MULTIPROJECT SCHEDULING FOR TRANSPORTATION CONSTRUCTION PROGRAMS

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In recent years, the complexities of managing and administering state transportation programs have increased markedly. Federal funding has a significant effect on the structuring of state transportation programs because of the strict and comprehensive controls on the use of such funds. Further, the total amount of federal, state, and local funds available for transportation programs has not kept pace with the needs for new or upgraded transportation facilities. Thus, pressure is being placed on transportation program managers to maximize the use of available resources. The key to efficient use of resources—work force, money, and time—is control of production. Such control can be exercised by applying multiproject scheduling principles during the preconstruction and construction phases of a transportation project. This paper discusses the elements and operation of a multiproject scheduling system that has been implemented successfully by three state departments of transportation. It points out how multiproject scheduling can be used to anticipate resource problems likely to occur in the future and to provide the basis for determining appropriate courses of corrective action.

•IN 1968, Florida Department of Transportation management recognized the need to more closely control its overall highway construction program and the resources necessary to carry it out. Accordingly, a project was initiated to develop a management system that would direct the efforts of all personnel toward the objectives of the department.

The resulting program development, management, and scheduling (PDMS) system has been in operation for more than 4 years. Essentially, PDMS integrates the management functions of multiproject programming, financial management, and multiproject scheduling as they relate to the department's transportation construction programs. The system is designed to

1. Ensure near-term financial balance of all construction funds (programs);
2. Provide the basis for forecasting work force and cash requirements;
3. Provide a direct link among the construction work program, the legislative budget, and the project activity schedules; and
4. Provide a mechanism for identifying areas that are not proceeding in accordance with plans and for determining the most appropriate course of corrective action.

During the last 3 years, the basic elements of the Florida DOT PDMS system have been adopted by the Tennessee and Georgia Departments of Transportation. Where appropriate, these were modified to account for the management environments within each department, but the basic system concepts have been retained. All three states recognize that the key to successful implementation of the system is to gain control of production. The PDMS element that is directed toward gaining production control is the multiproject scheduling system.

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Effective control of any large organization requires that the efforts of all personnel be directed toward desired ends and that deviations from the desired courses of action be detected at an early stage. The multiproject scheduling system provides the necessary information to control production effectively within a transportation department; more important, however, it can act as the nerve center for a comprehensive management system that touches all aspects of a department's construction operations.

Multiproject scheduling is a formal means of planning and monitoring the status of transportation facility preconstruction and construction activities. One of the primary purposes of multiproject scheduling, as opposed to project-by-project scheduling, is to optimize use of all available financial and work force resources. The principles underlying the technique are not new; in fact, they are derived from several accepted scheduling methods. Multiproject scheduling combines the project scheduling methodology of the critical path method, the manpower leveling capability of line of balance charting, and the simplicity of presentation of Gantt charts. In addition, it addresses the troublesome occurrence of multiproject interference—the situation that arises when a number of projects need a particular resource (work force or money) at the same time, i.e., when need exceeds capacity.

Conceptually, multiproject scheduling is rather simple, but in practice it is a complex operation. The routine monitoring and rescheduling would not be practical without the aid of electronic data processing equipment.

FUNDAMENTALS OF MULTIPROJECT SCHEDULING SYSTEM

Several fundamental elements are necessary before a multiproject scheduling system can be implemented; likewise, several basic principles guide the system during implementation and routine operation.

Requirements

Multiproject scheduling cannot operate effectively in the absence of a stable construction work program. By stable, we mean that the work program should include all the projects that are to be constructed in, say, the next 5 to 7 years, based on current priorities. Further, the work program must be financially balanced; i.e., the estimated costs of each project phase must be reasonably matched with expected revenues. When priorities change because of unanticipated developments or updates in transportation needs, the work program can be altered accordingly. Such systematic changes will not impair overall stability of the work program, but indiscriminate changes to priorities and program emphases will cause the multiproject scheduling operation to become unmanageable.

As is true with any new program, support by management is a requisite for success. This is particularly important during implementation of multiproject scheduling, which is a tedious, one-time task. When the system is in operation, however, the tangible benefits are more immediately apparent, and support follows naturally.

Ultimately, the success of the system is contingent both on the personnel who are responsible for operating it and on the capabilities of the support staffs, especially those involved with data processing. An adequate staff whose responsibilities are carefully defined can provide for a smooth transition.

Concepts

The concepts underlying multiproject scheduling and resource balancing are given in the following.

1. Preconstruction and construction activities and events are identified and defined, and their interrelationships are established.

2. Standards are developed specifying the time and work force required to perform the activities on various types of projects.
3. Construction projects that will be active during the next 2 years are identified from the construction work program.
4. Activities and events on these projects are scheduled, and the work force is assigned according to the standards.
5. Resources (work force, money, and time) are balanced to minimize multiproject interference by adjusting the timing of project phases and activities within phases consistent with funding and contract letting objectives specified in the construction work program.
6. Project activities are monitored routinely to alert management of conditions calling for schedule revisions and further resource balancing.

These concepts, their interrelationships, and their relation to other elements of construction program management are explained below.

DEVELOPMENT OF STANDARDS

Basic to the multiproject scheduling system is a set of time and work force standards used to guide the initial project scheduling. Because of differences in production methods, staffing patterns, and environmental conditions, each set of standards is unique to a given transportation department.

Alternative Approaches

A number of approaches are available for developing standards for engineering activities. One common approach uses work measurement techniques; another relies on the experienced judgment of personnel within the department. The selection of one over the other depends on the time constraints imposed and the degree of accuracy desired.

Knowledgeable transportation department engineers, working together in a conference environment, can produce standards of sufficient accuracy for multiproject scheduling purposes. Further, the conference approach can be completed in 2 to 3 months. After the scheduling system is in operation, the initial standards can be refined, if desired, through application of selected work measures or through comparisons with accumulated data. On the other hand, a formal work measurement program requires time to gather the necessary data, which may cause a significant delay in implementing the system.

Conference Approach

Using the conference approach, department personnel in open discussion arrive at acceptable time-work force relationships, based on their familiarity with the work requirements. A series of conferences can be held, one for each logical grouping of activities (e.g., corridor analysis, survey, design and drafting, and the like). Usually, the personnel involved have operating responsibility for the activities under consideration, and they are assisted, as necessary, by personnel with demonstrated expertise in the subject areas. During the conferences, activities critical to the scheduling process are identified and defined, and time and work force requirements are established from any historical data that may be available. At the conclusion of the conference series, the standards are documented and a reference manual is produced.

The conferences also serve as a forum for the exchange of ideas on operating methods and procedures and on areas of concern to individuals. Frequently, matters are introduced that require top management attention. In addition, members of the department who will be working with the multiproject scheduling system are given an opportunity to participate in its development.

Preconstruction Activity Standards

Preconstruction activity standards are used to establish detailed project schedules and to project department work force needs. Each standard includes (a) a description of the activity or event (an activity requires time and work force; an event is a point in time); (b) the skill classes of the work force required, if appropriate; (c) the expected time required of the activity for various types of projects; and (d) the relationship of the activity or event to other activities and events in the same project (i.e., its relative position on the critical path network). This provides the base of information necessary to schedule all the activities of a typical preconstruction project over time. Additional project parameters (such as project length, number of bridges, and estimates of land tracts to be taken) are necessary for the calculation of activity time and work force requirements applicable to a specific project.

Construction Engineering Supervision Standards

Standards for construction engineering supervision activities are used primarily to forecast work force requirements for construction sites. These are not standards in the same sense as preconstruction activity standards because of the differences in responsibility for work activities. In preconstruction, a department often performs most work in-house; therefore, it has the latitude to effectively control production. In construction, a contractor normally schedules and performs the work. The department observes, inspects, and otherwise supervises construction to ensure that it meets the requirements of the contract, but it does not exercise exacting control over the contractor in the scheduling of work. In view of this, the standards for engineering supervision activities represent standard work force requirements for those activities the department performs in its role as construction supervisor.

PROJECT SCHEDULE DEVELOPMENT

Detailed schedules are prepared for all projects, for which some preconstruction or construction phase has been programmed for the forthcoming 2 fiscal years. Projects programmed to begin after that period are not scheduled initially. Detailed schedule and activity control beyond 2 years becomes rather impractical, for even a relatively stable construction program will experience modifications in that time frame.

However, the project schedules that are prepared may include activities beyond the 2-year time frame. In such a case, the complete schedule for the project should be included in the schedule data base. It is simpler to develop the entire schedule for a project at one time than to return at a later date and complete the schedule. Projects that are programmed to begin after the 2-year period are brought onto the file in 6-month increments.

Schedule Data Base

The construction work program provides the essential data for schedule development (e.g., project description, project limits, fiscal-year cost of major phases, and project priority). The activity-event standards provide the guidelines for subdividing the project phases into schedulable elements—the specific activities that are to be performed and critical events that must occur. The schedule data base includes for each activity estimated start date, elapsed time (or activity duration), work force requirement by skill class, and name of person responsible. The status of projects that are under way at the time the system is implemented is obtained from appropriate engineering unit managers.

Project Plan Report

The initial product of the schedule development process is the project plan. The project plan report produced by the system is in the form of a bar chart that displays, for each project, all necessary activities and events in their proper sequence and the time frame during which they are scheduled to occur. Activity and event names for a given project are on the vertical axis, and week-by-week dates are on horizontal axis. The bar is comprised of one or more numbers, each of which represents the amount (in person-weeks) of a particular skill class of work force required during the week for a specific activity. The smallest unit of time considered in the multiproject scheduling system is 1 week, although work force assignments can be made in increments of $^1/_{10}$ person-week. Across the top of the project plan report is listed the key descriptive project information (number, name, limits, description, and programmed or allotted funds, by phase). Also shown for each activity are the name of the person responsible and his location.

After the initial project schedules have been developed, the project plans are reviewed by engineering unit managers to ensure that the activity duration and work force assignment are reasonable and to confirm the status of ongoing projects. The schedule data base then is revised to reflect any changes resulting from the review. Later, when work is reported on any activity, the work force actually used and the amount predicted for completion appear in a separate bar beneath the originally scheduled bar. In this manner, both scheduled and actual work force needs are shown on the project plan report.

RESOURCE BALANCING

A balanced construction work program and funding structure are achieved initially through the multiproject programming process. Full resource balancing is accomplished during the work scheduling operation, wherein work force requirements over the 2-year schedule period are leveled within the established funding and time constraints. During the schedule period, there must be continuous interchange between multiproject programming and multiproject scheduling because of resource interrelationships. If projects are programmed without regard to activity time and work force requirements, then the program is unrealistic. Conversely, if project activities are scheduled without regard to program funding availability, then the schedule is unrealistic.

Multiproject Interference

Schedules are developed on all projects requiring department work force during the forthcoming 2 fiscal years. These schedules first are reviewed by the responsible activity managers and then are revised as necessary so that individually they are reasonable. At this point, whether the schedules, taken as a group, are reasonable has not been determined.

Scheduled activities of many projects are drawing on a common resource, the work force. It is likely that this interaction between schedules has led to multiproject interference—the situation that arises when a number of projects require a common work force at the same time, such that all requests cannot be satisfied. The reverse case is also likely to occur, that is, periods when the available work force is operating below capacity because only a few projects need the resource.

Work Force Pools

As noted earlier, one of the elements of the schedule data base is the size of the work force required for each project activity. The available work force is identified in the data base by work force pool (road design, right-of-way), by skill class (engineer, technician, draftsman, appraiser), and by location (central office, district office, other).

Each pool has an established level of personnel available for project-related work during a given budget year, although this number may vary somewhat from week to week because of vacancies and part-time employment. Related project activities are grouped into separate work force pools. For example, the preliminary plans, right-of-way plans, signal plans, and construction plans activities all might be performed by the design pool. The pools then become the focal point for work force balancing.

Work Force Balance Report

Initially, project schedules are developed without consideration of potential work force conflicts. By comparing a number of project plans, it may be possible to identify areas where scheduled work force exceeds that available for a particular pool. But to locate many such areas, take action to correct them, and assess the impact of such action in this manner would be a tedious process.

To facilitate this task, the work force balance report summarizes the scheduled work force for all related activities in a given pool. Then the scheduled work force and available work force are compared on a week-by-week basis, and net differences are displayed. The result is a week-by-week look at excesses and deficiencies of the work force for the pool. The work force balance report uses basically the same format as the project plan report. However, it lists all projects, by activity, within a work force pool. In addition, it contains appropriate summaries of the number of personnel by skill class within each pool and provides comparisons of required versus available work force. It is distributed routinely to work force pool managers for control of their operations.

Work Force Balancing

The initial work force balance report typically exhibits a random pattern of excesses and deficiencies of the work force and denotes the peaks and valleys of the scheduled work load. The object of work force balancing is to even out these excesses and deficiencies over time and thereby to make more effective and efficient use of the available work force.

The first step in balancing the work force is to adjust the project schedules. On a priority basis, the starting dates of certain activities may be delayed or moved ahead, or an entire project may be shifted forward or backward in time. New work force balance reports are then produced to show the results of the project and activity shifts. This process continues until all pools show reasonable balance. In instances where short-run excesses or deficiencies persist, deliberate assignment of overtime for short periods of time on selected activities may accomplish leveling. Farming out work from pools with deficiencies to those with excesses may also be a short-term solution. But, if long-run deficiencies are apparent for several pools through a major portion of the 2-year period, three basic alternatives should be considered: hire additional personnel; use external personnel (consultants); or revise the construction work program.

This type of analysis is performed before the department's annual legislative budget request is prepared so that the need for additional personnel can be evaluated more realistically. It also provides excellent budget support, as requests for personnel may be expressed in terms of the work to be done. Thus, budget approving authorities, including the state legislature, can readily see the alternatives available.

From a personnel management standpoint, the work force balance report provides transportation program decision makers with a tool for assessing the effect of changes in the established construction work program. The effect of project additions, deletions, and phase shifts on planned work force levels can be readily identified. Thus, appropriate actions can be formulated at an early date to correct potential work force excesses or deficiencies.

Responsibility for Balancing

The responsibility for work force balancing must be assigned to the appropriate level within a department. The adjustment of project activities and phases on a priority basis to even out minor variances can be performed by work force pool managers in cooperation with a centralized scheduling group. Crossing organizational lines (such as farming out work to excess pools) or assigning overtime should be decided at the central or district office management level. Decisions on long-range alternatives (such as adjustments in the work program, use of consultants, and adjustments in major personnel) should be made at the executive management level.

SCHEDULE MONITORING

The multiproject schedules represent, at one point in time, the best estimate by department management of the plan for completing the construction work program. But department management operates in an extremely dynamic environment in which changes that affect the program occur daily. For the schedule to be useful in managing the program, it must present a realistic picture of the work to be done and when it is to be accomplished. To maintain this current status requires that routine progress checks and adjustment of discrepancies be made.

Monitoring the project is the key to successful operation of the multiproject scheduling system. Use of many scheduling systems has discontinued either because routine project progress reporting was not maintained or because the monitoring procedure was so time-consuming and tedious that it was not followed. Thus, a means must be incorporated that will provide ease of schedule monitoring but that will require a minimum of input from the engineering units.

Routine Updating

Periodically, the schedule data base is interrogated and all activities on projects for which work is scheduled in the current period are identified. The resulting update report specifically identifies, by work force pool, each project activity, the person responsible for its completion, and its scheduled status (e.g., due to start, in progress, due to end). The update report is transmitted to the responsible person, who enters the work force actually used during the current period and an estimate of the number of weeks to completion. For events, only the date of occurrence is required. Any work performed ahead of schedule is not printed on the update report; the responsible person must enter this information. The completed update report then is returned to the centralized scheduling group. After the status of all activities and events has been reported for those projects in progress, the schedule data base is updated accordingly.

Updating typically is performed on a biweekly or semimonthly basis. Longer time intervals result in activities and projects getting out of control, as well as a tendency toward improper status reporting. In addition, the biweekly or semimonthly period usually corresponds to the payroll period. Payroll data are used to audit information received through the schedule updates to ensure input data reliability.

Management Reports

The multiproject scheduling system produces management reports when projects are off schedule. If progress is being made as scheduled, no reporting is necessary. However, if projects or activities are ahead of or behind schedule, the work force managers affected need to know. The exception report points out, on an individual activity basis, where progress is deviating from the schedule. Thereby, the manager need not analyze a number of update reports, project plans reports, or work force balance reports to determine the overall status of work in the pool. Based on the exception report, sched-

ules can be adjusted to compensate for early or late completion. After such adjustment, the potential availability of additional workers to handle unforeseen work loads or priority changes can be assessed and the appropriate corrective measures taken.

In addition to furnishing each engineering unit manager with a copy of his own projected work load, progress of the activities that immediately precede his assignments is provided. For example, the design engineer is informed routinely of the progress of the location engineer and can take into account any expected variations in the upcoming work load.

The reports discussed provide detailed information on the project schedules and the progress being made on an activity-by-activity basis. In addition, a consolidated picture of each project and of the overall transportation program in general is required by department executive management. The project progress report is designed to fulfill this need. It groups activities so that only the most significant project elements are shown and displays past performance, present status, and predicted completion. Other pertinent project information is included, such as estimated construction cost, fund structure, and funds allotted to each phase. This report is provided to management on an exception basis. If deviations occur in a project that will alter the work schedule or the proposed contract letting date or if significant technical or funding problems are encountered, the project progress report calls this to the attention of top management.

CONCLUSIONS

Implementation of a multiproject scheduling system that is linked directly to a financially balanced construction work program can significantly change the decision-making processes of management. Specifically, it can transform what is often a mode of reacting to current problems into a forward-seeking process. Executive managers can deal primarily with establishing department policy with regard to future transportation programs. Division-level managers can focus on the near-term planning that is necessary to carry out the established policy. Activity and project managers can concentrate on the development of short-range schedules necessary to accomplish the near-term plans and on supervision of ongoing work. Responsibility for meeting the schedules is assigned to specific individuals, who periodically report their progress and have their productivity measured with respect to a standard. Indeed, successful implementation of multiproject scheduling is characterized by management asking, "What is likely to happen and what alternatives are available?" rather than, "What happened?"

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