Development, Implementation, and Use of a Project Management and Scheduling System in Minnesota Department of Transportation

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The Minnesota Department of Transportation (Mn/DOT) has a preconstruction engineering management system. The Project Management and Scheduling System (PMSS) encompasses activity scheduling, project funding, and human resource planning. The scheduling subsystem reflects the current development status, construction cost, and letting dates for every project in the work plan and communicates all changes throughout the organization. The funding subsystem tracks project funding from the program plan through the commitment process and identifies authorized amounts, committed dollars, and current program estimates. The human resource subsystem assists in making scheduling projections. As project schedules are developed, the impact on resource availability is monitored and leveling considerations are applied. System benefits include reinforcement of planning effort, identification of project delivery problems, support of budget requests, and actual versus planned evaluation of expenditures. PMSS is a user-controlled system supported by a centralized service group. For maximum responsiveness, PMSS provides interactive on-line capabilities for data entry, inquiry, updating, and simulation at cathode ray tube terminals located throughout the department. Hard copy reports can be generated on request. Development of PMSS was a joint effort involving consultants and state transportation department personnel, supported by the state's central computer center and a management committee, a user steering committee, and an activity task force made up of functional managers. Implementation was staged in four parts, phased over a 21-month period. Problems encountered in initiating the system included (a) the computer's intimidation of people, (b) the natural resistance to change, (c) the basing of the implementation on a predetermined time frame rather than on user acceptance, and (d) the failure of some programs to deliver as promised, which challenged the credibility of the entire system. The complete development cost for PMSS was $558 750. When amortized over five years, this amounts to less than 0.06 percent of Mn/DOT's average annual construction expenditure.

Never before has the need been greater for management systems to help transportation agencies improve their operational effectiveness and productivity than during the current period of declining resources and fiscal restraint. The Minnesota Department of Transportation (Mn/DOT) now has this capability with the development and implementation of a preconstruction engineering management system, the Project Management and Scheduling System (PMSS). This system encompasses three broad areas: scheduling, funding, and human resource planning.

PMSS

Scheduling Subsystem

The scheduling subsystem is a vehicle for project status and communication of approved change, both vertically and horizontally, throughout the organization. It reflects the current status of development, cost, and letting date for every project in the work plan. The commitments that preconstruction groups must satisfy in order for project managers to meet schedules are shown, and all groups involved in a project are notified when deadlines are passed or other predefined exceptions occur. This subsystem enables managers to define and control multiyear construction programs based on component project schedules and funding. For example, our department routinely conducts program review meetings that involve the districts, central office units, and top management. Historically, the status of projects would be ad libbed and real problems of meeting letting schedules would not surface until the eleventh hour. Beginning in 1981, the deputy commissioner directed that all future program meetings would use the data in PMSS. The result was the capability to look at the status of individual project milestones and focus on specific areas that need attention. The many questions left unanswered at previous reviews were now addressed through PMSS.

Funding Subsystem

With the funding subsystem we can track project funding from the program plan through the commitment process. We identify authorized amounts (both state and federal), committed dollars, and current program estimates. We are able to sort projects by account identification number, by program, or by year. On-line screens show a comparison of committed dollars to authorized amounts and the balance of uncommitted programs. We can monitor funds and expenditures by program category or account number and make adjustments to both present and projected work programs as needed. This is a great help when projects are delayed for unforeseen reasons and for evaluating district requests for program additions. We can see changes in cost estimates and produce exception reports that call attention to funding adjustments that exceed predetermined parameters. Expenditures and programs are monitored against our state budget and federal authorization to guard against overruns. Also, by comparing expenditures to revenue collection, we can adjust individual accounts in our statewide accounting system and prepare legislative requests for increased spending authority when income exceeds projections.

Human Resource Subsystem

The human resource subsystem provides a tool to assist in making scheduling projections and for evaluating the impact of alternatives. Two skill levels--professional and technical support--are monitored. As project schedules are developed, the impact on resource availability is monitored and leveling considerations are applied as appropriate. Either schedules are adjusted or resources reallocated, depending on priorities. Managers can analyze workloads and develop work plans accordingly by preconstruction group, by phase of work, by district, or by program. Through feedback of actual accumulated time charges and date of last work, the system provides a ready means to inquire on progress by involved groups. It also provides a basis for adjusting our standard planning value tables. These tables contain the assumed person hours and time durations needed to accomplish each type of project activity. Refinement of the tables will lead to more accurate schedule estimates for future projects.

Another use occurred following a recent legislative mandate to reduce complement. Top management called on PMSS to provide information on preconstruction resource needs. Our construction management system, the Construction Engineering Manpower Management System (CEMMS), was also used. Although

the information was not complete at the time, it did show management several areas where program changes had resulted in excess human resources. The de-emphasis of major new construction, for example, diminished the need for right-of-way acquisition, location surveys, and soils investigations.

Benefits of PMSS

Several benefits have accrued from the combination of these subsystems:

1. Our planning efforts are reinforced by focusing attention on workload forecasting in terms of feasible project delivery dates;
2. We are more aware of potential trouble when schedules are in jeopardy, costs are overrun, or priorities change;
3. The system supports budget requests by documenting the resources required for the current work program; and
4. We can evaluate actual expenditures in personnel, time, and dollars against planned effort.

DEVELOPMENT OF PMSS SYSTEM

The capability just described is much more the product of evolutionary, rather than revolutionary, change in our management process. Throughout the decades of the 1960s and the early 1970s, the Minnesota Highway Department experimented with various techniques and systems to help support the management of its complex preconstruction project development efforts. This included use of manual scheduling boards and several attempts to use commercially available critical path method (CPM) packages. The incentive for these efforts was almost always from the department's technical and administrative staff (rather than from top or operational managers) reinforced by recommendations from consultants and business advisors to the department.

With the formation of Mn/DOT in 1976, these early efforts were given new emphasis and commitment. The first Mn/DOT commissioner made a personal pledge to our legislature that, by the 1979 biennial budget hearing, a management system would be in place that would relate financial and human resource needs to work plans for all types and categories of highway project development. This ambitious pledge triggered two separate but related efforts within the department.

First, top-management support was given to an interim Project Monitoring System (PMS), designed internally, that used commercially available data base software through the University of Minnesota. The focus of PMS was limited to the scheduling and monitoring of major project activities as a means to communicate project development status. The basic objective of PMS was to improve our track record of getting projects to letting as originally programmed.

During implementation of PMS, project managers viewed with skepticism the need to develop schedules for major project activities. Three years later, when we began to implement our present system (PMSS), these same project managers argued that PMS provided all the detailed management information necessary to deliver a project to construction letting on schedule.

The second thrust, which resulted from the commissioner's pledge to the legislature, was authorization to develop and implement a comprehensive, interactive management system that would provide correlation between project development schedules and financial and human resource needs. After a review of management systems available and visits to a number of transportation agencies in other states, a consultant was retained in May 1978 to help develop our current system. The design, development, and implementation effort that followed continued to need, and received, the support of our top management. In fact, our present commissioner, Richard Braun, made PMSS development and use one of his personal objectives with the governor in both 1979 and 1980.

OPERATION OF PMSS

PMSS was tailored to meet the unique needs of our complex and dynamic preconstruction project development process and to support the effective management of a diverse construction program. PMSS functions in a large, generally decentralized organization that includes (a) nine district offices, each of which has design capability and project management responsibility; (b) various specialty service units in the central office; (c) external consultants; and (d) many governmental agencies.

We have nine categories of highway improvements with more than 2000 identified projects at any given point in time. These projects range from simple spot safety improvements to major urban Interstate. In addition, preliminary design projects often encompass major transportation corridors and frequently are separated into a number of smaller projects during subsequent detailed design phases. These factors severely complicate the project management and control processes.

To be successful in this environment, PMSS must be a user-controlled system supported by a centralized service group. For maximum responsiveness to the users, PMSS provides interactive on-line capabilities for data entry, inquiry, updating, and simulation at cathode ray tube (CRT) terminals located throughout the department and available more than 20 h/day. The interactive on-line capability provides easy access to information for inquiry or change and is maintained by personnel on the scene.

Monitoring of information available from the system can be performed at will by accessing a screen on the video terminal or by requesting a hard copy report. Only two reports are printed automatically--an exception report that lists project activities past due and a change report that lists the changes that occurred in the past week. The user can obtain other hard copy reports by entering the requests on-line. They may choose from more than 30 fixed-format and sort options and specify selection criteria (e.g., letting date range) and number of copies. In addition to the work program, reports are also available for funding, human resource use and projections, and cross-reference purposes. Overnight hard copy report service is available on demand but, as an economy measure, we currently print most reports weekly.

We refer to automatic project scheduling in the sense that, by using any one of the planning value tables and assigning a date to any activity, whether at the beginning, end, or in the middle, a complete project schedule will be developed. The planning value tables accommodate 16 types of work and 27 possible precedent diagrams based on the appropriate number and sequence of activities associated with the scope of the project. In addition, to compensate for individual project deviations from the assumption used to develop the planning values, a project manager may modify individual or all activity staff hours or durations by applying a modifier of 0.1 to 9.9. The human resource needs for each project are added to the previously scheduled projects, so that the cumulative resource demands for all functional groups over any time period can be assessed.

PMSS does not schedule projects based on availability of resources. Rather, it can look at the resource demands of an individual functional group and take necessary action by addressing only the critical resource. It also has an automatic rescheduling feature. A user may request that the duration for one or more activities be revised and a new schedule developed for all subsequent activities on that project.

Unlimited what-if simulation capabilities are provided in PMSS to identify the impacts that changes will have on work plans prior to making those changes. Seven files in the data base are duplicated for simulation purposes so that, while alternatives are being computed in the simulation mode, the real data base is not modified.

The importance of the development and implementation methodology to the ultimate success of a system like PMSS cannot be overstressed. Each organization must tailor this methodology to its own unique environment; but, above all, it must provide for effective involvement of managers and user personnel.

The development of PMSS was a joint effort of consultants and Mn/DOT personnel, supported by the state's central computer center. A consultant project manager and a Mn/DOT project coordinator directed the technical staff. Three committees were used:

1. A management committee made up of Mn/DOT executive managers who directed the development effort and resolved major decision issues,
2. A user steering committee composed of central office and district operational managers who served as a decisionmaking body representing users, and
3. An activity task force of functional managers who identified the functional groups, activities, precedent networks, and estimates that constitute the planning values.

These committees still function during the operation and enhancement of the system, but the extent of involvement has diminished considerably.

PMSS was staged in four parts, which resulted in two separate implementation efforts, eight months apart. The primary development effort encompassed 21 months.

Phase one was system initiation. This included all the activities that led to documentation of the system design. Phase two was program development and project status. It resulted in the implementation of the subsystems that relate to project identification, scheduling, and funding. At this time, a team of consultant and department staff visited each district office and offered a two-day training program on system and hardware use. Presentations were also made to central office resource groups.

Phase three was project scheduling, resource management, and simulation. It expanded the system capabilities by adding automatic scheduling, simulation of scheduling and funding subsystems, and human resource planning. Phase four was feedback and performance. It included subsystems for monitoring human resource use and led to the final implementation effort. At this time, a second round of visits was made to each district to reinforce the earlier training effort and explain the additions.

On completion of the major development effort, a PMSS service group was established to facilitate statewide operation. The three-person services group is responsible for ongoing system coordination, maintenance, enhancement, security, and training. It is supported by a parttime programmer. Debugging, enhancements, and further development are still in progress.

A number of problems are to be expected in initiating a computerized system like PMSS. Some people are intimidated by computers and on-line terminals. This can be partly attributed to a fear that improper operation can cause problems with the computer or program. Operators must be assured that system safeguards are built-in, no damage can be done, and errors can be easily corrected. Individual personalities are a consideration. The selection of enterprising individuals to carry lead responsibility at each location will result in suggested innovations to improve system responsiveness.

Initial staff reaction to the system was more negative than positive, but this has changed with time. In some districts and central office units a conscious decision was made to avoid using the system in the hope that it would go away. This has happened in the past with other ambitious efforts. Some people perceive the system as a threat. A diligent effort is needed to assure users that a management information system need not adversely impact individual autonomy or initiatives. The most successful implementation occurred when the district engineer or office director personally encouraged their staff to use the system.

On the positive side, districts need, and were finally getting, access to funding information that can affect project priorities. Each district has a work plan, but there needs to be a plan for all districts. We have always had a problem getting a handle on personnel.

One problem we encountered was directly caused by staging implementation based on a predetermined time frame rather than user acceptance. In the first implementation stage, we directed all districts to identify projects and develop schedules. Several months later, we added an automatic scheduling feature and asked the districts to go through all the projects again and add personnel requirements. This misled the districts concerning the labor intensity of the system. It has been difficult to overcome the misconceptions caused by this procedure. This is not a recommendation to avoid staged implementation. Many features of the system can be gainfully employed while other features are refined, but good coordination is essential during the extended implementation period.

Another problem that challenged the credibility of the system was the occasional failure of computer programs to deliver as intended. The user becomes frustrated when confronted by program bugs. A test data base was used in development, but we found it necessary to create a new and more comprehensive test data base to ensure the quality of programs before releasing further system modifications or enhancements to the user.

Since the beginning of operation, modifications have been continuous. Program modules are made to execute more efficiently to cut computer time and costs. Enhancements and additions are made to satisfy user requests for various combinations of information and formats. We are pursuing the addition of a computer graphics capability to plot human resource supply and demand curves that are now plotted manually from data provided. The same approach can apply to funding. Project networks can also be plotted to show, in schematic form, the activities and target dates applicable to individual projects.

The complete development cost for PMSS, including consultant charges, state central computer service center charges, and salary of project staff and committee participants, totalled $558 750. Amortized over five years, this amounts to $111 000/year or less than 0.06 percent of Mn/DOT's average annual construction expenditure. We believe this has been a sound investment that will generate benefits far

in excess of cost as time goes by. Our implementation started in 1980. Based on our experience and that of other states, we know PMSS is still in its infancy and its full potential will only be realized with time and use.

Idaho Transportation Department Project Development Management Scheduling and Control System

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The Idaho Transportation Department uses a commercial computer program, the Management Scheduling and Control System (MSCS), to schedule project-development work activities, forecast project completion dates, and forecast required staff within the 10-year construction planning schedule. The MSCS program is available from MCAUTO, a McDonnell Douglas company. Idaho has been forecasting and scheduling project development with MSCS since 1975. Idaho operates MSCS in a resource-constrained, multiproject mode against all projects simultaneously. MSCS calculates activity start and finish dates, extends project completion dates, splits activities, and sets priorities for resource allocation according to project start dates, project networks, personnel limits, and management priority for relative importance among projects in the same fiscal year. Management uses the personnel forecasts to determine five-year personnel complements. One person operates the system for 400-700 projects. New projects are modeled in 4-6 min/project from computer libraries of various networks. Activity durations and resource quantities are selected from the libraries according to the elements and complexity of each project. Bimonthly updates are transmitted to headquarters from six district minicomputers via telephone lines. The Idaho Division of the Federal Highway Administration has accepted Idaho's use of MSCS as the monitoring and reporting system for project development. This acceptance has eliminated written monthly reports and other proofs of monitoring required by FHWA under certification acceptance. Due to MSCS communication and scheduling, internal project action correspondence has been reduced by 70 percent. The information in this report is current to 1982.

The Idaho Transportation Department has been forecasting and scheduling project development with the Management Scheduling and Control System (MSCS) since January 1975. MSCS is a product of the McDonnell Douglas Automation Company (MCAUTO).

Idaho operates MSCS in a resource-constrained multiproject mode against all projects simultaneously. The MSCS program calculates activity start and finish dates, splits activities, sets priorities for resource allocation, and extends project completion dates according to project start date, network sequence, available personnel limits, and management priority. Personnel needs are also forecast by MSCS and are used by management in budgeting and setting personnel complements. MSCS provides a schedule of services by activity start and finish dates, provides ready-to-advertise dates for the 10-year construction program and through the administrator's report, and provides for reporting of the exceptions via staff comments. The Federal Highway Administration (FHWA) has accepted Idaho's use of MSCS as the monitoring and reporting system for all project development functions. This acceptance has eliminated a multitude of written monthly reports and other proofs of action and monitoring that were otherwise required by FHWA under certification acceptance.

The state highway administrator requires all federal aid and state projects to be on MSCS except for stockpiles, areawide pavement marking or signing projects, and buildings. All Division of Highways projects under consulting engineering contract are reported on MSCS.

The state highway administrator uses the forecast of ready-to-advertise date for each project to determine the not-earlier-than date for program fiscal year of construction in the 10-year program. If a project is not updated and, as a result, it slips two months with each two-month update reporting period, it will soon slip into the next fiscal year of the program. The state highway administrator requires MSCS to

1. Provide forecast ready-to-advertise dates for scheduling the 10-year construction program;
2. Provide a schedule of project activities for each section supervisor, group leader, or lead technician with project responsibilities in the districts;
3. Provide activity scheduling for headquarters project development services; i.e., bridge, right-of-way, materials, traffic, utilities, railroad agreements, environmental, and program control;
4. Provide statewide project development communication whereby all involved personnel see the same information at the same time on any given project;
5. Provide current and future resource requirements for personnel forecasts and provide analysis of available resources versus need for consulting engineering on projects by one district for another district or by outside private consulting engineering firms;
6. Provide exception reporting for management to detect delays on specific actions and project slippage versus the program target; and
7. Provide trial testing of program scheduling and project priority decisions before they are implemented by management.

REPORTS

The state highway administrator uses the program administrator's report (Figure 1), which contains all projects in the 10-year program, for determining the earliest letting dates when adjusting the 10-year construction program. The administrator's report is also used to determine exceptions via the staff comments. The state highway administrator has directed the format of a gain-slip report that shows the gain or slip of a project in relation to the program.

The gain-slip report was specified by the state highway administrator for the purpose of reviewing the state-sponsored federal-aid projects in the first three program years. The gain-slip report provides simple and direct indication of the progress being made in project development on the federal-aid program. Since larger projects will