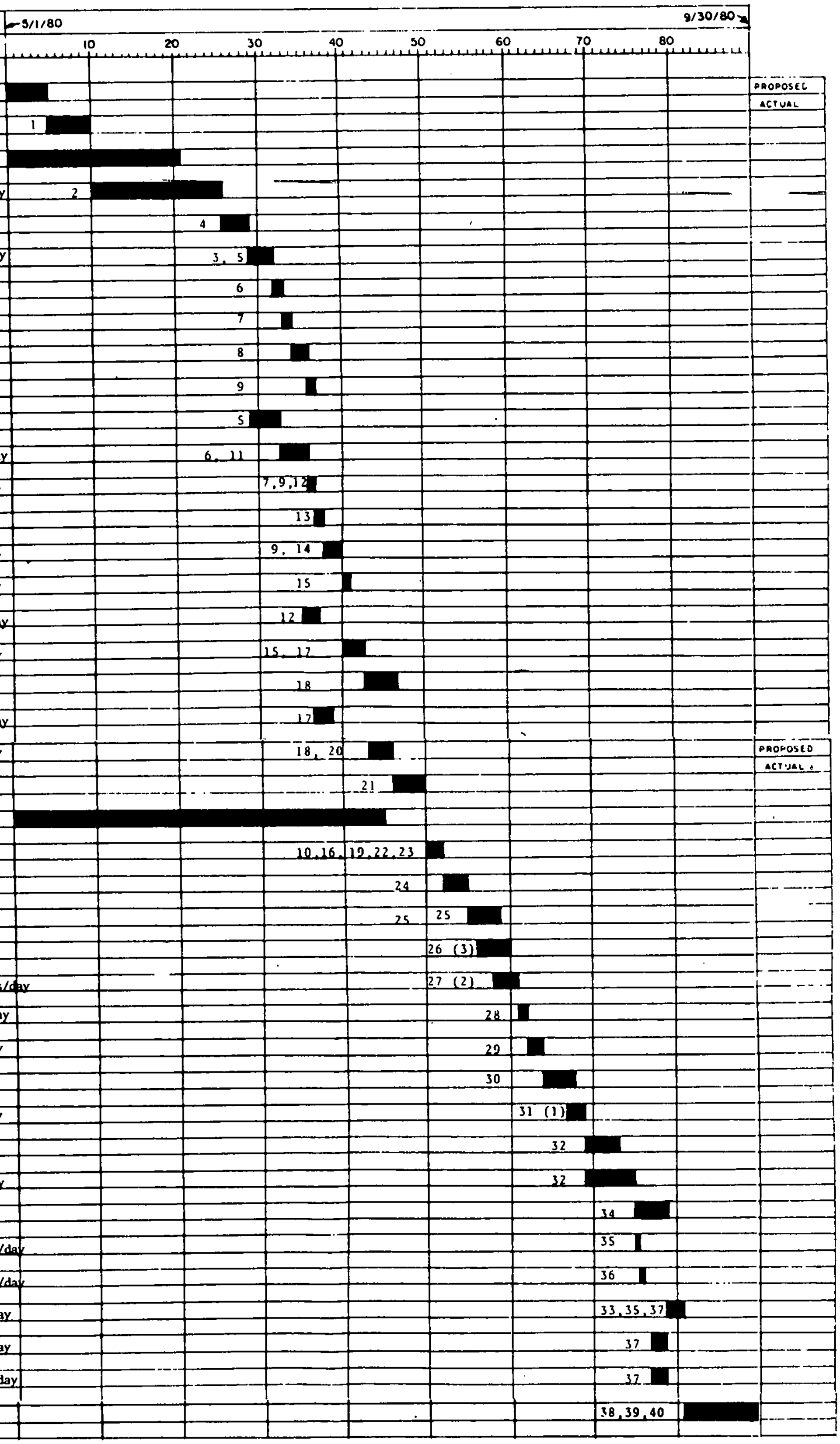


FIGURE 4 Bar chart for a highway project (Indiana).

FACTORS AFFECTING CONTRACT TIME

The contract time set by an agency using one of the techniques described above may require some adjustment because of external factors that affect the construction progress or necessitate the completion of a facility by a specific date. These external influences include:

- Coordination requirements,
- Commitments,
- Effects on road users and others, and
- Financial requirements.

As these external factors generally preclude extending the completion date, setting a specific date for completion instead of specifying contract time by working or calendar days may be necessary.

Coordination Requirements

Stage Construction

Some projects or portions of projects must be completed by a specific date to allow access by subsequent contractors to abutting projects. Delays in completion by the contractor can result in considerable claims for delay costs by the subsequent contractor. Therefore, a specific completion date associated with a sufficiently high rate for liquidated damages is advisable.

When the working-day or calendar-day method is used for setting contract times, the second-stage contractor may be put at a disadvantage by the failure of the first-stage contractor to overcome relatively minor obstacles of weather, delays in materials shipment, etc. Furthermore, the agency is vulnerable to such delay claims because the exercise of its authority to charge or not to charge working days affects the completion date of the first-stage contractor.

Delivery of Materials

Problems associated with the timely delivery of materials are common to all agencies. In some cases, contracts for major structures are awarded separately at earlier dates in order to ensure that materials are delivered on time. During the peak construction periods, shortages of bituminous materials, portland cement, and other essentials can delay project completion. One method of avoiding this problem is to schedule completion so that the critical stages will be completed before shortages develop. If an industry-wide shortage of required materials develops, time charges may be halted until the materials are available.

Coordination with Other Events

A specific completion date is usually required in order to coordinate the completion of a transportation facility with urban renewal, the opening of a major shopping center, construction of an industrial facility, utility or railroad project, special events, or the like. In some cases, although the transportation agency was not involved in the early planning of

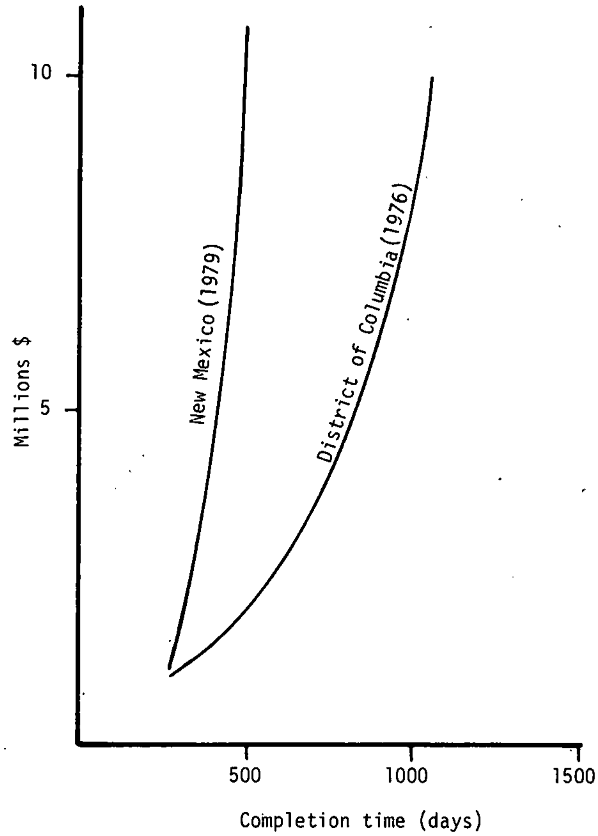


FIGURE 5 Cost versus completion time.

such projects, it may be asked to provide a completed facility on short notice.

Transportation facilities required for service to special events, such as the Olympics, a World's Fair, or other major events scheduled for a specific date, must be completed on time. To assure that every effort is made to meet this completion date, both a date for completion and a sufficiently large amount of liquidated damages must be specified in the contract. The working- and calendar-day methods are not appropriate in these cases, because it is critical that the contractor overcome all delays by means of the use of multiple shifts, overtime, additional work force and equipment, etc. A key football game, the opening of the hunting season, or other such activities may also be justification for completing a construction project rapidly.

Criticism by the public of street cuts or other utility work that follows highway or street paving has led to improved coordination between transportation agencies and utilities. It is common practice to have completion of a project somewhat dependent on a utility's effort to renovate or rebuild its facility. In some cases, the project work order may be delayed; however, more often there is a requirement that some part of the project be completed before a utility can begin work. Major natural gas line adjustments are critical, requiring special equipment that is not readily available and may warrant special consideration.

Much railroad construction or adjustment is performed by the railroad or contract firms that are responsible for the work on the entire railroad system. In some cases, problems in reaching agreements have caused major impacts on construction timing and completion. In a few cases, the railroad has contracted with the highway contractor, which can accelerate completion of work.

The completion of construction on major bridges by toll agencies or an abutting state can create a need for a period of accelerated construction. In most cases, the need for the new facility is recognized well in advance, but problems with right-of-way, design, or funding can contribute to a crisis.

Water levels in reservoirs or artificial lakes are controlled by generating demand, rainfall, recreational activity, mosquito control, and flooding streams. Contracts for construction across or adjacent to reservoirs either limit the time available or require that the contractor suspend operations during periods of high or low water levels.

Commitments

Occasionally, commitments are made to local governments for projects to be completed by a certain date. Pressure on meeting that date may necessitate a mandatory completion date to be specified in the contract.

Effects on Road Users and Others

The demands of traffic in urban areas have caused agencies to be extremely careful when setting completion dates. High traffic volumes can greatly delay a contractor's work. At the same time, construction work can seriously impede traffic. A lengthy detour around a project will generate considerable costs in terms of time, fuel, and maintenance. Travel on a project site that is hindered by construction delays also increases road-user costs in terms of time, safety, and convenience. The increase in such costs is largely affected by field conditions, the degree of completion of the project, and the adequacy of provisions for traffic maintenance and protection. On the other hand, if a contractor were to initiate double shifts to complete a project by an unreasonable date, greater exposure to hazards and traffic disruptions might result than would occur with the expeditious continuation of work with moderate use of overtime. Thus establishing a tight, optimum completion time cannot be justified in all cases solely by road user costs.

Even with comprehensive provision for the maintenance of traffic and allowance for access to abutting properties, a road under construction generally has a detrimental impact on business and abutting property owners. However, once the roadway and driveways are paved, the impact of minor completion work is generally negligible. It may be desirable to assess one level of charges when traffic or access is disrupted and another level of charges, on a smaller level, for failure to complete on time.

Financial Requirements

Although contract time limits are important to state finance and budgeting personnel in estimating expenditure requirements, some agencies have indicated that there are too many other factors affecting the expenditure rate to justify the necessity of precise computations of contract duration for the purposes of budgeting. Other agencies suggest that contractor payments and contract time are major factors in predicting cash flow and in scheduling projects.

Setting limits on contract time is important in conserving the limited engineering manpower of a state and holding down related supervision costs. These objectives can be fulfilled by means of the currently used methods for defining contract time limits.

Funds from other agencies or from a special category of federal or state funds may be made available with either an early-start or an early-completion requirement.

CHAPTER THREE

TIME CHARGES AND TIME EXTENSIONS

When contracts that provide for working days are used, the ability of an agency to have construction completed in a reasonable time depends to a large extent on the policy for making time charges and granting extensions. A lenient charging policy by an agency (central, district, or project engineer's office) can counteract efforts to predict work time and establish completion dates. It is important that the project engineer be consistent and reasonable in charging time on all contracts specifying the number of working days.

TIME CHARGES

Procedures for charging or not charging all or some part of a working day vary among the agencies. Key considerations in the charging of time include the amount of time in which the work can be completed and the controlling or major work item. Many agencies identify the controlling items. It is the responsibility of the project engineer to assess work conditions and make time charges.

The time charged is reported to the contractor, usually weekly, and any objections by the contractor must be presented within a specified period, usually within 2 weeks. Although agency specifications may state that the contractor must appeal a time charge within a specified time, a claim board or court may be persuaded to reexamine the time charges. Several agencies have indicated that objections to time charges are routinely made by some contractors if there is any question concerning their ability to complete work within the specified time.

Some agencies charge the contractor for a whole day if a major part of the day is suitable for work. A major part of the day may be as short as 2 hr; however, most agencies specify this time as more than one-half of a normal shift. Several agencies account for time charges to the nearest one-fourth of a day. The time unit used in Mississippi is rounded to the nearest one-tenth of a day, except that no time is charged if the total is less than two-tenths of a day (see Appendix E).

Time charges for completion-date contracts with a guaranteed number of working days are usually reported as on working-day contracts; thus it is important that careful attention be given to the determination of working days. Inattention to documentation and checking during the early stages of this type of contract can increase the chance of later claims and suits if the project is not completed in the time specified in the contract.

Adverse Weather

Determination of the effect of adverse weather on a working day can be difficult. Even those specifications that are precise in setting the conditions for charging a working day leave much to the discretion of the project engineer. It is difficult to be present at each site on a major project to evaluate the effect of adverse weather (temperature, rain, etc.) on specific controlling items of work. For example, supervisors for the contractor may be quick to point out real or imagined effects of a nearby shower on an isolated operation that may not actually affect work on a controlling item. The project engineer must be fair in determining work days and must be able to defend his judgment with adequate documentation. If an error is made, it should be corrected immediately with all parties being advised. Working days on a calendar-day or a completion-date contract with a guaranteed number of working days must be accounted for as carefully as the time on a working-day contract.

Shortage of Materials

Most agencies do not count working days when there is a genuine unforeseeable shortage of material that is not the fault of the contractor. In some cases, steel, cement, or asphalt that has been ordered well in advance cannot be delivered. It is the responsibility of the contractor to provide documentation for the delay that is acceptable to the agency. Documentation may include a letter from the manufacturer or vendor stating the date of receipt of the firm order for materials and the reason for the delay in delivery. Less documentation is required when there is an industry-wide shortage, as agencies are usually aware of the situation.

Delivery Time

Agencies are not always aware of the lead time for fabrication and delivery of key materials. If there is a delay in delivery, it is the responsibility of the contractor to show that the order for special materials was placed with a dependable supplier, that the fabrication and delivery times are reasonable, and that no other available supplier could have furnished the material on time.

Labor Problems

Most agencies give consideration in charging time, even on completion-date projects, when labor problems create a shortage or cause a delay. In most cases, the actual amount of delay is known; however, a strike that is remote from the work area can have an influence on the supply of material to a project and may need to be considered in charging time.

Agency Delays

Problems with right-of-way and access that affect the start or continuation of a controlling operation are considered sufficient justification for not charging work days to a project. All the facts and dates relating to the problem should be listed in the project diary. Design changes for structures or errors in field work by the agency that cause delays are also considered when charging work days. Some agency officials contend that admission of liability for delay by the agency encourages claims. Other officials find that acknowledging agency delays is the practical and straightforward way to handle the problem and that a better defense can be offered if there is a later claim by the contractor.

Additional Considerations in Charging Time

Utility adjustments, coordination with other contractors, court actions, scheduled public events, etc., can appreciably affect the scheduling and progress of work. However, the actual time delay is not easy to compute or estimate. The specific reasons for charging or not charging time should be carefully and fully explained in the engineer's diary and time reports. Fires, floods, war, and sovereign acts of government that could affect the project completion time are automatically considered in charging time.

TIME EXTENSIONS

It is common practice to consider time extensions for net quantity overruns, additional items of work, or for various delays previously discussed. When weather conditions or other problems prevent the contractor from completing work on a project within the given number of working days, the method most used for granting time extensions is not to charge for working days. Either the contractor or project engineer may request a time extension.

Quantity Overrun

Although the language of standard specifications and contracts may differ among the state agencies, the intent is usually to provide additional time, taking into account an increase in the quantity of controlling items and the relationship to total project cost. In some cases, time extensions are based on an increase in total project cost.

Additional Work

If new items of work are added to the contract, the need for additional time is discussed at that time and made a part of the supplemental agreement. The importance of agreement before the work is done should be emphasized.

CHAPTER FOUR

LIQUIDATED DAMAGES AND INCENTIVE PAYMENTS

The amounts of liquidated damages and the justification for incentive payments have caused much concern to both transportation agencies and contractors. The liquidated damages concept has been tested in numerous court cases and has been found valid as a method of compensating an agency for costs and delays when a project is not completed on time.

LIQUIDATED DAMAGES

Considerable literature has been published on the provision for liquidated damages in construction contracts. Cohen (*10*) and Sweet (*11*) provide information on liquidated damages and delay, citing numerous cases. More recent cases are cited in *The Government Contractor* and *The Construction Contractor*.

The right of an owner and a contractor to enter into a contract specifying amounts for liquidated damages if the project is not completed in the specified time has been accepted by the courts provided (*10, 12*):

- The damages anticipated by the parties are uncertain in amount or difficult to prove.
- The parties must have intended to stipulate or liquidate these damages in advance.
- The amount stated must be a reasonable estimate of the loss expected upon a breach of contract.

The items most often considered when estimating amounts of liquidated damages are (*10*):

- Additional costs of engineering, administration, etc.,
- Loss of time,
- Increased operating costs and the safety for facility users, and
- Damage and inconvenience to adjacent property owners.

SCHEDULE OF LIQUIDATED DAMAGES

Original Amount of Contract		*Per Diem Amount of Liquidated Damages*	
For More Than	*To and Including*	*Calendar Day**	*Workday*
$ 0	$ 25,000	$ 30	$ 42
25,000	50,000	50	70
50,000	100,000	75	105
100,000	500,000	100	140
500,000	1,000,000	150	210
1,000,000	2,000,000	200	280
2,000,000	....	300	420

*Calendar day amounts are applicable when the contract time is expressed on the calendar day or calendar workday or fixed date basis.

Schedule of Deductions for Each Day of Overrun in Contract Time

Original Contract Amount		* Daily Charge	
From More Than	To and Including	Calendar Day	Work Day
$ 0	$ 25,000	$ 30	$ 42
25,000	50,000	50	70
50,000	100,000	75	105
100,000	500,000	100	140
500,000	1,000,000	150	210
1,000,000	2,000,000	200	280
2,000,000	3,000,000	300	420
3,000,000	5,000,000	500	700
5,000,000	7,500,000	750	1,050
7,500,000	10,000,000	1,000	1,400
10,000,000	15,000,000	1,500	2,100
15,000,000	20,000,000	2,000	2,800
20,000,000	25,000,000	2,500	3,500
25,000,000	30,000,000	3,000	4,200
30,000,000	35,000,000	3,500	4,900
35,000,000	and over	4,000	5,600

* The daily charge shall be made for every day shown on the calendar beyond the specified completion date; and, when the time limit is specified as working days, the daily charge shall be made for each additional working day, computed as specified in Article 108.04.

Charge for liquidated damages for each day of delay

Original contract price		Calendar Day or Specified Completion Date	Working Day
From more than—	To and including—		
$ 0	$ 50,000	$150	$210
$50,000	100,000	250	350
100,000	500,000	400	560
500,000	1,000,000	500	700
1,000,000	2,000,000	600	840
2,000,000		700	980

LIQUIDATED DAMAGES. Unless otherwise provided in the contract, liquidated damages will be in accordance with the following schedule:

Original Contract Amount		**Daily Charge**
From More Than	**To And Including**	
$ 0	$ 25,000	$ 30.00
25,000	50,000	50.00
50,000	100,000	75.00
100,000	500,000	100.00
500,000	1,000,000	150.00
1,000,000	2,000,000	200.00
2,000,000	———	300.00

Schedule of Liquidated Damages for Each Day of Overrun in Contract Time.

Original Contract Amount		Daily Charge	
From More Than	To and Including	Calendar Day or Fixed Date	Work Day
$ 0	$ 25,000	$ 30.00	$ 42.00
25,000	50,000	50.00	70.00
50,000	100,000	75.00	105.00
100,000	500,000	100.00	140.00
500,000	1,000,000	150.00	210.00
1,000,000	2,000,000	200.00	280.00
2,000,000	4,000,000	300.00	420.00
4,000,000	7,000,000	400.00	560.00
7,000,000	10,000,000	550.00	770.00
10,000,000	———	700.00	980.00

FIGURE 6 Typical schedules for liquidated damages.

CONTRACT #33482
FAI Route 94
Section
1975-118-R&BR
Cook County

SPECIAL PROVISION--INCENTIVE/LIQUIDATED DAMAGES

Because time is of the essence in completing the contract work Sections 108.10, 102.07(c), and 102.07(f) of the Department's Standard Specifications for Road and Bridge Construction are hereby deleted in their entirety and the following is substituted therefor:

FAILURE TO COMPLETE THE WORK ON TIME

NORTHBOUND LANES

Should the Contractor fail to complete all the work including cleanup on the northbound lanes as required by this contract, on or before October 31, 1979, the Contractor shall be liable to the Department for each calendar day after October 31, 1979, as liquidated damages and not as a penalty, in the amount of $10,000. Such daily amount shall continue to accrue until such time as all work on the northbound lanes under this contract is completed. Provided, however, if this contract is part of a combination bid award, such daily amount shall continue to accrue regardless of completion of work on the northbound lanes under this contract until all work on contracts which are a part of the combination award has been completed.

INCENTIVE PAYMENT

NORTHBOUND LANES

Should the Contractor complete all the work on the northbound lanes including cleanup, as required by this contract; before September 30, 1979, the Contractor shall be entitled to $5,000 as an individual incentive payment for each calendar day of completion prior to September 30, 1979. No individual incentive payment will be made should any work not be completed before September 30, 1979, regardless of any extension of time. Individual incentive payments shall in no event be paid for more than 50 calendar days. If this contract is part of a combination award, no individual incentive payment shall commence on this or any other contract which is a part of the combination until all work on contracts which are a part of the combination award has been completed.

Should all work on the northbound lanes be completed for all six sections of the Edens Expressway reconstruction as covered by this contract and by Department contracts numbered 33434, 33470, 33461, 33432 and 33433, the Contractor shall be entitled to an additional $5,000 as a cooperative incentive payment for each calendar day of completion prior to September 30, 1979. No cooperative incentive payment will be made solely because the Contractor has finished early and no cooperative incentive payments will begin to accrue until the date of completion of all work on the northbound lanes under this contract and the five contracts enumerated above. The Contractor and the Department recognize that the prosecution of work by other contractors may not be effectively under the control of the Contractor; however, it is also recognized and agreed that the nature of the project is such that use of the highway cannot safely and efficiently begin until all sections are completed. No cooperative incentive payment will be made should any work not be completed before September 30, 1979, regardless of any extension of time. Cooperative incentive payments shall in no event be paid for more than 50 calendar days.

FIGURE 7 Special provisions for incentive payments and liquidated damages (Illinois).

Typical schedules for liquidated damages in relation to original contract amount are shown in Figure 6. Other penalty ranges for liquidated damages are given in Table 1.

INCENTIVE PAYMENTS

Agencies set bonus payments in an attempt to reward the contractor with an amount that is equal to the benefit of early completion or the cost of delayed completion. Bonus payments are used only for projects where there is a compelling public need. Incentive or bonus payments are not required in order to include a provision for liquidated damages in the contract. (Contracts with incentive payment clauses always include provisions for liquidated damages.)

In the survey of state transportation agencies conducted for this synthesis, only 10 of 43 respondents indicated that they provide for incentive payments on construction contracts. Some of these agencies indicated that incentive payments have been used on selected or special projects (see Table 1). For example, a recent contract in Maine to repair a vital bascule bridge contained a provision for a $10,000 per day bonus for early completion.

The special provisions for incentive payments and liquidated damages used by the Illinois Department of Transportation in contracts for rehabilitation projects are shown in Figure 7. The provisions provide for a maximum payment period of 50 days at $5,000 per day. During a 1-month period no incentive was to be paid or damages charged; thereafter, there would be a damage charge of $10,000 per day (Figure 8). The contractor completed the work during the 1-month period.

Transportation officials are reluctant to use an incentive or bonus payment. If a contractor concentrates forces and equipment to complete a project early and collects a substantial bonus, the individuals setting the time limits and the agency are subject to criticism by the press, federal officials, and others, even though (a) later completion of the project most likely would have increased construction costs, (b) the bonus payment probably resulted in earlier use of the facility, and (c) other contractors had the same opportunity to place bids and collect bonus payments.

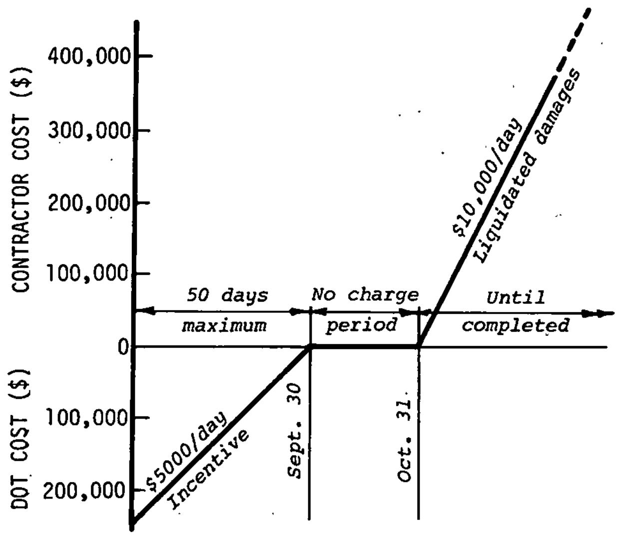


FIGURE 8 Computation of incentive payments and liquidated damages for a specific contract in Illinois. [An additional $5,000 per day incentive payment was available if all six contracts were completed early (see Figure 7).]

Arguments that have been presented against bonus payments include:

- Difficulty in budgeting an amount for bonus payments.
- Need for additional data to decide on an amount or rate.
- Value received may not be proportional to the additional cost.
- Increase in claims by contractors.
- Provision in contract for liquidated damages is sufficient incentive.

CHAPTER FIVE

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

State transportation agencies use various methods for setting time limits on construction projects. Some agencies rely on construction seasons; others rely on the predicted production rates for the work items in the contract; several use CPM or some other work-flow technique; and a few agencies use the estimated project cost as the basis for determining contract time. Many agencies use a combination or all of the above methods, depending on the size and type of the project and the degree of urgency for project completion.

When establishing a new time-estimation procedure or modifying an existing procedure, the performance of the existing procedure should be carefully monitored both for projects with major time overruns and for projects completed much earlier than the contract date. It is also important to identify projects that were completed on time, even though work was not continuous. Special attention should be given to identifying items of work that must be completed in specific sequence. Although the experience of other organizations can be useful in establishing estimating procedures, each agency should also use its own data and historical files to develop new methods or to check the validity of existing procedures.

The state construction contractor associations (e.g., AGC, ARTBA) can provide valuable information. Contractors are usually concerned with realistic construction time limits and will take an active role in assisting an agency in this effort. Some contractors contend that agencies need not be overly concerned with setting time limits because of the desire of contractors to finish each project at the earliest practical date. However, transportation agencies are able to cite projects that were not completed on time and for which the contractor made payment of liquidated damages. None of the agencies suggested that the contractor should have complete control over the setting of a completion date.

Provision in a contract for more time than is actually needed encourages a contractor to seek other work. In some cases, the contractor may place bids for other agency work, perform private work in the area, or work on projects in other states. Sometimes all work is stopped on projects for extended periods. Although the contractor may resume work and finish on time, these actions cause difficulties for the agency and may result in traffic problems.

Recognition of the need for improved methods of estimating the time requirements for transportation construction projects is a part of the trend toward overall improved transportation management and more efficient use of agency personnel. Funding is limited and interest rates are high; therefore, each opportunity to improve cash flow should be seriously considered. Recently, contractors have been rushing work, thus creating the need for increased cash flow.

Officials have been and continue to be criticized by the public, local officials, federal officials, and others for allowing an excessive amount of time for the completion of construction contracts. Some contractors have expressed concern that excessive amounts of time specified in contracts permit those with older, inefficient equipment to submit low bids. Others do not think that this is a serious problem because the firm with the more efficient equipment and organization can reduce costs by completing a project well under the time limit.

Ideally, an agency should use a construction data file (time, inflation rates, weather, production rates, etc.) that covers the previous 3 to 5 yr to develop a realistic work time schedule. This schedule should be reviewed and adjusted to reflect other factors (program size, money flow, seasonality, etc.). The work schedules of potential contractors, availability of materials, requirements for utility work, and the commitments of the agency's engineering and inspection forces also should be reviewed. Most agencies take into consideration many, if not all, of the above factors before setting the number of days or a completion time on construction projects. However, problems still occur: contractors bid more work than can be handled; there are union problems; and coordination of work is not as effective as planned. The effects of site conditions and terrain on production rates and the contractor's ability to work with particular materials can influence time requirements. Many unforeseeable difficulties can result in a project slowdown; this creates the need to establish procedures to monitor work progress, determine if the projected schedule is being met, and take steps to get back on schedule. All these procedures must be included in the agency specifications or in the project contract.

Should all efforts fail to prevent a time overrun, the project records should support or refute claims for time extensions and be used to assess the liquidated damages to be paid by the contractor. Excessive claims by contractors for time extensions and the assessing of liquidated damages by the contract agency may indicate that some parts of the procedure for setting contract time need modification. For example, if the time allowed is too short to complete construction, contractors may increase bid prices to cover anticipated liquidated damages.

Construction records should be carefully reviewed to update cost data and to validate time charges. Field diaries and other construction documents can provide information to aid in developing production rates. Representatives of the construction industry are usually available to work with state agencies in developing realistic time estimates. However, it is the agency that ultimately must accept the responsibility for setting the time limits for each construction project. The objective of the agency is the satisfactory and timely completion of work—not the collection of liquidated damages.

Except for projects that must be completed within narrow time limits, there does not appear to be a need for highly restrictive contract duration times. Time requirements on a contract that are too restrictive could result in higher bid prices. Also, frequent assessments of liquidated damages are likely to be reflected in the bidding on all projects. For paving and resurfacing projects, except where specific completion dates are critical and/or monetary incentives for earlier completion are specified, there is no need to be concerned about contract duration other than construction seasons.

The working- or calendar-day method has an apparent advantage over the completion-date method in that it relieves the contractor of being liable for liquidated damages due to circumstances beyond control (e.g., weather conditions). The specified completion-date method requires the contractor to overcome such delays at his own expense, because climatic conditions (except "acts of God") or other localized impediments to progress do not relieve liability. However, if the specified completion date is sufficiently liberal, it should have no adverse effect on bid prices. The specified completion-date method is simpler to administer and to defend in the event of the filing of a claim. The working- or calendar-day method requires careful documentation of each day charged in the event of later challenge in court.

RESEARCH STUDIES

Several state transportation agencies have completed studies that review current methods of estimating time and present recommendations for preparing future estimates. The Indiana and Mississippi reports are listed in the reference section (*8,9*). Appendix D contains a description of the practice implemented in New Mexico after a consultant-supported in-house study was conducted; Appendix E contains a description of the Mississippi procedures. Other agencies have conducted informal reviews of procedures in order to make modifications to current practices.

There does not appear to be any compelling need for a major research effort to identify the more successful procedures for estimating time or to develop new techniques. Each agency should study the procedures now in use to determine their effectiveness in ensuring that construction projects are completed as soon as practical and at reasonable costs.

RECOMMENDATIONS

In view of the established preferred procedures in each state for computing and administering contract time and the various benefits and disadvantages of the different methods, it is difficult to propose recommendations. However, the following general guidelines are suggested:

1. It is recommended that agencies be flexible in establishing project working days or completion dates. It is not desirable to be highly restrictive in specifying contract duration. For some projects, selecting contract time based on construction seasons appears to have merit. Liberal use of construction-season time limits on paving and resurfacing projects will help contractors in keeping bids reasonable.
2. When a contract must be completed within a narrow range of time, specifying a contract completion date is preferable to the stipulation of the number of working or calendar days.
3. Once specified, contract time becomes a contractual condition and should be rigorously enforced.
4. It appears desirable and equitable to prescribe liquidated damages at two levels: (a) for the time that traffic and/or the general public is inconvenienced; and (b) for direct engineering supervision costs of minor completion work off the roadway.
5. The time required to complete a construction project may be based on past experience with similar work. It is recommended that a formal rational approach be developed for use in determining time requirements.
6. Some means of showing the time available for specific items of project work is recommended. A precedence (CPM) chart or bar chart may be prepared manually or with the aid of a computer.
7. Time schedules should be compared with the actual progress on the project. The contractor should be required to prepare a revised schedule if a work slowdown occurs.
8. Enforcement of time charges on working-day contracts should be administered uniformly and fairly. The contractor should be given the opportunity to contest time charges.
9. Production rates and other variables used to estimate contract time should be updated monthly or after each major letting. Data not reflecting current conditions should be removed from the file.
10. In setting contract time limits, a decision must be made on whether to have the construction project completed by a specific date at any cost or to have the project completed in a reasonable period of time at reasonable cost. The agency should be responsible for identifying the projects that must be completed at the earliest practical date. The agency must also decide whether to use only liquidated damages or to specify incentive payments in addition to liquidated damages.
11. Each method of setting contract time should be evaluated by comparing contract completion times to actual completion times. An analysis of the frequency of the use of excessive liquidated damages and bonuses should be made when modifications of the methods are considered.

REFERENCES

1. CONNOR, C. N., and P. F. SEWARD. 1930. A survey in the 48 states of weather conditions, working days, bonus and penalty requirements. *ARBA Proc:* 71-77.
2. *AASHO Highway Definitions.* 1968. American Association of State Highway Officials, Washington, D.C.
3. *A Manual for Applying the Critical Path Method to Highway Department Engineering & Administration.* 1963. Prepared by E. S. Preston & Assoc. Ltd. for U.S. Bureau of Public Roads.
4. PEURIFOY, R. L. 1970. *Construction Planning, Equipment and Methods.* McGraw-Hill, New York, pp. 19-37.
5. DANIELS, R. L. 1968. *Engineering User's Manual.* ICES PROJECT-1, 2nd Ed. Massachusetts Institute of Technology, Cambridge.
6. PERT Fundamentals. Vol. I. Networking. U.S. Navy, PERT Orientation and Training Center, Washington, D.C.
7. BIRREL, G. S. 1980. Contruction planning—beyond the critical path. *J. Construc. Div., Proc. Am. Soc. Civ. Eng.* 106: 389-407.
8. ROWINGS, J. E., JR. 1980. *Determination of Contract Time Durations for ISHC Highway Contruction Projects.* Joint Highway Research Project No. C-36-67J. Final report prepared in cooperation with Indiana State Highway Commission. Purdue University, West Lafayette, Indiana.
9. OSWALT, J. H., L. R. JOHNSON, and D. G. HOTARD. 1975. *A Method to Determine Contract Work Duys—Implementation.* Report by Engineering and Industrial Research Station, Mississippi State University, for Mississippi State Highway Department in cooperation with the Federal Highway Administration, U.S. Department of Transportation.
10. COHEN, H. A. 1961. *Public Construction Contracts and the Law.* McGraw-Hill, New York.
11. SWEET, J. *Legal Aspects of Architecture Engineering and the Construction Process.* West Publishing Co., pp. 446-451.
12. HARP, D. W. 1978. Liability for delay in completion of highway construction contract. Pp. 1495-1524 in J. C. Vance (Ed.), *Selected Studies in Highway Law,* Vol. 3. Transportation Research Board, National Research Council, Washington, D.C.

APPENDIX A

CONSTRUCTION DAILY PRODUCTION TABLE—ILLINOIS

CONSTRUCTION DAILY PRODUCTION TABLE

ITEM	UNIT	RATE PER DAY
Adjusting Frames & Grates	Each	5
Aluminum Handrail	Lin. Ft.	80
Bituminous Concrete Base Course Widening 9"	Sq. Yds.	1,100
Bituminous Concrete Binder & Surface Course, Sub I-11	Tons	500-550
Bituminous Materials	Gals.	5,000
Bituminous Materials Pumped	Gals.	5,000
Borrow Excavation	Cu. Yds.	See Figure 8-501.02a
Catch Basins	Each	5
Chain Link Fence	Lin. Ft.	1,200
Channel Excavation	Cu. Yds.	650
Class "A" Concrete	Cu. Yds.	8
Class "A" Excavation for Structures	Cu. Yds.	150
Class "B" Excavation for Structures	Cu. Yds.	100
Class "X" Concrete (Culverts)	Cu. Yds.	8
Class "X" Concrete (Headwalls)	Cu. Yds.	4
Class "X" Concrete (Superstructure Bridge)	Cu. Yds.	12
Class "X" Concrete (Substructure Bridge)	Cu. Yds.	8
Cleaning & Painting	Lbs.	50,000 (3 men/day)
Cofferdams Excavation	Cu. Yds.	75
Combination Curb & Gutter	Lin. Ft.	300
Concrete Gutter	Lin. Ft.	500
Concrete Removal	Cu. Yds.	20
Concrete Riprap	Sq. Yds.	175
Continuously Reinforced Concrete Pavement	Sq. Yds.	See Figure 8-501.02b
Curb & Gutter	Lin. Ft.	300
Curb & Gutter Removal	Lin. Ft.	800
Driving Concrete Piles	Lin. Ft.	250
Driving Steel Piles	Lin. Ft.	350
Driving Timber Piles	Lin. Ft.	300
Electric Cable	Lin. Ft.	2,500
Embankment	Cu. Yds.	2,200
Erecting Handrail	Lin. Ft.	80
Erecting Right-of-Way Markers	Each	30
Erecting Structure Steel	Lbs.	25,000
Evergreens	Each	20-25
Excavation:		
Borrow	Cu. Yds.	See Figure 8-501.02a
Earth	Cu. Yds.	See Figure 8-501.02a
Special	Cu. Yds.	500
Channel	Cu. Yds.	650
Cofferdam	Cu. Yds.	75
Earth (Shouldering, Widening)	Cu. Yds.	500
Rock	Cu. Yds.	100
Expansion Bolts	Each	25
Exploration Trench, 52" Depth	Lin. Ft.	200
Fabrication & Furnishing Structural Steel (Avg. 3 Span Structures)		
WF Beam	Calendar Days	150
Welded Plate Girder	Calendar Days	180
Gravel or Crushed Stone Base Course	Tons	800
Gravel or Crushed Stone Shoulders	Tons	800
Gravel or Crushed Stone Surface Course	Tons	800
Granular Backfill	Cu. Yds.	300
Granular Embankment Special	Tons	800
Guard Rail	Lin. Ft.	275
Gutter Cracking	Lin. Ft.	1,000
Handholes (Electric)	Each	4
Handrail Concrete	Cu. Yds.	1
Hedge Removal	Unit	5-10
Holes Drilled	Each	250
Inlets	Each	5
Intermediate Trees	Each	25-50
Jute Matting	Sq. Yds.	1,200
Landscaping:		
Evergreens	Each	20-25
Intermediate Trees	Each	25-35
Seeding	Acres	10
Shade Trees	Each	15-20
Shrubs	Each	250-350
Sodding	Sq. Yds.	800-1,000
Top Soil	Cu. Yds.	350

ITEM	UNIT	RATE PER DAY
Laying Signal Conduit	Lin. Ft.	375
Lightweight Structural Concrete	Cu. Yds.	10
Limestone Ground Aggregate	Tons	10
Manholes	Each	3
Median	Lin. Ft.	300
Median Surface (Concrete)	Sq. Ft.	3,000
Membrane Waterproofing	Sq. Ft.	500
Metal Handrail	Lin. Ft.	80
Moving; Fire Hydrants, Light Standards, Traffic Signals, Buffalo Boxes, etc.	Each	2
Patching	Sq. Yds.	75
Paved Ditch	Lin. Ft.	300
Pavement Removal	Sq. Yds.	1,000
Pavement Removal and Replacement	Sq. Yds.	75
Pipe Culverts	Lin. Ft.	200
Pipe Underdrains	Lin. Ft.	500
P.C. Concrete Base Course	Sq. Yds.	See Figure 8-501.02b
P.C. Concrete Base Course Widening	Sq. Yds.	1,200
P.C. Concrete Driveway	Sq. Yds.	100
P.C. Concrete Median	Lin. Ft.	300
P.C. Concrete Pavement	Sq. Yds.	See Figure 8-501.02b
P.C. Concrete Sidewalk	Sq. Ft.	1,000
Porous Granular Embankment	Cu. Yds.	500
Precast Concrete Bridge Deck	Sq. Ft.	250-300
Preparation of Base	Sq. Yds.	4000
Prestress Concrete Beams	Lin. Ft.	3 weeks for approval of shop plans, then 3 beams @ 50'/day plus 3 days for curing
Protective Coat	Sq. Yds.	10,000
Raceway for Magnetic Detectors	Lin. Ft.	50
Reinforcement Bars (Culverts)	Lbs.	(Considered with Cl. X concrete)
Reinforcement Bars (Substructure)	Lbs.	2,500
Reinforcement Bars (Superstructure)	Lbs.	5,000
Relocate Existing Traffic Signal Posts	Each	4
Remove and Reset Metal Handrail	Lin. Ft.	50
Rock Excavation	Cu. Yds.	100
Seeding (Large Jobs)	Acres	10
Seedling Trees	Each	2000(By Hand) 10,000(By Machine)
Shade Trees	Each	15-20
Shrubs	Each	250-350
Sidewalk, P.C. Concrete	Sq. Ft.	1,000
Sidewalk Removal	Sq. Ft.	1,500
Slope Wall	Sq. Yds.	50
Sodding	Sq. Yds.	800-1,000
Special Excavation	Cu. Yds.	500
Stabilized Shoulders	Sq. Yds.	1,500
Stabilized Subbase 4"	Sq. Yds.	4,000
Steel Plate Beam Guard Rail	Lin. Ft.	250
Storm Sewers	Lin. Ft.	200
Straw for Asphalt Coated Mulch	Tons	4-6
Subbase Granular Materials	Tons	800
Thermoplastic Pavement Marking	Lin. Ft.	15,000
Thermoplastic Pavement Marking Symbol	Sq. Ft.	45
Top Soil	Cu. Yds.	350
Traffic Signal Head Alterations	Each	4
Traffic Signal Posts	Each	4
Tree Removal (6" to 15")	In. Dia.	110
Tree Removal (Over 15")	In. Dia.	110
Tree Removal	Acres	1.5
Trench Excavation (52" Deep Exploration)	Lin. Ft.	200
Trench and Backfill	Lin. Ft.	450
Vines	Each	2,000
Woven Wire Fence	Lin. Ft.	2,000

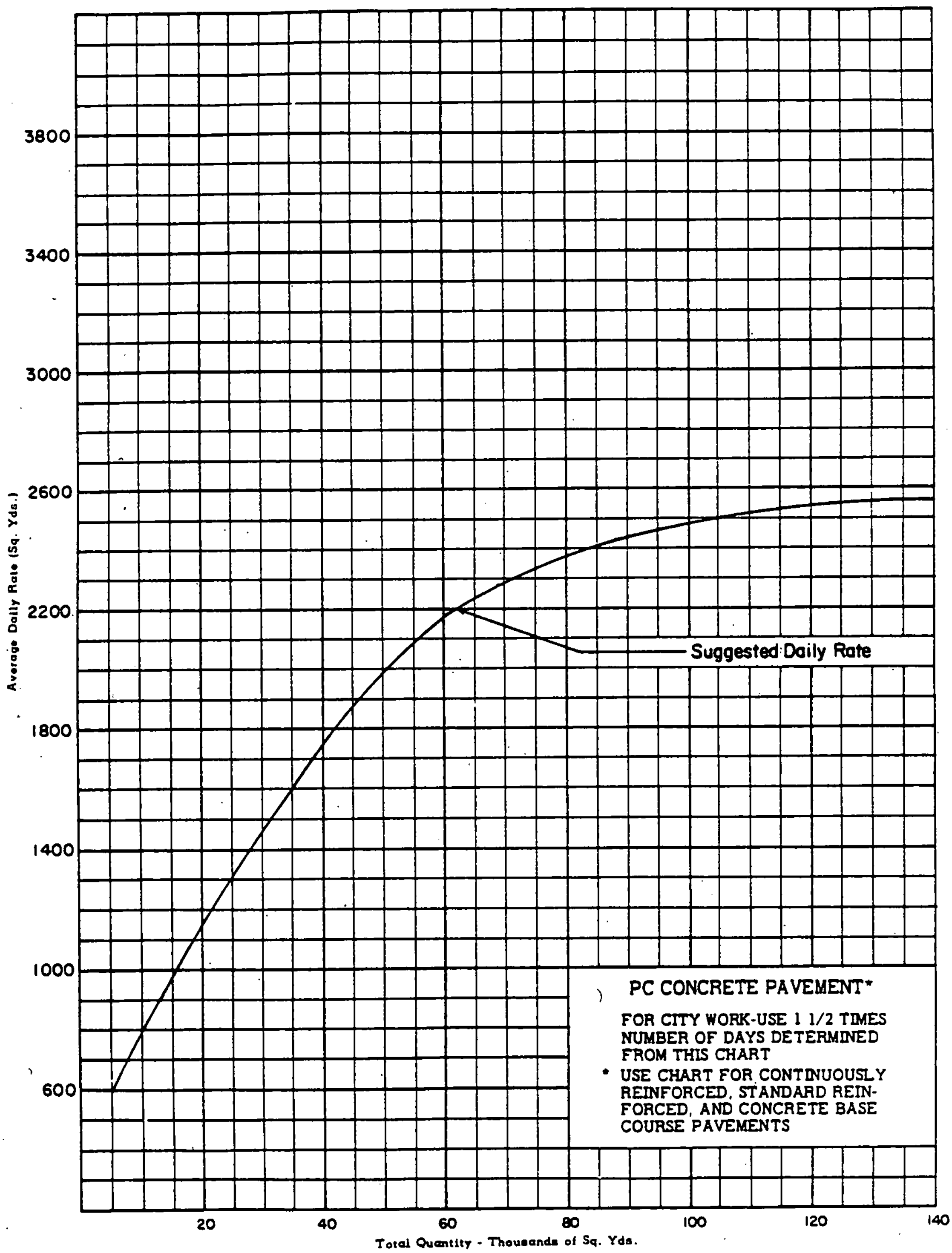


Figure 8-501.02b

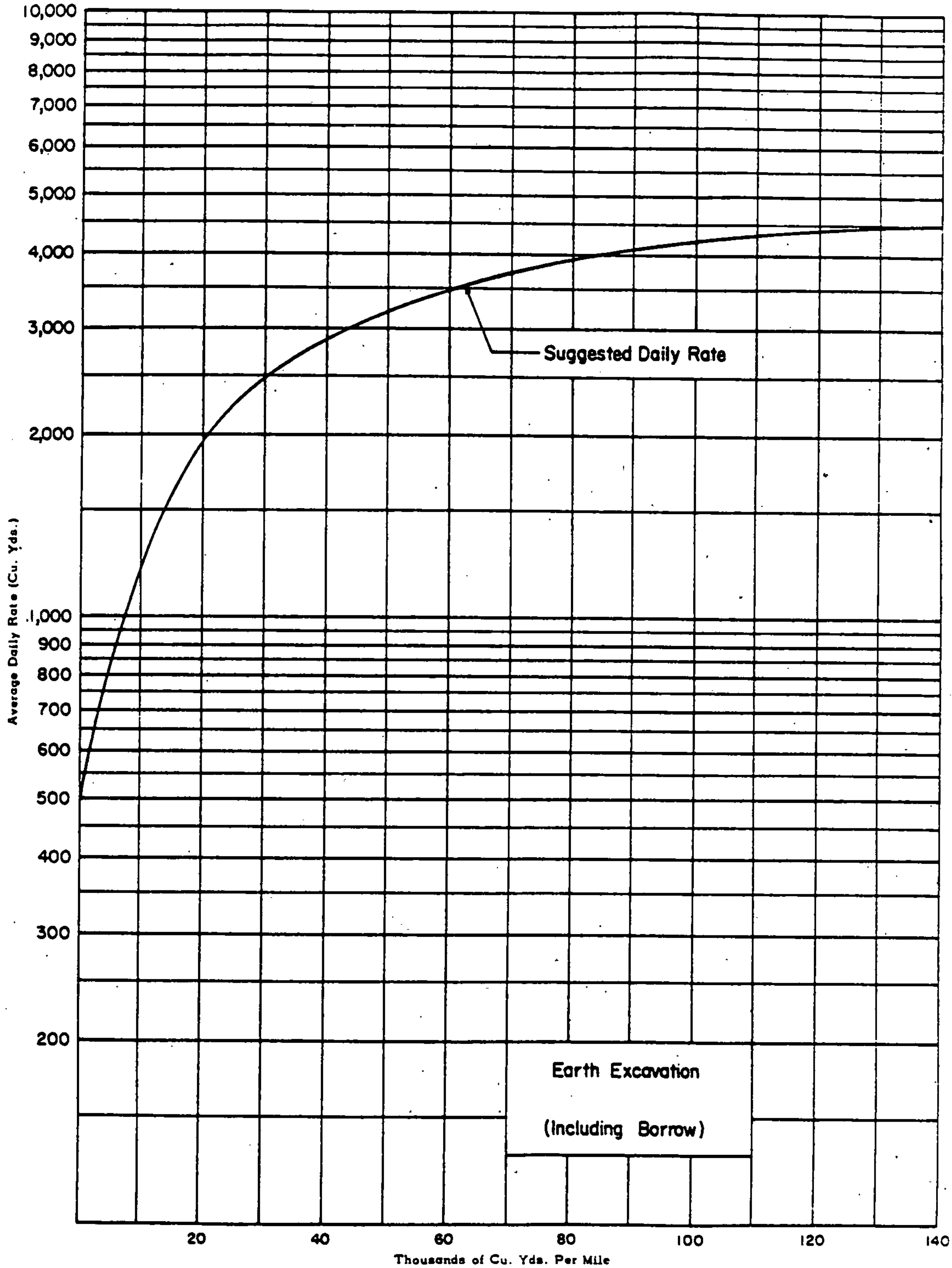


Figure 8-501.02a

BD-220 (Rev. 11-72)

STATE OF ILLINOIS

DEPARTMENT OF TRANSPORTATION

________Project________
________Route________
Section________________
________________County

ESTIMATE OF TIME REQUIRED

ITEM	UNIT	QUANTITY	RATE PER DAY	DAYS	DAYS NOT AFFECTING TIME LIMIT	TOTAL DAYS REQUIRED
Earth Excavation and Borrow Excavation	Cu. Yds.					
Rock Excavation	Cu. Yds.					
Channel Excavation	Cu. Yds.					
P. C. Concrete Pavement	Sq. Yds.					
Gravel or Crushed Stone Surface Course						
Curbs and Gutters	Lin. Ft.					
Gravel or Crushed Stone Shoulders						
Concrete in Bridges and Culverts	Cu. Yds.					
Guard Rail	Lin. Ft.					
P. C. Concrete Base Course	Sq. Yds.					
Bituminous Concrete Binder & Surface Course	Tons					
Total Actual Working Days Required						

Made by________________ Date________________ Examined________________________, 19____

Checked by________________ Date________________ ________________________ District Engineer

PROGRESS SC[illegible]ULE

County *EDGAR* Section *111* Route *F.A. 1* Project *U* Date of Starting *MAY - - - -*

Working days in Contract *110* Date of Estimated Completion *NOV - - - -* Date Contract was Executed *APRIL - - - -*

Date of Award *MARCH - - - -* Contractor *DOE CONSTRUCTION* Address *4TH ST. VILLA GROVE*

1. The working day count will start when work begins, but not later than ten days after execution of the contract unless otherwise provided.
2. The contractor must submit a copy of the progress schedule immediately after the award, and prior to the pre-construction conference.
3. The bar graphs must be drawn chronologically in the sequence that work will be performed. The legend below must be used to provide uniformity.
4. The estimated production rate shall be the quantity of work per day during the period that item is controlling.

MONTH-(Begin with month that work starts)			MAY		JUNE		JULY		AUG	SEP		OCT		NOV		PROGRESS
[redacted] Working Days [redacted]			10	10	10	10	10	10	10	10	10	10	10	10	
Work Items	Quantity & Units	Daily Production Rate	(17)												
TREE REMOVAL	16.8 ACRES	1													Proposed
											(19)(3)				Actual
EXCAVATION	24,000 C.Y.	2000													Proposed
											(4)		(6)		Actual
*SEEDING	28 ACRES	2													Proposed
									(2)		(3				Actual
STAB. SUB BASE	11450 S.Y.	2500													Proposed
									(4)			(8)			Actual
P.C.C. PAVING	12400 S.Y.	1000													Proposed
												(6			Actual
STAB. SHOULDERS.	8800 S.Y.	1500													Proposed
															Actual

Approved:

District Const. Engr. Date

Legend

Controlling Non-Controlling

Contractor

J. Doe

(Signature and Title) *V. PRES.*

AVE. NUMBER OF WORKING DAYS

J	F	M	A	M	J	J	A	S	O	N	D
0	0	0	0	15	17	17	17	16	16	14	4

NOTE: NO WORKING DAYS CHARGED FROM DEC 15 - MAY 1.

Distribution of Approved Copies: Contractor, Engineer of Construction, District Engineer, Resident Engineer

*FINAL SEEDING FOR EROSION CONTROL ON FINISHED GRADE [illegible] IN

Form BC-255

APPENDIX B

CRITICAL PATH METHOD—ESSENTIAL ELEMENTS AND TECHNIQUES (3)

THE CRITICAL PATH METHOD

During recent years the critical path method of planning, analyzing, and controlling a construction project has become a useful tool for engineers, architects, contractors, and others who are associated with construction. Many government and private agencies require the preparation and use of this method when planning the construction of a project.

In order to analyze a project by using the critical path method it is necessary to divide the project into activities. The number of units of work required to complete each activity should be determined. Then the time required to complete each activity, considering available equipment and labor, should be estimated in appropriate units, such as days, weeks, or months. Also, it is necessary to determine the time sequence in which the activities should be constructed. For example, concrete for a beam can not be placed until the forms have been erected and the reinforcing steel has been placed.

Each activity should be identified by a symbol or an appropriate description or both, and then listed in column form, with the duration of the activity, together with the activities which immediately precede and follow it, given. (This procedure is illustrated in Table 2-1.) Then the interrelationship of the activities can be indicated by a network or arrow diagram, in which each arrow represents an activity. Figure 2-1 illustrates an arrow diagram for a simple project involving five activities, designated by the letters, *A*, *B*, *C*, *D*, and *E*, for which the durations are estimated to be 4, 5, 3, 6, and 8 days, respectively.

Activities *A* and *B* can be started at the same time. Activities *C* and *D* cannot be started until *A* is completed. Activity *E* cannot be started until *B* and *C* are completed. An examination of Fig. 2-1

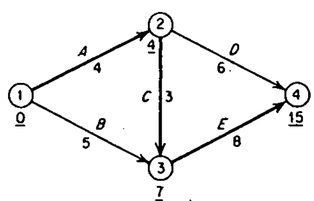


Fig. 2-1 Arrow diagram.

Table 2-1 List of activities, durations, and precedences

		Activities which immediately	
Activity	*Duration*	*precede*	*follow*
A	3	None	*B, C, D*
B	5	*A*	*E*
C	4	*A*	*F, G*
D	6	*A*	*G, H*
E	4	*B*	*I*
F	5	*C*	*J*
G	3	*C, D*	*K*
H	6	*D*	*L*
I	5	*E*	*N*
J	7	*F*	*O*
K	4	*G*	*P*
L	5	*H*	*M, Q*
M	3	*L*	*P*
N	4	*I*	*S*
O	5	*J*	*S, T*
P	6	*K, M*	*T*
Q	4	*L*	*R*
R	4	*Q*	*T*
S	5	*N, O*	*U*
T	4	*O, P, R*	*U*
U	3	*S, T*	None

reveals that the minimum total time required to complete the project is the sum of the durations of activities *A*, *C*, and *E*, which is equal to 15 days. This is the critical path for the network.

If the project illustrated in Fig. 2-1 is modified by eliminating activity *C*, with the condition that activity *E* cannot be started until activities *A* and *B* are completed, a method must be used to indicate

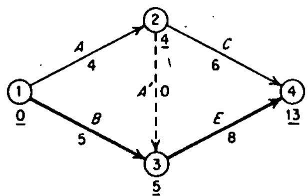


Fig. 2-2 Arrow diagram.

this requirement in the network. Since activity *C* does not appear in the network, it must be replaced with a dummy arrow, as illustrated in Fig. 2-2. A dummy is not a true activity, and it requires no time for completion. The critical path now lies along activities *B* and *E*.

DEFINITIONS OF TERMS AND SYMBOLS

Because terms and symbols are used in analyzing a project and constructing the arrow diagram, it is necessary to define these items.

Activity An activity is the performance of a specific task, such as placing reinforcing steel. It requires time to perform an activity.

Event An event represents the completion of an activity. It requires no time in itself. It is usually indicated on the arrow diagram by a number enclosed in a circle.

Arrow An arrow is drawn to represent each activity included in the network for a project, joining two events. An arrow is designated by two numbers, one at the tail and one at the head, with the number at the head always larger than the number at the tail. The length of the arrow has no relation to the duration of the activity which it represents.

Network This is an arrow diagram drawn to represent the relations of the activities and events. It is common practice to start time and the first arrow or arrows at the left end of the network and to proceed to the right.

Dummy A dummy is an artificial activity, represented on the arrow diagram by a dotted line, which indicates that an activity following the dummy cannot be started until the activity or activities preceding the dummy are completed. A dummy activity does not require any time.

Duration This is the estimated time, expressed in any desired unit, required to perform an activity.

Earliest start: ES This is the earliest time that an activity can be started.

Earliest finish: EF This is the earliest time that an activity can be finished. It is the earliest starting time plus the duration of an activity: $EF = ES + D$.

Latest start: LS This is the latest time that an activity may be started without delaying the completion of a project: $LS = LF - D$.

Latest finish: LF This is the latest time that an activity can be finished without delaying the completion of a project: $LF = LS + D$.

Total float: TF This is the amount of time that the start or finish of an activity can be delayed without delaying the completion of a project: $TF = LF - EF = LS - ES$. In Fig. 2-1 the earliest time for event 3 is the sum of the durations for activities *A* and *C* $= 4 + 3 = 7$ days. Because activity *B* has a duration of only 5 days, it can be completed 2 days prior to event 3. Thus its total float is $7 - 5 = 2$ days. If the start or finish of activity *B* is delayed 2 days, it will not delay the completion of the project.

Free float: FF This is the amount of time that the finish of an activity can be delayed without delaying the earliest starting time for a following activity. $FF = ES$ (following activity) $- EF$ (of this activity).

Critical path The critical path is the series of interconnected activities through the network for which each activity has zero float time. The critical path determines the minimum time required to complete a project.

The uses of these terms and symbols are illustrated more fully in the examples which appear below.

Persons who wish more comprehensive information on this subject may obtain such information from books devoted to the treatment of the critical path method.

STEPS IN CRITICAL PATH SCHEDULING

For persons who wish to apply the critical path method of scheduling the construction of a project it is suggested that the following steps be used.

1. Prepare a list of activities for the project.
2. Estimate the duration of each activity.
3. Determine which activity or activities immediately precede each activity.
4. Determine which activity or activities immediately follow each activity.
5. Draw a network with the activities and events properly interconnected.
6. Assign numbers to the events, being sure that the number at the head of each arrow is larger than the number at the tail of the arrow.
7. Prepare a chart with vertical columns and horizontal lines on which to list each activity with an appropriate designation: duration, earliest start, earliest finish, latest start, latest finish, and total float. A column for free float may be included, if this information is desired.
8. Determine which activities lie on the critical path.

DEVELOPING A CRITICAL PATH SCHEDULE

The following example illustrates a method of scheduling a project by the critical path method. Table 2-1 illustrates a form that can be used to tabulate the activities, together with the estimated durations, and the activities that immediately precede and follow each activity. Although the activities are designated by letters in this example, it is desirable in actual practice to designate each activity by appropriate descriptive words. Thus this example is intended to demonstrate how an arrow diagram and the related information are developed. This table provides the information specified in steps 1 through 4 of the preceding section.

Steps 5 and 6 are illustrated by Fig. 2-3. In this figure it will be noted that there are four dummies. The dummies *C′* and *D′* indicate that activities *C* and *D*, respectively, must be completed before activity *G* can be started. If activity *G* is drawn directly from event 4, without dummy *C′*, it will be necessary to draw dummy *D′* from event 5 to event 4. This then will indicate that activity *F* cannot be started until activity *D* is completed, which is not true. Thus the two dummies *O′* and *O″* are required for the same reasons.

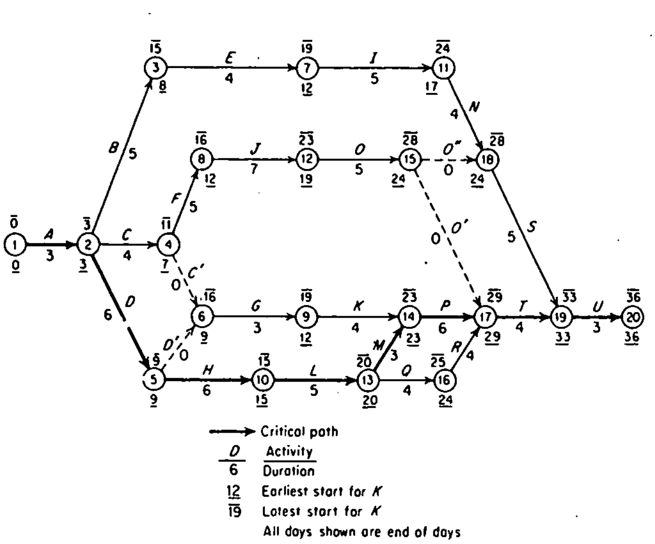


Fig. 2-3 Arrow diagram.

In the figure the heavy lines representing activities *A*, *D*, *H*, *L*, *M*, *P*, *T*, and *U* lie on the critical path. The estimated time required to complete the project is 36 working days.

Table 2-2 lists the activities, events, durations, starts, finishes, total floats, and free floats. Numbers appearing in the events columns should be taken from the arrow diagram after it is completed and the events numbered thereon.

Perhaps the easiest method of completing this table is to determine and record the earliest start time and finish time for each activity, including the dummies. The earliest start time for an activity is the controlling earliest finish time for the one or more immediately preceding activities. If two preceding activities have earliest finish times of 12

Table 2-2 List of activities and related information

Activity	*Events*		*D*	*ES*	*EF*	*LS*	*LF*	*TF*	*FF*
*A**	1	2	3	0	3	0	3	0	0
B	2	3	5	3	8	10	15	7	0
C	2	4	4	3	7	7	11	4	0
C′	4	6	0	7	7	16	16	9	2
*D**	2	5	6	3	9	3	9	0	0
D′	5	6	0	9	9	16	16	7	0
E	3	7	4	8	12	15	19	7	0
F	4	8	5	7	12	11	16	4	0
G	6	9	3	9	12	16	19	7	0
*H**	5	10	6	9	15	9	15	0	0
I	7	11	5	12	17	19	24	7	0
J	8	12	7	12	19	16	23	4	0
K	9	14	4	12	16	19	23	7	7
*L**	10	13	5	15	20	15	20	0	0
*M**	13	14	3	20	23	20	23	0	0
N	11	18	4	17	21	24	28	7	3
O	12	15	5	19	24	23	28	4	0
O′	15	17	0	24	24	29	29	5	0
O″	15	18	0	24	24	28	28	4	0
*P**	14	17	6	23	29	23	29	0	0
Q	13	16	4	20	24	21	25	1	0
R	16	17	4	24	28	25	29	1	1
S	18	19	5	24	29	28	33	4	4
*T**	17	19	4	29	33	29	33	0	0
*U**	19	20	3	33	36	33	36	0	0

* These activities are on the critical path.
NOTE: All days shown are the ends of days.

and 16 days, respectively, the 16 days will determine the earliest start time for the following activity.

After the minimum time required to construct the project is determined, 36 days for this project, the latest finish times for each activity can be determined by working backward from the 36 days. For example, the latest finish times for activities *S* and *T* are determined by subtracting the duration of activity *U*, namely 3 days, from 36 to give 33 days. The latest start time for activity *S* is its latest finish time minus the duration of *S*, namely 5 days, to give a value of 28 days. This procedure is applied along each path of activities.

The symbol *19* appearing under event 12 in Fig. 2-3 indicates that 19 days is the earliest finish time for activity *J* and the earliest start time for activity *O*. The symbol 23 appearing above event 12 indicates that 23 days is the latest finish time for activity *J* and the latest start time for activity *O*.

DETERMINING TOTAL FLOAT

The total float of an activity is the number of days or other appropriate units of time that the start or finish of an activity may be delayed without delaying the completion time for the overall project. Referring to Fig. 2-3 it will be noted that the earliest finish date for activity *B* is the end of the eighth day, while the latest finish time is the end of the fifteenth day. Thus there is a leeway of 15 − 8 = 7 days for completing activity *B*. This is the total float designated in Table 2-2. The total float of 7 days may be allocated to any one of the activities along the path *B*, *E*, *I*, *N*, or it may be allocated in parts to more than one activity, provided the total delays do not exceed 7 days.

APPENDIX C

CONTRACT TIME DETERMINATION—WYOMING

After completion of contract plans and determination of a letting date, the Highway Department determines the contract date of completion using the critical path method.

Contract time is determined independently by two individuals. Production factors and anticipated adverse weather days are considered. The critical path is based on expectations of the contractor's work methods. The time determination (contract completion date) of each analysis is reviewed by a staff engineer who compares the analyses, reconciles any differences, and determines the contract completion dates to be used in the contract documents.

Two independent analyses, the engineer's review, and the final time determination on a construction project in Wyoming are presented here.

CONTRACT TIME DETERMINATION

District 3

Project - SCPF-012-1 (27) Letting Date July 11, 1980
Road - Kemmerer By-Pass Award Date July 19, 1980
County - Lincoln Starting Date August 18, 1980

Determination Made by Al Tooker Date May 30, 1980

Node	Description	Working Days
1-2	Mobilization	10
2-4	Stripping Pits 58,000 C.Y. @ 3500 C.Y./day	17
2-3	Crushing Mtl. 278,860 Tons @ 2500 T./day	112
2-5 = 10 5-6 = 122	Uncl. Exc. 2,373,200 C.Y. @ 18,000 C.Y./day 10 122	132
6-7	Crusher Run Sub-base 163,600 Tons @ 5100 T./day	32
7-8	Cr. Base 72,000 Tons @ 2500 T./day	29
9-10	H.P. Mix Bit. Pvmt, Type I 40,100 Tons @ 2000 T./day	20
10-11	P.M. Wearing Course, Type A 6425 Tons @ 1500 T./day	4
8-9	Concrete Pvmt. 7400 Sq.Yds. @ 1500 Sq.Yd./day	5
~~2-20~~	Pipe Culverts 18" to 60" 4420 L.F.; C.M.P. 24" 154 L.F. } @ 150 L.F./day	30
12-26	Guard Rail, Box Beam 1032 L.F. @ 300 L.F./day	3
21-22	Fence, 32" WW 2BW 37,000 L.F. @ 1800 L.F./day	21
20-21	Cattleguards, 16' 2-Each @ 2-days Ea.	4
		419

CONTRACT TIME DETERMINATION

District 3

Project - SCPF-012-1(27)   Letting Date July 11, 1980
Road - Kemmerer By-Pass   Award Date July 14, 1980
County - Lincoln   Starting Date August 18, 1980

Determination Made by Al Tooker   Date May 30, 1980

Node	Description	Working Days
	Sign Structure & Sign Lighting — 2-Locations	
10-25	Drilled Shaft Foundations, 30" 100 L.F. @ 50 L.F./day	2
	– Str. Steel Delivery Time – 4 Months = Dec. 18, 1980 –	
11-12	Set Str. Steel 2-Locations @ 5-days Ea.	10
12-13	Sign Lighting, Electrical Connections, etc.	5
14-15	Paint Str. Steel	5
	Steel Break-Away Signs — 7-Locations	
23-24	Drilled Shaft Foundations, 24" 112 L.F. @ 50 L.F./day	2
	–Str. Steel Delivery Time – 4 Mos. = 12-18-80 –	} 16
	Set Str. Steel & Sign Installations 7-Locations @ 2-days Ea.	14
	Roadway Lighting System —	
5-23	Drilled Shaft Foundations, 30" 104 L.F. @ 50 L.F./day	2
	Pull Boxes, Concrete 25 Each @ 5 per day	5
	Trenching & Backfilling 4000 L.F. @ 300 L.F./day	13
	Service Points 3-Each @ 1 per day	3 } 40
	–Delivery Time - Steel Stds. — 6-Months = Feb. 18, 1981 –	
	Steel Stds., Type VI 13-Each @ 2 per day	7
	Electrical Connections, etc.	10

78

CONTRACT TIME DETERMINATION

District 3

Project - SCPF-012-1(27) Letting Date July 11, 1980
Road - Kemmerer By-Pass Award Date July 19, 1980
County - Lincoln Starting Date August 18, 1980

Determination Made by Al Tooker Date May 30, 1980

Node	Description		Working Days	
	Structure — Sta. 76+44.39 — U.S. 30 By Pass	215' b-b Abuts.		
5-18	Abut. 1 —			80
	Spread Footings (4-Ea.)	Form = 4, Pour = 2	6	
	Columns (4-Ea.)	Form = 4, Pour = 2	6	
	Cap	Form = 3, Pour = 1	4	
	Wall & Wingwalls	Form = 6, Pour = 3	9	
	Abut. 2 —			
	Steel Piling HP 10x42	437 L.F. @ 75 L.F./day	6	
	Cap	Form = 3, Pour = 1	4	
	Wall & Wing Walls	Form = 6, Pour = 3	9	
	Bent 1 —			
	Footings (3-Ea.)	Form = 3, Pour = 1	4	
	Columns (3-Ea.)	Form = 6, Pour = 3	9	
	Cap	Form = 4, Pour = 1	5	
	Bent 2 —			
	Footings (3-Ea.)	Form = 3, Pour = 1	4	
	Columns (3-Ea.)	Form = 6, Pour = 3	9	
	Cap	Form = 4, Pour = 1	5	
	— Str. Steel Delivery = 6 Months = February 18, 1981 —			
18-19	Set Str. Steel	7-Girders @ 2-days Ea.	14	61
	Deck & Curbs	Form = 20, Pour = 1	21	
	Strip Deck Forms		5	
	Approach Slabs	Form = 2, Pour = 2	4	
	Br. Railing	487 L.F. @ 100 L.F./day	5	
	Slope Paving	1820 Sq.yds. @ 150 Sq.yd./day	12	
	Paint - Str. Steel		14	

155

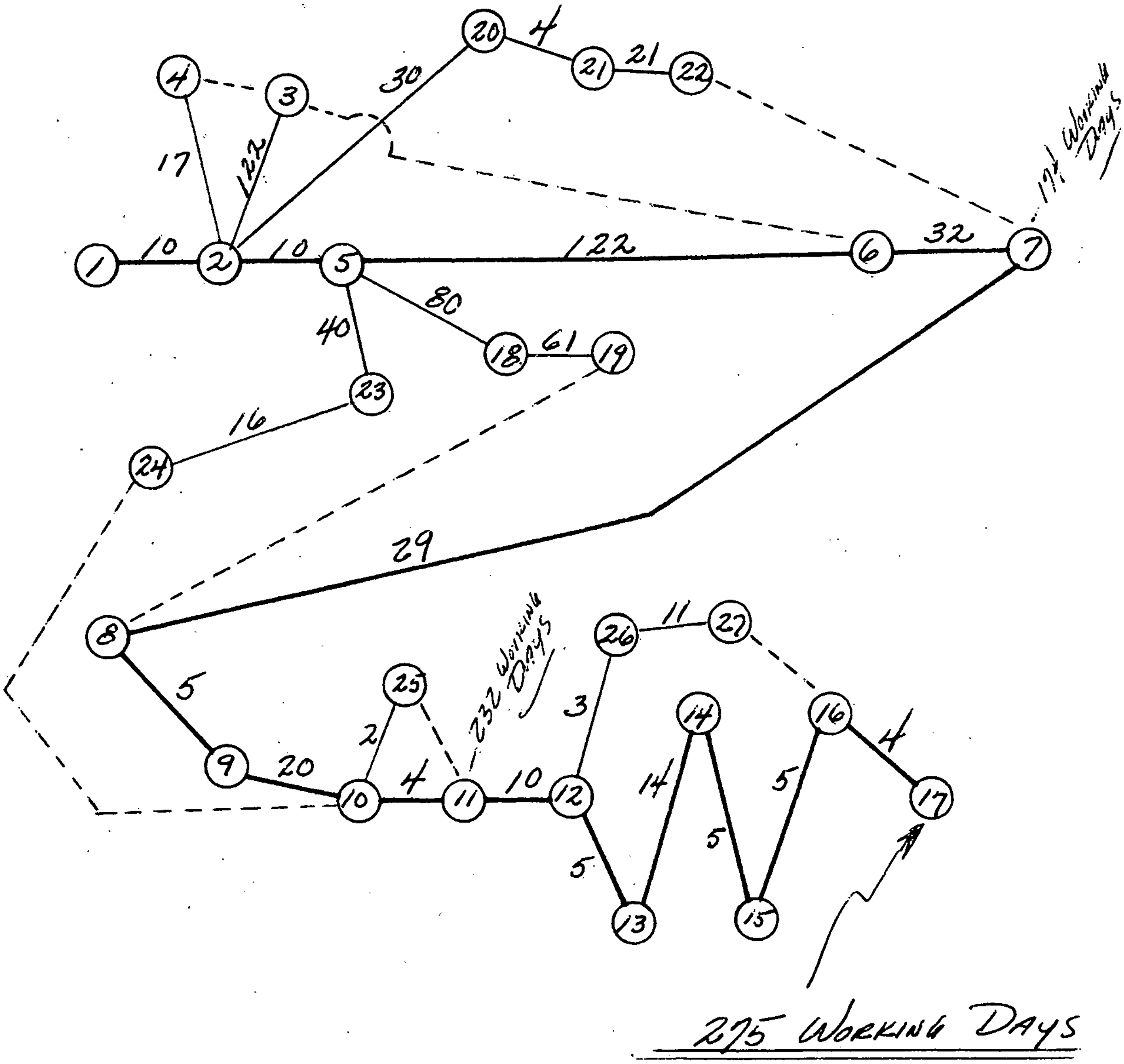
CONTRACT TIME DETERMINATION

District 3

Project - SCPF-012-1(27) Letting Date July 11, 1980
Road - Kemmerer By-Pass Award Date July 19, 1980
County - Lincoln Starting Date August 18, 1980

Determination Made by Al Tooker Date May 30, 1980

Node	Description	Working Days
15-16	Old Road Obliteration 2.3 Miles @ 0.5 Mi/day	5
26-27	Seeding (PLS) 2915 Lbs. @ 11 Lbs/Acre = 265 Ac. @ 25 A./day	11
16-17	Misc. & Cleanup Work	4
		672



STAFF REVIEW & COMMENTS:

Adjust production rate on grading to 25,000 c.y./day for last 2.2 million yds. so node 5-6 is 88 working days. Parallel 16 days of crusher run subbase. Working days will be reduced to 275 - 40 - 16 = 219 GSC

CONTRACT TIME DETERMINATION

District 3

Project - SCPF-012-1(27) Letting Date July 11, 1980
Road - Kemmerer By-Pass Award Date July 19, 1980
County - Lincoln Starting Date August 18, 1980

Determination Made by Al Tooker Date May 30, 1980

Node	Description				Working Days
	Days				
		Work	Weather	Avail.	Accum.
1980	Aug	10	1	9	
	Sep	19	4	15	24
	Oct	22	7	15	39
	Nov	20	10	10	49
1981	Apr	22	8	14	63
	May	21	6	15	78
	Jun	21	4	17	95
	Jul	22	2	20	115
	Aug	21	2	19	134
	Sep	21	4	17	151
	Oct	22	7	15	166
	Nov	17	10	7	173
1982	Apr	22	8	14	187
	May	20	6	14	201
	Jun	22	4	18	219
	Jul	22	2	20	239
	Aug	21	2	19	258
	Sep	21	4	17	275

Contract Completion Date = ~~September 30, 1982~~ Use July 31, 1982 [illegible]

[signature] 5-30-80

CONTRACT TIME DETERMINATION

District 3

Project - ICPF-012-1(27) Letting Date 7-11-80
Road - Kemmerer By-Pass Award Date 7-19-80
County - Lincoln Starting Date 8-18-80

Determination Made by Paul [signature] Date 5-30-80

Node	Description	Working Days
1-2	Mobilization	10
2-3 / 3-4	Stripping - 58000 cy - 3000/day	19
3-5	Crushing - 285000 Ton - 3000/day	95
2-2a / 2a-11	Uncl. Exc. - 2373200 cy - 15000/day	158
2-7	Pipe - 4644 L.F. - 200/day	23
2-8	Fence - 37000 L.F. - 2000/day	19
2-9 / 6-10	Cr. Run Sub-Base - 163600 Ton - 3000/day	54
10-12	Cr. Base - 72000 Ton - 3000/day	24
12-13	Conc. Pvm't - 7400 sq yd - 1800/day	4
12-14	HPMB Pvm't - 40100 Ton - 2500/day	16
14-15	PMWC - 6425 Ton - 1300/day	5
14-16	Gr. Rail - Box Beam - 1032 L.F. - 400/day	3
15-17	Standards - 13 ea - 2/day	7 } 9
	Str. Steel (Overhead Signs) - 2 ea - 1/day	2
14-18	Str. Steel (Breakaway Signs) - 7 ea - 10/day	1
18-19	Painting Overhead Signs - 2 ea - 1/day	2
19-20	Haul Road Restoration	2
20-21	Lighting System - Final Hook-up	2
17-22	Seeding - 2915 lbs - 265 acres - 40/day	7
22-23	Testing & Misc. Clean-up	10
		463
	6 mos. delivery - Str Steel	
	6 mos. delivery - Light Stds	
	4 mos. delivery - Sign Str.	

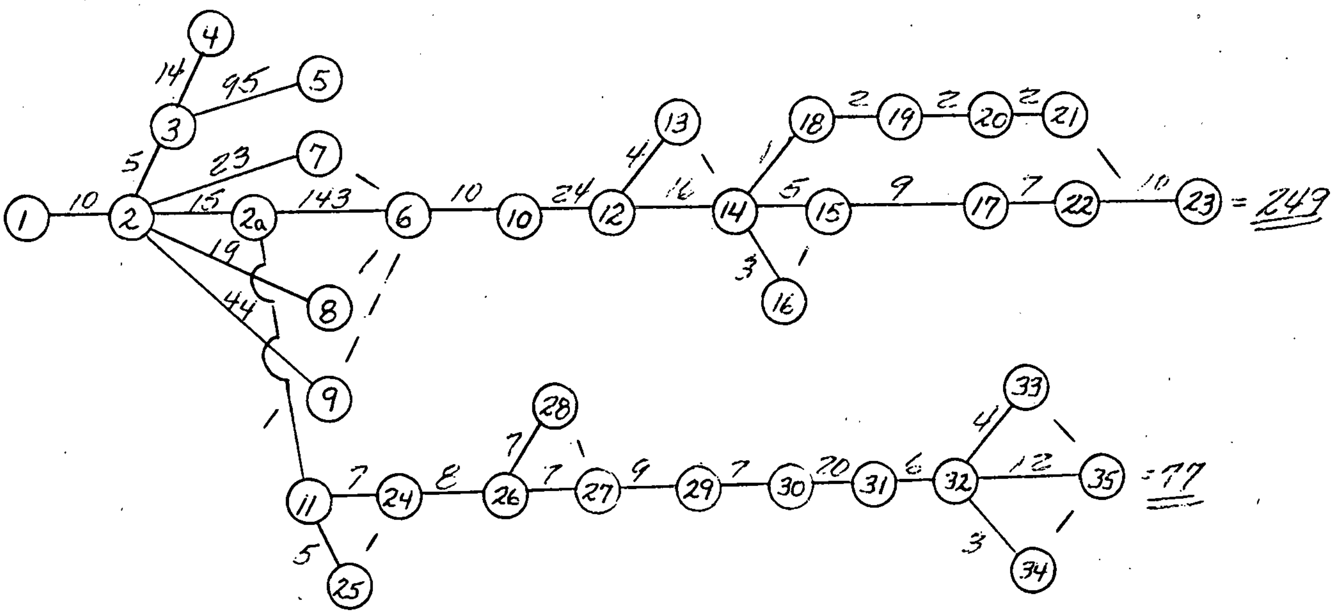
CONTRACT TIME DETERMINATION

District 3

Project - SCPF-012-1(27) Letting Date 7-11-80
Road - Kemmerer By-Pass Award Date 7-19-80
County - Lincoln Starting Date 8-18-80

Determination Made by Paul Ruethruch Date 5-30-80

Node	Description	Working Days
	Bridge - Sta. 76+44.39	
2a-11	Dry Exc.	1
11-25	Drive Piling - 434 L.F. - 80/day	5
24-26	Form & Pour Abut #1	8
11-24	Form & Pour Abut #2	7
26-27	Form & Pour Bent #1	7
26-28	Form & Pour Bent #2	7
29-30	Set Girders - 7ea. 1/day	7
30-31	Form & Pour Deck	20
27-29	Reinf. Slope Paving - 1820 sq yd - 200/day	9
31-32	Strip Deck	6
32-33	Appr. Slabs - 2days/ea	4
32-34	Br. Railing - 487 LF - 150/day	3
32-35 {	Paint Girders - 7ea. 1/day	7 } 12
	Misc. & Clean-up	5 }
		96
	Total Working Days	559
	Staff Review & Comments	
	Reduce grading to 88 working days. Increase activity 6-10 paralleling only ½ of the crusher run subbase. Working days = 249-70+17= 196 working days GSC	



Month	Work	Weather	Available	Accumulative
Aug	10	1	9	9
Sep	19	4	15	24
Oct	22	7	15	39
Nov	20	10	10	49
Apr	22	8	14	63
May	21	6	15	78
Jun	21	4	17	95
Jul	22	2	20	115
Aug	21	2	19	134
Sep	21	4	17	151
Oct	22	7	15	166
Nov	17	10	7	173
Apr	22	8	14	187
May	20	6	14	201
Jun	22	4	18	219
Jul	22	2	20	239
Aug	21	2	19	258

Use July 31, 1982 HSC

Completion Date = ~~August 31, 1982~~

APPENDIX D

ESTIMATING CONTRACT WORKING DAYS—NEW MEXICO

ESTIMATING CONTRACT WORKING DAYS

The steps listed below detail the process of estimating contract workdays for a construction project.

1. To obtain the Table Estimate, multiply the current engineer's estimate by the ratio of the 1970 Construction Cost Index to the current construction cost index.

2. Using the Table Estimate, select the base value for workdays from the Contract Workday Table.

3. From Attachment 5, select the appropriate adjustment factors for use in the "Workday Equation".

4. The number of workdays are computed using the "Workday Equation."

5. The number of workdays computed must be evaluated in relation to the letting date and the number of construction work seasons required to complete the project. Adjust the letting date whenever possible to keep the number of work seasons to a minimum. An average of 180 days per construction season should be used as a basis for this analysis.

6. Compare the number of workdays determined in Step 5 to the range of acceptable values in the Contract Workday Table.

7. The above procedure can be superseded to obtain an earlier completion date when a contract end date is required due to extenuating circumstances.

TABLE ESTIMATE

Table Estimate = Current Engineer's Estimate x [1970 Cost Index(131.20 / Current Index]

Reference: Construction Cost Indices

1967 = 100.00%	1973 = 167.80%
1968 = 114.38%	1974 = 252.94%
1969 = 117.81%	1975 = 235.27%
1970 = 131.20%	1976 = 225.92%
1971 = 149.20%	1977 = 292.87%
1972 = 137.36%	1978 = 350.00% (Estimated)

CONTRACT WORKDAY TABLE

TABLE ESTIMATE	BASE VALUE	ACCEPTANCE RANGE
Less Than $100,000	1/	≤ 100
$ 100,000	100	75-125
250,000	125	100-150
500,000	150	120-180
750,000	200	170-230
1,000,000	250	215-285
2,000,000	300	260-340
3,000,000	350	305-395
5,000,000	400	350-450
7,000,000	450	400-500

WORKDAY EQUATION

Workdays = Base Value x(1 + Σ Factors - Number of Factors)

1/ For projects less than $100,000 workdays are assigned by evaluating plan quantities and type of work.

ADJUSTMENT FACTORS
FOR PROJECT COMPLEXITY

Contract Type	
New Construction	1.00
Reconstruction	0.90
Overlay & Widening	0.80
Overlay	0.70
Safety	0.60
Number of Major Structures	
0	0.90
1-2	0.95
3-5	1.00
> 5	1.10
Traffic Handling	
Minor	0.90
Moderate	1.00
Major	1.10
Location	
Rural	0.90
Urban	1.10
Terrain	
Flat	0.95
Rolling	1.00
Mountainous	1.15
Special Considerations	
Unusual Items	0.90-1.10
Other	0.90-1.10

CONTRACT WORKDAYS CALCULATION

DATE ____________________ PROJECT NUMBER ____________________
NAME ____________________ BID ESTIMATE ____________________

Table Estimate = Bid Estimate X (131.20) / Current Index

Table Estimate = (____________) X (____________) / (____________)

Base Value = ____________ (Using Table Estimate, Interpolate from Table)

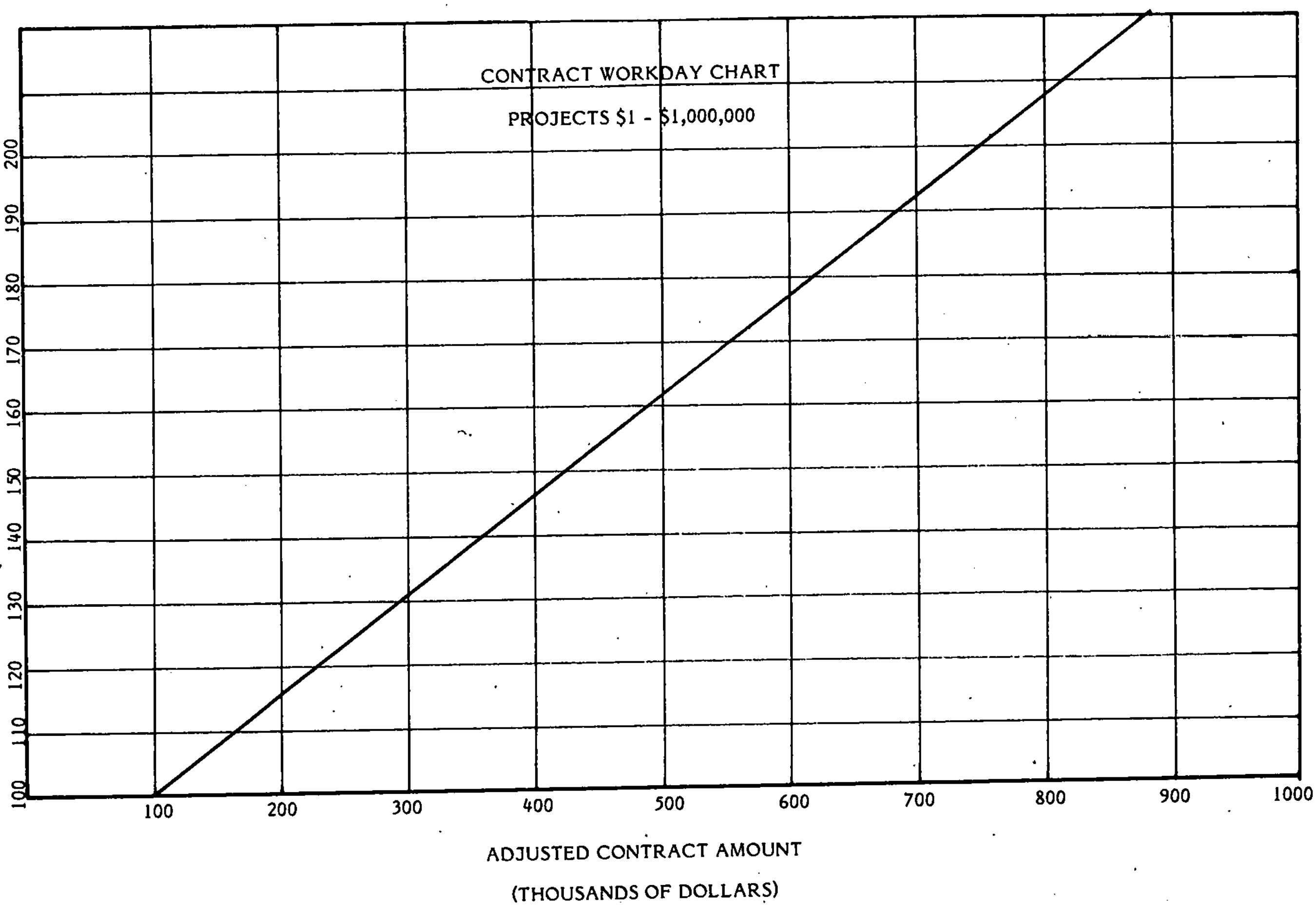
ADJUSTMENT FACTORS

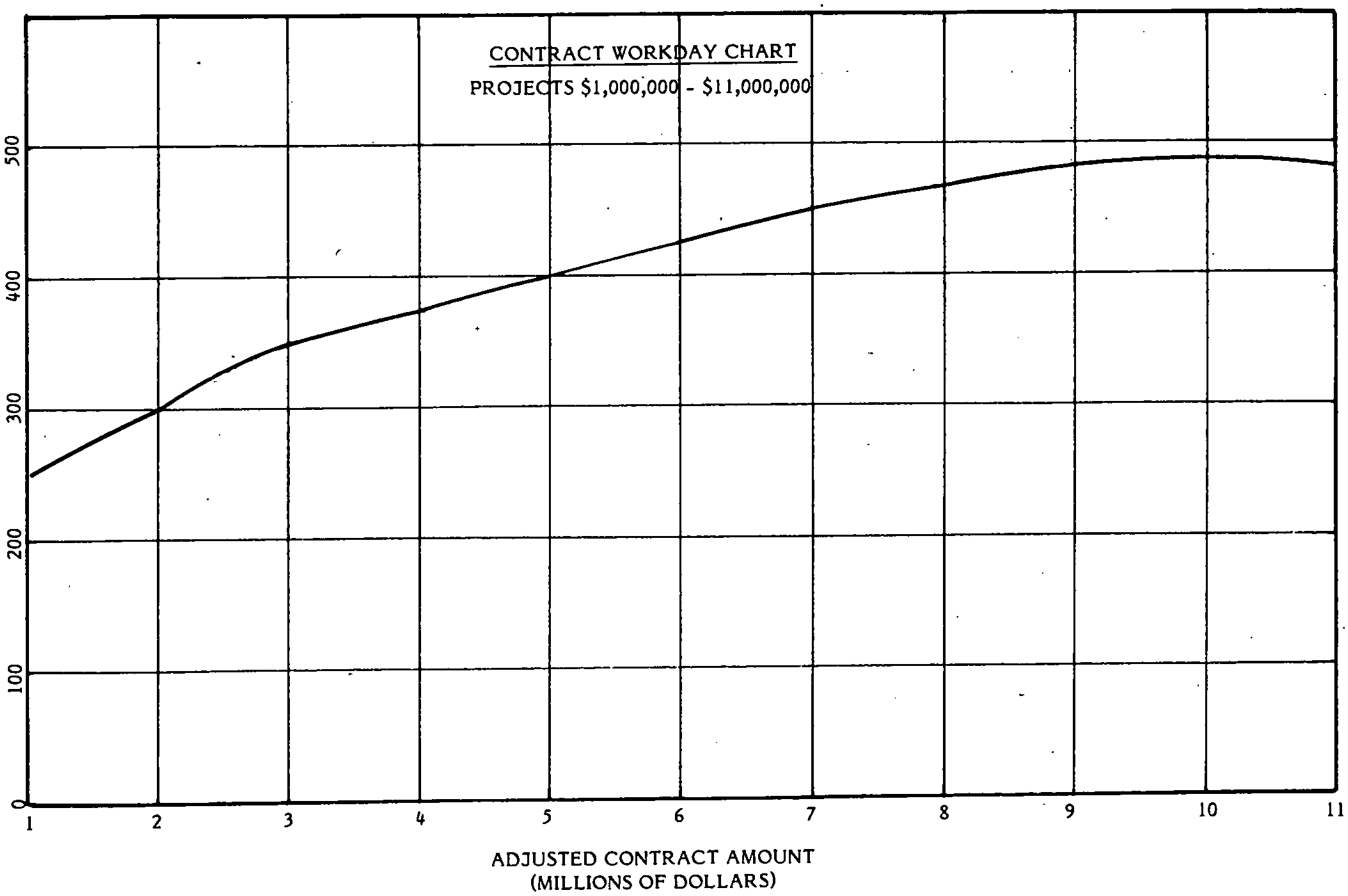
Factor	Range		Selected Value (one per factor)	Remarks
Contract Type	New Construction Reconstruction Overlay & Widening Overlay Safety	1.00 .90 .80 .70 .60		
Number of Major Structures	0 1-2 3-5 >5	.90 .95 1.00 1.10		
Traffic Handling	Minor Moderate Major	.90 1.00 1.10		
Location	Rural Urban	.90 1.10		
Terrain	Flat Rolling Mountainous	.95 1.00 1.15		
Special Considerations	Simple Items Unusual Items	.90 1.10		
Other		.90 1.10		
		Factor Total		

Workdays = Base Value X (1 + Factor Total - No. of Factors Selected)

Workdays = (____________) X (1 + ____________ - ____________)

Workdays = ____________ (Compare against Acceptance Range)
(See NOTE)


CONTRACT WORKDAY CHART
PROJECTS $1 - $1,000,000
100
110
120
130
140
150
160
170
180
190
200
100
200
300
400
500
600
700
800
900
1000
ADJUSTED CONTRACT AMOUNT
(THOUSANDS OF DOLLARS)


CONTRACT WORKDAY CHART
PROJECTS $1,000,000 - $11,000,000
0
100
200
300
400
500
1
2
3
4
5
6
7
8
9
10
11
ADJUSTED CONTRACT AMOUNT
(MILLIONS OF DOLLARS)

APPENDIX E

SUMMARY OF CONTRACT TIME DETERMINATION—MISSISSIPPI

The Mississippi State Highway Department uses a progress schedule (bar chart) both to establish and to charge contract time.The progress schedule is published in the proposal so that a bidder can identify the items and rates of work that were considered in determining the time and thus reasonably estimate resources; i.e., personnel, equipment, etc., required to complete the work within the allotted time.

The progress schedule is developed by applying production parameters to the contract work items. Allied or similar work items are grouped into phases that are positioned on a bar chart in logical sequence. The positioning allows for mobilization and transition among the various phases. Additionally, applicable seasonal limitations are taken into consideration. The resulting chart indicates the number of productive days (termed time units) that are considered necessary for the work.

Contracts are let on a completion-date basis. To establish the completion date, a monthly allotment of time units is used (see Table E-1). This table was formulated by a review of monthly contractor estimates for the various types of projects and is indicative of the contractors' ability to earn money in any given month according to previous performance.

These monthly divisions are graphically indicated on the bar chart form. The work phase bars are entered on the chart in their proper calendar position oriented to the beginning of construction date. The end result after positioning the bars establishes the specified completion date.

As previously stated, the contracts are let on a completion-date basis. However, in recognition that abnormal weather conditions may occur within the life of a contract that could prevent the timely completion of the work, the contractor is guaranteed access to the number of time units determined by the state as necessary to do the work. If, on the completion date, the contractor has not been afforded the time units, the contract is automatically extended daily until the required time units have occurred.

The progress schedules govern the daily assessment of contract time and, as uniformity is vital, they are all prepared in the central office of the Construction Division where consistent oversight can be more easily exercised.

It is recognized that the actual management of a project rests with the contractor. In order not to mandate the sequence of operations, the contractor is given the option of either accepting the state's progress schedule or submitting his own. He may not, however, modify the specified completion date.

Examples of production parameters, a progress schedule that shows the grouping of work items into phases and bar interrelationships, and instructions relative to the daily time assessments follow.

TABLE E-1
TIME UNITS

MONTH	COLUMN A	COLUMN B	COLUMN C	COLUMN D
January	5	5	6	7
February	5	6	7	8
March	9	9	11	13
April	13	14	14	17
May	17	19	19	19
June	19	20	22	19
July	21	22	23	18
August	21	22	23	18
September	20	20	22	17
October	15	17	17	15
November	10	11	11	12
December	5	5	5	7
Calendar Year	160	170	180	170

Column A: Grading and Drainage Projects
Column B: Base and Paving Projects
Column C: Bridge or Specialized Projects
Column D: Widening and Overlay (Asphalt) Projects

PRODUCTION PARAMETERS

		Small Projects 0-750 M	Medium Projects 750-1, 500 M	Large Projects 1,500 M-Greater	Overlay Projects
1.	Mob.	10 TU	12 TU	14 TU	15 TU
2.	C & G	5 TU (lead)	8 TU (lead)	10 TU (lead	
3.	Small Struct.	5 TU (lead)	8 TU (lead)	10 TU (lead)	
4.	Unclass. Exc.	2500-400 CY/TU	3500-600 CY/TU	6000-12000 CY/TU	
5.	Embankment (CF)	1500-3000 CY/TU	2000-3500 CY/TU	2500-5000 CY/TU	
6.	In-Gr. Mod.	10000 SY/TU	10000 SY/TU	10000 SY/TU	
7.	Lime Treat A	8000 SY/TY (+20 TU)	8000 SY/TU (+20 TU)	8000 SY/TU (+20 TU)	
8.	Lime Treat B	8000 SY/TU (+20 TU)	8000 SY/TU (+20 TU)	8000 SY/TY (+20 TU)	
9.	Lime Treat C	10000 SY/TU	10000 SY/TU	10000 SY/TU	
10.	Lime Treat D	15000 SY/TU	15000 SY/TU	15000 SY/TU	
11.	Cement Treat	8000 SY/TU	8000 SY/TU	8000 SY/TU	
12.	Gran. Mat. (CF)	1000-2000 CY/TU	1500-2500 CY/TU	2000-3000 CY/TU	
13.	Top Soil	500 CY/TU	1000 CY/TU	1500 CY/TU	
14.	Plating Mat.	500 CY/TU	1000 CY/TU	1500 CY/TU	
15.	EC	22,200 SY/TU	39,000 SY/TU	56,000 SY/TU	0.5 MI/TU
16.	HB Base	700 Tons/TU	850 Tons/TU	1000 Tons/TU	700 Tons/TU
17.	HB Leveling				500 Tons/TU
18.	Trench & Widen				1 Mile ea. side/TU
19.	Grout. Slabs				150-300 holes/TU
20.	Rem. RCP				250 SY/TU
21.	Clean & Seal Jts.				2000 FT/TU
22.	Prelim. Rolling				2 MI/TU
23.	HB Binder	700 Tons/TU	700 Tons/TU	850 Tons/TU	700 Tons/TU
24.	HB Surface	500 Tons/TU	500 Tons/TU	700 Tons/TU	500 Tons/TU
25.	DBST	0.5 MI/TU (2 Lane)	0.5 MI/TU (2 Lane)	0.5 MI/TU (2 Lane)	0.5 MI/TU (2 Lane)
26.	SBST	1.0 MI/TU (2 Lane)	1.0 MI/TU (2 Lane)	1.0 MI/TU (2 Lane)	1.0 MI/TU (2 Lane)
27.	Sho. Mat.				500 CY/TU
28.	RC Curb	100 FT/TU (min. 5 TU)	200 FT/TU (min. 5 TU)	300 FT/TU (min. 5 TU)	100 FT/TU (min. 5 TU)
29.	HB Curb	500 FT/TU	500 FT/TU	500 FT/TU	500 FT/TU
30.	Curb & Gutter	100 FT/TU (min. 5 TU)	200 FT/TU (min. 5 TU)	300 FT/TU (min. 5 TU)	100 FT/TU (min. 5 TU)
31.	Traffic Stripe	4 MI (of stripe)/TU (min. 5 TU)	4 MI/TU (min. 5 TU)	4 MI/TU (min. 5 TU)	2 MI/TU (min. 5 TU)
32.	Detail Stripe	2000 FT/TU	2000 FT/TU	2000 FT/TU	2000 FT/TU
33.	Legend Paint	500 SF/TU	500 SF/TU	500 SF/TU	500 SF/TU
34.	Conc. Base	5000 SY/TU	8000 SY/TU	8000 SY/TU	
35.	CP (Plain)	5000 SY/TU	8000 SY/TU	8000 SY/TU	
36.	RCP	5000 SY/TU	8000 SY/TU	8000 SY/TU	
37.	CRCP	5000 SY/TU	8000 SY/TU	8000 SY/TU	

FORM CSD-606

PROGRESS SCHEDULE NO. 2

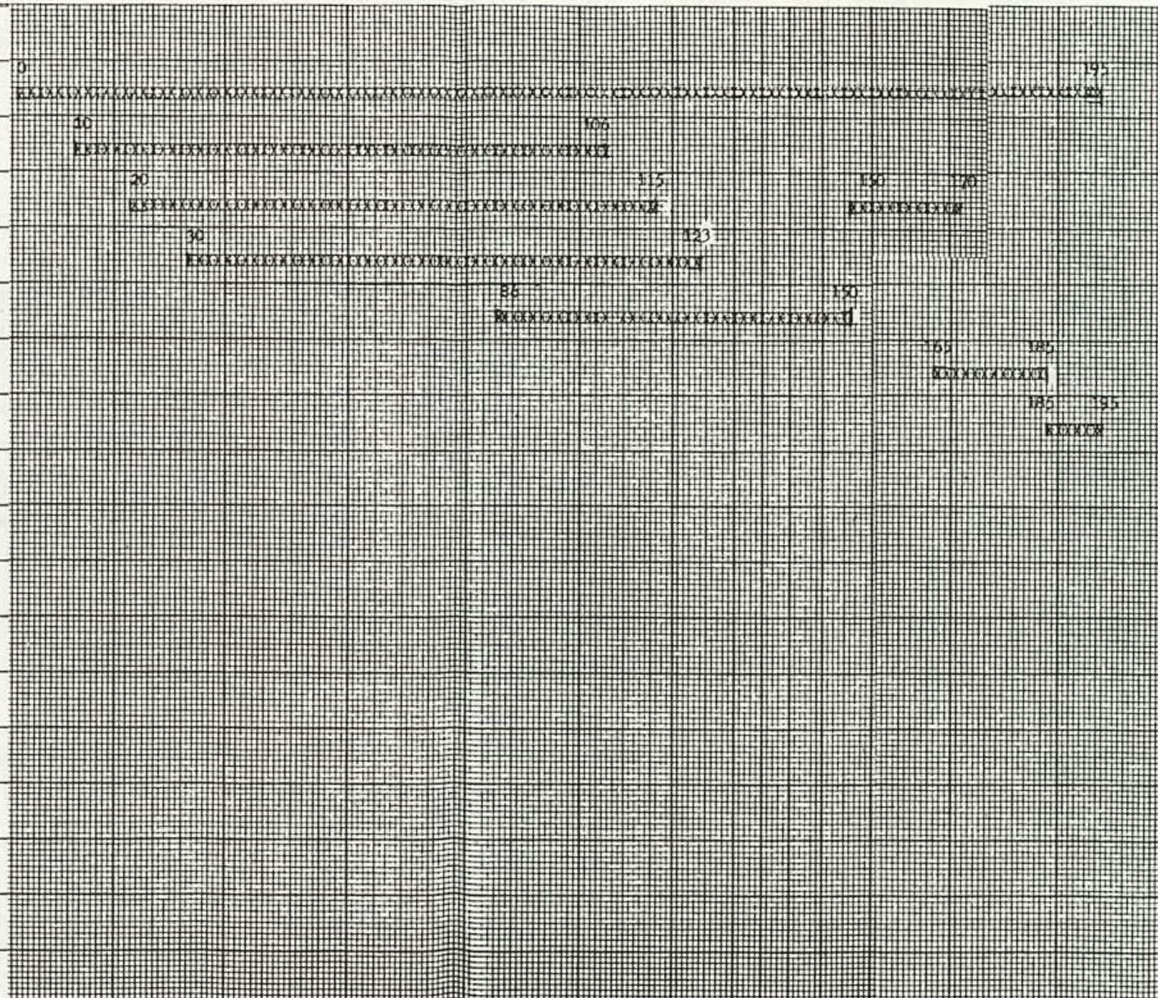
FOR USE WITH COLUMN "B" IN THE TABLE OF TIME UNITS

PROJECT NUMBER TQF-019-2(11)/09-0019-02-011-10

COUNTY Yalobusha

WORK PHASE NO.	DESCRIPTION	CONTROLLING QUANTITY	IBM NUMBERS	PHASE VALUE
1	MISCELLANEOUS		1-4, 56-58, 68, 69, 76,	
2	DRAINAGE STRUCTURES & RIP-RAP		9, 41-50, 75,	
3	EXCAVATION & GRANULAR MATERIAL		5-8, 26, 27,	
4	ASPHALT, SOIL, CEMENT, CURB AND GUTTER		25, 28-34, 54,	
5	CONCRETE PAVING		35-40,	
6	EROSION CONTROL, MED. & ISLAND PAVEMENT, & GUARD RAIL		10-24, 51-53, 55,	
7	PERMANENT TRAFFIC STRIPE, DELINEATORS & RAISED MARKERS		59-67, 70-74	

LET: Feb. 27, 1979
NTP: April 2, 1979
BCT: May 3, 1979
SCD: June 12, 1980
TIME UNITS: 195



	NO.	AVTU

5 CALENDAR DAY INCREMENTS														
MONTH	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE
TIME UNITS PER MONTH	19	20	22	22	20	17	11	5	5	6	9	14	19	20
CUMULATIVE TIME UNITS														

170 TIME UNITS PER YEAR

HORIZONTAL SCALE-1"=20 TIME UNITS

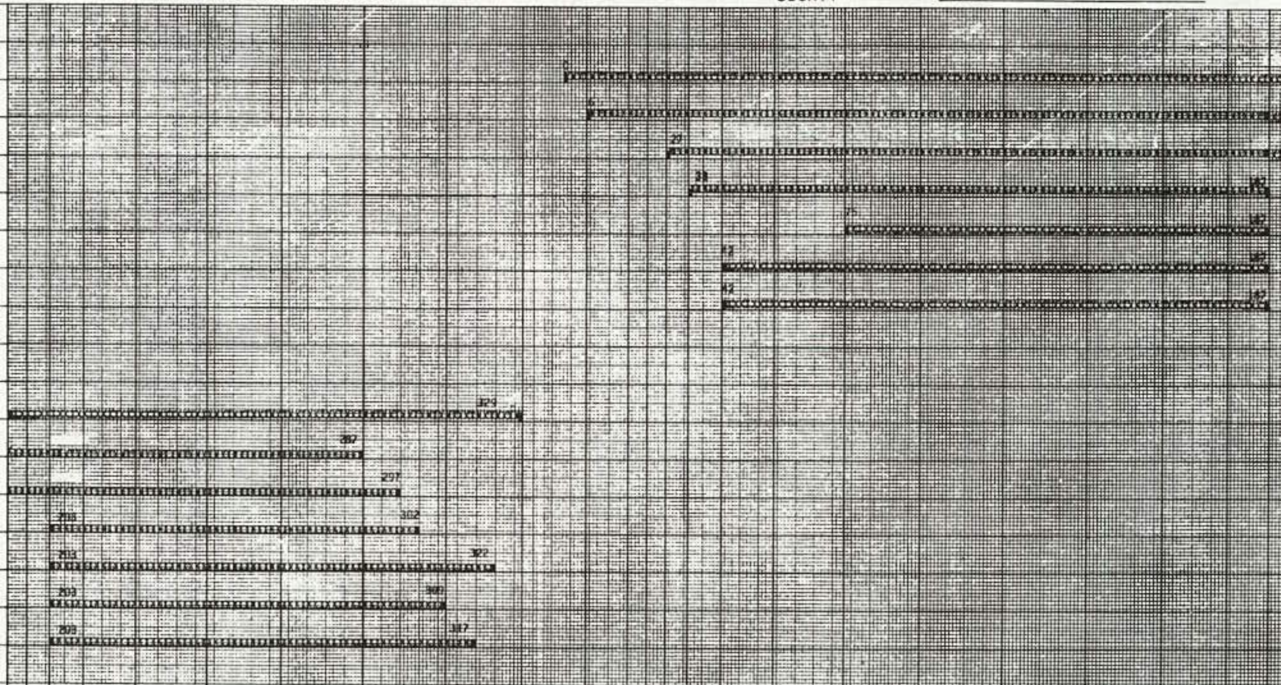
REVISED DUE TO LATE NOTICE TO PROCEED

FORM CSD-606

YEAR 1980 **PROGRESS SCHEDULE** NO. 1 YEAR 1981 **PROJECT NUMBER** 97-0008-04-035-10

FOR USE WITH COLUMN "B" IN THE TABLE OF TIME UNITS **COUNTY** Yazoo

WORK PHASE NO.	DESCRIPTION	CONTROLLING QUANTITY	IBM NUMBERS	PHASE VALUE
1	MISCELLANEOUS		3-5,27, 51-81,	
2	CLEARING & GRUBBING		1, 2,	
3	STRUCTURE		8, 33-50,	
4	EXCAVATION		6, 7,	
5	EROSION CONTROL		9-22	
6	GRANULAR MATERIAL		24,	
7	PAVEMENT		23,25, 26, 28-32	
	YEAR 1982			
1	MISCELLANEOUS		3-5, 27, 51-81,	
2	CLEARING & GRUBBING		1,.2,	
3	STRUCTURE		8, 33-50,	
4	EXCAVATION		6, 7,	
5	EROSION CONTROL		9-22,	
6	GRANULAR MATERIAL		24,	
7	PAVEMENT		23,25,26, 28-32	



5 CALENDAR DAY INCREMENTS																									
MONTH	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC	JAN	FEB	MAR	APRIL	MAY	JUNE	JULY	AUGUST	SEPT	OCT	NOV	DEC	170 TIME UNITS PER YEAR
TIME UNITS PER MONTH	5	6	9	14	19	20	22	22	20	17	11	5	5	6	9	14	19	20	22	22	20	17	11	5	
CUMULATIVE TIME UNITS																									

NO.	AVIL

HORIZONTAL SCALE-1"=20 TIME UNITS

LET: August 26, 1980
NTP: September 19, 1980
BCT: October 20, 1980
SCD: September 30, 1982
TIME UNITS: 329

DAILY REPORT OF TIME UNIT ASSESSMENT

EXAMPLE

Work Phase (1) No.	(2) Description	(3) AVTU	Ratio to Daily Total (5)	(6) Work Condition Sat.	Uns.	(7) Hours Worked	Productive Hours Available (8)	Adjusted Productive Hours (9)
2	Excavation	5,935	.55	X		4	4	2.2
3	Granular Mat'l & Prime	3,030	.28	X		7	8	2.2
5	Minor Dr Str, Etc	1,429	.13	X		10	10	1.3
8	Erosion Control Items	392	.04	X		0	8	0.3
	Daily Total (4)	10,786					(10)	6.0

÷8= 0.7* (11)

\+

Previously Assessed Time Units 69.9

=

Cumulative Time Units Assessed To Date 70.6

(1) This is a list of all the controlling phases of work that should be in progress on the date shown. The phase numbers are as they are shown on the Progress Schedule.

(2) This is a plain language description of each phase, also from the Schedule.

(3) This is the Average Value per Time Unit (AVTU) to the closest dollar for the phases shown. This value is determined by dividing the total value of all contract items in a phase by the total number of time units allotted to the phase.

(4) This is the AVTU total for all phases that should be in progress this day.

(5) This is the ratio of the individual AVTU to the total-- (3)÷(4).

(6) These columns are where the Project Engineer must exercise unbiased judgement when making entries. If soil and weather conditions are satisfactory for any part of the day, enter an X under Sat. by each of the phases for which conditions were satisfactory for work even if for only part of the day. If conditions were unsatisfactory during the entire day, enter an X under Uns.

(7) This column is self-explanatory, it is the hours actually worked on a phase.

(8) This is another column where the Project Engineer must depend upon his judgement to make an entry. It shows the total number of productive hours that the Contractor could work on each phase. The hours for each phase should not exceed 8 unless the Contractor actually worked more than 8 hours. If he works more than 8 productive hours, the entry is to be the hours actually worked. If the productive hours available are shown to be less than the hours worked, the Project Engineer should make a note of explanation on the front sheet of the diary.

(9) This column shows the adjusted productive hours for each phase. The adjusted productive hours for each phase is determined by multiplying the ratio under (5) by the productive hours available shown under (8).

(10) This figure is the total Adjusted Productive Hours for the day or the sum of the Adjusted Productive Hours for each phase.

(11) This figure is the number of time units to charge for the day. It is the quotient of (10) ÷ 8. For contracts awarded in and after June 1975, this figure is not to exceed 1.0 time unit per day.

* Round down to nearest tenth

THE TRANSPORTATION RESEARCH BOARD is an agency of the National Research Council, which serves the National Academy of Sciences and the National Academy of Engineering. The Board's purpose is to stimulate research concerning the nature and performance of transportation systems, to disseminate information that the research produces, and to encourage the application of appropriate research findings. The Board's program is carried out by more than 250 committees, task forces, and panels composed of more than 3,100 administrators, engineers, social scientists, attorneys, educators, and others concerned with transportation; they serve without compensation. The program is supported by state transportation and highway departments, the modal administrations of the U.S. Department of Transportation, the Association of American Railroads, and other organizations and individuals interested in the development of transportation.

The Transportation Research Board operates within the Commission on Sociotechnical Systems of the National Research Council. The National Research Council was established by the National Academy of Sciences in 1916 to associate the broad community of science and technology with the Academy's purposes of furthering knowledge and of advising the Federal Government. The Council operates in accordance with general policies determined by the Academy under the authority of its congressional charter of 1863, which establishes the Academy as a private, nonprofit, self-governing membership corporation. The Council has become the principal operating agency of both the National Academy of Sciences and the National Academy of Engineering in the conduct of their services to the government, the public, and the scientific and engineering communities. It is administered jointly by both Academies and the Institute of Medicine.

The National Academy of Sciences was established in 1863 by Act of Congress as a private, nonprofit, self-governing membership corporation for the furtherance of science and technology, required to advise the Federal Government upon request within its fields of competence. Under its corporate charter the Academy established the National Research Council in 1916, the National Academy of Engineering in 1964, and the Institute of Medicine in 1970.

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

ADDRESS CORRECTION REQUESTED

NON-PROFIT ORG.
U.S. POSTAGE
PAID
WASHINGTON, D.C.
PERMIT NO. 42970

000015M001
JAMES W HILL
RESEARCH SUPERVISOR
IDAHO TRANS DEPT DIV OF HWYS
P O BOX 7129 3311 W STATE ST
BOISE ID 83707