Development of an Integrated Highway Management System

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The West Virginia Highway Department has developed a management system designed to improve the planning, scheduling, and control of operations in the fields of engineering, right-of-way acquisition, and construction. The program of development includes three major phases: (a) highway program definition-management system feasibility study; (b) system design and initial operation capability; and (c) full-scale system implementation and personnel training. The paper concentrates primarily on the second phase, describing the system and the results of its application to Interstate System work during 1963. The new system was productive of marked progress in work achievement over the year 1962.

•THE STATE Road Commission of West Virginia began a program to improve its planning, programming, scheduling and control of operations in engineering, right-of-way, and construction in August 1962. The program recognized the need for new and pervasive approaches and consequently, was conceived as research and development work in the field of highway management. The objective of the program was to design, install and test an integrated management information system which would supply on-line, updated information to functional, program and top management in regard to time, cost and physical performance of its program in Interstate, ABC, and secondary roads.

The program has been conducted in three major phases: Phase I, Highway Program Definition—Management System Feasibility, August 1962 to February 1963; Phase II, System Design and Initial Operational Capability, February 1963 to January 1964; Phase III, Full-Scale Implementation and Training, continuing from January 1964.

This paper is directed primarily to a description of the results of the Phase II effort, describing the system and the initial results achieved in its applications to the Interstate program. The Phase II activity was supported as a Federal-Aid Research Project under contract HPS-HPR1(24).

PHASE I: HIGHWAY PROGRAM DEFINITION—MANAGEMENT SYSTEM FEASIBILITY

In early 1962, State Road Commissioner Burl A. Sawyers recognized that the West Virginia program in roads was falling farther behind in both its Interstate and Federal-assistance programs. The Interstate program, for example, was on a performance trend line such that only slightly over 50 percent would be completed in 1972—the target year for completion. Although many efforts were under way to improve the situation, and a major portion of the problem could be explained by the fact that nearly 30 percent of West Virginia's 520 miles of Interstate had been added to the program as recently as the previous two years, the Commissioner was not satisfied. He and his top management staff were determined to see that all possible steps were taken to achieve full completion by the target date.

As a first step, it was recognized that the overall program needed better and more detailed definition in terms of the manpower required, the funding required from the state legislature, the facilities required, etc., to meet specific completion schedules involved. It was also recognized that an improved organization and attendant procedures were needed and that supporting management information and control systems were required to establish targets

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and to update and control the plan. In July 1962, the Commission was convinced that networking technology—the critical path method (CPM or PERT)—could be used as the core for developing an "integrated management system" which would establish targets of performance for each operating organizational element, spell out the required manpower and financial resources, and would provide a dynamic means of "statusing" the plan, monitoring accomplishments and identifying potential problem areas before occurrence.

At that time, CPM had been used on various construction and planning projects in West Virginia and many other states, but had not been used in any highway department as the means for planning and controlling the internal operations of its large multiproject engineering organization. The Phase I effort was therefore directed toward two principal objectives: (a) the immediate need was to bring the overall program into sharp definition, hence the term "program definition"; and (b) the effort was considered a research effort to determine the feasibility and practicality of utilizing CPM as the basis for an integrated highway management system.

Accomplishments

During the period August 1962 through February 1963, study effort was directed to the following accomplishments:

Overall highway program definition was achieved.
- Performance objectives, policies, priority rules were explicitly stated.
- Integrated master schedules for both department and projects were developed.
- Funds and manpower required to meet schedules were developed.
- A comprehensive report to the legislature on the programs at present and a plan for the future was developed.

Feasibility of applying CPM to internal management of commission.
- Preliminary networks for engineering, right-of-way and construction were developed and analyzed for improvement and proper control points.
- Standard CPM modules (networks) were deemed feasible.

Preliminary system description of proposed management information system was developed.
- Design concept for integrated management system was developed and approved.
- Initial training and indoctrination of Commission personnel in system concept was achieved.

Necessary organization for implementation of management system was established.
- Management scheduling and control division established on a level with operating (often called functional) divisions.

Design Concept for Integrated Highway Management System

In developing the design concept, the following general guidelines were laid down at the outset:

- The system should provide the common language and basis for all management communication in the Commission.
- The system should be rapidly responsive to requests for information concerning: status of schedule, costs and manpower, potential slippages and progress outlook, simulated effects of proposed changes.
- The system should make most efficient use of existing procedures and data sources.
- The system should be simple and flexible.
- The implementation should be approached in an evolutionary manner, yet obtaining management control at an early date.

From these guidelines, the following design criteria were established:

- Management performance objectives, policies and priorities shall form the basis for planning and scheduling activities.

Information generated must serve both functional (i.e., divisional) and program management needs—both functional and program cuts of information are required.

Functional and program goals must be consistent at all times. All internal and external milestones showing responsibilities should be identified. BPR events are to be included.

The three classes of information (schedule, cost, manpower) shall be consistent and from a common source.

Plans must be updated and obtained weekly from actual experiences, to provide realistic control information.

Planning and actuals information shall be in the same format.

Information generated should be designed to serve all levels of management from the same source data and file.

Contractor proposals and reporting should be in a format directly usable in the management system.

In developing a realistic design concept to meet these criteria, it was found necessary to treat explicitly four major management tasks:

Establishment of performance objectives.

Development of a specific plan to attain objectives.

A means for execution and updating of the specific plan.

Specification of an organization for implementation and operation of the management system.

In discussing each of these tasks, it is helpful to examine the information structure and flow pattern of management decision and data involved. Figure 1 shows the information structure—a hierarchy of reports from the task level up to the total state program. Figure 2 shows the data flow and the dynamic nature of management decision. The arrows, or feedback loops, describe the continuing nature of the management process. These two illustrations describe the principal features of the design concept.

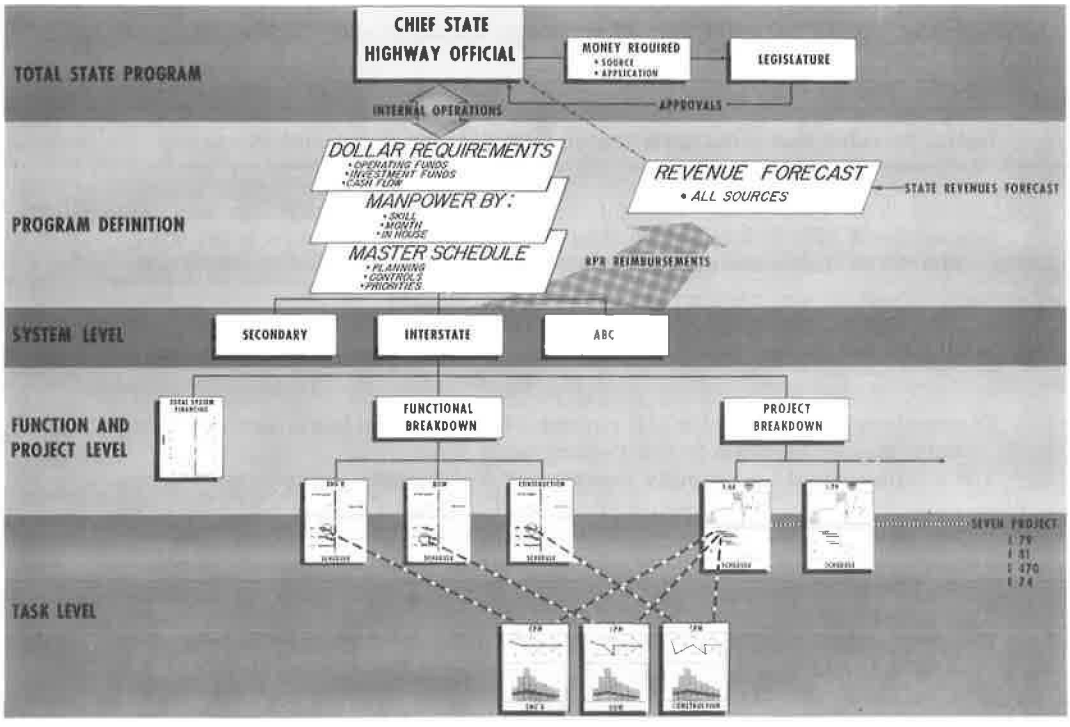


Figure 1. Information structure—integrated management system.

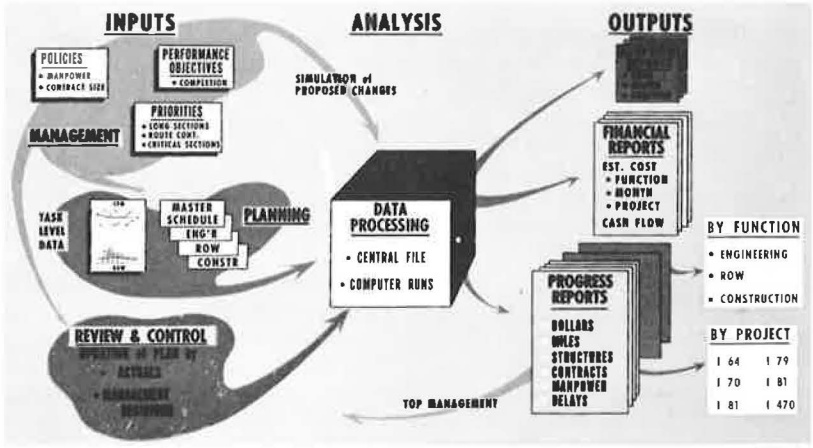


Figure 2. Management decision and data flow.

Establishment of Performance Objectives

Management must first establish its overall goals in a manner which provides criteria for the planners. In the Phase I effort, the goals were stated as a commitment to complete the Interstate System by June 1972, and to attain the maximum level of effort possible with the resources available in the ABC and 100 percent state-funded programs.

Following this, important policies and priorities were set down as guidelines in planning. Typical policy statements were the uniform employment policy and the maximum size of construction contract desired. Priorities to be followed in planning were also stated. In Interstate, for example, these included a planning directive to develop continuous long sections of highway, to work on hazardous areas, and to emphasize connections with adjacent states or major metropolitan areas within the state as a first priority consideration. Armed with these specific guidelines, the task of developing a specific plan is undertaken.

Development of a Specific Plan

The total state program should be defined internally in three ways, each of which is consistent with achieving the same overall goal (Fig. 1). First, a master schedule is

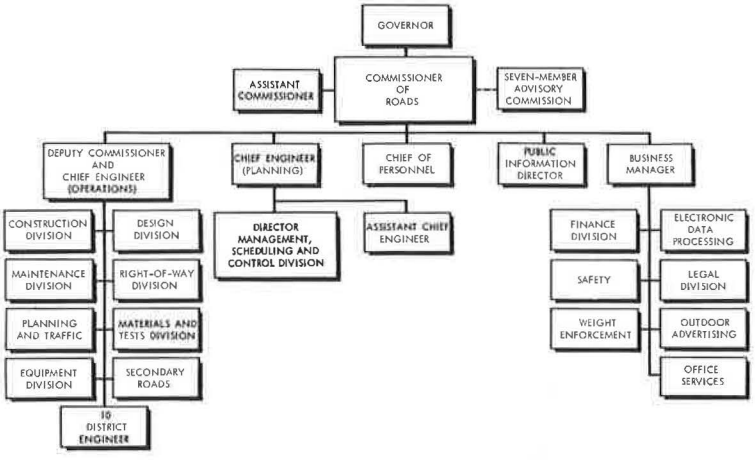


Figure 3. West Virginia State Road Commission—organization chart.

required which shows what projects are to be performed and at what time. These are overall inclusive schedules for each engineering, right-of-way and construction project involved in a section. Second, the dollar requirements to support each project should be laid out by time interval. Third, the manpower requirements for each project should be developed by skill category and by time interval for the total program. These three control concepts, when consistent, provide the necessary program definition. This was accomplished in Phase I in a gross way based on broad planning standards. The Phase II effort was directed to integrating the task level CPM data into the planning and reporting structure.

As a second level of information, the three "systems" comprising the total program: Interstate, ABC and 100 percent state highway programs, are broken out separately. This breakout is necessary to insure managerial attention to the competing nature of these various systems for available resources in the overall program and to provide data for decisions covering allocation of resources. Decisions which lead to on-again, off-again attention to the various programs do not produce the best morale or results.

Below the system level, it is necessary to develop information to support two different management looks at the same job of work. These are the functional division and the route manager (or project level) responsibilities. The engineering, right-of-way and construction divisions need clearly established goals showing what specific projects are to be accomplished, at what time and cost and with what resources. Then, since the work flow is roughly through the divisions, it is desirable to have a route manager concentrating on orderly, timely completion of total projects which generally cross back and forth between the functional divisions several times before completion.

A detailed "task level" type of information that shows individual project schedules and resources is required by each of these managers. These detailed plans and schedules must be consistent with the overall master schedule. As indicated in Figure 1, task level information will be based on a CPM network for the particular project in question. Standard networks or "modules" were developed which eliminate the need for constructing initial networks for each project.

Execution and Updating of Specific Plan

When a feasible plan has been developed and authenticated by management, the total process of work is set in motion. At this time, reports on actual accomplishments to the date of the report are needed which show compliance with the schedule, cost and manpower targets, and which clearly identify the physical accomplishments.

Management also needs a class of information in the form of reports that provide early identification of potential problem areas before they occur. Reports that predict the amount and cause of program slippage, identify administrative bottlenecks, and that point up required decisions concerning long lead time actions are needed in order to obtain and maintain managerial initiative. Management also needs the capability to determine the effects of proposed policy changes. In a properly designed computer-assisted management system, it is possible to perform quickly required replanning to determine the effects of proposed policy changes. This feature is called the capability to "simulate" the effect of a proposed policy change.

Finally, management requires a series of data that shows the present as well as the projected fiscal status of the program and the resulting financial requirements and implications. Financial status information includes the monthly reports of apportionments available, programmed obligations, obligations, expenditures and reimbursements. These should be updated to include transactions made. Periodically, top management must make a realistic forecast of financial requirements. Data required will show the planned source and application of funds. Estimates of funds to be derived from all sources, e.g., reimbursements and taxes, must be available and consistent with the official master program plan. The application of these funds must consider the Commission's operating costs, the program costs and cash flow requirements to support the reimbursement cycle and must also be consistent with the official update program plan.

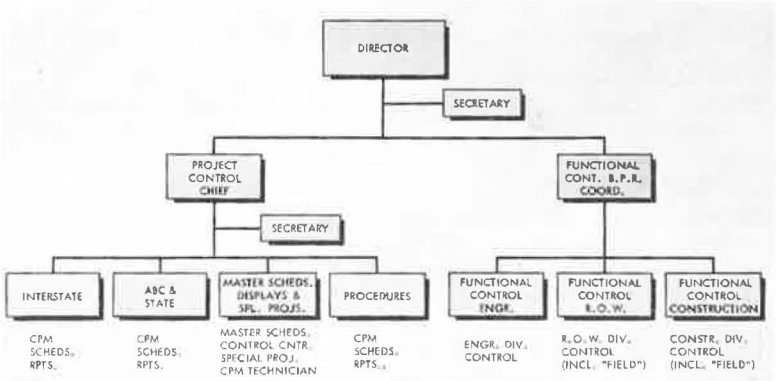


Figure 4. Management scheduling and control division—organizational structure.

Organization for Implementation and Operation of Management System

It was recognized early that effective cross-functional control could be obtained only by developing a group which had the responsibility and authority to acquire the necessary data and update the master schedule in a reliable manner and in the common format as designed. Therefore, a management scheduling and control division (Fig. 4) was created and was made responsible to the chief engineer, planning (Figs. 3 and 4). The new division has organizational status equivalent to the operating divisions and it permits the development of the necessary checks and balances over the flow of work between the operating (functional) divisions. The division has no authority to direct the work of the operating divisions. Rather, it acts in an advisory capacity concerning priorities, the predicting of slippages and their impact, and is custodian of the schedule.

PHASE II: SYSTEM DESIGN AND INITIAL OPERATIONAL CAPABILITY

Results of the Phase I effort led to the conclusion that detailed design test and implementation of the design concept should be undertaken immediately. Five principal objectives were established for this phase of the work:

1. Design and develop a CPM system capable of providing administrative information vital to highway department management, utilizing a Univac SS90 computer for data processing and integration.
2. Development of operating procedures that will permit successful operation of the CPM system. These procedures will be designed to promote accuracy, completeness and uniformity of system input and output data.
3. Development of project planning and scheduling methods and data that will establish realistic plans for the timely completion of all highway projects, with primary emphasis on completion of the Interstate System.
4. Development of a highway status reporting system that satisfies internal administrative needs as well as those of "external" agencies. Emphasis will be primarily on devising meaningful and useful management reports concerned with schedule achievement. Methods of reporting and forecasting manpower and funding information will also be developed.
5. Development of the most practical organization and staffing concept that permits the CPM-based highway management system to function in the most efficient manner.

In Phase II, three main tasks were accomplished: the detailed design of the operating integrated management information system, the programming of the computer, and the implementation and test of the system, including training.

Initial CPM Data Acquisition

The conference method was judged to be the most effective way to develop the detailed CPM networks. The conferences also provided a means of training appropriate division personnel in the CPM method, permitting all personnel "to grasp the big picture," preventing important steps being overlooked, providing an awareness of the interrelationships between personnel within a specific division as well as with other divisions or agencies, arbitrating terminology differences, and stimulating thinking in devising new and more efficient methods of accomplishing the tasks. This last point, termed "procedure purification," proved to be one of the most rewarding aspects of the study and resulted in eliminating, resequencing and combining many activities in the preliminary networks.

Several conferences were held with each of the three major divisions. At each of these meetings, there were generally 15 to 25 individuals present, including representatives of the Bureau of Public Roads and other divisions that might play an important role in developing the networks.

The ground rules established for developing the networks during these meetings were basic, yet extremely important to the overall system. These were as follows:

Module Concept.—The networks would be developed based on a typical situation in engineering, right-of-way and construction. The networks, when developed, were to provide control from the point in time when the advance planning division completed required studies until the project was open to traffic. These modules would attempt to accommodate 85 to 90 percent of the situations that might arise. The same networks would be used to monitor every project.

Desired Sequence.—The networks would reflect the sequence of operations that was desired for use with every project.

Problem Areas.—Known problem areas would be treated with particular care; emphasis would be placed on these areas through the definition of these problems in detail.

Interstate Oriented.—The networks would be oriented around the Interstate problems, with careful attention to providing enough steps to cover any particular problem that might arise when using the "modules" to control projects on the Primary and Secondary Highway Systems within the State.

After a brief explanation of CPM and the establishment of the basic ground rules, all personnel were aware of what was needed and the network development began. The development of the modules generally took three conferences with each division. The first conference began with the establishment of a "job list." The purpose of the job list was to provide a check list to be used while developing the networks. It helped to remind the attendees of the major steps involved in the overall operation and reduced the possibility of overlooking tasks. It also served as an "icebreaker"; for the development of the job list encouraged personnel in attendance to participate fully in discussions and to arbitrate any problem areas that might arise.

The job list prepared for engineering was particularly helpful in establishing the stages of a project as it progressed through design. The first phase was termed the "reconnaissance phase" and included design from advanced planning until a corridor was established. The second phase was termed the "design report phase" and included design from establishment of a corridor until a line had been defined. The third phase is the "contract plans phase" which covers the detailed design of the construction section.

After the job list was completed, networking was started. Having established the parameters of each network, the task was to "fill in the blanks" so as to provide a continuous chain of activities that linked the two end points—start of the project and completion of the project. In developing the networks, each activity was tested by the following questions:

> What task(s) must be accomplished before the activity in question can begin?

What task(s) cannot proceed until the activity in question has been accomplished?
What task(s) can or should be accomplished concurrent with this activity?

The objective was to show the earliest possible start and the latest possible completion date for each task, even though it is customary to accomplish the job at some specific point between these two extremes.

The network took shape until a complete arrow diagram was constructed, connecting the beginning and end of the module in question and showing all the activities with proper interrelationships and interdependencies. A master plan, in the form of a network, was now available which would provide all personnel with a step-by-step "road map" through the project. This completed the first conference.

The next step was to draw the network in a "smooth-rough" form so that it could be properly reviewed by the conference attendees. While redrawing the network, the planner examined it carefully in order to insure that good networking techniques had been utilized.

Once the network was drawn in a "smooth-rough" form, it was distributed to the attendees for review. The review provided the attendees with an opportunity to look objectively at the network, in their own offices, so as to insure that it accurately portrayed the plan. When all the attendees at the second conference were satisfied that the network reflected the plan, the final step was ready to be accomplished.

The planner next redrew the network in smooth form, representing the work of the two previous conferences. Again, networks were distributed to the attendees for their review. At this third meeting, little additional sequence information was obtained from the attendees. Those present were asked to examine each activity on the network under review and to determine the length of time necessary to accomplish each task. This action started the scheduling phase. The same approach was utilized in the obtaining of time estimates, for it is extremely important that the person responsible for the task estimate the time required to perform it. In this way the validity of the estimates are improved and an effective "commitment" is obtained.

When considering times for an activity, the estimator must remember and record those factors that control the length of time necessary for each activity's completion. Such items as type of manpower skills required, number of men available, the number of hours per day and shifts per day should be recorded. By analyzing an activity in this manner, the estimator was able to give a time estimate that reflects the expected elapsed time expressed in working days. If the estimator determines that performance of the task requires six consecutive days of work, he gives a time estimate of six working days.

The third conference had as its specific purpose the application of time estimates to each activity, as well as the suggestion of any final changes that might be required in the network. Once this purpose had been accomplished, the planner made these minor changes and applied the time estimates to the smooth network. Thus, for each activity on each network module, there was associated the following data elements: responsible division; elapsed time for the activity; manpower required (number of men, skill category, and percent of time required); direct costs incurred as a result of the activity.

When the networks had been approved, they were ready for use in conjunction with the Commissioner's computer. Figures 5, 6, 7 and 8 represent network developed in conferences with the right-of-way and engineering divisions.

Use of Standard Networks for Specific Projects

These networks are referred to as "standard modules" and have been found directly applicable to about 85 percent of all projects. For these cases, there is no need to draw networks for each project. Rather, the tabular listing of the module, such as shown in Figure 9 for right-of-way, is used as the basis for project estimation and as the input form to the computing center. Variations in the elapsed time, manpower or direct costs are simply made on this tabular listing, authenticated by the appropriate management and then entered into the active project file.

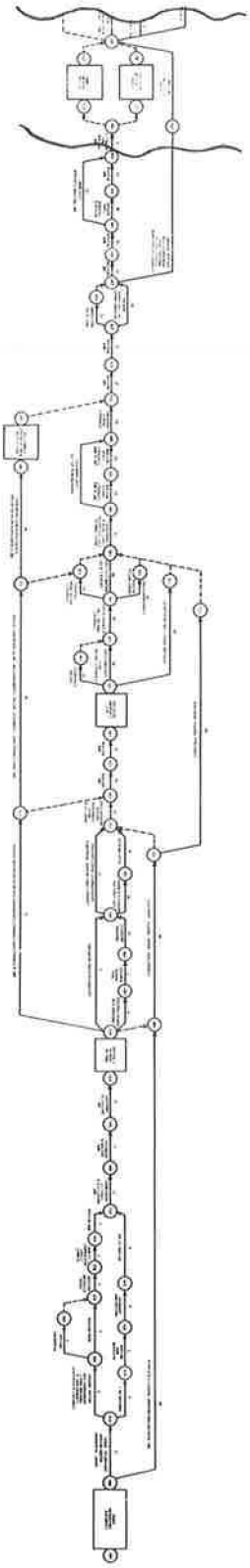


Figure 5. CPM module reconnaissance and design report phase—Part 1: reconnaissance.

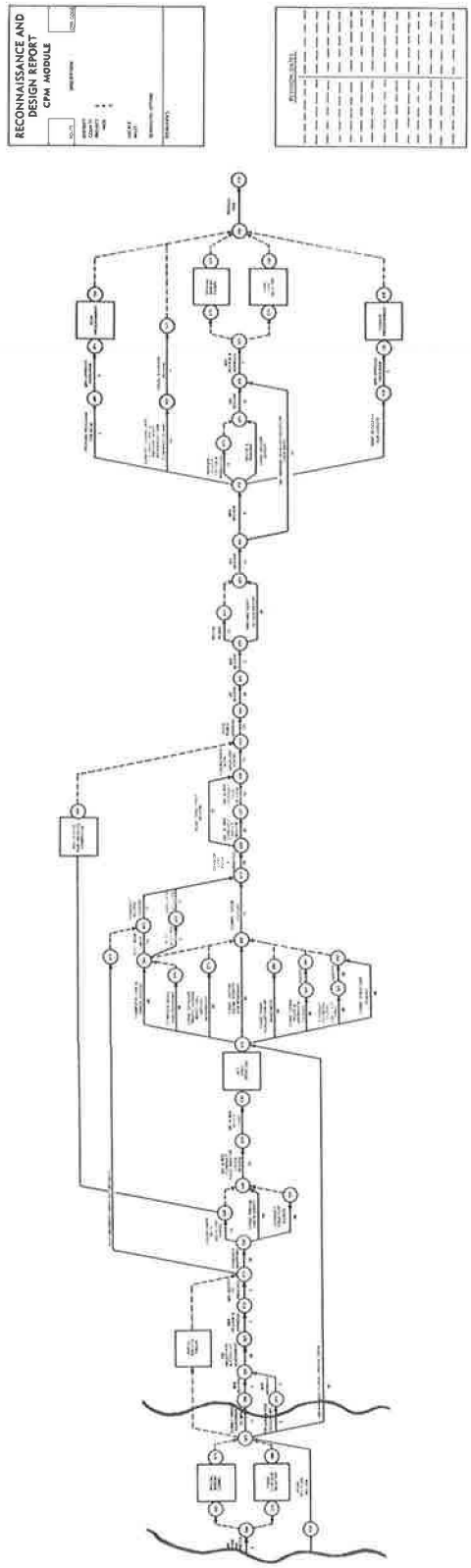


Figure 6. CPM module reconnaissance and design report phase—Part 2: design report phase.

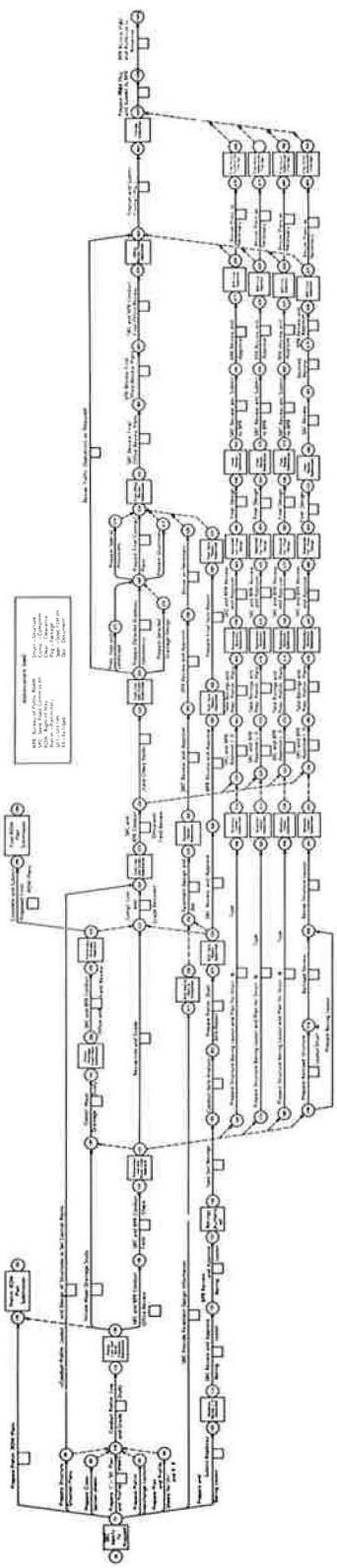


Figure 7. Contract plans CPM module.

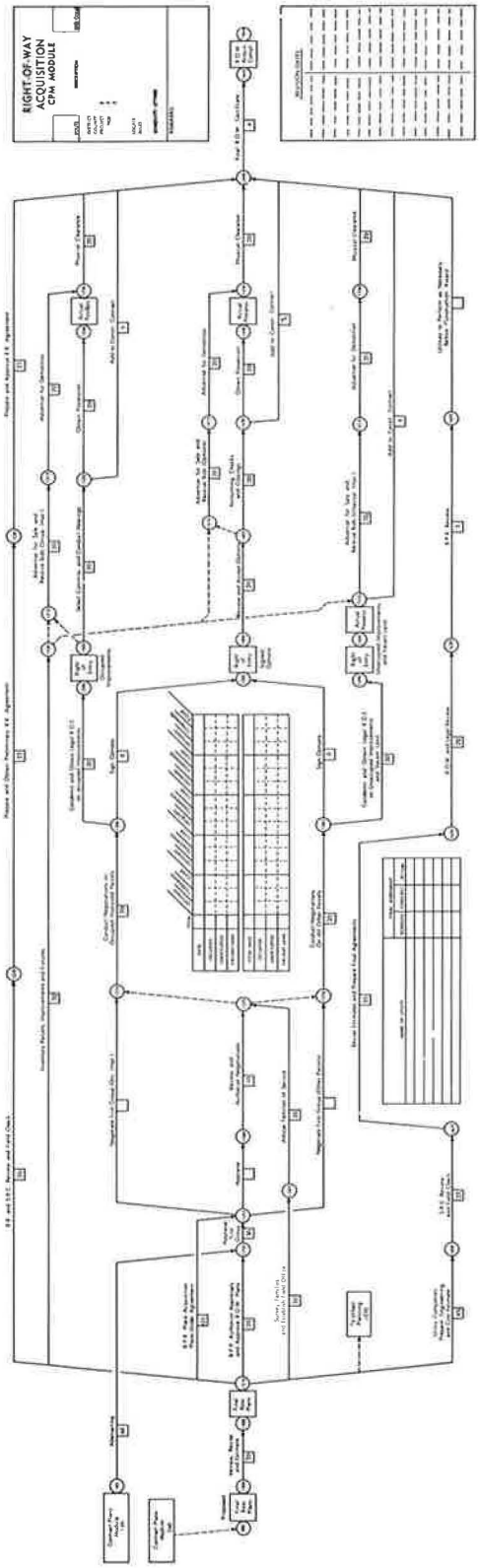
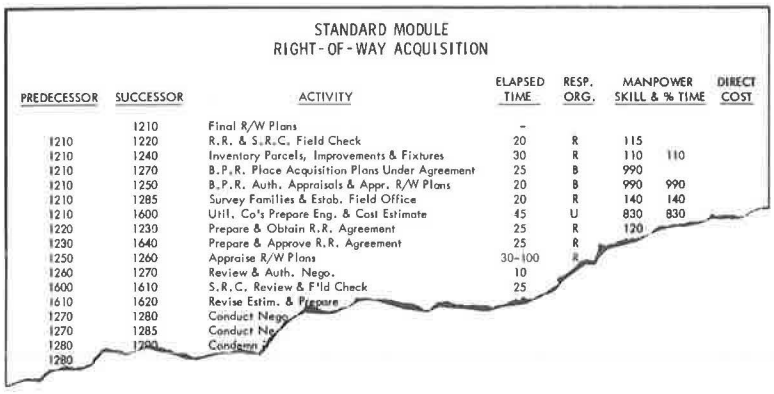


Figure 8. Right-of-way acquisition CPM module.



STANDARD MODULE
RIGHT-OF-WAY ACQUISITION

PREDECESSOR	SUCCESSOR	ACTIVITY	ELAPSED TIME	RESP. ORG.	MANPOWER SKILL & % TIME		DIRECT COST
	1210	Final R/W Plans	-				
1210	1220	R.R. & S.R.C. Field Check	20	R	115		
1210	1240	Inventory Parcels, Improvements & Fixtures	30	R	110	110	
1210	1270	B.P.R. Place Acquisition Plans Under Agreement	25	B	990		
1210	1250	B.P.R. Auth. Appraisals & Appr. R/W Plans	20	B	990	990	
1210	1285	Survey Families & Estab. Field Office	20	R	140	140	
1210	1600	Util. Co's Prepare Eng. & Cost Estimate	45	U	830	830	
1220	1230	Prepare & Obtain R.R. Agreement	25	R	120		
1230	1640	Prepare & Approve R.R. Agreement	25	R			
1250	1260	Appraise R/W Plans	30-100	R			
1260	1270	Review & Auth. Nego.	10				
1600	1610	S.R.C. Review & F'ld Check	25				
1610	1620	Revise Estim. & Prepare					
1270	1280	Conduct Nego					
1270	1285	Conduct Ne					
1280	1290	Condemn					
1280							

Figure 9. Tabular listing of module.

For some projects, activities in addition to the standard module are deemed desirable. Such net activities are added simply by modifying the tabular listing with the following: defining the activity predecessor and successor events, estimating direct cost and manpower, writing the activity name.

In this way, the labor of network construction and updating is avoided, while at the same time, there is the benefit of reference standard networks to visualize the flow and status. The data from the tabular listing for each project are entered on a CPM input sheet (Fig. 10). Next, the desired completion date from the master schedule is entered into columns 13-16, and the input cards are punched. When all projects are similarly entered, all the necessary data for processing have been "inputted."

Computer Program

A standard CPM computer program for the SS90 was redesigned and modified to obtain the following capabilities: relate working days to specific calendar dates, insert scheduled starting day and scheduled completion day, determine positive, negative or zero slack for each activity, and handle cost and manpower inputs for each activity. The revised computer program was used to provide the outputs at the project and program levels.

Data Outputs at Project Level

The output printout for each project contains the following information for each activity in the project:

Column Heading	Data Description
PREDECESSOR EVENT	- 4 digit number
SUCCESSOR EVENT	- 4 digit number
ACTIVITY DESCRIPTION	- Word description
ACTIVITY COST	- Direct costs
ACTIVITY DURATION	- Working days
EARLY FINISH DATE	- Work days from project start
LATEST ALLOWABLE FINISH DATE	- Date
ACTUAL COMPLETION DATE	- Date (when completed)
SLACK	- Working days
MANPOWER	- By Division, skill and percent of time

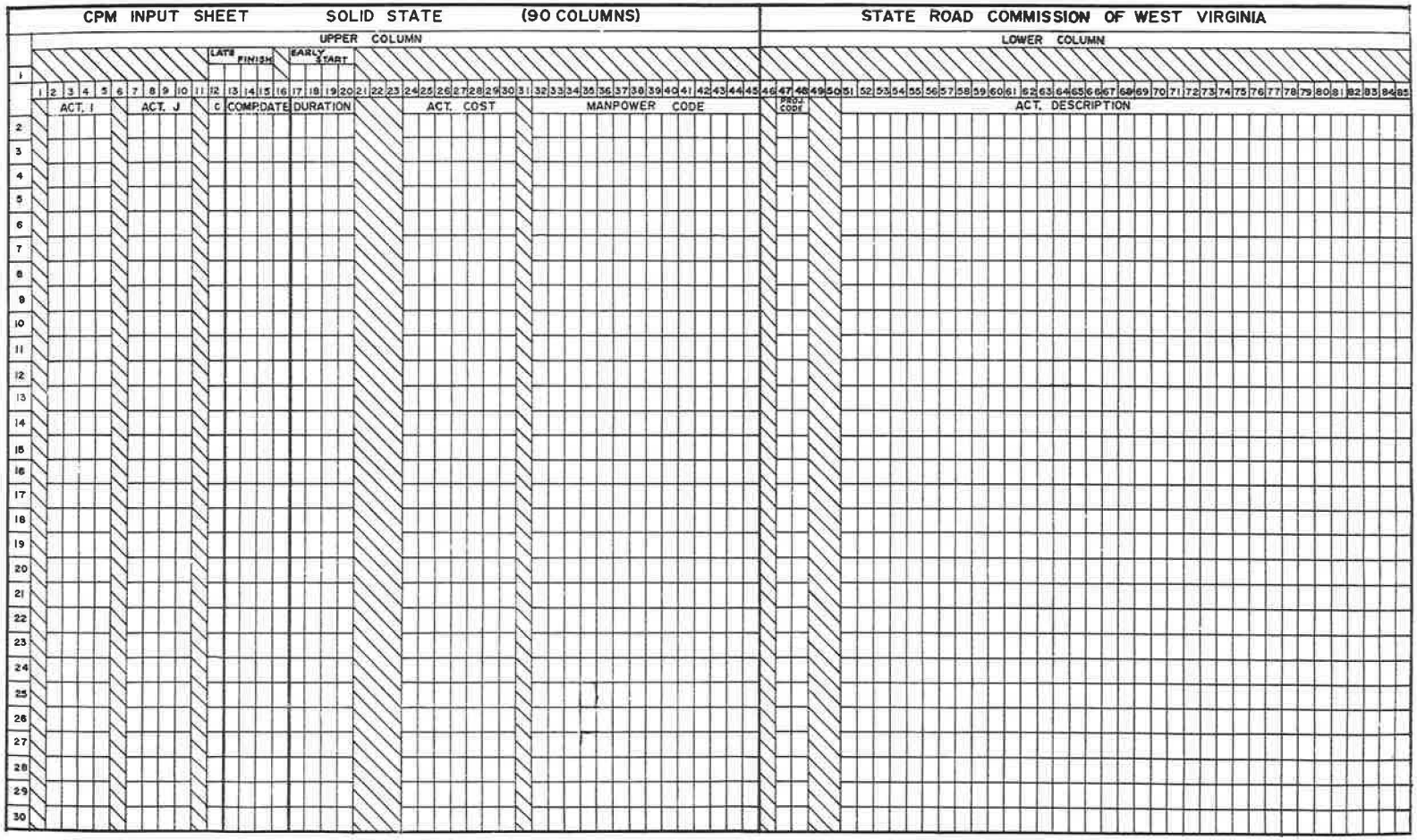


Figure 10. CPM input sheet.

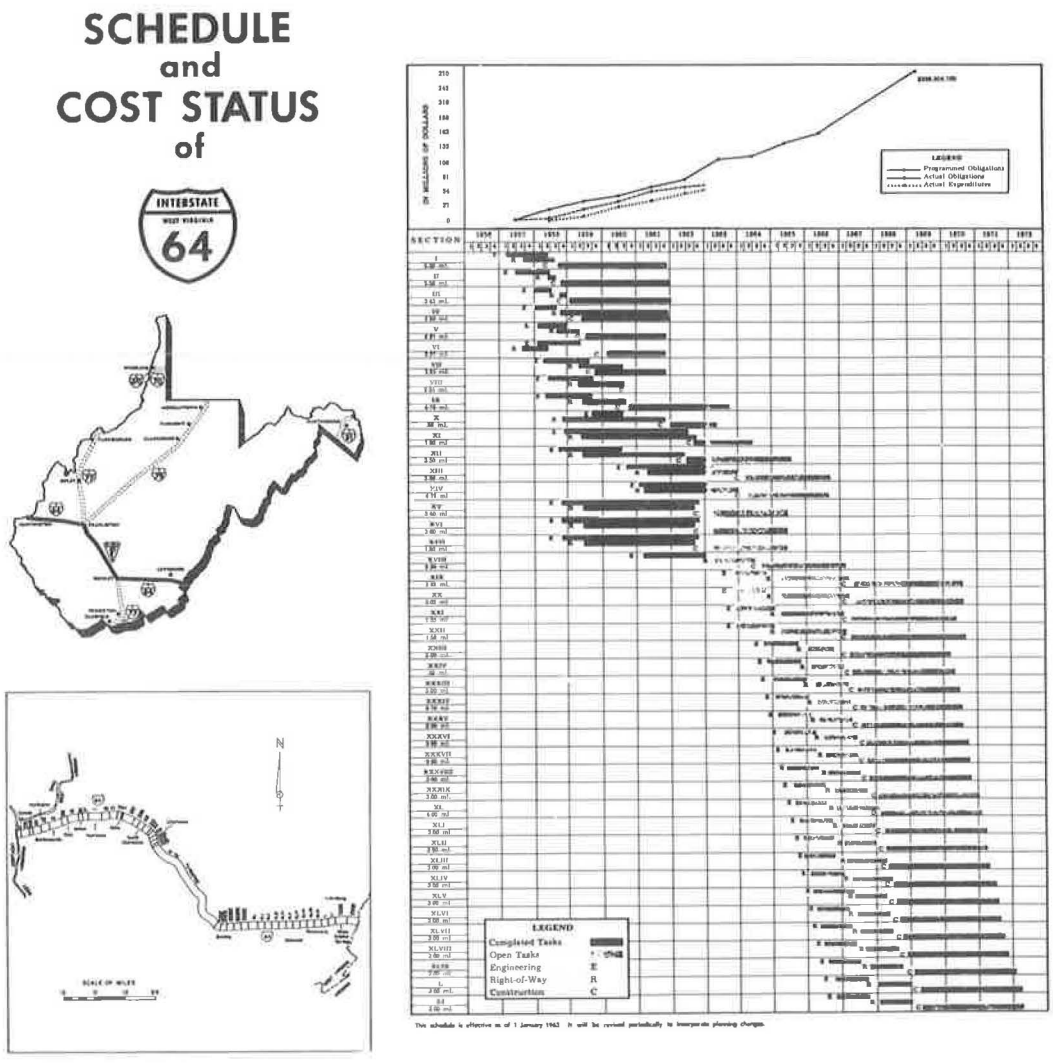


Figure 11.

Each output sheet has the project name and appropriate word description of the project printed out at the top of the sheet. These data are used in monitoring and managing the work within the project and permit "statusing" and rescheduling of internal project tasks to meet established due dates. These reports, produced at regular intervals, give each project manager the status of his project, a prediction of activities that may slip schedule date, and the manpower requirements expected.

Data Outputs at the Program Level

Revised master schedules and progress reports are prepared for both functional division and route manager uses. The functional manager concentrates on quality of work, assignment and development of personnel and meeting specific project dates; the route manager concentrates on program goals, priorities and work flow. Figure 11 is a typical route program master schedule. This chart, along with functional master schedules (Fig. 12), is on display in the management center. Several other short-range charts and progress reports not shown in this paper are made from the same data sources and show milestones completed and those in jeopardy.

RIGHT-OF-WAY MASTER SCHEDULE FOR INTERSTATE SYSTEM
(1957-1972)

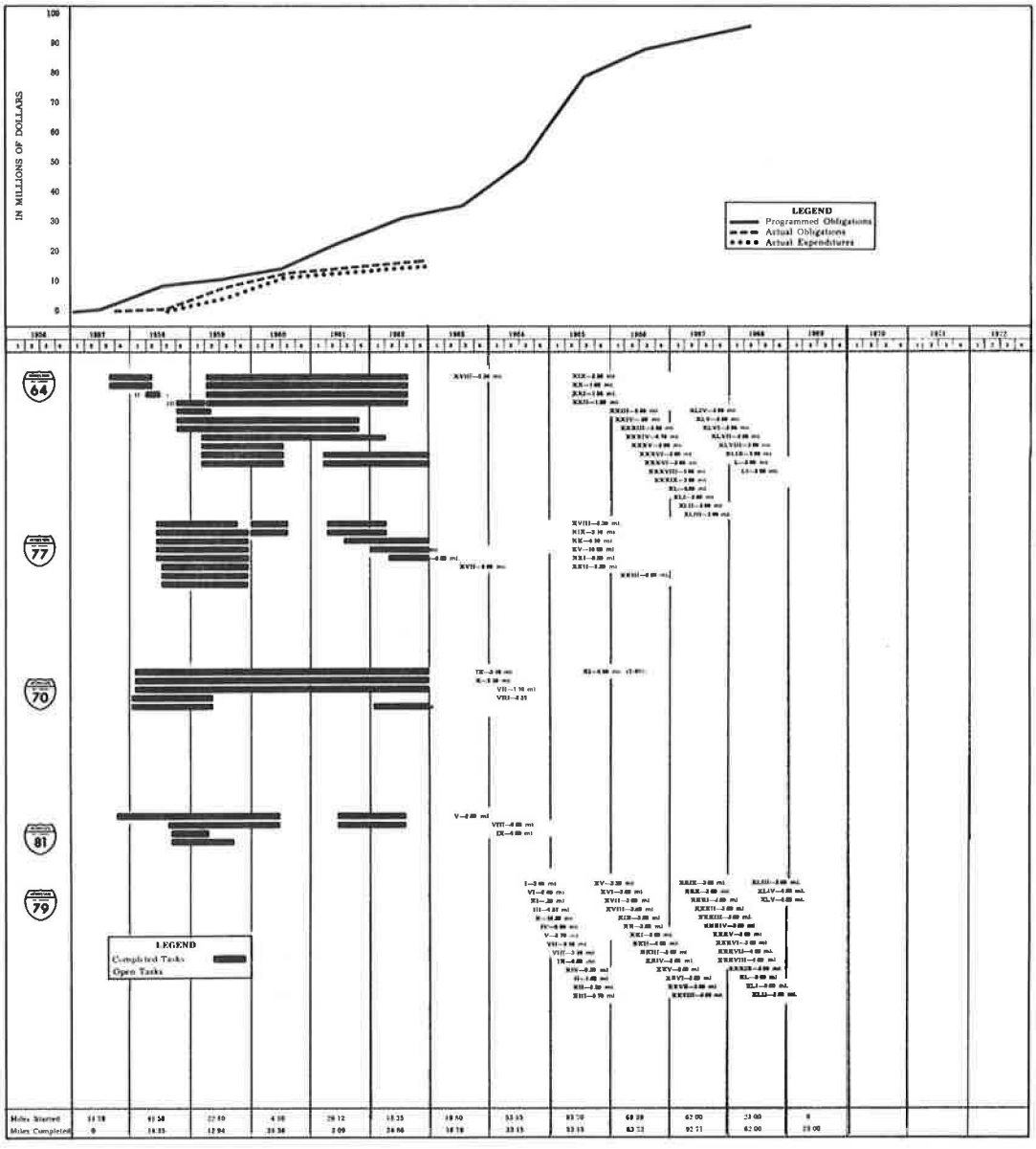


Figure 12.

It should be pointed out that with the more refined data now available at the project level, it is necessary to rework the master schedules. There are two main reasons for this required reworking: (a) the original estimates used in developing the master schedules were based on broad planning factors due to the lack of any detailed work standards, and (b) the question of available manpower in the various skill categories to meet the "desired" schedule had not been evaluated. It is thus necessary to re-examine the proposed schedule to determine whether it is feasible from a manpower-workload point of view in each component of each division.

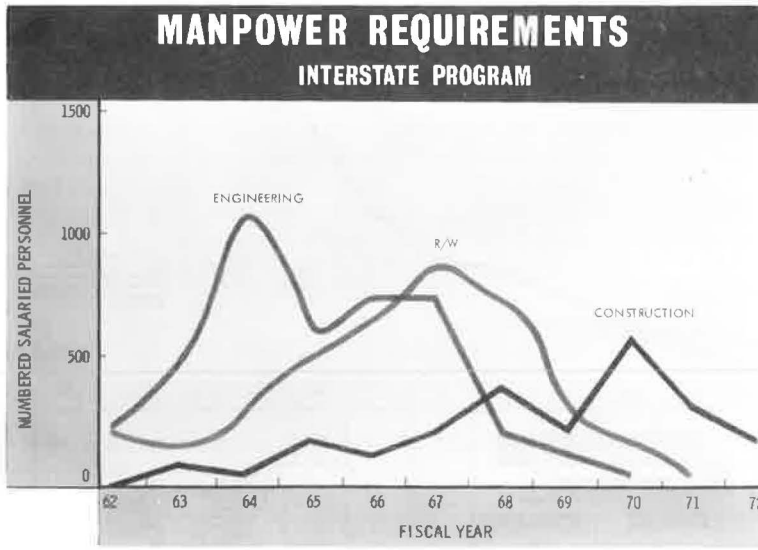


Figure 13.

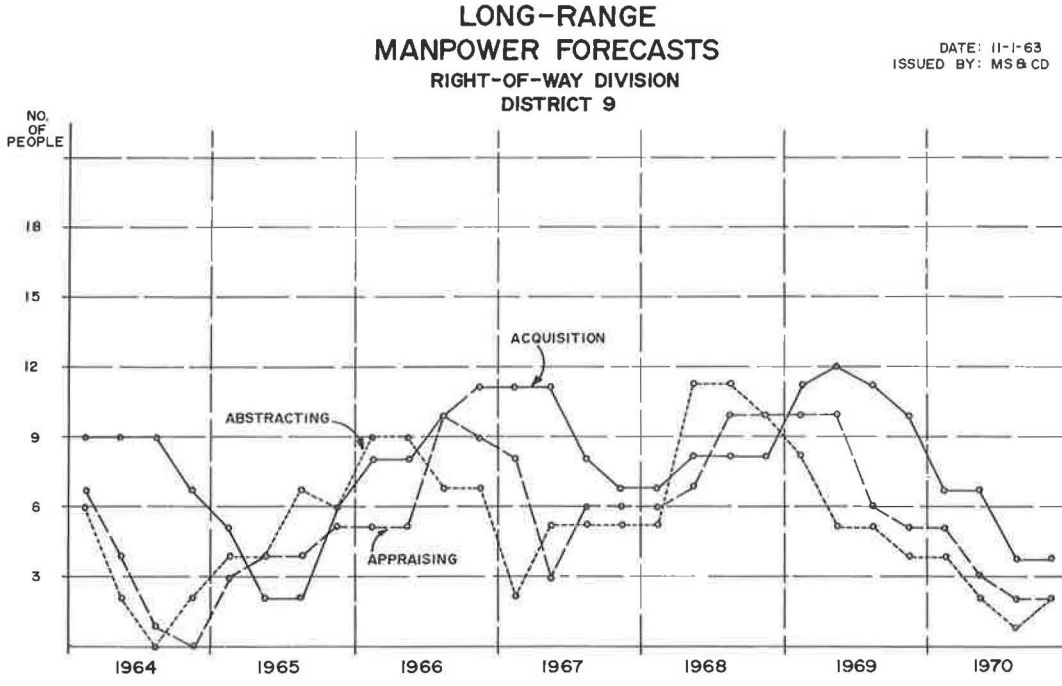


Figure 14.

Multi-Project Scheduling and Manpower Balancing

With all projects scheduled using the refined project data, the total manpower requirements are easily computed by skill, division and time frame. A graph of overall requirements according to initial master scheduling is shown in Figure 13. Divisional managers and the personnel function participated in assessing whether these requirements were attainable. When agreement was reached, a commitment was made by the

functional manager in relation to the program goals. Manpower acquisition and training is continuously approached on a planned, reviewable basis. In the setting of any schedule, the manpower feasibility check is made to see whether the skills are available at the right time. If not, the detailed schedule is adjusted until a schedule compatible with the availability of personnel is achieved. The responsible manager always participates in this analysis and commitment. Figure 14 shows the manpower requirement for District 9 of the right-of-way division derived from computer outputs.

Automatic computer allocation and assignment of resources, while an attractive concept, was deemed infeasible due to human factors involved and the high variability of input data. Rather, by this iterative approach, all elements of the organization have participated in the planning and have committed themselves to the goals established. This has been found by many researchers in the defense establishment to be the most realistic approach to multi-project scheduling. For one thing, it rec-

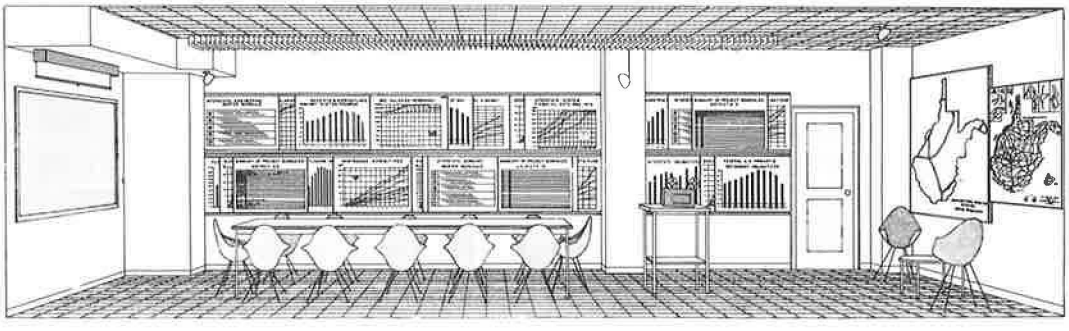


Figure 15. Management center.

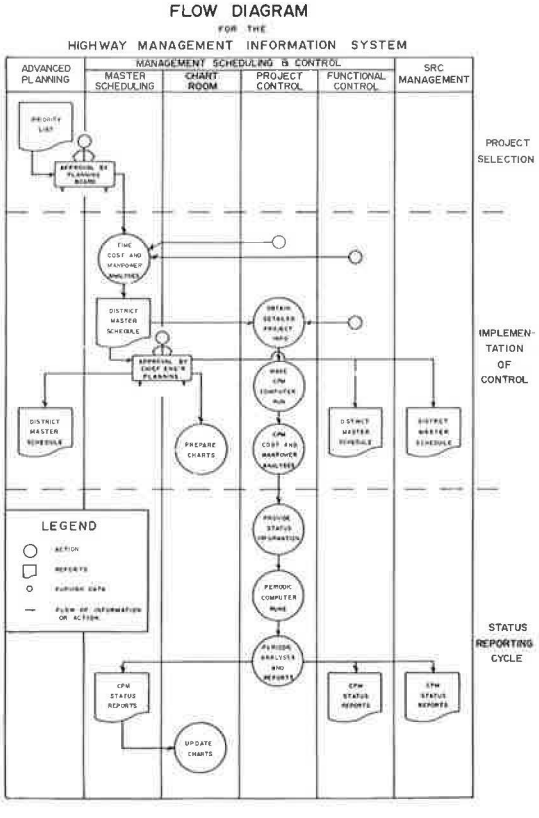


Figure 16. Flow diagram for the highway management information system.

ognizes the role and function of management at all levels in carrying out the plan and schedule. Furthermore, the approach is designed to face up to the fact that a project may change considerably from the planning phase to the execution phase, and that input planning data are in reality estimates having a significant probable error. The principle of participation and commitment is a very important one to observe in the design and implementation of management systems.

Total System Reports

In addition to the manpower report described in the previous section, several reports and displays are made, showing goals and progress at the total system level. Typical reports are summary schedule—miles completed by years, status of Interstate System, Interstate System total cost and mileage, Interstate System total expenditures, Federal-aid primary and secondary obligations, expenditures and receipts, SRC salaried personnel plan, and summary of project schedules by district. The data for each of these reports is based on updated project planning. Other reports deal with actual and potential slippages in projects. These reports and others form the setting for the management center.

Management Centers

The previously indicated charts are displayed in a management center which provides a common format for biweekly management review. Slippages and potential slippages are reviewed. The center has been called "arena for decision" (Fig. 15). Functional managers and route managers review the status and progress of their program against a common format and corrective action can often be taken on the spot. Revised schedules are developed following management meetings. In this way, management action is formed more in the future, rather than discussions centering on reasons and responsibility for current problems.

Management control centers are also being established in functional divisions of the Commission. In particular, the real time control center in the right-of-way division has proven most effective. Plans are currently under way to create appropriate management subcenters in each of the Commission's ten district offices managing operations throughout the state. The need for common format and source data is now well recognized in designing the reporting system. Also under consideration is the concept of a mobile management center, utilizing many of the program displays developed in this project, which will communicate the nature and progress in the road program to the citizens of West Virginia.

Operation of the System

Operating procedures were established in order to insure complete understanding of the system. A typical flow diagram of the system in operation is shown in Figure 16. A final report on the Phase II effort has been submitted. This report, for use by the various organizational elements of the Road Commission, is in the following twelve volumes:

Vol. 1	System Definition
Vol. 2	Organization and Staffing
Vol. 3	Personnel Information
Vol. 4	The Critical Path Method
Vol. 5	Scheduling
Vol. 6	Reporting
Vol. 7	Chart Room
Vol. 8	Procedures
Vol. 9	Engineering Consultant Specification
Vol. 10	Construction Contractor Specification
Vol. 11	Application of Statistics to Highway Forecasting
Vol. 12	Glossary

Portions of the report were used early in Phase II efforts to effect on-job training, a major requirement in the correct use and acceptance of a new system. One of the criteria in system development stated that "Contractor proposals and reporting should be in a format directly usable in the management system." Volumes 9 and 10 contain the specifications for such compliance. It is expected that this requirement, nearly identical to that employed by the Corps of Engineers, the Bureau of Yards and Docks, and the General Services Administration, will encourage better managerial practices at the controller level and will improve the quality of reporting. In this way, the current amount of time spent in interpreting contractor status will be reduced through the "common language" provided.

PHASE III: FULL-SCALE IMPLEMENTATION AND TRAINING

Full-scale implementation of the automated system has been under way over all road programs of the state since late 1963. Concentration in Phase II gave priority to the Interstate portion of the program, and the system was operated manually until computer programming was completed. Thus, the Interstate program has been under CPM control since early 1963, with extension to ABC and secondary programs proceeding in a time-phased manner, with full coverage planned for early 1965.

Results to Date

Calendar year 1963 was the peak year in terms of the total dollar volume of work let to contract in the history of the state road commission. Broad measures of improved performance are found in the fact that the Commission has been able to let to contract approximately 5 times the dollar volume of Interstate construction in 1963 as in 1962 ($65.9 million in 1963; $13.2 million in 1962). Also, about 5 times the dollar value of Interstate right-of-way was acquired in 1963 as compared with 1962 ($14.5 million in 1963; 2.8 million in 1962). In addition, over 3 times the dollar volume of Federal-aid primary and secondary construction work was let to contract in 1963 as was in 1962 ($17.1 million in 1963; $5.2 million in 1962). Further, the program for 1964 provides for approximately the same dollar volume in contract lettings. West Virginia has also moved some thirteen positions upward in the ranking of states in regard to the obligation of funds in the Interstate program. The CPM-based management system has been credited by West Virginia Road Commission management with a major assist in the improved performance shown in Figures 17 and 18.

Perhaps the most important result has been the clearly-evident renewed purpose and direction given to the organizational elements through the improved definition of the program, its statement of goals, and progress and exception reporting. In summary, the system provides the information means to:

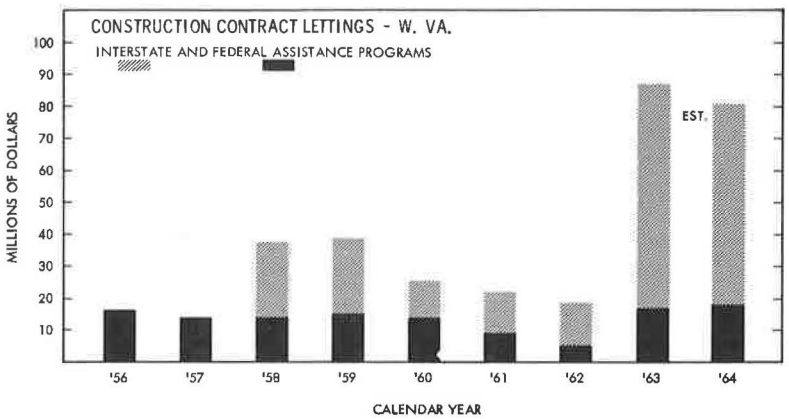


Figure 17.

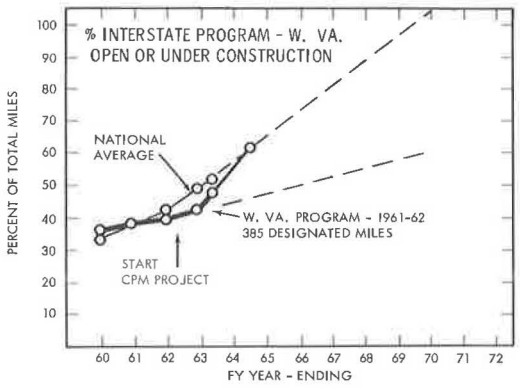


Figure 18.

1. Define the total road program by dollars, physical projects and functional tasks;
2. Integrate financial, engineering, right-of-way and construction planning;
3. Link long-range planning and operations management;
4. Predict likely problem areas before they occur, on an "exception" basis;
5. Illustrate or simulate the effects of work accomplishments and planning changes;
6. Improve schedules to meet deadlines and/or reduce cost;
7. Reduce the probability of overlooking important jobs and decisions;
8. Call out quarterly manpower and dollar requirements by function, project and system;
9. Establish performance targets for each organizational unit within the Road Commission;
10. Provide the yardstick for measuring performance of divisions and sections; and
11. Communicate better with the Bureau of Public Roads, the legislature and the public.

Training

Training has been accomplished on the job through use of a joint consultant-Road Commission implementation team. Frequent discussion and lecture sessions have been held to bring awareness and understanding of the management's objectives in the program to divisional personnel. Use of the materials in the final report proved useful in communicating the logic of the system and the new procedures required.

Systems Research in Management

There are unique problems facing a research and development effort in the management domain. Such research cannot be conducted in a laboratory or under the experimental conditions usually employed in physical and engineering research. The test laboratory for management research, or operations research, is necessarily the real world with the real people and their objectives, which are only partially polarized with those of the organization. This poses very special and difficult measurement problems.

There is difficulty in measuring, except in the broadest of terms, the cost and effectiveness of proposed management innovations such as, for example, the development of better, more integrated management information. Generally such measurements must be at the level of the total organization, since there are many interdepartmental interactions and a long time is required for significant data to be derived. During this time, external conditions may change and individual motives may change. If the results are adverse to certain individuals, they may take actions to compromise the "system" and its predictions. This added human factor makes it virtually impossible to measure accurately results of an operations research or management study in the real-world environment, where the desire for freedom from control is such an important factor.

Changes in an organization's performance can be ascribed to many coincidental forces. Thus, with the inadequacy of the experimental method in management and operations research projects recognized, a more direct comprehensive approach has been found necessary. This approach recognizes the following as requirements for successful management research:

1. Top management must be convinced of the need for the recommended improvement and give active direction to the program.
2. The design team must be made responsible for being intimately involved in the implementation of the research.

3. A development plan showing measurable milestones of accomplishment, assignment of responsibilities, resources required in both the design and implementation phase.
4. Critical and frequent top management review of the developmental plan.

In the final analysis, improved performance can be made only by a dedicated management. An improved management system is only a means to the desired end, a totally inadequate means if the information is not used wisely and continuously. The evaluation of the effect of a given system resides mainly in management's judgment concerning how much better it has been able to discharge its responsibilities with the new tools provided.

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