TRANSPORTATION RESEARCH RECORD 856

Highway Preconstruction Management

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NATIONAL RESEARCH COUNCIL

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Managerial and Human Resource Experiences with Preconstruction Engineering Management Systems—Washington State Perspective

DENNIS B. INGHAM

Washington has had more experience with a preconstruction engineering management system (PCEMS) than most other states. This paper deals not so much with details of this system but rather with recommended developmental criteria that, based on Washington's experience, should be considered. Although the reasons for developing a PCEMS and the use it will receive will vary significantly from state to state, some fundamental questions exist that must be asked and evaluated to help ensure successful implementation.

Based on Washington's experience with a preconstruction engineering management system (PCEMS) package (one of the earliest in the nation) this paper gives guidance for those who are contemplating or have recently begun the development of a PCEMS package in their jurisdiction. Details of Washington's PCEMS can be found elsewhere (1).

BACKGROUND

Washington's system, called Manpower Management Information System (MMIS) was conceived in 1972 but was not fully operational until 1978. At the heart of MMIS are a computerized critical path scheduler and 85 work standards. These work standards represent each of the significant steps performed during the preconstruction process, which work unit performs the step, its duration, and the manpower necessary. The summation of the work standards necessary for one project gives not only the necessary project duration but also the personnel required, by month, to complete the work.

The resulting schedules and personnel demands by project can then be totaled by work unit, state route, district or statewide, and project engineer. As a planning tool, both short-term and long-range reviews are possible. The only limitation is the knowledge of future work. During this planning process, program adjustments may be necessary to balance work loads, or the need for staff increases or decreases can be foreseen.

Soon after the budgeted plan is established, two events begin. First is the continual program adjustments to correspond to revenue changes and priority changes. Continual system updating is necessary. Second is the collection of expenditure data. Because each work standard has a corresponding accounting charge number, collection of these expenditures and monitoring of progress of a project compared with its plan is generally easy. Management decisions can be and are made during each of the steps in this process.

The description just given is very brief, but for anyone seriously contemplating a PCEMS, the elements are certainly familiar. A fair question to ask is, "With the extensive development work on MMIS, has it met its goals and is it worth the expense?" The answer is that all the goals have not yet been met in making the cost justification borderline. But, the system operation and subsequent feedback have yielded invaluable experience and the direction for improvement. I hope that this experience, often painful and expensive, can be passed on to others to minimize their developmental problems.

PCEMS CRITERIA

Following is a list of considerations and criteria that should be addressed before proceeding with the development of PCEMS in a jurisdiction. The list is in order of priority. The order of priority will undoubtedly vary from state to state but all items merit evaluation.

1. System use--Determine how the system output will be used in your management process. The intended use of this output will determine the type and complexity of the system.
2. PCEMS is a tool--PCEMS, as with any other resource management system, is a tool for program managers. Remember that all results produced must be analyzed by managers before the computer data can be used. People carry the responsibilities of decisions; systems are but one of their management tools.
3. Support of top management--No management system can succeed without the total endorsement and support of top management. This support must include actual use of certain reports generated and insistence that the system is used and updated. In some states this support should include legislative support, and if applicable, commission or gubernatorial support.
4. Schedule control--The heart of any program management process is the schedules. All project managers keep schedules for the projects under their control. These schedules are often kept mentally, on hand written lists or computer listings. It is critical for an effective PCEMS that one and only one schedule be used and updated by everyone. The bridge designer, soils engineer, and financial manager must all be aware of the current plans and necessary revisions. Only in this way can individual units be held responsible for the timely completion of their activities within the total project.
5. Coordinated system--The usefulness of PCEMS is proportional to the number of users who benefit from its existence. For maximum usefulness, it must be made compatible with your jurisdiction's accounting, revenue, and projected cash-expenditure systems. By such coordinated files, which use a common data base, expenditure data can be compared with initial plans, projected cash flow can be updated automatically as schedules change, and the program can be adjusted to projected revenue.
6. Formatted for users--The success of a PCEMS is also related to whether or not it fills the information needs of the users. The system must be geared to function like your department. For instance, if project advertising or letting dates are the one critical element, then the system should use these dates as the key factor and gear all else to them. However, if predictable cash flow or balanced personnel are the most important elements, then the PCEMS must be designed accordingly. Do not expect people to change. If possible, tailor the system to the users rather than force users to become acquainted with whole new procedures and data format.

This will produce less resistance and enhance chances for success.

7. Design in flexibility--As the state or federal revenue picture changes, program adjustments are necessary. If the weather is unexpectedly good or bad, project schedules are affected accordingly. As environmental or permit procedures are altered, complete dates may be postponed. For these and innumerable other reasons, adjustments to your PCEMS may be necessary. Therefore, your PCEMS must be easily updated with an affordable computer cost.

8. Timeliness of data--All system elements should be kept current at all times. However, careful weighing must be done between this timeliness versus the personnel effort to keep it current and the data-processing charges in an interactive system.

9. Desired accuracy--Your PCEMS will not be totally accurate. You can design in the level of accuracy you require. In general, the cost and complexity of your PCEMS will increase with greater accuracy, as will the need for a more frequent and accurate manual input. An attempt to be too accurate is probably more detrimental than the recognition that a 5-10 percent deviation is tolerable.

10. Input simplicity--Tied in closely with system accuracy, but in direct opposition, is input simplicity. Let the computer do as much of the work as possible (e.g., use of files in other systems, use of screen data input). Also, do not require any more details than are absolutely necessary. Whether by forms, keyboard, or cards, make sure that all input is easily codable and requires a minimum of training.

11. Initial system data requirements--Whether based on manpower standards or data retrieval from other systems, extensive base data must be collected, analyzed, and put into usable form. Do not overlook this sizable system development cost.

12. Interactive processing--Computer technology now allows users to inquire, update, or delete system elements immediately as the data are available. Careful review of your computer system capabilities is necessary before adopting this option. Although highly desirable, this prime-time use is often expensive, ties up the system when many others are using it, and may degrade response times. Often a mix of interactive and overnight processing results in optimum system performance.

13. Degree of computerization--The increasing predominance of computers in our lives may lead us to believe that they are a cure-all of our information needs. This is not necessarily so. If your processing needs are small, a portion of the work could be done manually. Remember, you will have not only the system development costs but also the resulting ongoing system operation and maintenance costs.

14. System maintenance--Carefully evaluate the system development procedures to minimize future maintenance problems. As in highway construction, often a slightly higher initial cost may result in substantial savings in ultimate maintenance costs.

15. Adaptability--New system uses will be developed, management personnel will change, funding changes will take place, and your transportation program will change significantly in size and complexity. Your PCEMS must be able to adapt to this changing environment and still fulfill its requirements. Recognize this need and plan for it.

16. Learn from others--Many others have advice and observations on existing systems from which you can learn. If possible, use developed systems from others (e.g., the Federal Highway Administration PCEMS) if they meet the criteria discussed above for you.

17. Involvement in development--In the process of developing a PCEMS, solicit and use input from as many individuals as practical. Their involvement during the development process not only provides extremely valuable input but also helps to ensure their support during implementation.

18. Do not oversell--Those who have recognized the need for a PCEMS and have or will actively work for its development in their jurisdiction will undoubtedly be enthusiastic about its promise of success. A word of warning is needed. Do not oversell the capabilities of the system. A PCEMS will be most vulnerable to criticism during the first few months after implementation. If it was oversold and cannot deliver all that was promised, the credibility gap generated may never be closed. Be enthusiastic, be salespersons, but also be cautious when dealing with people's expectations.

OVERVIEW

The criteria described are general in nature and cannot be much more specific until applied to each individual location. However, if you obtain top management support, ensure that the system works for you (not you for it), and learn as much as possible from others, your chances of successfully implementing a PCEMS are excellent.

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Building a Preconstruction Management System: Effect on Human and Fiscal Resources

R.G. RINGER

This paper addresses some of the psychological and emotional issues involved in employee response to the implementation of a preconstruction management system. The material included is based on experience with the design and implementation of the Manpower and Project Scheduling System for the New Mexico State Highway Department. Some of the technical features have been included to provide a basis of reference for these human factors. The paper recommends that the level of reporting into the system and output from the system should be kept to a minimum. It also points out that the people who operate and manage the system are more important than the system itself. The personality profile of these managers and the style of management is related to employee acceptance and response. Several other peripheral issues regarding the successful operation of a scheduling system and its effect on employee morale have been included.

The first step in developing a preconstruction management system is to analyze existing management practices within the transportation agency. Problem areas as well as successful practices must be identified. An effective management system is then designed to correct the problems and incorporate areas of sound management.

New Mexico, like the other states contacted prior to the development of its system, designed the system to address known and perceived problem areas. Each state had developed its own special problems. Typical examples of problems are

1. Poor financial management;
2. Inadequate funding sources;
3. Manpower problems; i.e., too many or not enough employees, lack of proper training, improper use of consultants, or deficient compensation plans;
4. Incomplete or inaccurate scheduling systems;
5. Poor communication and coordination between work centers;
6. Poorly defined work responsibilities; and
7. Poor planning processes, including political control of the planning process.

The top management of the New Mexico State Highway Department was aware of many of its own management problems. These included the following:

1. Inadequate state revenues;
2. Poorly defined work responsibility;
3. Poor financial management; i.e., inability to predict expenditures or revenues accurately, inability to predict cash flow, and incomplete understanding of federal-aid highway funding;
4. Only a fraction of the work scheduled by a formal central path method (CPM) process;
5. Time estimates for work generally inaccurate and not kept current throughout the development process;
6. Work not monitored in all areas to ensure orderly development and timely completion;
7. People who operate the scheduling system unfamiliar with the work they were attempting to schedule and not knowledgeable in financial matters related to the projects and programs; and
8. People in charge of operating the scheduling system lacked the personality traits necessary for the successful operation of a management system.

SOLVING THE PROBLEM

The people in charge of the operation of a preconstruction management system are more important than the system itself. Even a system that has the best computer programming and that accurately embraces all technical aspects of project development is certain to fail if the people who operate the system fail to create an atmosphere of cooperation with the employees who interact with it. They must see the system as a useful, helpful tool. If the system is used as a club to make employees perform or as a monitoring system to report their failures, the employees will undermine the system and thereby guarantee its demise. The system cannot and must not appear to be responsible for their work; the managers are responsible for their work.

One should not get the impression that a scheduling system does not monitor work progress; it must. However, the way in which work is monitored is crucial. A system reports incomplete or late work, but it must not be used as a basis for reprimanding employees responsible. Rather, the goal should be to find out why the work is behind. Is there something management can do to avoid this problem on other projects or to bring the project back on schedule? The emphasis must be on what corrective action can be undertaken now, not on disciplinary actions. Certainly, poor performance cannot be allowed to continue. A scheduling system will highlight poor performance as well as exceptional or exemplary performance. Rewarding outstanding performance is a much better management practice than the singling out of poor performers for disciplinary actions; nevertheless, sometimes disciplinary action is necessary.

DEVELOPING THE SYSTEM

The system must have the essential technical elements that have proven to be successful. These are as follows:

1. Well-defined work activities,
2. Flow chart that defines developmental sequence and work interrelations,
3. Planning values that predict the amount of work hours and workdays for each activity for each project type,
4. Computerized scheduling system that schedules all work simultaneously against identified resources,
5. Computer reports that inform managers of scheduled work and personnel requirements,
6. Monitoring system that identifies and reports incomplete work,
7. Computer reports that serve as the basis of a management information system for all projects, and
8. Computerized cash-flow system to aid in proper financial management.

Several other key elements must exist. Among these are a financial system that can accurately predict available revenues for the required work program. Another is a stable, long-range work program, consisting of specific projects developed in conjunction with available or forecast revenues and required project development time (this is determined from the scheduling system). A stable program will have relatively few political projects that preempt scheduled work. Logically, new projects are added to the program at the end of the queue rather than at the head. (Of course, a successful scheduling system must consider and be flexible enough to handle emergency projects.)

Finally, top management must not only support the system but also understand it. This is necessary to ensure that decisions are not made that undermine the system. For example, managers must not promise completion dates that are unrealistic nor should they promise more projects than can be funded.

Several other factors must be considered to ensure the success of a preconstruction system. These elements are the ones most-often forgotten. The system must provide managers at all levels with the information they need to manage their work. The system should not provide too little, or worse, too much information. Too much information inundates the user. If information is provided about everyone else's work to each manager, an environment is created where managers are checking on other manager's work instead of their own.

The system must be tailor-made to the needs of the individual transportation agency. It must consider work procedures and the people who will use it. If it is too sophisticated at the user level, employees will not understand it. Employees will be suspicious of a system that they do not understand. They must believe that it is their system. It is best if they help to create it. It does not matter whether they really do create it as long as they think they did.

The use of technical panels comprised of agency employees works very well to accomplish three main objectives:

1. The system is developed specifically for the agency that will use it;
2. Employees help design the system; they have input into the process and develop a sense of authorship; and
3. Employees begin learning about scheduling systems and preconstruction management long before the system is implemented.

Pilot reporting is a term used to describe a reporting process used to collect statistical data regarding how long it takes to perform work activities for various types of projects. New Mexico did pilot reporting for six months. It was not well received by the employees, who saw it as additional paperwork and a watch-dog feature that would be used to check up on them. In reality, the useful data obtained were small compared with the time and effort expended on data collection, computer processing, and output reports. The real value of pilot reporting was in giving employees the perception that the data were used to establish planning values, that their work times were accurately reflected in the scheduling process, and that the system was tailor-made to people and practices of our agency.

Two key features of a scheduling system are project overrides and activity reporting.

Project overrides give employees an opportunity to use their judgment to change computer values generated for project schedules. It lets employees feel like they are controlling the work and the computer rather than the computer controlling them. This is an extremely important psychological factor that must be properly integrated into the system. It must achieve a proper balance; i.e., employees must not be given carte blanche to input whatever values they want; and, on the other hand, the computer-generated values cannot be used without employee review and revision.

To properly monitor project development, employees must report the completion of scheduled work. If the reporting process is complicated, time-consuming, or cumbersome, employees will not report accurately. In New Mexico payroll reporting was rejected at the activity level. It appeared to be much like pilot reporting--too much data collection for the benefits derived. It may be added at some point in the future, but only when people who use the system clearly understand the objectives and are willing to expend the necessary reporting time. Instead of payroll reporting, employees fill out a card that contains five items:

1. The unit performing the work (a four-digit number assigned to each management unit or work center);
2. The project's control number (a four-digit number assigned uniquely to each project; it appears on all computer documents and is readily available to the unit manager);
3. The activity being completed (a three-digit number for the specific work activity being completed; management units quickly become familiar with the half-dozen or so activities that relate to their work);
4. The date the work was finished; and
5. The initials of the reporting employee.

It typically requires about 15 s to complete a card and most managers are required to submit fewer than 15 cards/week. Psychologically, employees do not feel antagonistic when reports show that they failed to complete an activity since they had responsibility in helping to determine both the value and completion date. Managers welcome the opportunity to report that they have completed the assigned work.

USE OF THE SYSTEM

The scheduling system should be used to schedule all required developmental work against available resources. It should provide all the information managers need to plan, organize, direct, and control their work. It should be a monitoring system to report late work. It should provide information regarding cash flow for projects. It should be used to build long-range programs. It should be used as a stabilizing force to ward off advancing projects arbitrarily. It should be used to predict personnel requirements, both short-term and long-term.

It should not be used as a whip to make people do work. One of the initial fears unit supervisors had was that this system and the people who operate it would attempt to issue daily orders on which work should be done. These fears arose because they did not understand the mechanics of a scheduling system or its real purpose. Their fears were reinforced during pilot reporting when each employee had to fill out time sheets of exactly what they had done all day long. Employees did not see this as an attempt to establish reliable planning values but rather, as an attempt by the computer system to keep tabs on them.

In reality, the computer system does provide schedules for work and does report failure to complete the work as scheduled. This is done without recrimination, however. Employees know when they are late and why. Their concern is that other people will not understand why the activity is late. This concern is addressed by contacting managers responsible for the late activities and noting their comments on the late report. This is done before it is distributed. Complete reports are distributed to their supervisors (usually section heads) and to bureau chiefs. A copy of just the unit's manager's late activities is sent to each unit manager. This process has worked very well. In fact, unit supervisors have expressed their appreciation for being reminded of overlooked activities as well as being given the opportunity to let everyone know why a particular activity was late. These opportunities for human intervention in the scheduling and monitoring process are crucial and cannot be overemphasized.

In the development of the New Mexico system, some top managers expressed the opinion that projects should be scheduled solely on the basis of computer-stored planning values. They also stated that employees would accept the system or they would be subject to disciplinary action. The best way to ensure acceptance, however, was to allow employees to help create the system and have checkpoints where they could at least express their opinions. Employees are sure to reject a system they do not understand if it is being forced on them. It was necessary that I (as project team leader) act as a buffer between employees and top management. The project team leader had to win the confidence of both sides.

CONCLUSION

The single-project CPM scheduling system we had before worked, but it did not work well. It did not address manhours nor the multiproject scheduling environment in which the work occurs. It did not monitor project progress and was poorly supervised and managed. No system could have worked well because at that time we had poor financial management and were unable to accurately predict future revenues and expenses.

Acceptance of the system has filtered down. The agency head initiated development of the new system and assistant agency heads endorsed this action. Division heads were initially reluctant to admit they had problems that a new scheduling system could solve. During development they recognized the potential and began to support the system. Now, section heads support the system and use it more and more. Acceptance by unit managers has been steadily increasing. Some areas are still lagging, but these holdouts will become more supportive as time goes on and as exposure to the system increases. Right now, most employees do not love the system or hate it; they see it as part of the job, part of the routine. We expected to have at least a full year of implementation and an additional year after that to build confidence and gain user acceptance. We are right on schedule.

Stable funding is a key factor. We have made a lot of progress in this area in conjunction with the scheduling system. Obviously, we cannot have a stable letting schedule if we have sudden funding cuts or sudden large increases. Our program is really only as good as our ability to predict revenues.

One area in which the system has helped a lot is in the area of consultant contract negotiations. The system identifies areas of needed consultant work. It provides manhour estimates and contract-completion dates. It provides an excellent basis for negotiating consultant contracts. It is easier to keep track of consultants since they must submit completion cards just like everyone else. Progress payments to consultants have been greatly simplified since the cards document how much work has been completed.

We have a lot fewer crises now. We have an improved credibility with the legislature because of our stability. We are actually operating with fewer personnel than before and accomplishing a larger program. The proof of this is reflected in their approval of our requests for additional funds.

The scheduling system has provided a sound basis for effective management. New programs can be analyzed and evaluated prior to implementation to determine their effects on human and fiscal resources. In the summer of 1980 we were involved in a lawsuit with the Federal Highway Administration (FHWA) because obligational authority was withdrawn after New Mexico had obligated only 16 percent of its authority through the first two quarters. A year later we had obligated 80 percent of our authority before the end of the third quarter. In addition, we had three times the anticipated 20 percent remainder in authorization requests submitted to FHWA in July.

New Mexico received $12 million in authority beyond that anticipated. The scheduling system has been in operation since July 1980. It was the single-most-important factor in bringing about the complete, one-year turnaround. This additional release has had a very positive impact on morale. Employees feel like they really accomplished something, and they did. Although they perceive additional reasons for the stability and improved financial situation, they recognize that the system has orchestrated our efforts and given them a powerful tool for managing their program.

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

ROGER M. HILL AND GERALD F. TESSMAN

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. Online 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 deemphasis 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

HUGH F. LYDSTON

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

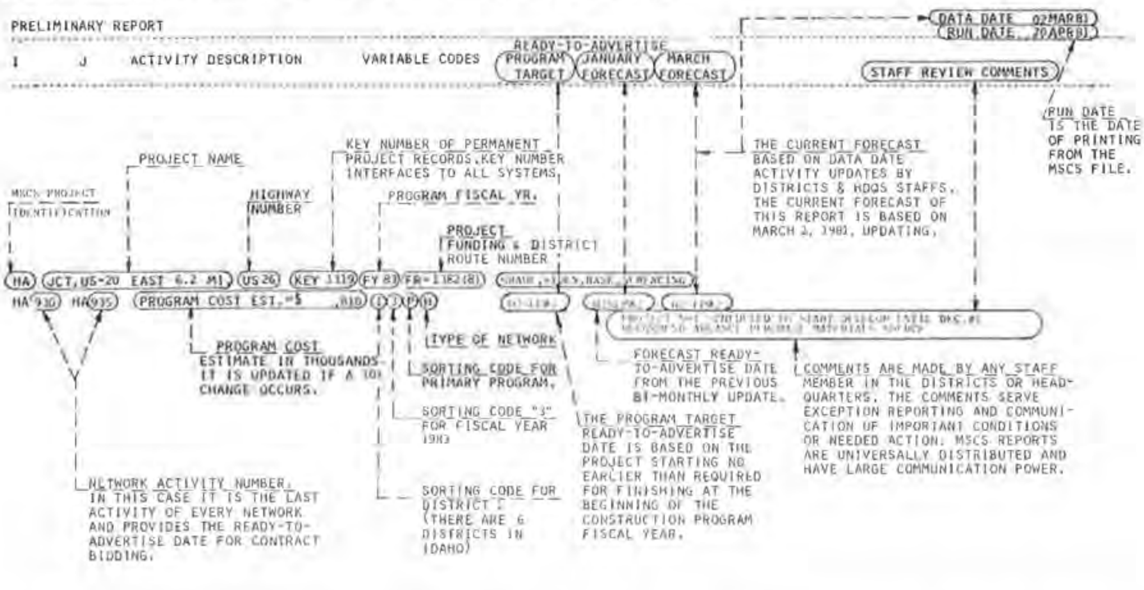
1. Provide forecast ready-to-advertise dates for scheduling the 10-year construction program;
2. Provide a schedule of project activities for each section supervisor, group leader, or lead technician with project responsibilities in the districts;
3. Provide activity scheduling for headquarters project 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

Figure 1. Idaho Transportation Department program administrator's exception report.



vary substantially in gain or slip as work goes on, slippage of more than three months (60 working days) is cause for management to request status evaluation.

The gain-slip report excludes the following categories of projects:

1. Environmental and location-only projects,
2. State maintenance projects,
3. State safety and rehabilitation projects,
4. All locally sponsored projects,
5. The six-year source acquisition program, and
6. All projects scheduled for construction beyond fiscal year (FY) 1983.

The gain-slip report includes all state-sponsored federal-aid projects programmed for FY 1981, FY 1982, and FY 1983.

Gain or slip is shown by program plus or minus working days. The July forecast is subtracted from the program target finish date. If the July forecast is earlier than the program, the working days are a plus (+) gain. If the July forecast is later than the program target finish, the working day difference is a minus (-). When the September update arrives, the September forecast will be the date subtracted for each project.

The program target is the model of the project set to finish on October 1, the beginning of the program fiscal year approved by the transportation board. If a project has been reprogrammed due to slippage from the original program year, the original program year is still the program target. If reprogramming occurs due to funding shifts or priority or need decisions, the program target model is shifted to meet the new program fiscal year. Program targets are only changed with the approval of the state highway administrator.

The gain-slip report is distributed with the regular MSCS administrator reports. An example report is shown in Figure 2. The state highway administrator feels that this report provides the necessary management control of project development.

The Idaho Transportation Department Director uses a special program administrator's report that shows public hearing and environmental clearance forecast dates in addition to predicted bid advertising dates and staff exception comments.

Any report can be revised or created for content or format at the request of the user. Report creation and generation requires about 45 min. Although all sorts of special analysis reports can be devised, the two usual categories of reports are staff reports and management reports.

Staff reports are activity reports selected on activities desired by the individual and needed for updating. The activity reports provide scheduling of start and finish dates, duration of original activity, and duration remaining for activities in progress. A sample staff report, a bridge group leader report, is shown in Figure 3, with updating marked by that group leader.

Management reports usually are selected on event activities--i.e., those that do not have substantial duration in working days and do not have assigned resources.

START DATES

Project start dates are selected so that predicted ready-to-advertise-for-bids dates fall on or near the October 1 beginning of the federal fiscal year. Start dates are adjusted to an earlier date in the operating MSCS file if resource limitation causes the project forecast to slip past the program target finish date. Projects that must start immediately in order to meet their program year do not have an entered start date. MSCS automatically starts a project on the current date if a late start date has not been used.

ENTERING NEW PROJECTS, UPDATES, COMMENTS, CHANGES

The Idaho Transportation Department's data-processing computer center uses Remote On-System Conservation Entry (ROSCOE) software for handling all computer entry data and submittal of computer jobs to the main machine processing queue. ROSCOE's application to operation of MSCS is the tool by which we are able to maintain precoded network activities and resources and build data sets of updates, corrections, new projects, and report requests for submittal to the MSCS file. MSCS operation commands and report requests are also stored in ROSCOE for selection in operating the MSCS program.

Rather than using the planning value and additive methodology, we have precoded all types of networks with activity durations and resources and stored

Figure 2. Sample gain-slip report.

```
                                          IDAHO TRANSPORTATION DEPARTMENT                                    PAGE     6
GAIN/SLIP-1ST 3 PROG YRS            STATE HIGHWAY ADMINISTRATORS EXCEPTION REPORT                      DATA DATE  01JUL81
                                                                                                       RUN DATE   3AUG81
-------------------------------------------------------------------------------------------------------------------------
                                                       READY-TO-ADVERTISE                                      PROGRAM
             ACTIVITY DESCRIPTION                 PROGRAM    MAY       JULY        STAFF REVIEW COMMENTS        PLUS
                                                  TARGET   FORECAST  FORECAST                                   MINUS
-------------------------------------------------------------------------------------------------------------------------
41  LEW.INT.BR.I.C.INT     US12-X-KEY2268,FY82,F 4114(60),,,URBAN,KEY2267/M 7C54(001) IACL

           PROGRAM COST EST.=$ ,180               23FEB82   30JUN82   24AUG82                                 128.0-
                                                                      NEED RAILROAD AGREEMENT FOR TRACK RELOCATION
                                                                      PRIMARY PROJECT IN STATE SAFETY&REHAB PROGRAM

41  PARADISE CREEK  MOSCOW SH8 -N-**Y1891,FY83,BRM-7744(1),1-STRUCTURE

           PROGRAM COST EST.=$ ,460               14OCT82   07DEC82   25OCT82                                   7.0-
                                        FY SHIFT JAN 81               C

4   RESERVE CR  ROSE LAKE IC190-R-*EY2255,FY83,I-90-1(129)29,MP29.21-35.09,WON,G.RAIL,SURF

           PROGRAM COST EST.=$ 6,420              07SEP82   17NOV82   08NOV82                                  43.0-
                                                                      ACCESS CLOSURES RESOLVED LETTER  3/10/81
                                                                      NEED MATERIALS RPT&FIELDWORK FROM DIST 5
                                                                      COMB LOC/DES HRNG PLANS HAVE BEEN SENT TO DIST 5

OC  21ST&G ST. LEWISTON    US12--KEY2504,FY83,HHS-4114(43), INTERSECTION IMPROVEMENT

           PROGRAM COST EST.=$ ,160               07OCT82   30DEC82   22NOV82                                  30.0-
                                                                      C

KZ  OROFINO-GREER          US12--KEY1540,FY83,F FR 4201(36),WIDEN&SHOULDERS & OVERLAY

           PROGRAM COST EST.=$ 1,100              27SEP82   07OCT82   27SEP82                                   0.0
                                                                      C

4M  ARROW-CHERRY LANE BR.  US12-X-KEY2630,FY83,F-FR-4201(46),WON,OVLAY,MP 15.824-21.15

           PROGRAM COST EST.=$ ,740               23OCT87   13OCT87   09OCT87                                  10.0
                                        FY SHIFT JULY 81              THIS PROJECT SHOULD BE EXCHANGED WITH KEY 259 WHICH
                                                                      IS CURRENTLY IN FY82

4L  DEARY-YALE (STAGE 2)   SH9-N-KEY2457,FY83,SR-RS-4808(8),GR,DR,BS,SURF,MP.7.245-3.63

           PROGRAM COST EST.=$ 1,000              17SEP82   08JUL81   04SEP81                                 260.0
                                                                      READY FOR FINAL DESIGN REVIEW
```

them in the ROSCOE utility library. By using a systematic index we call up copies of desired networks or parts of networks and assemble the project on the cathode ray tube (CRT) screen by using ROSCOE. The assembled project is stored as a submittal data set in another part of the ROSCOE utility library. The loading of a new project requires the usual project identification numbers, descriptive name of the project, intended fiscal year of construction in the program, and selection of the type of network, selected activity legs such as utilities and railroad, number of right-of-way parcels, and designation of each structure. With the exception of network selection and number of right-of-way parcels, all of this information is normally required for programming approval. An example of project input with network selections, right-of-way, and structures is shown in Figure 4. ROSCOE takes 4-6 min to assemble a project network with all modifications peculiar to that project and have it ready for submittal to the MSCS file.

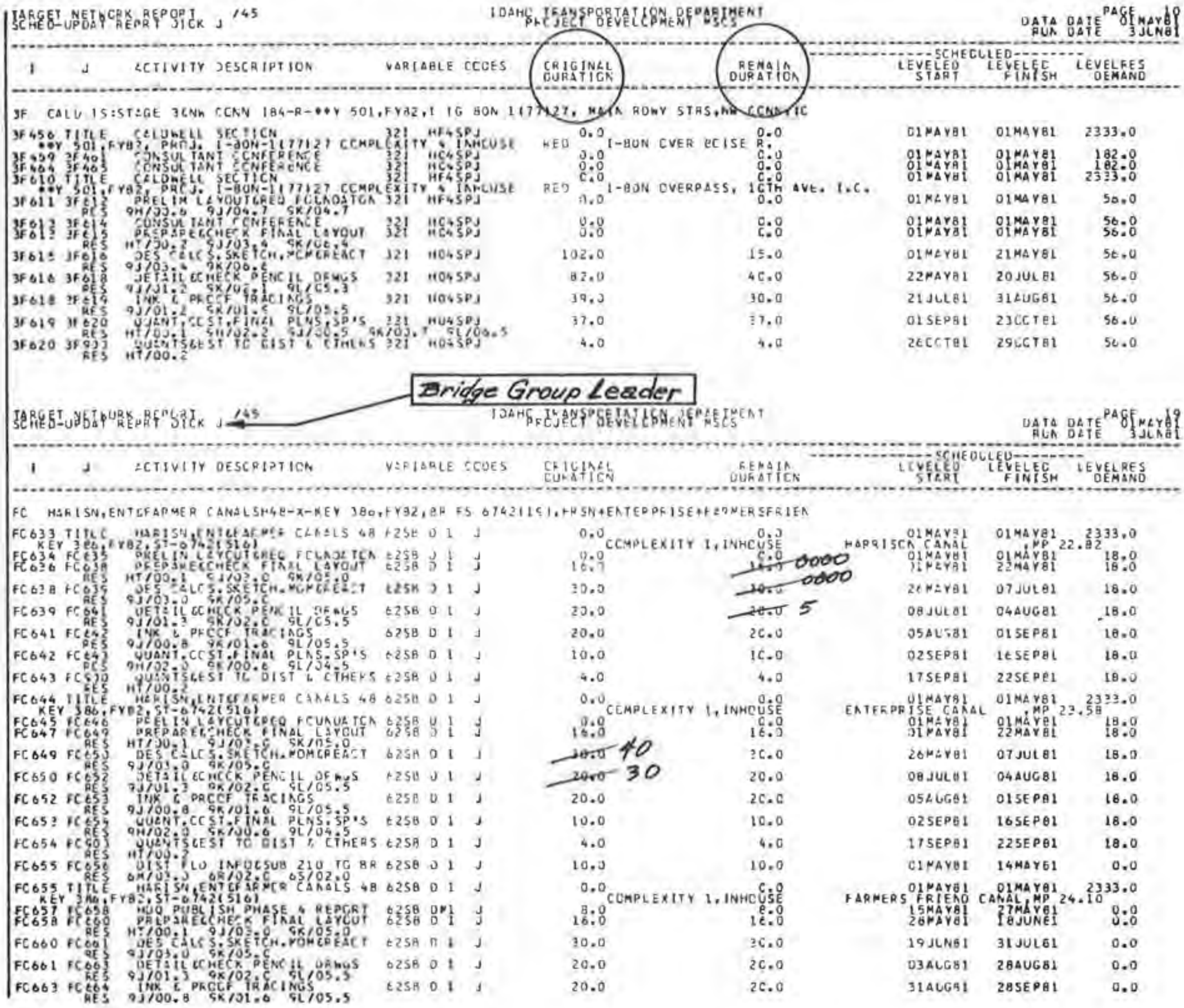
NETWORKS

A few of Idaho's project-modeling networks are in Figures 5-7 and the MSCS program follows these networks in its calculation of start and finish dates. The networks are created by roadway design in cooperation with the districts and affected headquarters sections. District recommendations for network changes are used to make network revisions. The networks are models of the relation of activities in developing projects. As work procedures change due to new requirements or regulations, the networks on the ROSCOE library and project networks that exist on the MSCS file are changed to fit the new conditions by using computer commands that find networks and activities by defined characteristics.

External priority is used on management-selected projects where management has decided that a project is more important than other projects in the same year of the program. Priority is attached to the allocation of resources for the activities within that project. By attaching priority to the allocation of resources, all projects that use those same resources feel the effect of the prioritized project.

Each project has its own network. Individual activities or sections of networks can be linked between related projects so that the sequence of stage development can be controlled automatically. If one of the linked projects is moved in the program or if work lags, the subsequent stage projects automatically change dates. Linking of projects as a methodology with multiprojecting provides an automated monitor that reveals when sequenced projects require additional resources before the crisis develops. For example, the Wallace Interstate project consists of an historical relocation project, a major railroad relocation project, and three roadway and structures projects. The programming sequence spans five years. Each project has its own development network and networks are tied together according to many activity relations associated with the modeling of work. If the first project is moved in the program by management or if the project slips due to problems in development as reflected by updating by the production staffs, all of the subsequent-stage projects are adjusted automatically in the calculated finish dates by the MSCS program. The impact of the proposed programming decision on all of the project stages is automatically carried out due to a single start date entry. Further, the high resource priorities designated by management for the Wallace project have an automatic impact on all other projects in the program that use the same resource pools, and those projects, if affected, will have new start and finish dates calculated by the MSCS program.

Fgiure 3. MSCS bridge staff report for activity scheduling and update changes.



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TARGET NETWORK REPORT    /45                  IDAHO TRANSPORTATION DEPARTMENT                                   PAGE    10
SCHED-UPDAT REPRT DICK J                          PROJECT DEVELOPMENT MSCS                         DATA DATE  01MAY81
                                                                                                     RUN DATE   3JUN81
                                                                                       ------------SCHEDULED---------
  I      J      ACTIVITY DESCRIPTION      VARIABLE CODES   ORIGINAL          REMAIN          LEVELED  LEVELED  LEVELRES
                                                           DURATION          DURATION        START    FINISH    DEMAND

3F  CALD IS:STAGE 3CNN CONN I84-R-**Y 501,FY82,I IG BON 1177127, MAIN ROWY STRS,NW CONN IC
3F456 TITLE   CALDWELL SECTION            321  HF4SPJ        0.0              0.0          01MAY81  01MAY81   2333.0
   **Y 501,FY82, PROJ. I-80N-1177127 COMPLEXITY 4 INHOUSE  RED  I-80N OVER BOISE R.
3F459 3F461   CONSULTANT CONFERENCE       321  HC4SPJ        0.0              0.0          01MAY81  01MAY81    182.0
3F464 3F465   CONSULTANT CONFERENCE       321  HC4SPJ        0.0              0.0          01MAY81  01MAY81    182.0
3F610 TITLE   CALDWELL SECTION            321  HF4SPJ        0.0              0.0          01MAY81  01MAY81   2333.0
   **Y 501,FY82, PROJ. I-80N-1177127 COMPLEXITY 4 INHOUSE  RED  I-80N OVERPASS, 10TH AVE. I.C.
3F611 3F612   PRELIM LAYOUT&REQ FOUNDATON 321  HF4SPJ        0.0              0.0          01MAY81  01MAY81     56.0
        RES   9H/03.6   9J/04.7   SK/04.7
3F613 3F614   CONSULTANT CONFERENCE       321  HC4SPJ        0.0              0.0          01MAY81  01MAY81     56.0
3F613 3F615   PREPARE&CHECK FINAL LAYOUT  321  HC4SPJ        0.0              0.0          01MAY81  01MAY81     56.0
        RES   HT/00.2   9J/03.4   SK/06.4
3F615 3F616   DES CALCS.SKETCH.MOMCREACT  321  H04SPJ      102.0             15.0          01MAY81  21MAY81     56.0
        RES   9J/03.4   9K/06.6
3F616 3F618   DETAIL&CHECK PENCIL DRWGS   321  H04SPJ       82.0             40.0          22MAY81  20JUL81     56.0
        RES   9J/01.2   SK/02.1   9L/05.3
3F618 3F619   INK & PROOF TRACINGS        321  H04SPJ       39.0             30.0          21JUL81  31AUG81     56.0
        RES   9J/01.2   SK/01.5   9L/05.5
3F619 3F620   QUANT,COST,FINAL PLNS,SP'S  321  H04SPJ       37.0             37.0          01SEP81  23OCT81     56.0
        RES   HT/00.1   9H/02.2   9J/00.5   9K/03.7   9L/06.5
3F620 3F933   QUANTS&EST TO DIST & OTHERS 321  H04SPJ        4.0              4.0          26OCT81  29OCT81     56.0
        RES   HT/00.2

                                        Bridge Group Leader

TARGET NETWORK REPORT    /45                  IDAHO TRANSPORTATION DEPARTMENT                                   PAGE    19
SCHED-UPDAT REPRT DICK J                          PROJECT DEVELOPMENT MSCS                         DATA DATE  01MAY81
                                                                                                     RUN DATE   3JUN81
                                                                                       ------------SCHEDULED---------
  I      J      ACTIVITY DESCRIPTION      VARIABLE CODES   ORIGINAL          REMAIN          LEVELED  LEVELED  LEVELRES
                                                           DURATION          DURATION        START    FINISH    DEMAND

FC  HARISN,ENTEFARMER CANALSH48-X-KEY 386,FY82,BR FS 6742(516),HRSN+ENTERPRISE+FARMERSFRIEN
FC633 TITLE   HARISN,ENTEFARMER CANALS 48 625B 0 1  J        0.0              0.0          01MAY81  01MAY81   2333.0
   KEY 386,FY82,ST-6742(516)                            COMPLEXITY 1,INHOUSE        HARRISON CANAL    ,MP 22.82
FC634 FC635   PRELIN LAYOUT&REQ FOUNDATON 625B 0 1  J        0.0              0.0          01MAY81  01MAY81     18.0
FC636 FC638   PREPARE&CHECK FINAL LAYOUT  625B 0 1  J       16.0         16.0 0000         01MAY81  22MAY81     18.0
        RES   HT/00.1   9J/03.0   9K/05.0
FC638 FC639   DES CALCS.SKETCH.MOMCREACT  625B 0 1  J       30.0         30.0 0000         26MAY81  07JUL81     18.0
        RES   9J/03.0   9K/05.0
FC639 FC641   DETAIL&CHECK PENCIL DRWGS   625B 0 1  J       20.0         20.0 5            08JUL81  04AUG81     18.0
        RES   9J/01.3   9K/02.0   9L/05.5
FC641 FC642   INK & PROOF TRACINGS        625B 0 1  J       20.0             20.0          05AUG81  01SEP81     18.0
        RES   9J/00.8   9K/01.6   9L/05.5
FC642 FC643   QUANT,COST,FINAL PLNS,SP'S  625B 0 1  J       10.0             10.0          02SEP81  16SEP81     18.0
        RES   9H/02.0   9K/00.6   9L/04.5
FC643 FC930   QUANTS&EST TO DIST & OTHERS 625B 0 1  J        4.0              4.0          17SEP81  22SEP81     18.0
        RES   HT/00.2
FC644 TITLE   HARISN,ENTEFARMER CANALS 48 625B 0 1  J        0.0              0.0          01MAY81  01MAY81   2333.0
   KEY 386,FY82,ST-6742(516)                            COMPLEXITY 1,INHOUSE        ENTERPRISE CANAL  ,MP 23.58
FC645 FC646   PRELIN LAYOUT&REQ FOUNDATON 625B 0 1  J        0.0              0.0          01MAY81  01MAY81     18.0
FC647 FC649   PREPARE&CHECK FINAL LAYOUT  625B 0 1  J       16.0             16.0          01MAY81  22MAY81     18.0
        RES   HT/00.1   9J/03.0   SK/05.0
FC649 FC650   DES CALCS.SKETCH.MOMCREACT  625B 0 1  J       30.0 40          30.0          26MAY81  07JUL81     18.0
        RES   9J/03.0   9K/05.0
FC650 FC652   DETAIL&CHECK PENCIL DRWGS   625B 0 1  J       20.0 30          20.0          08JUL81  04AUG81     18.0
        RES   9J/01.3   9K/02.0   9L/05.5
FC652 FC653   INK & PROOF TRACINGS        625B 0 1  J       20.0             20.0          05AUG81  01SEP81     18.0
        RES   9J/00.8   9K/01.6   9L/05.5
FC653 FC654   QUANT,COST,FINAL PLNS,SP'S  625B 0 1  J       10.0             10.0          02SEP81  16SEP81     18.0
        RES   9H/02.0   SK/00.6   9L/04.5
FC654 FC903   QUANTS&EST TO DIST & OTHERS 625B 0 1  J        4.0              4.0          17SEP81  22SEP81     18.0
        RES   HT/00.2
FC655 FC656   DIST FLO INFO&SUB 210 TO BR 625B 0 1  J       10.0             10.0          01MAY81  14MAY81      0.0
        RES   6M/03.0   6R/02.0   6S/02.0
FC655 TITLE   HARISN,ENTEFARMER CANALS 48 625B 0 1  J        0.0              0.0          01MAY81  01MAY81   2333.0
   KEY 386,FY82,ST-6742(516)                            COMPLEXITY 1,INHOUSE        FARMERS FRIEND CANAL,MP 24.10
FC657 FC658   HQQ PUBLISH PHASE 4 REPORT  625B 0P1  J        8.0              8.0          15MAY81  27MAY81      0.0
FC658 FC660   PREPARE&CHECK FINAL LAYOUT  625B 0 1  J       16.0             16.0          28MAY81  18JUN81      0.0
        RES   HT/00.1   9J/03.0   SK/05.0
FC660 FC661   DES CALCS.SKETCH.MOMCREACT  625B 0 1  J       30.0             30.0          19JUN81  31JUL81      0.0
        RES   9J/03.0   SK/05.0
FC661 FC663   DETAIL&CHECK PENCIL DRWGS   625B 0 1  J       20.0             20.0          03AUG81  28AUG81      0.0
        RES   9J/01.3   9K/02.0   9L/05.5
FC663 FC664   INK & PROOF TRACINGS        625B 0 1  J       20.0             20.0          31AUG81  28SEP81      0.0
        RES   9J/00.8   SK/01.6   9L/05.5
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Figure 4. MSCS precoded project development networks.

** MAJOR INCLUDES PRE-CODED HEARING
NOTE: USE OH-2280-B FOR ATTACHING ADDITIONAL STRUCTURES

1. F.O.N.S.I. = FINDING OF NO SIGNIFICANT IMPACT (FORMERLY NEG. DEC.)
2. CATEGORICAL EXCLUSION (FORMERLY NON-MAJOR)

Figure 5. MSCS design or combined location and design control network.

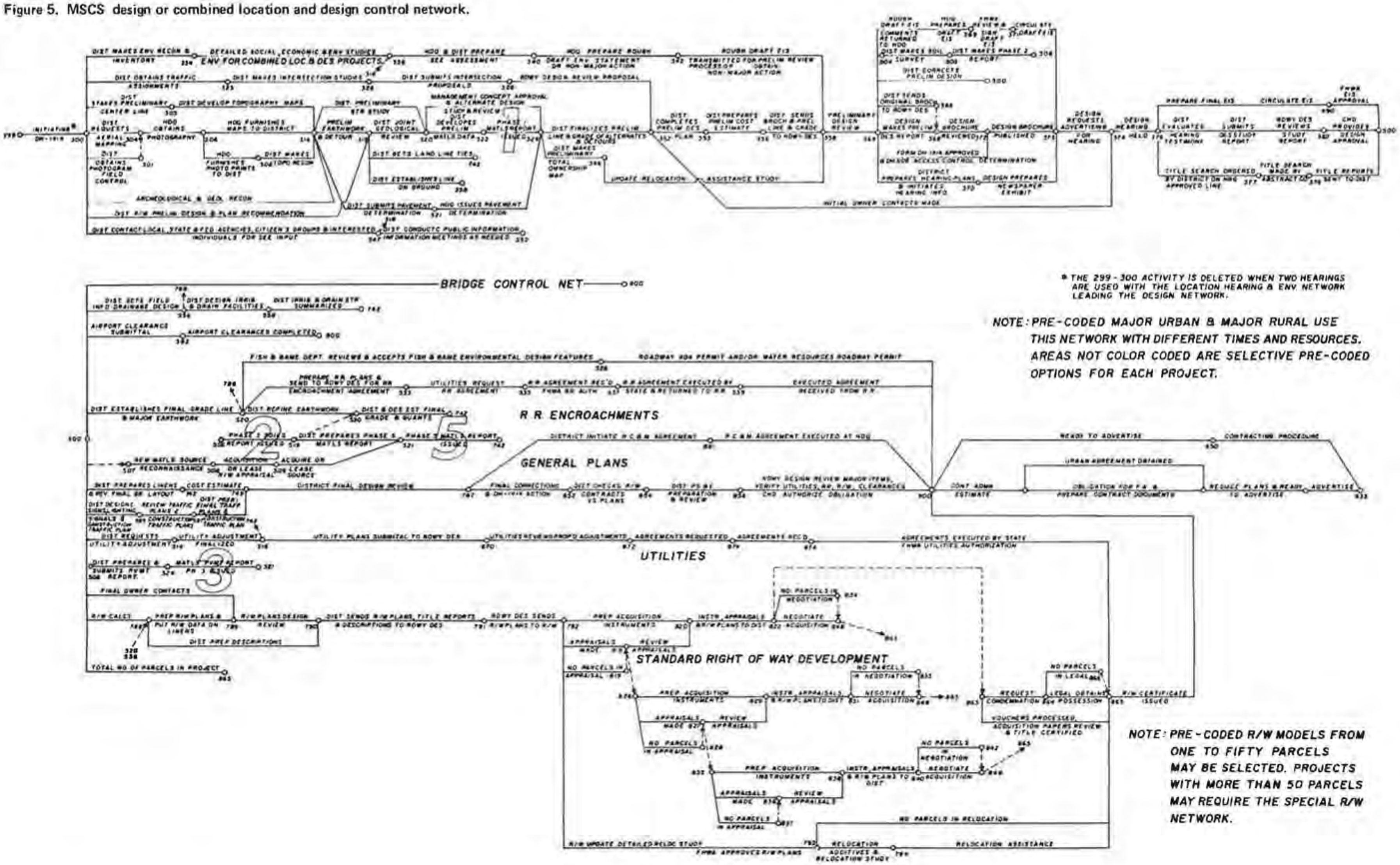


Figure 6. MSCS bridge design control network.

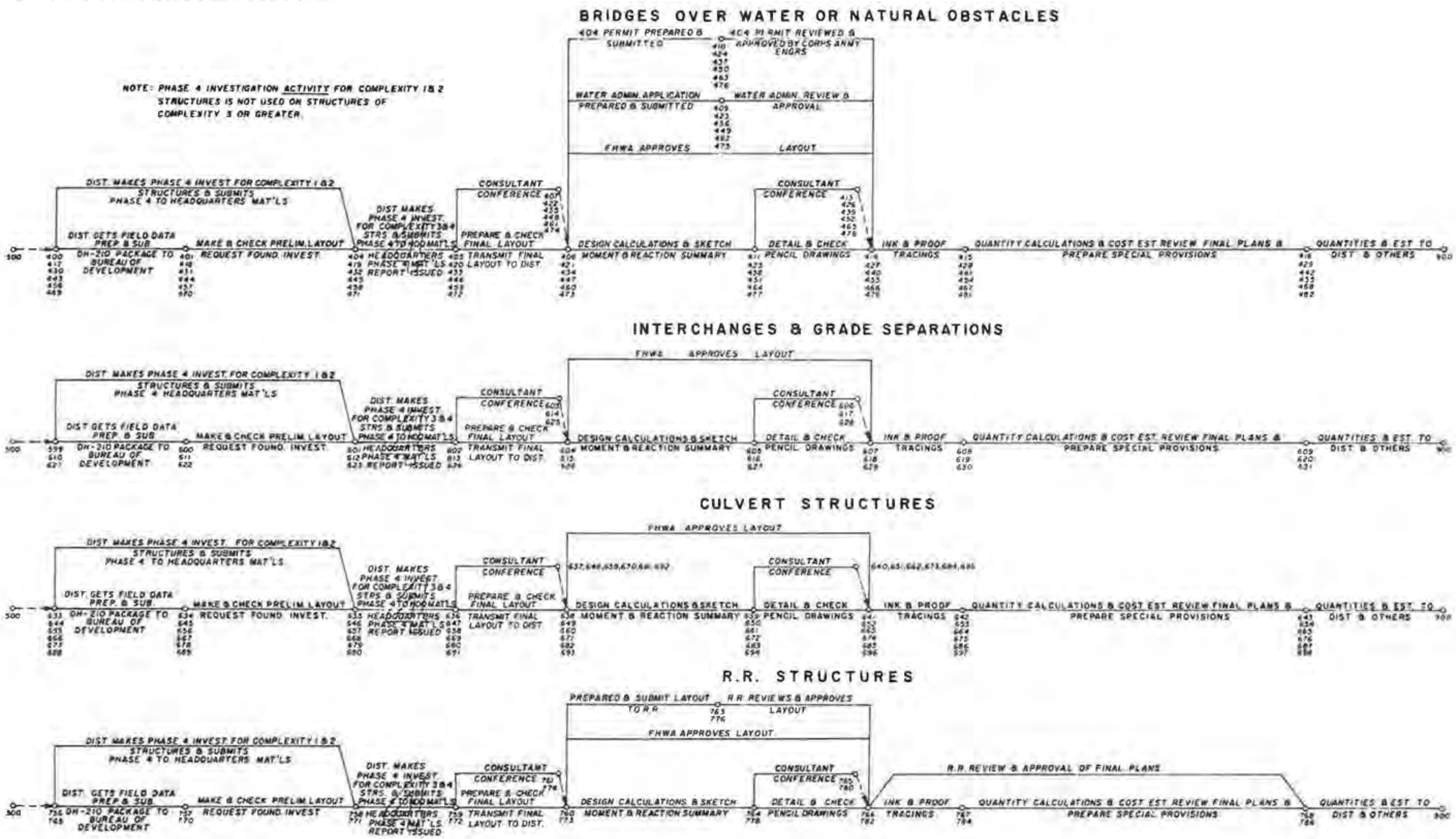
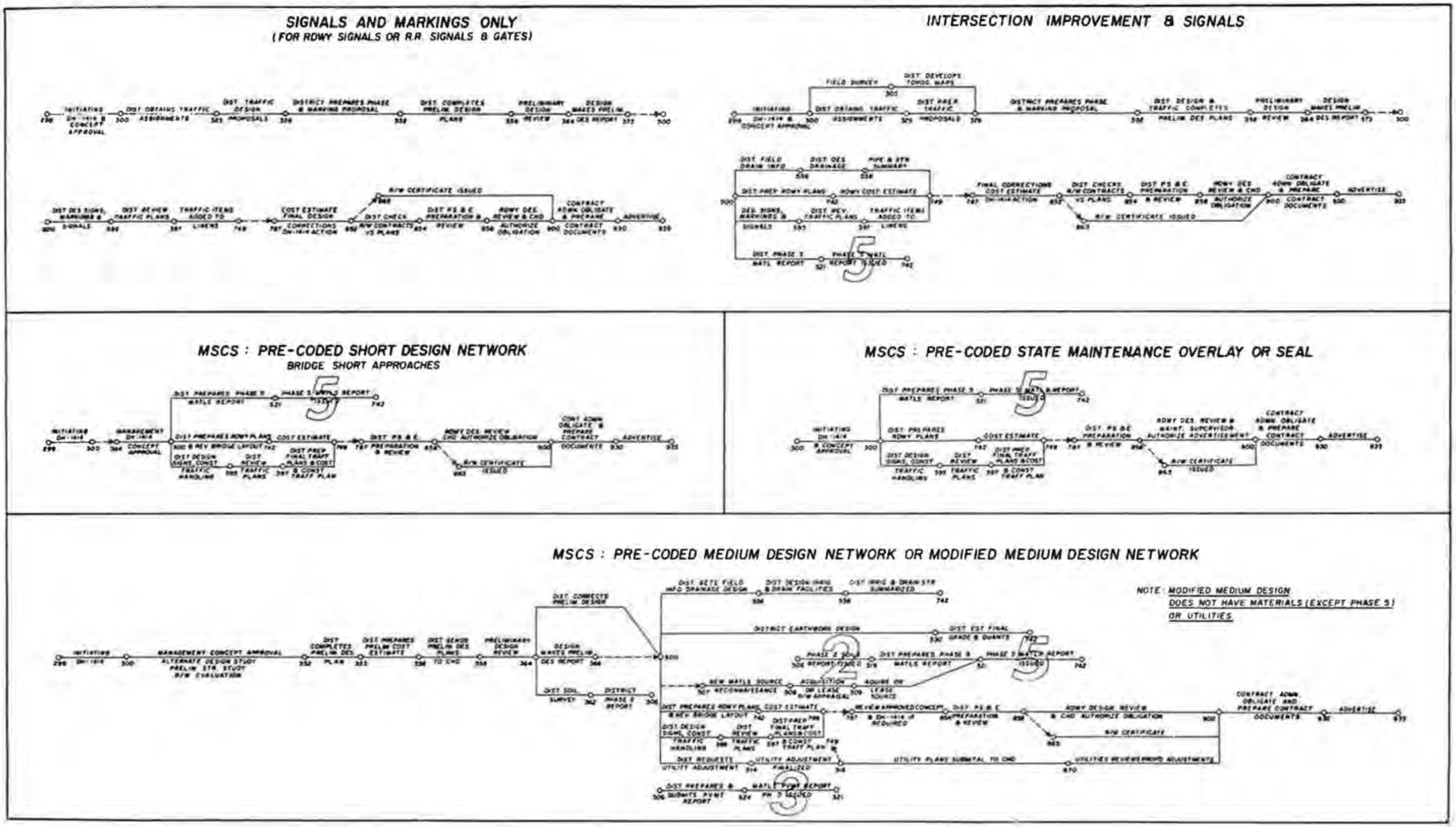


Figure 7. MSCS precoded intersection design networks.



HISTORY

Idaho's MSCS became operational in January 1975. Operational means that the forecasts were used by top management for forecasting when a project would be ready and for detection of delays.

In December 1977, management required that 205 new projects be added to the six-year construction program. This new program configuration was based on a major increase in state funding as well as on a potential major increase in federal funding. The project modeling methods at the time required an average of four district person hours per project, with headquarters proofing, key punching, and correcting final errors added to the district time. The network activity and resource modeling of the 205 new projects was going to require at least two months in straight-line time. In addition to the immediate problem of 205 new projects, the following conditions had reached a crisis point in their own right.

1. The system operation had to be compatible with the time required for management programming decisions. These decisions included adding of new projects, switching of category of funding and fiscal year of construction, and changes in priority between projects of the same fiscal year. Total reshuffling of the six-year construction program for management trial runs could not have more than three-day turnaround for MSCS forecasting.
2. Production personnel did not have time for person-hour type of involvement in estimating activity durations or resource parameters for initial loading of a project into the forecasting system.
3. Production personnel demanded accuracy in the project models and direct correlation to reality. Only production personnel possessed the timely knowledge for accurate updating of a project. The districts agreed that, on any given project, relatively few activities had considerable variance, but these activities were not predictable on a systematic basis.
4. Management thought that all projects, except stockpiles and areawide striping projects, had to be on MSCS. This would encompass the effective total workload of project development.

Roadway Networks

MSCS operations were suspended in November 1977 and the roadway design assistant devised networks for the various types of roadway projects, complete with activity durations and resource quantities. By telephone and personal contact with the districts, the networks were verified and amended as they were devised. In consultation with the bridge design section, bridge design networks were devised in four configurations. For each of the configurations, four levels of complexity (variations in activity duration times and resource amounts) were coded.

The four configurations were arrayed in 17 structure design networks so that a single project could have up to 17 structures separately identified and forecast. The 17 networks were then coded in each of the four levels of complexity, for a total of 68 bridge design networks, complete with activity durations and resources. Three types of environmental action were precoded as network legs. Right-of-way was precoded in batches of subnetworks that could be selected by number of parcels. Utilities, railroad encroachments, 404 permits, and materials sources were set up as network legs, each with two levels of complexity so they could be attached to main networks if they were needed.

As the networks, their activity durations, and resources were completed, they were loaded on ROSCOE utility libraries in the main computer disc storage. At the end of four weeks the entire task was completed and we began loading the 205 projects based on information that the districts had already submitted for programming purposes. In six days all of the projects were on the MSCS file and all other project fiscal year adjustments had been entered. The MSCS file was then run against the MSCS program and reports for management were provided in one night.

All project loading since that time has been done by headquarters. Districts provide normal programming information plus network selection and number of right-of-way parcels.

Updating Screens

Updating screens for input into ROSCOE were devised in November 1977 so that district personnel could annotate their schedule reports with their updating notes and eliminate input forms. These reports are collected by the district design engineer and are turned over to a terminal operator for entry on the ROSCOE screens and transmission by telephone line to computer facilities at headquarters. Production personnel need change only the days remaining on activities that are in progress or they may change the future by changing the original durations for those activities that are known to have changed in complexity but are not yet in progress. Thus, on the same report production personnel can adjust the future activities that vary from the precoded model and show the progress on in-progress activities by just changing days of duration. Since the resources operate as a percentage of activity duration, the resource person-days are automatically adjusted by activity duration change.

CURRENT OPERATIONS

One production specialist handles all updates, new loads, corrections, and reports. Every day 40 new projects can be loaded by the one specialist. Normally, only a few new projects occur during the week. New projects are loaded from regular programming information with telephone confirmation with the district on network selection and estimated number of right-of-way parcels. A major reshuffle of the program for a management what-if situation can be run overnight. There have been a few daytime turnarounds when management deemed it necessary. As a rule, management takes more time to decide on proposed changes than the time it takes to make the changes and run the MSCS system.

Production personnel do not have to code new projects. After a new project appears on the network report, the district and headquarters service sections modify the network to fit the actual project conditions by changing activity durations where necessary and calling for additional network legs, such as utilities, if they were overlooked. Key punching and cards no longer exist since the production specialist assembles all project models on ROSCOE from the ROSCOE utility libraries where all precoded networks and special networks legs are stored. Updates are transmitted from the district datapoint 4530 minicomputers via telephone line direct to ROSCOE data set library space set up by the production specialist. After updating into the MSCS file, the temporary ROSCOE space is cleared.

Production personnel have the final authority on the file input data: activity durations, resource amounts, and resource pool limits. District section supervisors and headquarters section supervisors select the resource limits and have final authority. Changes in the resource quantities on the precoded models as well as resource changes on the operating MSCS file cannot be made without district concurrence. Any change in resource pool constraints also requires district concurrence.

All projects except stockpiles and striping projects are loaded into MSCS.

Implementation and Guidelines for Current Operation

The district production staffs aided MSCS implementation. Perhaps the biggest reason for the willingness of production people to help create the MSCS operation was that it gave them the opportunity to communicate reality to management.

The original guidelines for implementation and operation have never changed.

1. The MSCS system is used by top management as the only source of earliest ready-for-contract forecasted dates. The other parameters such as funding, project need, geographic distribution, public demand, safety, and operation are involved in management's decision of priority and scheduling, but a project cannot be scheduled for contract earlier than the earliest MSCS forecast.
2. Information acquisition cuts across boundaries of authority but does not affect the chain of responsibility or authority. Information is accepted from anyone at any time by any method of communication. The system is not used as a whip and thereby contains true information to the best of the project development staff's knowledge.
3. The roadway designer is in sole charge of project development and has direct access to top management as far as MSCS is concerned. Production personnel are the final authority on time and resources.
4. The system is operated on the philosophy that the system conforms to the methods and desires of production personnel. Operation is constantly improved on suggestions from production personnel and all improvements must have least inconvenience to staffs and reduce the time required by production staffs. All reports are tailored to suit the preference of the users. Any request, question, or complaint by a production person is acted on immediately and solved to his or her satisfaction. Corrections or modifications are made for the user.

Resource Constraint Versus Unlimited Critical Path

During the first year of operation we found that it was important to answer the question, "What is the effect of resource constraint versus unrestrained resources on each activity?" MSCS, during its program operation, calculates the resource-unrestrained critical path start and finish dates and stores these dates on an internal file for use during resource allocation. Selection of command allows subtraction of the resource-leveled finish date from the resource-unrestrained critical path finish date. The result is shown as negative or positive working days.

We have chosen to name this number level resource demand because it is the number of working days after (-) or before (+) the critical path late finish that is needed to obtain resource availability for that activity. Thus, an activity that shows -42.0 in the LEVEL RES DEMAND column of a report has been delayed by 42 working days beyond the unresourced critical path late finish due to lack of available resources. All scheduling and update activity reports, such as the sample of the bridge group leader report in the exhibits, have been report-formatted to show the level resource demand value. Any production person or supervisor can see at a glance which activities will be in trouble due to lack of forces during that period of time.

MSCS Program Capacity

The most recent MSCS program improvement by MCAUTO allows 42 350 activity and resource records to be resource-allocated simultaneously under resource constraints in one file of projects. Each resource record can have 12 resources or work centers per activity. We have chosen to allow a maximum network size of 999 activities/project. This limits a single file of projects to 1296 projects. If we chose a limit of 99 activities, the theoretical limit would be 46 656 projects/file, which makes the resource allocator record limit of 42 350 records the controlling factor.

OPERATION COSTS AND PERSONNEL

Idaho purchased a paid up license for MSCS from McDonnell Douglas and remained in its 1700-member user group. The user group maintenance fee obtains requested enhancements and new, advanced versions of MSCS that are released periodically. The most recent release, version 9.0, reduced the space requirement for processing from 1400 virtual K to 640 virtual K, reduced the central processing unit time from 2.5 h to 35 min, and added more commands and options, including conditional change. The reduction in time is significant when 638 projects with 37 500+ activities are under resource constraint.

The total investment to date, including paid up lease, is approximately $56 000. The 1982 maintenance fee will probably increase from $3700 to $4500. In 1975 the maintenance fee was $1200. The personnel commitment and time required to operate project development MSCS with statewide updating every two months are described as follows: Six districts with 4-8 production personnel per district with updating responsibilities, for 52.2 person days/year. Also needed are a total of 9 headquarters personnel from bridge, utilities, environmental and mapping, local roads, and right-of-way who have updating responsibilities for 24.45 person days/year. Total production personnel time required for updating is 76.65 person days/year.

Along with the time of production personnel required for updating, system management and operation requires one full-time engineering systems analyst and one full-time data processing production specialist at headquarters. The total salary cost per year for updating, system management, and operation is $54 000, which at the loaded rate for benefits, translates to approximately $72 000.

It is difficult to quote meaningful costs for computer hardware and software use because it depends on cost-accounting procedure and in-house facilities that use an IBM 370-158 (VS-1). The ROSCOE software is the tool used to handle updating, creation of data sets, MSCS operation commands, and job control language commands in assembly and submittal to the main machine processing queue. Reports are printed on two 1200-line/min printers. The cost of ROSCOE, an Applied Data Research Corporation product, is not included in cost of MSCS operation because it is used departmentwide. ROSCOE is similar to TSO, CMS, and other data-handling software.

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