Evaluation of Scheduling Techniques for Highway Construction Projects

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In recent years there has been a substantial increase in the number and magnitude of delays in the construction of highway projects. The late completion of transportation projects is usually the result of inefficient construction processes. Delays can endanger public safety, increase the number of claims, and cause the loss of federal funds. In order to improve the current scheduling procedures in highway construction, a review was conducted of the various scheduling methods found in the literature, and of the methods used by state departments of transportation and by highway contractors. The survey has revealed dissatisfaction of all parties involved with the current procedures. Based on research conducted for the Florida Department of Transportation, a few major conclusions and recommendations have been made. There is no one rigid scheduling technique that can be applied for every highway project. The user must develop a few scheduling procedures and tailor them to each specific project according to its type, size, and complexity. In addition, new programs must be developed to improve the motivation of contractors to bid and to complete highway projects on time. The implementation of more adequate incentive fees for the early completion of construction projects and of more substantial penalties for the late completion of such projects is also recommended. Although the research has been conducted for a specific sponsor, it is based on general principles that can be adapted to other users.

The Florida Department of Transportation (FDOT), like many other state and federal transportation agencies, is in dire need of an effective method to determine, monitor, and update the scheduling methods used for highway construction projects.

Accuracy in scheduling has historically been a complex task to accomplish. Today, delays in the completion of a project can mean stiff financial penalties. Completion time delays have a major adverse effect on the federal funding of highway projects. Many states have had to forfeit federal funds due to such delays. It is, therefore, essential that a critical degree of scheduling precision be used for the successful and profitable completion of all highway construction projects.

Recognizing these problems, the FDOT sponsored a research project to evaluate the existing scheduling methods and to recommend new methods that can improve the scheduling process of highway construction projects. Because this scheduling problem is common to the departments of transportation in most states, the research methodology and conclusions can be applied to most departments of transportation and similar organizations.

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SCHEDULING PROCESS FOR HIGHWAY CONSTRUCTION

The scheduling process is composed of various steps. The first one is determining contract duration. This is the time value allowed for project completion as determined by the sponsoring agency. In most cases, it is part of the contract documents and it is set in the early bidding stage. Because contract time has a major effect on the whole construction process, it has to be based on reasonable, realistic assumptions. Hancher and Rowings (*1*) explained that severe time limitations placed on construction will result in high bidding prices and could lead to extensive claims. On the other hand, when excessive contract time is allowed, the public is denied the benefit of a needed facility, be it an intersection, a road, or a bridge.

The second step in scheduling deals with the method used by the contractor in order to comply with the proposed construction time. This step includes factors such as the scheduling techniques and the level of detail used by the contractor and the contractor's ability to complete the project on time.

The third step involves monitoring and updating the initial schedule. Delays caused by various factors, change orders, time extensions, and many other changes can affect the original schedule. The updating procedures vary depending on the organization. A few state agencies are requesting the submittal of a monthly updated schedule with the contract as a prerequisite for payment. Other agencies use their own personnel to keep an updated record of the progress. The monitoring and updating part is one of the most important as it can detect delays in early stages.

The last step includes the various factors related to the completion of the project, primarily time-related claims from both parties, but also liquidation damages and incentive fees. A few agencies have tried to avert the increasing number of claims by adding to the contract a clause providing no damage for delay. The original idea of this clause was to minimize the number of claims by contractors for projects that were delayed by their sponsors. However, from a few legal cases of the last year, it appears the courts do not have a clear-cut opinion on this subject. More time is needed to evaluate the effect of scheduling procedures on this issue.

Figure 1 is a schematic flowchart showing the various steps in the construction process.

SURVEY OF EXISTING METHODS

A survey was performed to evaluate the existing scheduling techniques. The study was based on three sources:

1. Known scheduling methods from a general literature survey.
2. Review of methods used by various departments of transportation across the United States.
3. Review of methods used by highway construction contractors.

LITERATURE SURVEY

From the overall known scheduling methods available in existing literature, only those related to highway construction were evaluated. The following is a summary list of the existing techniques in their different categories.

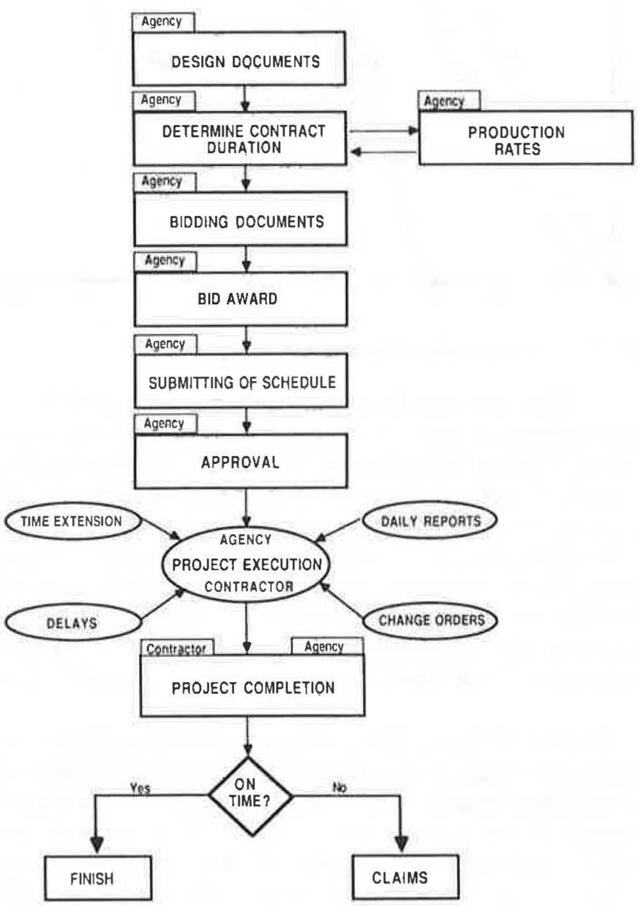

FIGURE 1 Flowchart of current scheduling procedures.

1. Linear methods
   a. Bar charts: Gantt chart
   b. Line-of-balance (LOB) methods
      (1) Linear schedule method
      (2) Vertical production method
      (3) Time-space scheduling method
      (4) Linear balance chart
2. Networks: critical path methods (CPM)
   a. The arrow diagram
   b. The precedence diagram
   c. Project evaluation—review technique

Linear Methods

Bar Charts

The bar chart, sometimes called the Gantt chart (*2*), is a graphical schedule that illustrates the progress of the project in the form of a time scale. These charts, in use since early times, are widespread in the construction industry. There are many variations in the design of the bar charts, but most are based on similar principles. A bar corresponds to each activity, and the length of the bar on a specific scale indicates the time allowed to complete the activity. The end of the last bar represents the completion day of the overall project. Figure 2 shows an example of a bar chart for a highway construction project.

Many researchers, such as Barrie (*3*), Antill (*4*), and Thomas (*5*), recognized the many advantages in using the bar chart. Among the most important are its simplicity and its graphic visibility. The bar chart is the preferred tool for scheduling in-field operations; superintendents, foremen, and laborers can easily understand and apply these charts.

However, bar charts do have a few limitations. The major one is the difficulty in showing interrelationships and interdependencies among the project activities. The second disadvantage is generated by the first one in that the bar chart does not identify the critical activities that control the project duration.

Changes and adjustments are difficult to perform on a bar chart manually; however, this limitation has been solved by use of computerized bar charts (*6*). The bar chart technique is an efficient tool in demonstrating the proposed schedule for construction projects, but it is not as effective in managing, controlling, and updating the schedule of such projects.

LOB Methods

Many highway construction projects are from a type commonly called a linear project (*7*), or sometimes called a repetitive project (*8*). The basic characteristic of a linear project is that it is executed by a series of operations all of which are repeated in each part or section of the project. In each part in the construction of a new road, the same operations such as clearing and grubbing, placing the subbase, the base, the asphalt course, and so on, have to be repeated. If the project is divided into working sections of 0.5 mi each, then the previous series of operations has to be repeated in

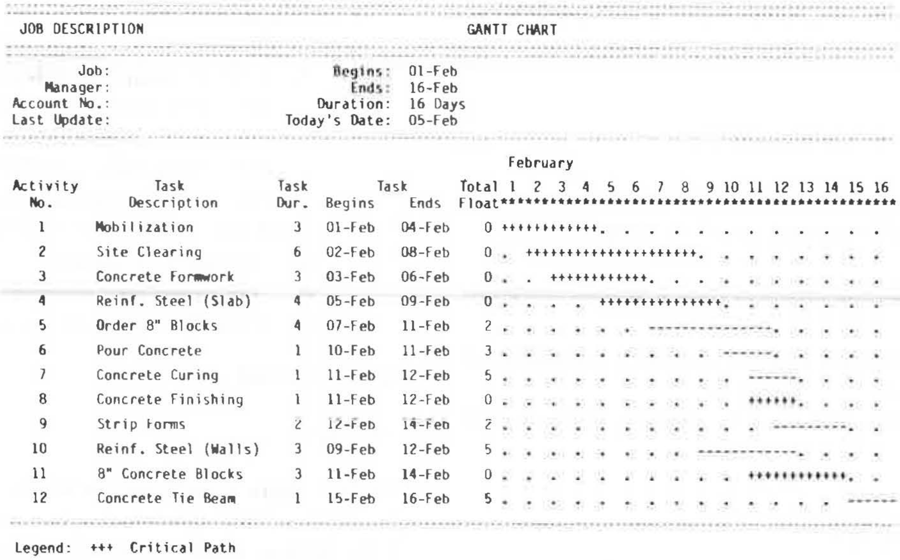

FIGURE 2 Example of a bar chart for a small highway project.

each section. Projects such as roads, pipelines, tunnels, railroads, and shoulder improvements are examples of linear projects. Because of their repetitive aspects, the use of a bar chart or CPM would not be adequate for these types of project.

Simple graphical methods known by various names have been developed in several countries during the last 40 years. These techniques include the line-of-balance (LOB) (*9*), vertical production method (VPM) (*10*), linear schedule method (LSM) (*11*), and many other versions. These techniques are popular in the Middle East and Europe, and their use is increasing in the United States.

The basic representation technique of the LOB is an x-y graph on which the vertical axis represents the location, and the horizontal axis represents the time in a reasonable scale. A series of lines represents the operations, and their slopes indicate the rate of operation in terms of time per unit distance.

Table 1 and Figure 3 are examples of the use of the LOB for an 8-mi road construction project. Table 1 presents the list of consecutive activities and their rates; Figure 3 graphically shows the design progress of the same project.

The LOB is flexible enough that each user can develop his own version. As a scheduling technique, the LOB has only two major constraints.

1. Under no circumstances can two consecutive operations overlap. This constraint is a technological one because of the nature of a linear project. The concrete course cannot be poured before the base is completed, and so on.

TABLE 1 LOB DATA FOR A HIGHWAY PROJECT

Activity No.	Activity Description	Productivity Rate (days/mi)
1	Clearing and grubbing	$r_1 = 5$
2	Earth moving	$r_2 = 6$
3	Subbase	$r_3 = 3$
4	Base	$r_4 = 2$
5	Paving	$r_5 = 6$
6	Finish shoulders	$r_6 = 4$
7	Move out	$r_7 = 3$

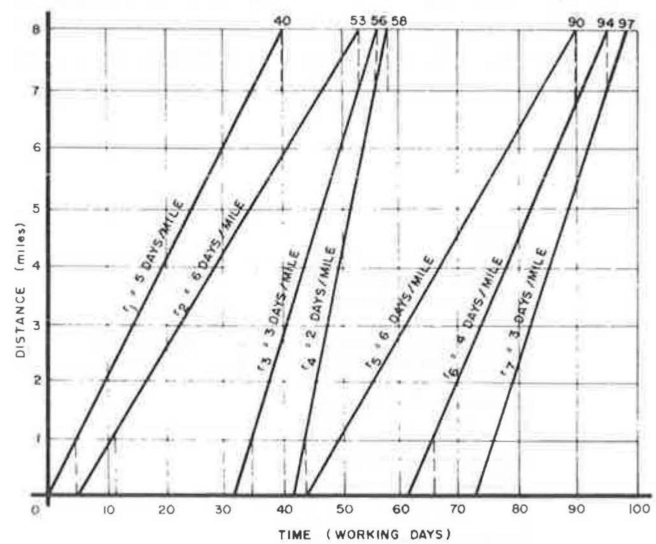

FIGURE 3 Example of the application of LOB.

2. The user has to establish a minimum interval—in terms of space or time—between the start of an operation and the start of the following one. This constraint is caused by organizational considerations because the contractor cannot start two operations in the same location at the same time. The contractor needs some interval between their starting times. As an example, a contractor wishes to determine when to start the base after starting the subbase in a specific location. The contractor's decision can be based on time intervals (at least 1 day) or distance intervals (at least 0.5 mi).

The use of LOB methods in highway construction has an enormous potential as a management and operational tool. They are extremely visual and most construction operation personnel can easily relate to them. These methods are flexible and can be used as planning devices for comparing different scheduling alternatives of various working rates, different section divisions, and so forth.

Changes and delays can be incorporated easily and the effect of these changes on the time is minimal. However, in spite of these advantages, LOB methods have a major limitation when the project is not a pure linear project (i.e., when the operations do not need to follow each other in the same order at every section). Under these circumstances, it is difficult to use the LOB, and many modifications are needed. For example, for the construction of a road in a rural area the LOB can be used successfully, but in the city where there are many interferences—utilities, obstacles, culverts, bridges, and so forth—the flow of the operation is disrupted and the LOB is no longer effective as a scheduling tool.

A second limitation of LOB techniques is that they are not well known in the United States yet, and many practitioners in highway construction are not familiar with the details of these techniques.

Networks

The CPM was developed after World War II as practitioners realized the limitations of using the bar chart in handling complex projects in construction after the war. The CPM uses a network diagram to represent the project schedule. The input information for each activity shows the interrelationship of the activities using an algorithm developed by C. Clark in 1957 (*12*). Thus, the schedule contains substantially more information for the user than the bar chart. In addition to the total time, the CPM supplies a list of values for each activity. These values are the early start, early finish, late start, and late finish for each activity. The CPM results indicate which activity is critical and give a list of activity priorities as represented by the values of the float. As this method is widely used and well publicized, the reader can find valuable information from many sources (*13-15*). Figure 4 shows an example of the CPM as used on a highway construction project by the Michigan DOT.

Although the CPM has existed for over 30 years, its application in highway construction projects has been limited. Davis (*16*) and Jaafari (*17*) state that the reason for this limited use can be attributed to the complexity of the method. The CPM has many advantages, especially as a planning and management tool. This technique enables the agency to identify the critical activities and closely monitor them. The network diagram can concisely represent many activities and show the logical interrelationships among activities. This is useful for forecasting future problem areas such as delays, effects of change orders, and so on. However, the CPM has one major drawback: due to its complexity, it is not effective as a communication tool, particularly between management and site personnel.

With the slow changes in the highway construction industry, the CPM has eventually become more accepted. This new attitude is attributed primarily to the upgrading of professional education and to the popular use of microcomputers and the availability of simple, inexpensive CPM software packages. By reducing the computation efforts and by producing explicit graphs, the microcomputer has overcome most of its deficiencies. The future common use of CPM in highway projects appears imminent.

SCHEDULING METHODS USED BY VARIOUS DOTs

The survey was based on a questionnaire that was sent to most of the departments of transportation across the United States and on two other previous research projects by Rowings (*18*) and Thomas (*19*), on related subjects.

From the survey a few major conclusions can be drawn. Most states are using the bar chart as their primary scheduling tool. By using the data of project work items and their respective quantities derived from the design department, the contract duration is determined. In many cases this is done by the engineer in charge, based on his personal experience and judgment. Other states use a list of standard production rates to aid the scheduler in calculating contract duration. Among these states are Arkansas, which uses regression curves of past data, and Louisiana, which uses zoning maps to determine how many working days are in every month in various locations.

A few states have tried a more sophisticated approach. Michigan has used a CPM diagram as part of the bid

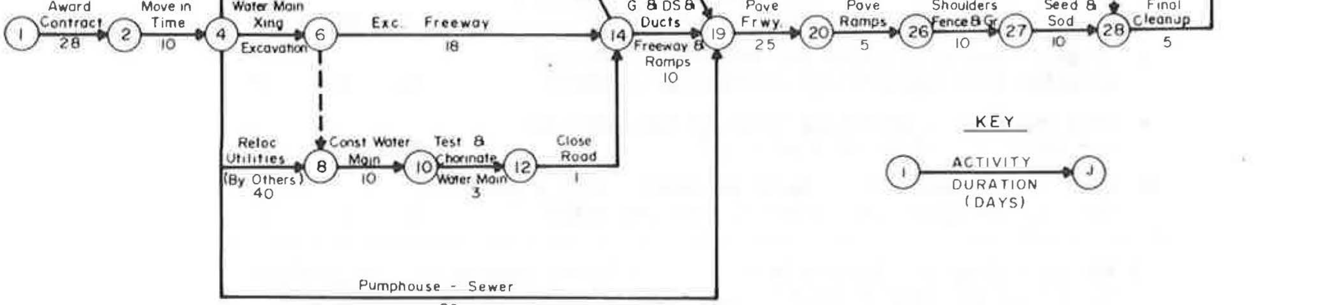

FIGURE 4 Example of a detailed CPM for a highway project (*19*).

documents, and Kentucky has used a computerized CPM schedule utilizing 14 standard items.

A few states have developed interesting methods for increasing the motivation of contractors to complete their projects ahead of schedule. Among these states is New Jersey, which includes a substantial incentive/penalty clause for critical projects performed ahead of schedule.

A different approach has been developed by Texas, Kentucky, and Mississippi that require the contractor to bid on his completion time, in addition to the estimated cost.

Though there are many new ideas in scheduling improvements, the majority of states are now using bar charts based on standard production rates as their major scheduling technique.

Survey of Scheduling Methods Used by Highway Contractors

Contractors who are involved in highway construction projects are directly affected by the scheduling procedures used by the sponsoring agency. Therefore, it is essential that the average highway contractor be able to cope with the agency's procedures, and vice versa. A survey of 70 contractors in Florida was conducted to obtain feedback from the construction industry. The survey was based on a written questionnaire and informal interviews. The results of the survey are presented in Table 2.

From the interviews and the general comments made by the contractors, a few interesting conclusions can be drawn:

- The majority of the contractors feel that the contract duration as established by most federal and state agencies is not reasonable. It does not take into account the specific conditions of each project and it is based on general assumptions only.
- The state agency should consider the effect of administrative requirements such as minority programs, environmental regulations, and other factors in the total completion time of a project.
- The majority of contractors are in favor of high liquidation damages only if they are accompanied by a substantial bonus for early completion.

TABLE 2 RESULTS OF SURVEY OF HIGHWAY CONTRACTORS IN FLORIDA

No.	Question Description	Response(1) (%)		
		Yes	No	No Comments
1	Does your company use any schedule technique to determine its own evaluation of project time?	90	9	1
2	Does your company prepare any schedule when it is not required by the contract specification?	92	7	1
3	Does your company use a schedule for each project?	83	16	1
4	If your company uses a schedule, which technique does it use?			
	4a. Bar chart	79	0	
	4b. CPM	34	0	
	4c. Line-of-Balance	4	0	
	4d. Other techniques	22	0	
5	When your company uses a schedule technique, how are the computations performed?			
	5a. By computers (only)	12	0	
	5b. Manually (only)	67	0	
	5c. Both of the above	21	0	
6	Does your company verify the proposed contract duration as established by the owner in the bid documents?	84	16	0
7	If your answer to #6 is yes, have you been given an opportunity to challenge the given duration?	39	61	0
8	If your company exceeded the stipulated contract duration have you paid any liquidation damages?	96	4	0
9	Have you ever received any bonus or incentive fee for early completion of a project?	27	31	42
10	Would your company be in favor of establishing a substantial bonus/penalty system for new projects?	87	7	6

(1) The percentage was figured based on 70 relevant answers to the questionnaire that was sent to highway contractors around Florida.

The primary conclusion from the survey is that highway contractors are ready to deal with more sophisticated scheduling methods. Many contractors have computerized their companies and now have the potential of using scheduling software packages.

Current Scheduling Procedures in the FDOT

A detailed analysis of the current scheduling procedures used in the FDOT has been performed. These procedures are common in many states. The conclusions of the analysis can be applied to many other state and federal organizations. The current FDOT procedures are based on a number of major steps.

Step 1 Contract Duration

Based on lists of quantities for specific items used by the design department, the construction district engineer prepares an evaluation of the time needed to complete the projects. A primary source is the list of standard production rates established by the state. Table 3 presents a few of these production rates.

Using a standard form for the scheduling, the engineer computes the contract time. This form is based on 15 standard operations, some of which are limited to a certain maximum time (e.g., clearing and grubbing should not exceed more than 20 days). In addition, there are two supplements for general terms and for budget work.

The total time measured in working days is converted to calendar days by multiplying by a factor of 1.825, which represents the total of weekends, holidays, and seasonal delays in a calendar year. It is based on the assumption that there are 200 working days per 365 calendar days, 365/200 = 1.825. The final figure is the contract time as it appears in the bid documents.

Figure 5 shows an example of such a computation for a resurfacing project. This method is not a pure mathematical calculation and the state construction engineer can adjust the time based on the engineer's judgment and experience.

TABLE 3 FDOT PRODUCTION RATES FOR ESTIMATING WORKING DAYS*

Work Item #	Work Item Description	Production Rate
1	Clearing and grubbing	1 to 10 acres per day (not to exceed 20 days)
2	Stabilized roadbed	5,000 sq.yds. per day (not to exceed 10 days)
3	Surface treatment	200 cu.yds. per day
4	Cement concrete	5,000 sq.yds. per day
5	Milling existing pavement	4,000 sq.yds. per day (not to exceed 20 days)
6	Storm sewers	100 to 400 linear ft. per day
7	Curb and gutter	300 to 700 linear ft. per day
8	Sidewalk	300 sq.yds. per day
9	Grassing	15,000 sq.yds. per day (not to exceed 15 days)
10	Guardrail	1,500 linear ft. per day
11	Breaking and compaction of existing concrete pavement	5,000 sq.yds. per day

* This is a partial list from the FDOT List of Production Rates

ESTIMATE OF CONTRACT TIME

COUNTY: Marion, Florida

Work Involved on Project			Working Days
1. Clearing and Grubbing	____	acres @ ___ day	-
2. Excavation (Resurfacing either cy or 1 mi/day)	6,891	cubic yards	6
3. Stabilizing	____	square yards	-
4. Base Construction	12,106	square yards	11
5. Surface Treatment	____	cubic yards	-
6. S.B.R.M. or Concrete Pavement	____	square yards	-
7. Milling Existing Pavement	102,854	square yards	20
8. Plant Mix	14,068	tons	17
9. Storm Sewer, etc.	12 L.F.	@ ___ day	1
10. Curb and Gutter	2,489 L.F.	@ 500 day	6
11. Sidewalk	____	square yards	-
12. Sprigging (Incl. Sod, Seed & Mulch)	2,310	square yards	1
13. Guardrail	____	L.F.	-
14. Breaking and Compacting Existing Concrete Pavement	____	square yards	-
15. Utility Delays			-
Total estimated working days			62
General Time: (15 days normal, 25 days Resurfacing) (Moving in preparatory to commencing work, etc.)			25
Bridge Working Time: (Only if significant part of contract)			-
TOTAL WORKING DAYS			87

TOTAL CALENDAR DAYS 87 WD x 1.825 = 158.775

Contract Duration 165 Days*

* An extra 6 days were added by the scheduler based on his personal judgment

FIGURE 5 Example of FDOT estimate form for determining contract time.

Step 2 Submittal of Schedule By Contractor

After the bid award and within the following 30 days, the contractor must submit a bar chart indicating how the contractor plans to comply with the contract duration. In many cases the contractor submits a simple bar chart to the FDOT for approval. This bar chart serves as the guideline for the performance of the project.

Step 3 Execution of the Project

During execution of the project, the project engineer follows the performance of the job. After completion of the project, the state accepts the project if it was done on time. When there are delays without any approved time extension, the contractor can either pay the liquidation charges or appeal for arbitration.

The analysis of the current FDOT procedures reveals a situation where no one party is satisfied. The main criticisms that have been heard—from FDOT and other state personnel—are centralized on a few main issues:

1. The current procedures used by the FDOT are not adequate for the large complex projects that have been common in recent years.
2. The present system of computation of contract duration does not take into consideration the special conditions for each project, such as overlapping activities, traffic interference, utilities, and so forth.
3. The contractor timetable is more of an administrative document to satisfy the wishes of the sponsoring agency than a real schedule representing how the contractor plans to execute the project.
4. The updating and control of the preliminary schedule are, therefore, not sufficient. The agency does not have the tools and the manpower to monitor the actual performance. This lack is one of the main reasons why delays are detected in late stages and why there are so many claims.
5. The current liquidation damages are too small and must be increased drastically.

Proposed Scheduling Procedures

The main conclusion of the research is that no single scheduling method can be applied for all highway projects. The variation in projects, scope, size, and duration is so large that one single technique cannot solve all the problems. The proposed procedure recommends that highway projects be classified into four categories and that a different scheduling method be used for each category. The agency scheduler would make the decision of the suitable category of each new project based on a set of guidelines and personal judgment. In each category the trade-off to the FDOT will be discussed. These proposed new procedures will have an effect on the cost and manpower involved in preparing and monitoring the scheduling. These new procedures will have an effect on most of the state highway contractors and, therefore, their potential capability to adapt these procedures must be examined. Table 4 presents a summary list of the four categories and their main characteristics.

Type I Projects

This category would include small standard projects that have little effect on public use. Such projects might include a shoulder improvement, building a culvert when there is an easy bypass, and so forth. The average cost of such a project would be under $1 million, and execution time would be less than 6 months. Bar charts would be used for determining and monitoring the time. The contract duration would be determined by production rates and other additional devices such as zoning maps and regression charts. The contractor would submit a schedule showing in detail how the contractor intends to comply with the contract time. The updating and control of the project would all be done by the project manager using the approved contractor schedule submitted by the contractor.

Type II Projects

This category includes the majority of highway construction projects that are of medium size costing from $1 to $5 million. This type of project would include bridges, roads, resurfacing urban projects, and so forth. For these projects it is recommended that the sponsoring agency determine the contract time using a milestone CPM. This method would provide the state with a few intermediate completion dates for major events in addition to the total time. The advantage of this approach is that delays can be detected in the early stages by comparing the execution time with the designed event completion. Figure 6 shows an example of a milestone CPM for a highway construction project as designed by a sponsoring agency.

The contractor would design his schedule on a a detailed CPM, but in compliance with the total contract duration and the completion time of the critical events as indicated on the preliminary milestone diagram.

Type III Projects

This category would include large projects in the range exceeding $5 million and with at least 12 months of contract time. The most important characteristic would be the complexity of the project. Typical projects in this category would include projects such as highway intersections, road improvements in heavily populated areas, and segmental bridges. For this category, the sponsoring agency would establish the contract time based on a detailed CPM that would include

TABLE 4 CLASSIFICATION OF HIGHWAY CONSTRUCTION PROJECTS

Category	Characteristics			Recommended Scheduling Technique	
	Scope	Size	Time Span	Owner	Contractor
Type I Projects	simple & standard	small, < $1 m	short, < 6 months	bar chart based on production rate	detailed bar chart
Type II Projects	typical highway project	medium, $1 - 5 m	6 to 12 months	milestone CPM	a) detailed CPM, or b) line of balance
Type III Projects	mega project, very complex	large, $5 m	long, > 12 months	detailed milestone CPM	detailed CPM
Type IV Projects	unique projects	various	very urgent	uses conventional scheduling techniques. accompanied by procedures for fast track projects (bidding on cost/time, high liquidation damage or high incentive)	bar chart CPM or LOB depends on the type of project

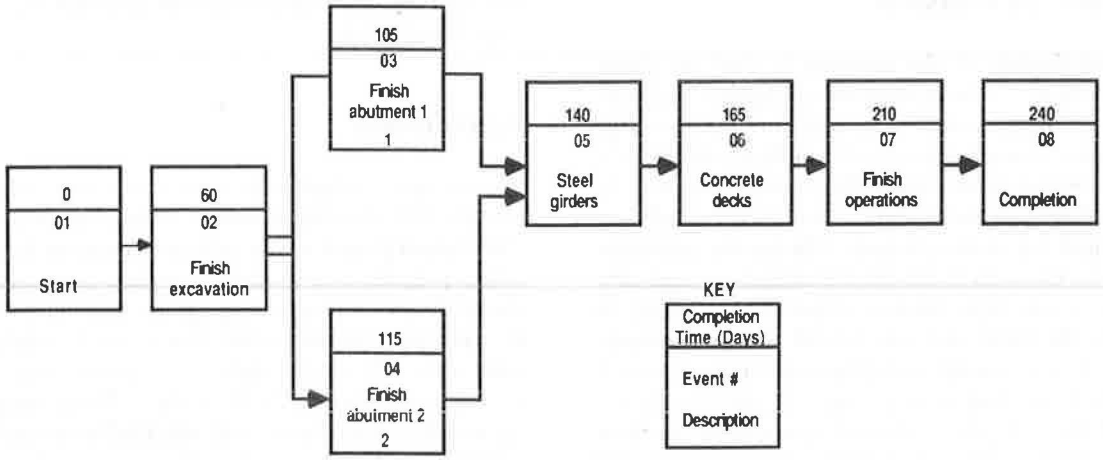

FIGURE 6 Milestone diagram for a highway project.

such activities as design, right-of-way, administrative procedures, permits, utilities, and construction. All monitoring and updating procedures would be based on the original network.

Type IV Projects

This category includes projects of various sizes and time scales the completion of which is critical to the public or the state. There could be many reasons for this completion urgency: safety, budgeting and funding, and emergency requirements. The scheduling procedures of both parties are the same as those described for Type III projects. However, additional tools must be added to the scheduling techniques to increase the probability that the contractor will meet the proposed schedule. It must be emphasized that these tools are not replacing the conventional techniques, but rather are complementing them., Some of these tools have been used in the past in the form of high incentives, penalty clauses, and so forth. Among these tools, a new concept—bidding on performance time—stands out as having a great potential for fast track applications.

Bidding on Performance Time

In this approach the state allows the contractors on certain jobs to bid on the performance time in addition to the cost. The contractor estimates his completion time and multiplies that time by the value of the time unit, which has been predetermined by the state. The lowest bidder is chosen by the lowest combination of cost and time. The following equation is used to determine the lowest bidder:

$$CBP = EC + (ET \times PUC) \qquad (1)$$

where

CBP = comparative bid price,
EC = estimated bid cost by the contractor,
ET = number of days to complete the project in calendar days as was estimated by the contractor, and
PUC = project user cost as established by the sponsoring agency for a particular project per calendar day.

From an example of an actual case based on four bidders, data for the first bidder were as follows:

EC = \$4,721,539.83
ET = 151 days
PUC = \$7,000 per calendar day (as established by the Mississippi DOT)

Using Equation 1 with the given values to determine the comparative bid price,

$$CBP = \$4,721,539.83 + (\$7,000 \times 151) = \$5,778,539.83$$

Table 5 presents a summary of the results for the example project. The first bidder, who did not submit the lowest-cost bid, was awarded the job because of his estimation of a fast completion time.

Evaluation of the Proposed Scheduling Procedures

The proposed scheduling system will require additional investment in computer hardware and software and, primarily, in manpower resources. Although these investments are substantial, they are minor when compared with the advantage that can be achieved in reducing the project completion time and in indirectly reducing the number and amount of schedule-related claims.

TABLE 5 SUMMARY OF BIDDING RESULTS FOR THE EXAMPLE PROJECT

Bidder	Estimated Cost (EC) ($)	Estimated Time (ET) (calendar days)	Project User Cost (PUC)[a] ($/calendar day)	Comparative Bid Price (CBP) ($)
1	4,721,539.83	151	7,000	5,778,539.83
2	4,544,930.41	250	7,000	6,294,930.41
3	5,271,196.81	212	7,000	6,755,196.81
4	5,215,617.24	266	7,000	7,077,617.24

NOTE: Based on the results of an actual project bid by the Mississippi DOT.
[a]The value $7,000/day was established by the Mississippi DOT.

Scheduling Procedures

The proposed scheduling system is based on the availability of high-quality professional manpower. It is essential that the state or federal organization establish a function of scheduler or time engineer, such as cost engineer, value engineer, or design engineer. The scheduling system must be managed by three levels of professional schedulers:

1. A project scheduler, in charge of monitoring the on-site time element for the construction projects assigned under his control.
2. A district scheduler, in charge of all scheduling activities of the construction projects in his district.
3. A state scheduler, in charge of all scheduling activities in the entire organization.

Using design data, the district scheduler decides to which category the new project belongs, then the district scheduler evaluates the contract duration using the previously described procedures. For Type III and IV projects, the state scheduler with the cooperation of the district scheduler determines the detailed scheduling procedures.

SUMMARY AND CONCLUSIONS

The main objective of the research was to investigate scheduling techniques for highway construction. Although the research was sponsored and conducted towards owner needs, it was apparent that it must also deal with the highway contractors' scheduling applications.

The evaluation of the current situation based on both formal and informal surveys has revealed a mutual dissatisfaction of the current procedures among all parties. With the constant delays in project completion and the increasing number of claims, there is an urgent need for better procedures that will enable the sponsoring agency to use improved methods for determining contract duration, and that will later help to monitor the project progress so it can be completed on time.

From the research a scheduling procedure is indicated that, while designed for a specific agency, can be adjusted easily to many other state or federal agencies that deal with highway projects.

Other conclusions drawn are as follows:

- Because of the variety of highway projects, it is recommended that the agency use several scheduling techniques (e.g., bar chart, CPM, and LOB). The choice of a specific technique would be predetermined by the agency scheduling procedures according to the special characteristics of each project.
- It is essential that an agency determine a reasonable contract duration. This duration must be based on sound engineering knowledge and familiarity with the special conditions of the highway construction industry. It is estimated that by using improved techniques the allowed contract duration would be decreased substantially in most cases and that the public would gain earlier use of the transportation projects. Improved scheduling procedures by the sponsoring agency force the contractor to adopt more sophisticated scheduling methods and in the long run to improve their construction performance.
- In addition to application of the existing scheduling techniques, additional tools must be developed for special projects, mainly those that are urgent and need fast track completions. These new tools would not replace the existing scheduling techniques but would be additional motivational devices for encouraging the contractor to achieve early completion of a project.
- The use of computers must become an integrated part of the scheduling process. The computerized process must also be accompanied by upgrading the professional quality of the manpower dealing with scheduling projects.
- Finally, scheduling is tied to many other areas such as estimating, budgeting, funding, claims, and more. Thus, any improvement in the scheduling process would have a positive effect on the whole construction process.

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