Cash Flow and Budgeting Using Network Scheduling

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•PENNSYLVANIA'S Highway Department is, by many measures, a big business. It has 18,000 employees, and a budget of $600 million including construction exceeding $250 million annually. Current plans are to more than double annual construction expenditures during the next few years. An undertaking of this size, especially if it is undergoing such an expansion, requires careful control through systems of the most modern design.

With the assistance of the accounting and management consulting firm of Ernst and Ernst, the Pennsylvania Highway Department has designed and is now completing installation of its new Network Scheduling System—Project ROADS. The Governor's expanded road program and an increased need for new roads have brought about requirements for more exacting financial controls and budgets, careful scheduling and monitoring of engineering, and the best possible utilization of scarce highway engineers. Network Scheduling is therefore part of an integrated management information system which ties together project schedules, mechanized control of right-of-way acquisition, current billing and concurrent audit, budgeting, accounting, and cash flow. The relationship of Network Scheduling to these other areas is discussed in the remainder of this paper.

More specifically, it is the purpose of Network Scheduling to calculate the schedule of events for approximately 2,000 major projects under design and construction. The techniques of the Critical Path Method (CPM) and PERT have been adapted for this calculation. (It is assumed in the remainder of this paper that the reader has some familiarity with the terminology of PERT and CPM.) The schedule of events for each project produces forecasts of six types of expenditures, as well as projections of forthcoming departmental workloads. This information, on a project-by-project basis and in summary form, is used by Department executives as the basis for the following.

1. Planning. The Highway Commission provides a list of the road projects to be built during the next 6 years, together with priorities. It is necessary to arrange these projects into a plan or long-range schedule that either balances expenditures and revenues or indicates necessary borrowings or revenue increases. Simultaneously, manpower requirements for the plan must match the available manpower, by function and skill, or mismatches must be indicated.
2. Monitoring. Once the long-range plan has been established, progress on each project must be monitored to indicate any variances from the plan, how serious these variances are, where they are occurring, and what corrective action must be taken.
3. Budgeting. As a new fiscal year approaches, the schedule of expenditures as currently indicated for the new fiscal year becomes the basis for the budget. These expenditures are outside contractual costs, and are given for each project and in appropriate totals for engineering (location, preliminary and final design), rights-of-way, utilities relocation, and construction.
4. Cash Flow. During the fiscal year, cash flow must be predicted on a month-to-month basis, and any necessary short-term borrowings indicated.

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There are actually two separate but interrelated systems. First, the Long-Range Network (Fig. 1) is used for long-range planning and scheduling, fiscal planning and budgeting, and long-range monitoring. This network covers from 4 to 8 yr and includes the phases of: (a) location studies, (b) preliminary design, (c) final design, (d) right-of-way (acquisition during final design, but expenditures during and beyond construction), (e) utilities relocation (work and expenditures both before and during construction), and (f) construction (some expenditures after the road is open to traffic).

The completed Long-Range Network, as used on the computer, has a total of 66 activities, nine of which are restraints or dummy activities. This standard network is used for all projects. The activities that do not apply to a particular project are eliminated to adapt the network to that project. This network is used to calculate the dates of events that are the basis of the expenditure schedules.

In the type of report produced from the Long-Range Network for the purpose of long-range schedule monitoring (Fig. 2), activity numbers are given in the first three columns, durations (here illustrative only) in calendar days in the fourth column, codes for sorting by work unit in the fifth column, and activity descriptions in the center of the report. Scheduled activity completion dates are shown next to the right. Actual completion dates are shown in the next column, and the result of CPM calculations, based on the actual activity completions, are given next. These are compared with the scheduled dates and the status, calendar days ahead or behind schedule, is given. At the far right, the CRIT symbol appears if the activity is on the critical path. The project shown here is partially through preliminary design, and has recently been rescheduled, so that there are no actual completion or status entries shown. Long-range reports are produced monthly, and summaries showing only the status of each project are produced for top management.

The construction phase is for passive monitoring only, because the contractor has a contract with a fixed price and a completion time of so many working days. This portion of the network is not intended to schedule or control the contractor's work.

The second system, which will not be covered extensively here, consists of a more detailed network covering final design only. This phase is the more complex and requires the most careful monitoring if the construction contract is to be let on schedule. The Final Design Network contains 100 activities, 20 of which are restraints or dummies. Again, a standard network has been established that can be used for every project by eliminating inappropriate activities. This network has two primary functions. First, it is used to monitor the progress of projects and to maintain schedules. Second, the bulk of the work for the Department in the coming two or so years is concerned with projects in final design. Therefore, a good measure of the work facing an operating unit or bureau is obtained by separating from each project network the unit's activities, using the codes shown in column 5 of Figure 2. These are sorted in chronological order to provide the unit with a list of the tasks facing it over the next several years. This is the basis for consideration of imbalances in manpower.

Reports similar to Figure 2 are obtained from the Final Design Network every two weeks. Summaries are also produced so that the status of about a thousand final design projects can be reviewed quickly, the status of the indicated letting date being the prime point of control.

Establishing these networks is an extremely important part of designing the system. They must be truly representative of all the processes. Inasmuch as the remainder of the system depends on the network detail, they deserve very careful and detailed consideration. These networks were assembled from extensive interviews with men in all agencies, bureaus and operating units. Each knew his own activities quite well, but did not necessarily know the details of previous or subsequent activities or the interrelationships with other units. As in many PERT-CPM applications, developing these networks helped in many ways to clarify the operations of the Highway Department. During the network research and investigation phase, necessary decisions and policy changes were indicated, inconsistencies were revealed, and ways of improving the flow of plans were brought to light. The networks became a pictorial manual of operations, which was useful as a means for each person to see how his work fitted into the overall operation. It was proper that network development should be a large portion of the project.

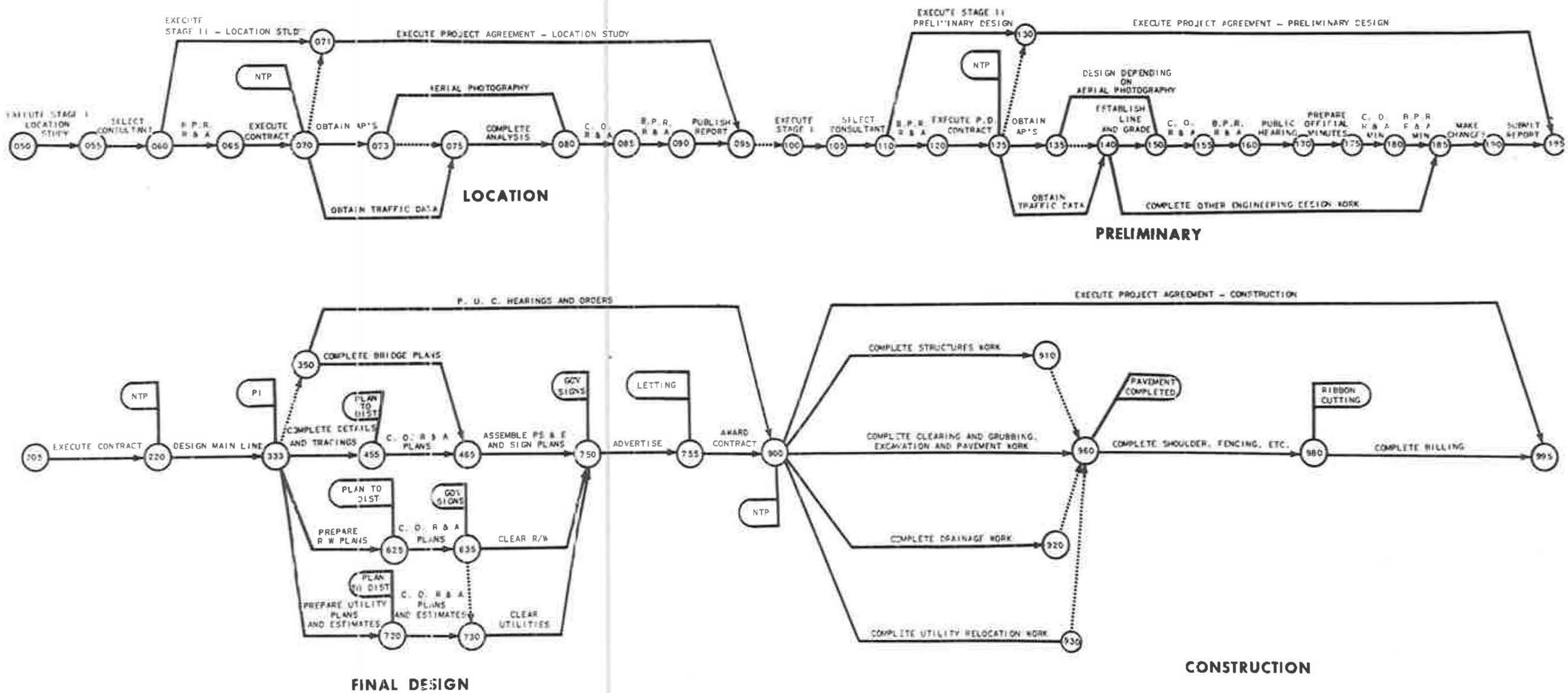

Figure 1. Long-Range Network.

	ACTIVITY START	ACTIVITY FIN	ACTIVITY TIME	ACTIVITY CODE	ACTIVITY DESCRIPTION	ACTIVITY COMPLETION DATES SCHEDULED	ACTUAL	INDICATED	STATUS	CRITICAL
305	100	105	14	F 4 S	EXECUTE STAGE I P.D.	8/15/65		8/15/65		CRIT
310	105	110	56	C 2 S	SELECT CONSULT-NEGOTIATE FEE	10/10/65		10/10/65		CRIT
315	110	120	7	F 7 S	BPR R/A P.D. CONTRACT	10/17/65		10/17/65		CRIT
320	110	130	14	F 4 S	EXECUTE STAGE II-P.D.	10/24/65		10/24/65		
325	120	125	7	C 4 S	EXECUTE P.D. CONTRACT	10/24/65		10/24/65		CRIT
335	125	135	34	A 2 V	OBTAIN AP,S ,ESTIMATE GR. CONT	11/27/65		11/27/65		CRIT
340	125	140	34	T 2 V	OBTAIN TRAFFIC FOR CONSULTANT	11/27/65		11/27/65		CRIT
330	130	195	28	F 4 S	EXECUTE PROJECT AGREEMENT P D	11/21/65		11/21/65		
347	135	150	34	D 3 V	DESIGN DEPENDING ON A.P.	12/31/65		12/31/65		CRIT
350	140	150	34	L 5 V	ESTABLISH LINE + GRADE	12/31/65		12/31/65		CRIT
360	150	155	7		C.C. R+A - LINE , GRADE	1/07/66		1/07/66		CRIT
365	155	160	28	F 7 S	BPR R+A - LINE , GRADE	2/04/66		2/04/66		CRIT
370	160	170	14	L 1 S	HOLD PUBLIC HEARINGS	2/18/66		2/18/66		CRIT
375	170	175	28	L 2 S	PREPARE OFFICIAL MINUTES	3/18/66		3/18/66		CRIT
380	175	180	7	L 2 S	C.C. R+A MINUTES	3/25/66		3/25/66		CRIT
385	180	185	14	F 7 S	BPR R+A MINUTES	4/08/66		4/08/66		CRIT
395	190	195	14		SUBMIT P.D. TRACINGS + REPORT	4/22/66		4/22/66		CRIT
405	205	220	84	C S	SELECT CONSULT NEG FEE CONT	7/15/66		7/15/66		CRIT
415	220	333	324	D V	DESIGN ROADWAY	6/04/67		6/04/67		CRIT
452	333	455	216	D V	COMPLETE DETAILS TRACINGS	1/06/68		1/06/68		
454	333	625	156	V	PREPARE R/W PLANS	11/07/67		11/07/67		CRIT
457	333	720	203	D V	PREPARE UTILITY PLANS + EST,	12/24/67		12/24/67		
460	350	465	251	B V	COMPLETE BRIDGE TSL DETAIL P	2/10/68		2/10/68		
464	350	900	260	G S	PUC HEARINGS + ORDERS	2/19/68		2/19/68		
468	455	465	35	S	C.C. R+A PLANS	2/10/68		2/10/68		
475	465	750	14	P S	ASSEMBLE PS+E, SIGN PLANS	2/24/68		2/24/68		
480	625	635	21	R S	C.C. R+A PLANS	11/28/67		11/28/67		CRIT
486	635	750	271	R S	CLEAR R/W PREP CLEARENCE CERT	8/25/68		8/25/68		CRIT
488	720	730	35	U S	C.C. R/A PLANS + ESTS	1/28/68		1/28/68		
490	730	750	63	U S	CLEAR UTIL + PREP CLEAR CERT	3/31/68		3/31/68		
496	750	755	49	C S	ADVERTISE LET CONT CONTRACT	10/13/68		10/13/68		CRIT
499	755	900	28	C S	AWARD-EXECUTE CONTRACT	11/10/68		11/10/68		CRIT

Figure 2. Detailed scheduling report.

In Pennsylvania, as in many states, a location study on a new road, for instance 16 mi long, considers alternate locations and results in the specification of the corridor for the whole road. This length is generally divided into shorter pieces for preliminary design, which provides 200-ft/in. drawings (Fig. 3). Again, each preliminary design can result in two or more final design sections which are generally 2 to 5 mi long and which correspond to the construction sections. In the early stages of planning, the network for preliminary design, final design, and construction is a composite of the networks for the several pieces of road in these phases. The network is later made into several separate ones for these sections as they are defined.

In initiating a project, the operating unit for each activity estimates the activity's duration. Design consultants are asked for durations of design activities, the U.S. Bureau of Public Roads for their approval times, Central Office engineering for their reviews, and so on. Although individual estimates can vary in accuracy, it appears that the totals are quite adequate and that over- and under-estimates tend to balance one another. As historical data are gathered, they will be analyzed for bias in any of the estimates.

Figure 3 shows the overall concept of estimating future expenditures for each project. ("Costs" and "expenditures" as used here mean the amounts paid for work done outside the Highway Department, i.e., for engineering, soils work, construction, right-of-way, etc.) It is necessary both to schedule the project and to obtain the estimated expenditures in each category for future quarter-years, including:

1. Scheduling the project phases, which involves both duration estimates and the CPM calculation;
2. Estimating the total cost in each phase; and
3. Spreading these costs to the quarter years in which they occur.

This process leads not only to a long-range project schedule but also to the means of loading this schedule against the available funds and of budgeting and controlling expenditures on both a long-range and short-range basis.

CALCULATING EXPENDITURES FOR A PROJECT

Expenditure rates for a project are related to the progress of work in each phase, and hence to points in the network. In many approaches to the problem of deriving costs from PERT-CPM networks, a cost is associated with each activity in the network, and costs are accumulated as individual activities are completed. In dealing with one to two thousand highway projects, a more practical approach is to consider that costs will be incurred between two events in the network, and that they will follow some type of curve between these two events and between the two points in time they represent. The reason for this approach is that an activity will incur costs in one of three ways:

1. If it is performed by the Highway Department personnel, the costs are part of those of the fixed engineering staff, and hence are period costs, not variable ones, and will be so budgeted.
2. If the activity is performed outside the Department, but not under contract (such as BPR reviews) there is no direct cost applicable to the project or to the Department.
3. The remaining activities are those done under contract (with design consultants, or construction contractors), under an agreement (with a public utility for relocation work) or under negotiation and legal process (right-of-way). In each of these cases, the expenditures are spread over a series of connected activities, and hence must begin after a particular activity and end (or reach a certain point) before the end of another activity, following some expenditure curve between.

Data were gathered on the behavior of expenditures between beginning and ending points to be assured that individual deviations from a calculated expenditure curve would result in an error of less than one percent of the total quarter's expenditures, provided the curves are without serious bias. New records will permit even further refinements of the expenditure curves.

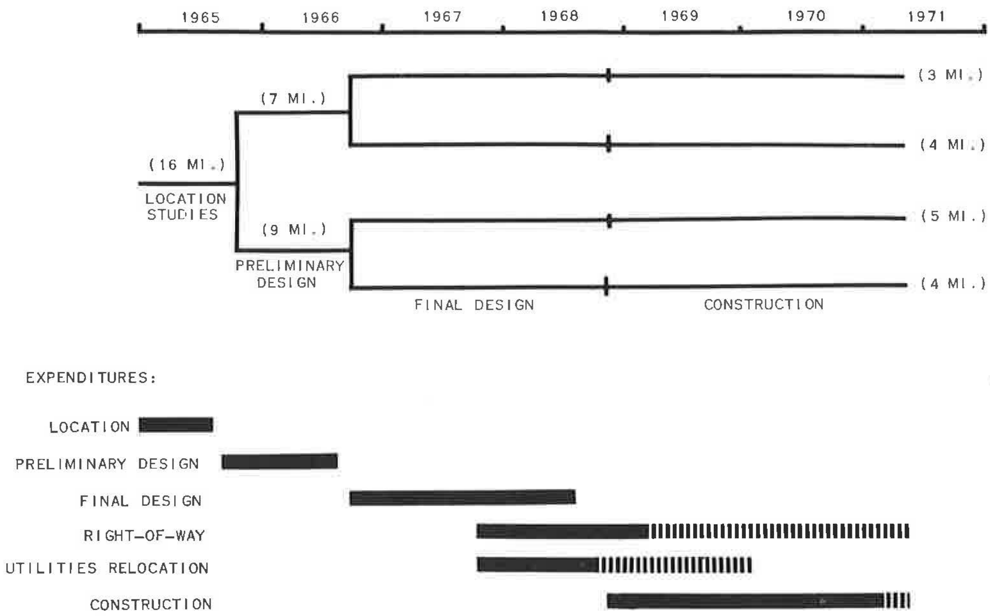

Figure 3. Typical expenditure schedule.

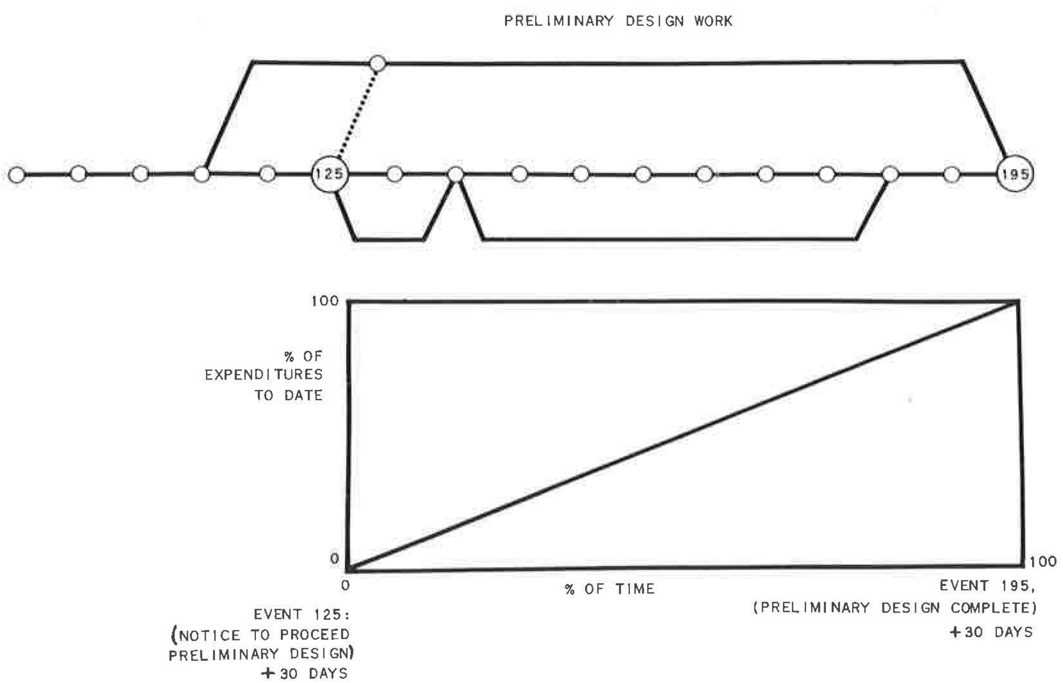

Figure 4. Expenditure curve, preliminary design.

A typical expenditure curve is the one for Preliminary Design (Fig. 4). Expenditures begin 30 days after the Notice to Proceed to the design consultant (Event 125), they proceed linearly, and they are complete 30 days after Preliminary Design is complete (Event 195). Knowing the dates of these two events from the network and the total preliminary design costs, the expenditures by quarter year can be calculated.

Similarly, expenditures for location studies, final designs and utilities relocation are also nearly linear.

Right-of-way presents a special problem since the bulk of acquisition payments occurs over a relatively short time, and roughly 20 percent of the payments can be extended over as long as 6 years. Further, Pennsylvania has a new eminent domain law which will change the expenditure rate. This curve must remain as an estimate until more data are gathered on the effect of the new law.

Construction costs are the most complex to calculate, primarily because of the construction season. This seasonality is illustrated by the construction workdays shown in Figure 5, which is a composite of all 11 districts for a 3-yr period. This seasonal

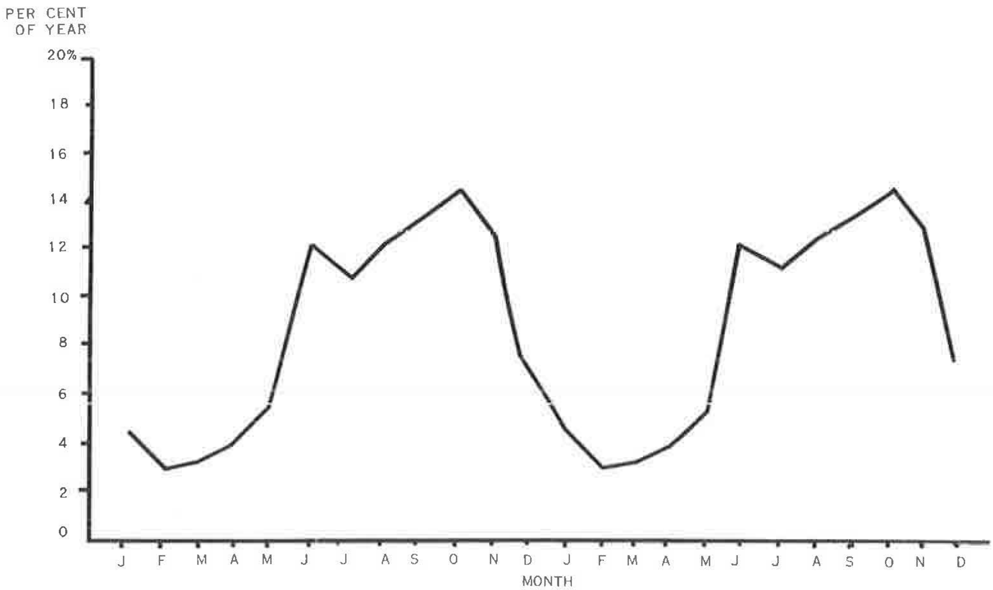

Figure 5. Seasonality of construction expenditures.

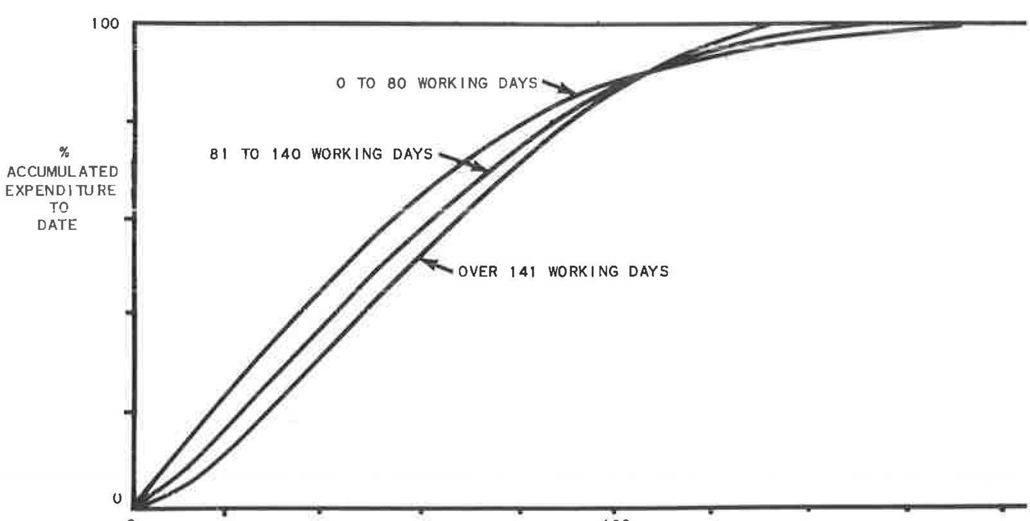

Figure 6. Construction expenditure curves.

pattern differs very little from the northern to the southern parts of the state. Contracts are written and work is completed in terms of work days, and it is necessary to convert the calendar time scale to a work time scale using the seasonal curves (Fig. 5). Construction expenditures, now in terms of work days, are consistent in following the several different curves shown in Figure 6. These curves were developed by investigating the expenditure histories of 640 contracts. The shape of the expenditure curves was strongly dependent on the number of contract work days. The individual expenditure curves fell into three closely related groups, 0 to 80, 81 to 140, and over 141 working days. Expenditures continue beyond the completion of construction because of billing and settlement delays, retainage of a certain portion of the fees, and other deferred financial settlements.

In a typical expenditure projection for a project (Fig. 7), detailed costs are given for the three phases of engineering, right-of-way, utilities relocation, construction and a total in the right-hand column, all of which are used in the planning process. Budgeting and planning must be done by district and by system (FAI, FAP, 100% state, etc.). Summary reports, totaling expenditures of many projects, are therefore provided by (a) system within district, (b) district (total of all systems), (c) system (total of all districts), and (d) the total state. These summary reports have the same format as Figure 7.

Although the basis of the Highway Department's planning is a 6-yr plan, provision is made for obtaining expenditures for 40 quarter years, i.e., 10 years, because expenditures on projects starting within the next 6 years may appear in the tenth year, and it may be desirable to extend the planning horizon in the future.

DEVELOPMENT OF LONG-RANGE PLAN

The process of developing a long-range design and construction plan begins when the Department has (a) a number of projects partially through design or construction; (b) a list of projects—the Highway Commission's 6-yr plan—together with a priority on each (some of these are new, some partially done); (c) a projection of the money available to cover construction, right-of-way, etc.; and (d) the availability of manpower by type of skill and location.

The problem resolves itself into arranging the new and existing projects into a schedule that meets as nearly as possible the requirements of staying within available funds and manpower and of maintaining the order of priorities. The words "as nearly as possible" are necessary in stating this problem reasonably, because it is mathematically impossible to meet even two of the three conditions of exactly balancing expenditures with funding, balancing manpower exactly, and maintaining priorities among projects. This is a form of the "job shop scheduling" problem, which is the subject of numerous papers, especially in the literature on Operations Research (1). With Pennsylvania's 2,000 projects to schedule, and some latitude in money, manpower and priority, it is very difficult to obtain satisfactory results from techniques such as RAMPS or RSPM at the present state of development (2). For the time being, the actual development of the schedule is a task to which to apply "the flexibility and imagination that management personnel should possess and use."

This task is not an easy one, but it is made much more tractable by having the system under discussion here, a means of evaluating the results of any particular schedule. The system, in this context, is a simulator.

The process of forming a long-range schedule, then, consists of taking an apparently reasonable schedule, examining the results, and proposing changes that will come closer to the desired goal. This process repeats until a satisfactory plan is obtained. This procedure has the elements of cut and try within it, but more importantly, it also has the elements of executive judgment, experience and skill. In the next few years as experience is gained and the logic of the process becomes more clearly defined, it may be possible to mechanize more and more of the planning procedure.

BUDGETING

Pennsylvania's fiscal year runs from July 1 to June 30, and it is a requirement of the legislature that a budget be presented by November 1 of the previous year. The

PROJ NO 258045 2   37 COST SPREAD DATED 9/27/65   PAGE NO 3 - 9

QUART	LOCATION	PRELIMINARY	FINAL	RIGHT OF WAY	UTILITIES	CONSTRUCTION	TOTAL
65-3	56760	0	0	0	0	0	56760
65-4	0	0	0	0	0	0	0
66-1	0	9733	0	0	0	0	9733
66-2	0	10209	0	0	0	0	10209
66-3	0	308	2556	0	0	0	2864
66-4	0	0	38866	0	0	0	38866
67-1	0	0	38866	0	0	0	38866
67-2	0	0	38866	0	0	0	38866
67-3	0	0	38866	0	0	0	38866
67-4	0	0	38866	16604	8432	0	63902
68-1	0	0	10116	68868	14797	0	93781
68-2	0	0	0	68868	14797	0	83665
68-3	0	0	0	68868	14797	0	83665
68-4	0	0	0	18962	14797	392119	425878
69-1	0	0	0	2869	14797	552102	569768
69-2	0	0	0	2869	14797	1014894	1032560
69-3	0	0	0	2869	14797	1875523	1893189
69-4	0	0	0	2869	6803	922781	932453
70-1	0	0	0	2869	1184	236903	240956
70-2	0	0	0	2869	0	349700	352569
70-3	0	0	0	2869	0	340472	343341
70-4	0	0	0	2869	0	128447	131316
71-1	0	0	0	2869	0	41776	44645
71-2	0	0	0	2869	0	77941	80810
71-3	0	0	0	2869	0	67341	70210
71-4	0	0	0	2869	0	0	2869
72-1	0	0	0	2869	0	0	2869
72-2	0	0	0	2869	0	0	2869
72-3	0	0	0	2869	0	0	2869
72-4	0	0	0	2869	0	0	2869
73-1	0	0	0	2869	0	0	2869
73-2	0	0	0	2869	0	0	2869
73-3	0	0	0	2869	0	0	2869
73-4	0	0	0	2869	0	0	2869
74-1	0	0	0	440	0	0	440
74-2	0	0	0	0	0	0	0

Figure 7. Cost spread report.

budget is assembled by Fiscal Management from individual budgets submitted by each of the Districts and the Central Office operating units, bureaus, etc. New budgeting procedures require each district to be responsible for budgeting the maintenance, construction and engineering for their roads. The cost spreads described previously are the basis for budgeting the last two of these items.

On September 1, the projected costs by project are given to the districts and Central Office for budget estimates. County maintenance programs are developed and channeled into the districts for consolidation. This information is all sent to the Bureau of Fiscal Management for checking and assembly into a total Highway Department budget for submission to the Budget Secretary (Fig. 8). After review and approval, the Budget Secretary and the Secretary of Highways present the budget to the Legislature for review. The approved budget is then returned through channels to the Districts and Central Office Bureaus.

In the future, the computer will have both project budget information and data on manpower standards, costs, etc. Actual expenditures for payroll, invoices, and material usage reports will be put into the system and compared with budget and standards to produce a very important control document, the Project Cost Report (Fig. 9). In this illustration a construction project in District 1 was budgeted at $48, 000. Cost-to-date is $44, 000, the difference of $4, 000 showing as cost under budget in the second column from the right. However, the work performed has earned $42, 000 at standard. This shows as a $2, 000 cost over standard in the right-hand column. This is an important control point: the project appears to be under budget, but in reality is lagging

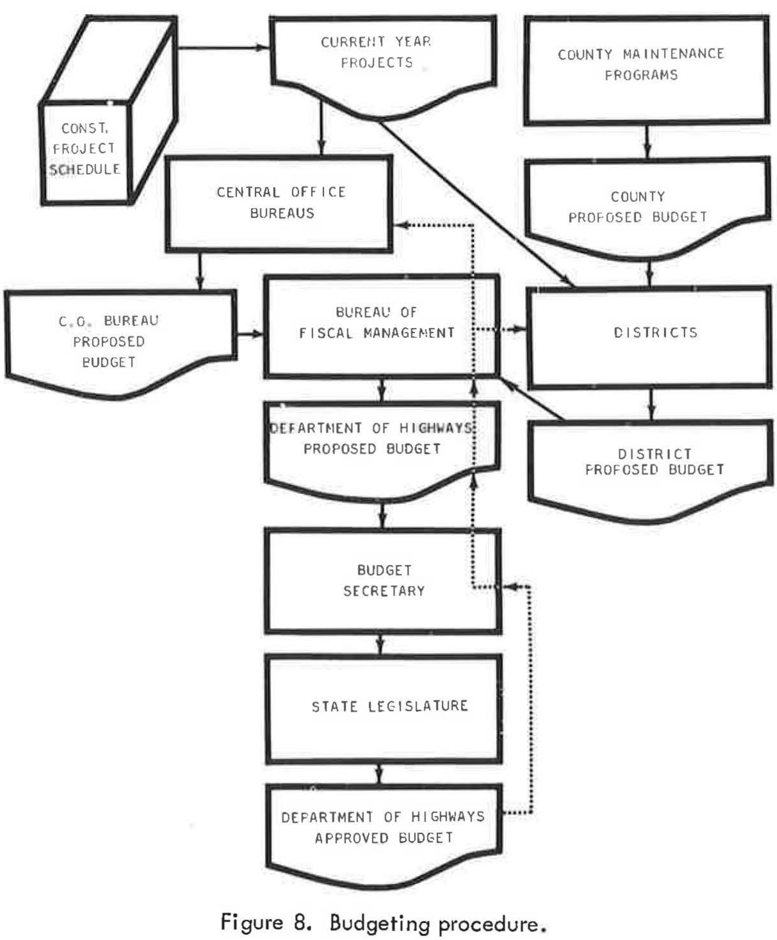

Figure 8. Budgeting procedure.

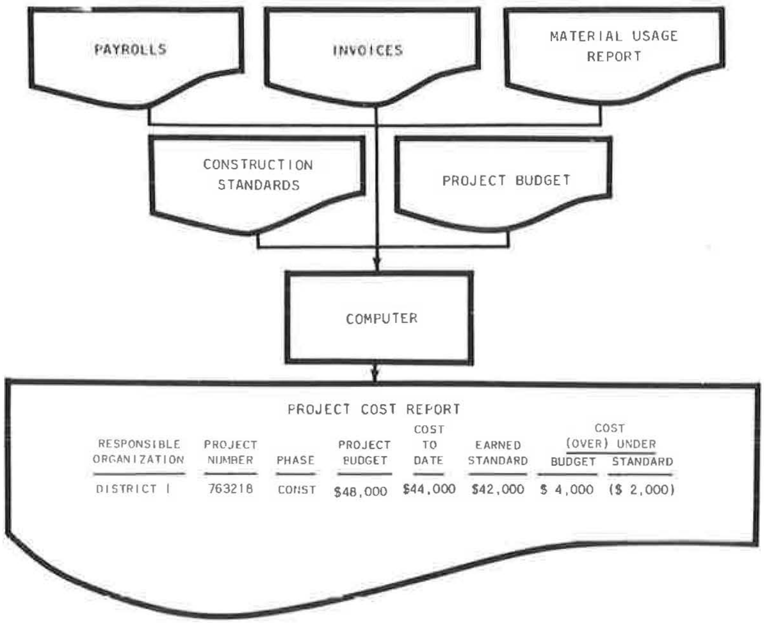

Figure 9. Development of project cost report.

behind. Only $4,000 remains in the budget, but $6,000 worth of work remains to be done.

CASH CONTROL

The procedure for projecting the month-end cash position of the Motor License Fund is to perform the following calculation for each month during the coming 12 mo:

Reference	Calculation	Percent of Total[a]	Monthly Projection By
1	Opening cash		Previous month or actual
2	+ Motor license fund receipts	64	Fiscal management
3	+ Federal aid reimbursements	36	Calculation using cost spreads
4	= Total available cash	100	
5	- Other departments' cash receipts	9	Appropriate department
6	- Highway department - noncontractual expenses	32	Fiscal management
7	- Highway department contractual expenses	59	Cost spreads
8	= Closing cash	100	

[a]Based on 1964-1965 fiscal year budget.

This projection will be made each month, using the actual opening cash figure and the most current estimate for the remaining items. Further detail on the foregoing items is as follows:

1. The first opening cash entry is an actual figure, and the subsequent figures are the closing cash figures from the previous month.
2. Motor license fund receipts, exclusive of federal-aid reimbursements, can be fairly accurately projected by the means now employed by fiscal management.
3. Federal-aid reimbursements are related to construction expenditures, and are therefore highly seasonal. They are projected on a project-by-project basis, using the cost spreads given previously and appropriate percentages based on system, and recognizing the portions of some federal-aid road costs that are financed 100 percent by the state. This amounted to 36 percent of the total receipts in 1963-1964; it had been the most difficult item to project, and now has a firmer basis.
4. The total of the foregoing three items.
5. Other state departments which have substantial cash requirements on the motor license fund are the Treasury Department, the Department of Labor and Industry, the Department of Property and Supplies, the Department of Public Instruction, the Department of Revenue, the Department of State, and the Pennsylvania State Police. Some of these requirements reflect services provided to the Highway Department, and their monthly cash requirements will be projected jointly by the two Departments. Others, especially the State Police, will provide the figures.
6. Highway Department noncontractual expenses include all wages and salaries, materials, supplies, equipment, rents, capital expenditures and other cash items not covered in item 7. Most of these are period costs that are readily projectable by the Bureau of Fiscal Management.
7. Highway Department contractual expenses are payments for construction, right-of-way acquisition, utilities relocation and engineering, which are obtained by factoring the quarterly cost spread figures into monthly figures. This single item accounted for 59 percent of motor license fund expenditures in 1964-1965, and can account for over 70 percent in the peak months of October and November.
8. The closing cash figure for this month becomes the opening cash figure for the next month.

A fairly large share of the cash, both receipts and expenditures, results from the cost spread from Network Scheduling. Further, these were the most difficult items to project. They have now been put on a realistic basis tied directly to the Department work schedule.

CONCLUSION

The Network Scheduling System is an essential part of Pennsylvania's plan to build more and better roads, faster and at less cost. Specifically, the system will have a major role in providing the following advantages.

1. Close control of project schedules, which will help to produce plans and roads on time.
2. Increased engineering productivity which is necessary in the face of the expanded program. A productivity increase of 40 percent is projected and appears reasonable, due primarily to a firm plan and tight schedule, with every set of plans resulting in a road.
3. Reductions in paperwork; each of twenty operating units reporting to Network Scheduling (Bureau of Management Information Systems) prepares an average of seven cards per day on which are reported activity completions and changes. These replace several regular reports and numerous special reports.
4. Accurate and more timely budgets, built on the solid foundation of a firm engineering and construction schedule.
5. Accurate cash flow projections, also resulting from firm schedules.

The Network Scheduling System requires five to six technical people for both operation and further systems design, and four hours per month of IBM 7040 computer time. A great deal of work has gone into making the system uncomplicated, efficient, and moderate in cost, given the fact that it controls a large, complicated enterprise.

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