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Foreword

A highway department today is classed as a "big business" and accordingly requires the application of advanced management techniques for planning, organization, control, and administration. The development and application of new tools and new procedures is necessary to enhance efficiency of operations and to facilitate the decision-making process.

The four papers included in this RECORD are emblematical of the search for more effective management methodology with particular respect to financial and budgeting operations and to manpower utilization.

The first paper establishes the need for improved financial reporting as expressed by questionnaires completed by the chief administrative officers of the highway departments. A large number of administrators reported that financial reports currently received by them are of little use in making management decisions and that financial reporting can be improved in content, format, and timing. Guidelines are set forth for the development of a system of information reports and control reports to meet the needs and desires expressed by the highway administrators. Five distinct methods of presenting financial information are explained and illustrated. The author has concluded, however, that each financial report to management should be specifically tailored to provide in the clearest possible manner the essential financial information needed by management for its specific purposes.

In recent years, the techniques of PERT and Critical Path Method have been recognized as significantly useful to management in the development of an integrated information system. The second paper reports on the application of network scheduling procedures by the Pennsylvania Highway Department. Although the paper is directed primarily to the determination of cash flow, recognition is given to such ancillary benefits derived from the system as more accurate and timely budgets, closer control of project scheduling, increased manpower utilization and productivity, and reductions in paper work.

The third paper is primarily directed toward improved manpower utilization. Work sampling techniques are described which may be applied to a given function, in this instance the design function, to determine engineer-technician ratios, advanced technician-subordinate technician ratios, personnel classification development, and staffing patterns. The author has concluded that the taking of work samples and the analysis thereof is relatively simple, that the time required is usually less than that required for a job audit program, and that the work sample program is significantly accurate.

The "investment analysis" approach to estimating highway needs establishes needs from the relationship which exists between travel requirements and highway investments remaining in service. The determination of investments remaining in service is one of the major tasks involved in the use of this approach. The determination is further complicated by the fact that outdated methods of record keeping and analysis have relegated road life studies to be of little use. The fourth paper in this RECORD sets forth the methodology developed for the application of computer techniques in the performance of investment studies. The methods have proved satisfactory in Wisconsin and accordingly provide a stimulus for the revitalizing of road life and investment studies.

Contents

Financial Reporting to Management

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•IN 1964 more than $12 billion was spent in the United States on costs directly related to roads and streets. In at least two instances, a single state's expenditures approached one billion dollars. Was the money spent prudently and efficiently? Did highway users obtain maximum value for their money? Charged with responsibility for the great volume and variety of activities suggested by the foregoing figures, the highway manager must depend on reports, especially financial reports, to answer these questions.

The degree of administrative emphasis on fiscal matters is evident on all sides, and one need only refer to the activities of the Highway Research Board itself during the past few years to reinforce the point. Good financial reporting is vital to successful financial management.

IMPROVED FINANCIAL REPORTING NEED

There is ample evidence to suggest that the art of financial reporting to highway management has not kept pace with the greatly expanded highway programs and, therefore, with highway managers' requirements and desires. AASHO was keenly aware of the need for improved financial reporting and, in 1961, named a task force on financial reporting headed by A. H. Lawrence of Michigan to investigate financial reporting needs in highway departments and to recommend improvements in reporting procedures.

By means of questionnaires directed to the chief administrative officers and chief fiscal officers of all state highway departments, the task force gathered valuable data regarding the strengths and weaknesses of prevailing reporting practices and procedures, as well as many suggestions for improved reporting. A disturbingly large number of administrators stated that the financial reports they received were of little use to them in making managerial decisions. Their comments suggested that reporting could be improved in content, format, and timing. After Lawrence reported the findings of his group at the AASHO Convention in 1962, another task force, under the direction of Roger R. Shipley of Indiana, was appointed with the assignment of preparing material on the subject of financial reporting to management which would be suitable for incorporation in the AASHO Manual of Uniform Highway Accounting Procedures.

After examining the available material on the subject, Shipley's task force decided that research was needed in at least two areas of the subject: in determining the financial reporting needs and desires of highway administrative officals, and in developing a systematized approach to financial reporting. To perform the needed research, the Indiana State Highway Commission, with the support of the U.S. Bureau of Public Roads, entered into a research contract with the Graduate School of Business of Indiana University. The material which follows was developed under this research contract.

Paper sponsored by Committee on Highway Organization and Administration and presented at the 45th Annual Meeting.

RESEARCH PROCEDURES

To meet the general objective of the project, which was to develop financial reports and reporting techniques which would provide highway officials with better financial information for their use in planning, directing, and controlling operations for which they are responsible, the project research procedures included:

1. A review of the existing literature on the subject of financial reporting to management, from the point of view of both public and private enterprise, to glean any information applicable to financial reporting in highway departments.
2. Assembling and evaluating examples of current financial reports to state highway management. These reports were used to detect desirable as well as inferior reporting practices and procedures and to provide data for the development of pilot reports with a variety of content, form, analysis, and reporting techniques for use later in interviewing highway administrative officials.
3. Conducting interviews with those interested parties believed to be most able to provide data pertinent to the project. The study was based on the premise that highway management itself is in the best position to appreciate the type, format, content, and timing of financial reports essential to most effective administration. Therefore, the investigative emphasis was on detailed, depth type interviews with highway administrative officials to obtain their views, preferences, and reactions relating to the different types of reports and reporting techniques previously developed. No attempt was made develop statistical inferences from the interviewees' responses.
4. Conducting extensive correspondence with both administrative officials to gain further information regarding the impressions, problems, requirements, and desires of highway officials relating to financial reporting. This correspondence further served to provide all chief administrative officers of state highway departments with an opportunity to express their views and spell out their needs in financial reporting. Correspondence was also used to clear up points of confusion or misunderstanding, and to serve as a checkback on findings.

LITERATURE ON FINANCIAL REPORTING

The review of the literature confirmed the judgment that financial reporting is no simple task. Although elaborate, complete financial reporting systems have been developed for specific business enterprises, the research disclosed no systematized examples of financial reporting to management which would be suitable for application to highway reporting. However, the literature revealed a continual emphasis on the fundamentals of good reporting: basic purposes, general reporting principles, criteria for a desirable reporting system, and the proper use of a variety of reporting media.

Fundamental Purpose of Reporting

The fundamental purpose of financial reporting to management is to provide a sound basis for management decisions, by showing compliance with or deviation from adopted programs or approved policies. To accomplish this purpose, financial reports must do two things: portray the facts accurately, and motivate whatever management action is required.

The literature emphasized that an effective reporting system must "communicate information," which means a great deal more than merely providing a mass of figures for management to unscramble and interpret.

Reporting Principles

If reports are to communicate financial facts to management, they must present the necessary information in a clear, concise, forceful way, and in time to be of maximum use. A good report should have the following ten characteristics:

1. It shall contain all the essential facts of the situation reported, without extraenous information or unnecessary detail to waste the reader's time or confuse him.
2. It shall be presented in a format which allows quick and easy grasp of the essential information, and is expressed in terminology with which the reader is completely familiar.
3. It shall permit the executive to concentrate on exceptions by focusing attention on comparisons which highlight trends or deviations from targeted performances.
4. It shall be timely and, if routine, produced on a regular schedule, so that executives may expect reports at specific times and rely on them.
5. It shall be tailored to fit the requirements, personality, preferences, and capacity of the recipient as to format, amount of backup detail, and other report characteristics.
6. It shall be designed for eye appeal and easy reading, easy storage for reference, and shall be attractively packaged.
7. It shall facilitate the establishment and maintenance of rapport and communication in both directions between the reporter and the user.
8. It shall be distributed only to the executive charged with responsibility for the subject matter reported on, thus conserving user time and effort, as well as decreasing the danger that other recipients might take action outside the scope of their authority and responsibility.
9. It shall be supported by appropriate analysis of the financial information supplied, and shall be accompanied by significant summaries.
10. It shall be sufficiently useful to justify completely the time and cost involved in its preparation and presentation.

Analysis and Interpretation in Reporting

The modern capacity for gathering and disseminating financial information has overwhelmed management's facilities for absorbing it. In this situation, analysis and interpretation are indispensable to complete reporting. No other highway official is in a better position than the financial officer to analyze and interpret the financial information reported, or to point out the alternatives available within the legal, financial, and policy limitations imposed upon the organization. According to the literature, the financial officer's report is not ready for submission to management until he has completed his evaluation of these alternatives and, when needed, his carefully supported recommendation for a course of action.

Management thought patterns involve basic relationships, not figures and statistics as such. The core of the analytical process is the establishment of relationships, i.e., comparisons. In analysis, a mass of figures is reduced to easily manageable proportions, and condensations of figures are compared with some predetermined acceptable standard, such as a budget, a goal, the achievement of previous periods, the achievement of other highway organizations, or even some preconceived notion of what should have been accomplished. The end product of analysis is the expression of valid relationships in a clear, simple thought or idea. Relationships provide the answer to a fundamental question: "What is the situation, and should something be done about it?"

General Criteria

The financial officer must know for what purposes highway managers need financial information and must provide reports which satisfactorily cover these needs.

In designing his reporting system, the financial officer must provide for both information reports and control reports. He must also distinguish between reporting for external purposes and reporting for internal purposes. For internal purposes, reporting should be provided along the lines of authority and responsibility as shown by the organization chart. Coordination of the reporting system with the organization plan will prevent gaps or overlaps in the coverage of reporting by functions, and will permit the reporter to direct to each manager specific information pertaining to that user's duties and responsibilities.

The reporting system should provide for the continuing study of measures for evaluating performance, and should have a built-in mechanism for report review and change. The system should have sufficient flexibility to handle unusual informational requirements. Where absolute accuracy of certain figures is not as important as quick preliminary estimates, the reporting system should be geared to provide reliable estimates promptly.

Related reports should be carefully coordinated, and their relationships be made clear. The reporting system should be such that the reporter will know the financial effects of decisions made as a result of his reports so that he can, in turn, provide reports of the results of these decisions.

The individual reports should be clear and concise. The place to start establishing these qualities is in the title of the report. All pertinent facts should be presented in such a manner that important data and relationships are clearly set forth and emphasized. Insofar as possible, information should flow from one part of the statement to the next. Reports should be designed to provide for comparsions—yardsticks for evaluation of progress or costs. Excessive detail, which obscures significant facts and relationships and may delay report completion to the extent of affecting its timeliness for management, must be avoided. Unless the report is to be considered an historical record, the figures in it should be rounded to the significant digits, so that the reader's mind is not cluttered or encumbered with useless detail.

In planning report layouts, financial officers should always provide significant summaries. Management should not be expected to make its own summaries.

In reporting, technical vocabulary and unidentified code designations should be avoided whenever possible. The financial officer may be so completely familiar with certain terminology and special coding that he may incorrectly assume that all of the users of the financial reports will be equally familiar with them. Many persons beginning administrative duties may find financial reports, in their usual form, almost incomprehensible.

Reporting Media

Effective reporting requires the selection and skillful use of reporting devices which will best present the financial information involved. The reporting vehicle chosen should make the data clear and should convey ideas smoothly and rapidly.

Essentially, there are five distinct methods of presenting financial information: (a) oral presentations, (b) narrative reports, (c) conventional financial statements, (d) tabular presentations, and (e) graphic presentations. Depending on the type of data and the purposes of the reports, the financial officer is likely to find that a skillful blending of all of these methods will prove most effective in his reporting. Each method has a significant place in financial reporting to highway management; each has certain merits and defects as a financial reporting medium.

Oral Presentations.—The reporter will find many situations in which oral reporting may be especially appropriate, either by itself or combined with other media. The reporter is able, on the spot, to interpret and emphasize significant material, clear up questions, and save managers considerable time and effort in studying reports. The oral report may easily be adapted to fit the wishes, interests, and personality of the manager involved. Oral reporting fits neatly into the pattern of management by exception.

However, oral reporting has certain inherent limitations. It may be time-consuming, and scheduling problems may cause reporting delays. Many administrators "want it in writing." Regularity in reporting may be difficult, and not all financial officers are effective in making oral presentations.

Narrative Reports.—Certain financial information may be communicated most effectively in narrative form, especially in situations in which it is desirable to recommend specific action. Narrative memoranda are likely to be very useful in summarizing data and in drawing comparisons, presenting recommendations, and as a followup procedure.

The narrative report should be presented in a clear, simple style; it must be carefully organized and designed to permit the reader to locate the key points quickly, without looking back. It must be easy for the reader to grasp the basic outline and master the summaries.

Conventional Financial Statements.—These statements form the backbone of any reporting system. They should follow professionally acceptable accounting principles and are designed to present, in summary fashion, the results of operations and the situation which has developed from these operations. The statements should be designed for quick comparisons. For greatest usefulness, the data should be organized into homogeneous groupings, and should flow smoothly from detail to final summaries, so that the user may quickly and easily select information of immediate concern to him.

Tabular Presentations.—With tables more data may be organized for inclusion in reports than is likely to be true if only other forms of presentation are employed. When carefully prepared, tabulations are almost indispensable as documentation or backup material.

When included in a report, tabular presentations should contribute significantly to the process of analysis and interpretation. The most important task in the construction of tables is to arrange the data in such a way that the significant relationships can be most easily studied. The reporter must avoid the construction of overly complicated tables, because a table must be easy to understand if its purpose of effective presentation of financial data is to be served.

Graphic Presentations.—The purpose of graphics is to show comparisons quickly in visual form; they should be used chiefly to supplement other forms of presentation. In a world oriented to speed and pictorial presentations, well-designed graphics and charts lend clarity, appeal, and dramatic impact to financial reports. In general, graphic presentations make effective comparisons and contrasts; they are also effective in attracting and retaining the reader's interest and attention. Thus, the relationships portrayed in charts and graphs are easily grasped, understood, and remembered. Problems may be more clearly identified and defined.

In the use of graphics, certain principles are very important. The reporter must be thoroughly familiar with his data. He must carefully plan the number and type of graphics to include, and must be sure that there is a clear and convincing reason for each. He must select the graphic type which best fits the reporting job to be done. He must have sufficient knowledge of graphic techniques to get the effect he wants.

The bar chart is a very simple and popular means of making comparisons and illustrating relationships, by size, among comparable items. Depending on the reporter's purposes, he may use one or more of many variations of the bar chart, such as the grouped bar chart, the component bar chart, the subdivided one hundred percent bar chart, the paired bar chart, and the deviation bar chart. The column chart (in which the bars are arranged vertically instead of horizontally) is another useful reporting device. The column chart is more suitable than the bar chart for presenting data running over a period of time. As in the case of the bar chart, there are many possible variations of the column chart which the reporter may find useful.

The line chart is probably the simplest, best known, and most versatile visual device for presenting statistical information. When emphasis is to be placed on changes over time rather than simply on the quantities themselves, the line chart is unequaled. It is useful in presenting estimates and forecasts, and can be used to show cumulative amounts over time. Pie charts are frequently used to show the percentage breakdown of the components of a total, such as total revenues or total expenditures. Since the pie chart possesses more weaknesses than most other graphic forms, it should be used sparingly. The most effective device for portraying relationships on a geographical basis is the map chart. When data are to be compared and analyzed by geographic areas, maps are indispensable.

In general, graphic aids should be limited to main points, and not applied to side issues. They must be simple enough to be readily comprehended, otherwise they will not accomplish the reporter's purpose. For best effect, the reporter must strive for a satisfactory balance between graphic aids and other devices for the presentation and analysis of data.

EVALUATION OF CURRENT REPORTING PROCEDURES

One of the important aspects of the research project was a critical examination and evaluation of current financial reporting practices, as evidenced by reports now being prepared by state highway financial officers. For this purpose, reports from more than three-fourths of the highway departments were reviewed.

Judging from the principles enunciated in the literature, the impressions of the researchers, and the expressions of opinion of highway administrators, current financial reporting practices could be improved in the following important respects:

1. Enormous quantities of detail should be eliminated. In too many cases reports contained an indigestible amount of information spread over too many columns of too many pages.
2. More numerous and adequate summaries should be included with the reports.
3. The information in the reports should flow so that it would be easy to follow the manipulation of the figures across the page to the significant amounts.
4. There should be much more clarity and consistency in the use of terminology. Highly technical terminology should be avoided. In many cases, the terminology employed was entirely too complicated and, therefore, incomprehensible to management personnel.
5. Far fewer cost accounts should be used, thus conserving operational time and eliminating proliferation of detail in reporting. The greater the number of cost accounts used, the greater the inaccuracies in the reports.
6. Interpretation or evaluation should have been supplied, thus making the reports submitted much more usable. Interpretation and evaluation were almost completely lacking.
7. More comparative information should be included. When such information was included, insufficient use was made of the comparisons.
8. There should be greater use made of the variety of reporting media, especially to provide quick, convincing explanations of financial situations.

THE ADMINISTRATORS' POINT OF VIEW

As previously indicated, the chief thrust of the research investigation involved obtaining the opinions of highway administrative officials regarding their needs and desires in the area of financial reports. Their views were solicited in both personal interviews and through extensive correspondence. Interviews were conducted with persons representing a considerable range of administrative responsibility: from subdistrict personnel all the way up the line, including chief administrative officers, members of a part-time commission reporting directly to the governor of the state, and officials of the U.S. Bureau of Public Roads. All chief administrative officers of the various state highway departments were invited to express their views, by letter, regarding financial reporting, and considerable correspondence was conducted with them.

Administrators' General Observations

Possibly the most striking and frequently expressed comment was that financial reports should not be cluttered with detail, but should be properly analyzed and summarized for quick assimilation by the administrator. A sampling of such comments is presented below.

> Reports must be brief, concise, and readily interpretable to other officials in high positions; supporting information is definitely not warranted if I am going to rely on the competence of those preparing the reports for me.
>
> Except when analyzing specific problems, I do not need supporting information beyond summary statements. . . .The data submitted to this office become so voluminous that the detail cannot be comprehended by one individual.

> There is a tendency to allow financial reporting to become a mere takeoff of data-processed records and the resulting summary information forwarded to management in a perfunctory manner without comment.
>
> Voluminous reports transmitted to a chief administrative officer generally do not serve a useful purpose. . . . The Commissioner should not receive a report which is cluttered with extraneous information which may be essential to the support of the report but which, per se, is not essential to his grasp of the conclusions.
>
> The problems which top management encounters in attempting to use finnancial statements are too many details, time-consuming analysis required to decipher the pertinent information, and implied budgetary problems rather than specifics . . ..
>
> Excessive detail results in no one paying any attention to the report.
>
> Detailed reports must be summarized on a single letter-size sheet, with supporting evidence available on call, but not attached.

Several respondents indicated that a mistake frequently made is to attempt to cover too much in a single report; they suggest that it is far better to have several reports, each bringing out one or two central facts, and that each should be confined to a single page whenever possible. Another point stressed is that management is interested in exceptions and problems, and that reports should carry recommendations for corrective action in these cases.

Certain chief administrative officers made a plea for standardized reporting and terminology, which they hoped would lead to greater exchange of data among the various states for purposes of better communication, comparisons, and the development of standards for operating performance.

Administrators appeared less united in their preferences regarding oral and narrative reporting. Most administrative officials apparently do not want to rely to any great degree on narrative and oral reports. Many believe that such reports should be confined to special situations and not included in the reporting routine. One commissioner stated: "Verbal and narrative reporting are not particularly useful unless on a specific project or problem area." Another administrator wrote that "verbal reports are acceptable for minor items only, and all major report items should be made available in writing." Another indicated that verbal and narrative reports have a useful function at lower levels only. Several said that short summary statements amplified by verbal explanations are helpful. Others pointed out that verbal reports are difficult to recall if the same information is needed at a later date. One commissioner pointed out that narrative comments pertaining to conventional statements should be helpful, but should not repeat the obvious. Another suggestion was that a one-page narrative report should accompany each quarterly report, presenting in capsule form what has taken place during the quarter.

In general, it appears that most administrators favor the employment of graphics to supplement conventional reports and for limited purposes, such as for showing long-term trends, showing expenditure peaks, helping in predicting exenditures in succeeding years, presentations to legislative committees, training purposes within the highway department, comparing expenditures of one period with another or of one district with another, and comparisons of actual income and expenditures with budgeted amounts for the appropriate period. One administrator stated that graphics were not required for his personal consumption, but they were handy items to have in his briefcase to be shown to other state officials and for limited or public consumption. In one state "a liberal use of graphic presentation provides a descriptive view of our operations in prior years and projection estimates for the future. Statistical tables support the graphs."

Most administrators favoring graphics appear to want them used in combination with other reporting devices. Statements such as the following were made:

> We prefer graphic presentations supplemented by terse, explanatory narrative. A busy administrator will carefully examine a meaningful abstract supplemented with graphics and be guided by its message much more than if he must wade through a compilation of statistics that he does not have time to digest.
>
> Graphs and charts combined with short pointed statements are, I think, the most effective method of presenting a status of affairs and circumstances, regardless of the subject matter.
>
> Graphic illustrations accompanying the reports are definitely an assist.
>
> Graphs are very helpful and are easily understood by most people. We have experimented with several types of monthly financial reports and are now using one which is a combination of current information, statistical data, and graph.

Other administrators stressed the need for research within each highway department to find better, easier, and more accurate methods of financial reporting. One administrator noted that he must be in a position to interpret financial reports for various individuals who may not be very conversant with highway operations or accounting procedures.

In summary, simplicity, brevity, and ease of use appear to be the keys to successful financial reporting to highway administrators.

Specific Reporting Requirements

1. Long-Range Planning. Most highway officials stressed the need for good financial information for long-range planning. The concept of what constitutes an appropriate forecasting period appears to vary considerably among administrative officials, apparently depending on the situation within the respective states. Although a few administrators believe that projections of revenues and expenditures beyond a 5-yr period are completely worthless ("conditions change too rapidly"), others were convinced that 10- to 15-yr projections are an absolute necessity. One commissioner reported that he had required the development of a short-range 12-yr program, which was being updated every 2 yr. Several interviewees expressed approval of a model of a 5-yr program, revised and updated annually.

Short summaries and the use of state maps showing locations of projects within the long-range program appeared to be very desirable from the administrators' point of view.

2. Budgetary Reports. Few chief administrative officials indicated a significant interest in the process of budget formulation, apparently considering budget preparation as a clerical job within a general policy framework. Almost without exception, however, these officials were seriously concerned with budget status reports. In one case, the commissioner apparently had successfully delegated budgetary control to a subordinate. All of the other administrators were concerned with monthly summaries of expenditures against budget for maintenance, administration, and construction, by major object. Most of these men emphasized the usefulness of budget status reports as an important guide to management. One commissioner reported:

> I am much concerned with the status of the fiscal year budget which is used for monitoring the state's overall expenditure program. Expenditure lags or excesses beyond acceptable limits are compared with the amounts expected on a time basis and action taken to the extent required.

Most officials wanted budget status information on a comparative basis. Suggested comparisons were: the percentage of funds spent to percentage of budget period elapsed; amounts in the current period against amounts for corresponding period of the previous year; or estimated expenditures and receipts as presented in the budget against actual data. Several men wanted a budget status report shortly after the end of the third quarter to compare free balances against fourth-quarter requirements.

There were complaints registered that budget status reports were too late in reaching management to be useful and that the reports were broken down into too many minor categories.

3. General Purpose Statements. Interest in these statements centered chiefly in revenue and expenditure statements, especially maintenance cost expenditures. Several administrators wanted reports of trends of major types of engineering costs, and a few found statements of garage and/or equipment operation revolving funds useful. There appeared to be little interest in balance sheets as such, which suggests that financial officers have not fully informed administrative officials of the value of such statements.

4. Special Purpose Statements. In this area, interest appeared to center in reports reflecting the status of Federal-aid programs. The information needed concerned the status of Federal-aid apportionments and obligations, both ABC and Interstate, progress in programming with the U.S. Bureau of Public Roads, status of Federal-aid billing, and amounts available for programming, agreement, and reimbursement. Areas of lesser importance in which the administrators expressed interest were project control reports to show status of project programs, including the availability of funds for construction projects, and various types of inventories. There was little mention of debt financing reports, even though debt programs are significant in many states.

5. Unclassified Schedules and Exhibits. Several administrators expressed at least mild interest in reports of contract awards, perhaps with some comparative feature built in, such as awards for the year to date. Certain subordinate administrators could make use of monthly listings of awards, with engineers' estimates. A few administrators liked to receive, at selected times, employment counts, totals of wages and salaries by major classifications, and other information with comparisons on a time basis.

REPORTS FOR PLANNING, OPERATIONS, AND CONTROL

State highway department accounting and reporting is unique, both in comparison with that of any industry or other governmental organization and within the fifty state highway organizations themselves. Because of differences in legislation, personnel, geographical and demographic conditions, natural resources, commerce and industry, and other factors, no present state highway department and no present state highway accounting and reporting system would be suitable, without extensive modification, for another state. However, there are many financial circumstances, conditions, and requirements which are common to most of them.

Based on the results of the research as well as the researchers' background and observations, selected examples of financial reporting to highway administrators have been developed for presentation in this study. The chief purpose of including these illustrations is to show how the financial data may be presented to management and, in certain of the examples, to provide illustrative narrative comment of the type the financial officer might choose to include with his reports. It is not the intent, in this paper, to discuss or illustrate how the amounts were derived for the exhibits and figures included herein.

Long-Range Planning. —From several examples available to the researchers, a sample report of a long-range program has been developed. Exhibit 1 (Appendix) shows the financial picture of an 8-yr program—three years of actual experience as a springboard for five years of projected costs and revenues. Figure 1 shows the same information in graphic form. In line with the frequently made suggestion that summaries should be prepared for the chief administrative official and backup schedules supplied on demand, the researchers prepared a sample schedule, the construction component of the 8-yr program (Exhibit 1A, Appendix).

Budgetary Reports. —In addition to financial forecasting, the budget function involves the interrelated processes of budget formulation and budget administration. Exhibit 2 (Appendix) illustrates a biennial budget request form, all of which, except the column for Budget Request for the 1965-1967 biennium, is filled out in the financial section before routing to the appropriate administrative officer charged with budgetary responsibility for the budget unit. Exhibit 3 (Appendix) shows a budget status report in-

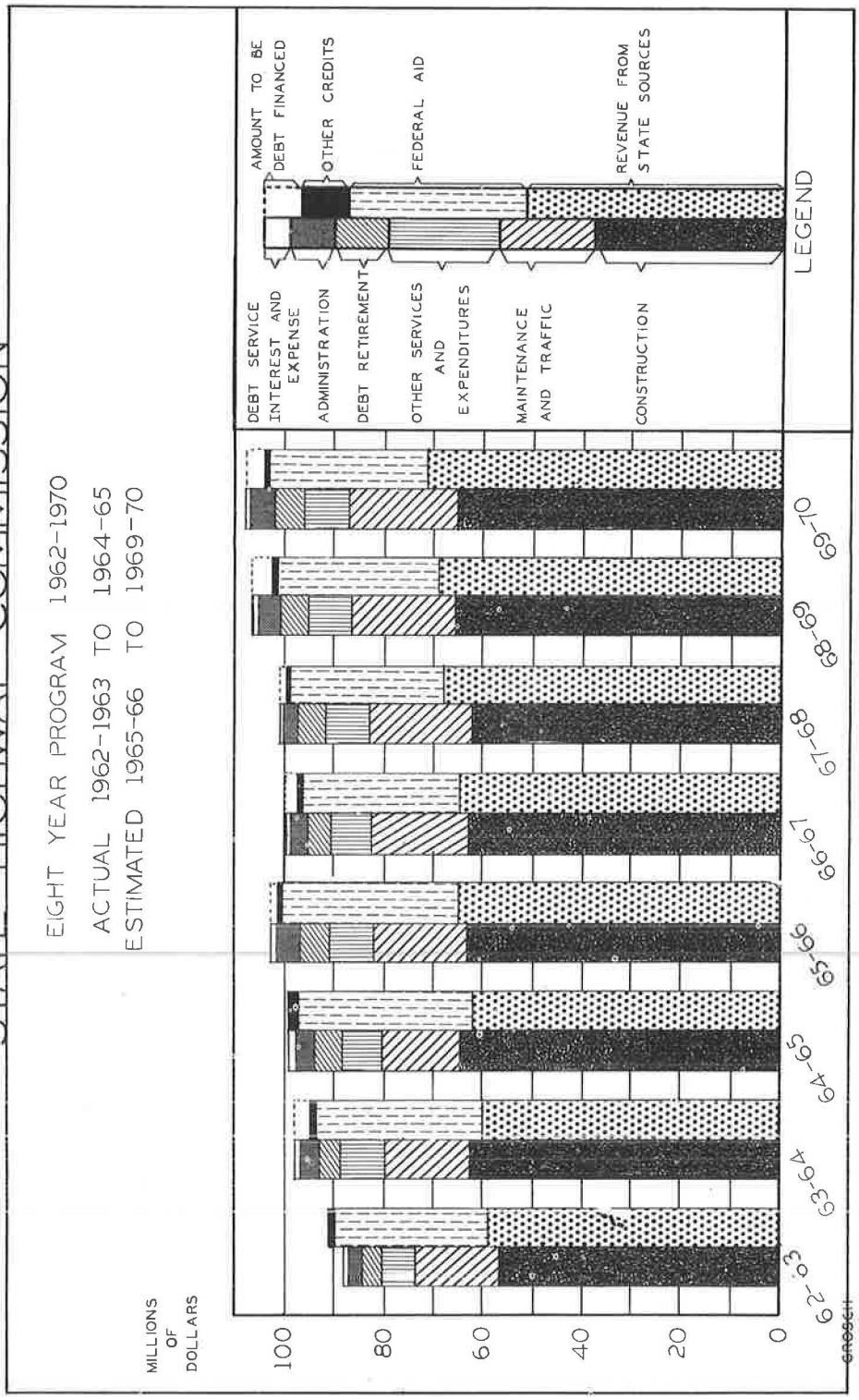

Figure 1. Financial picture for 8-year program.

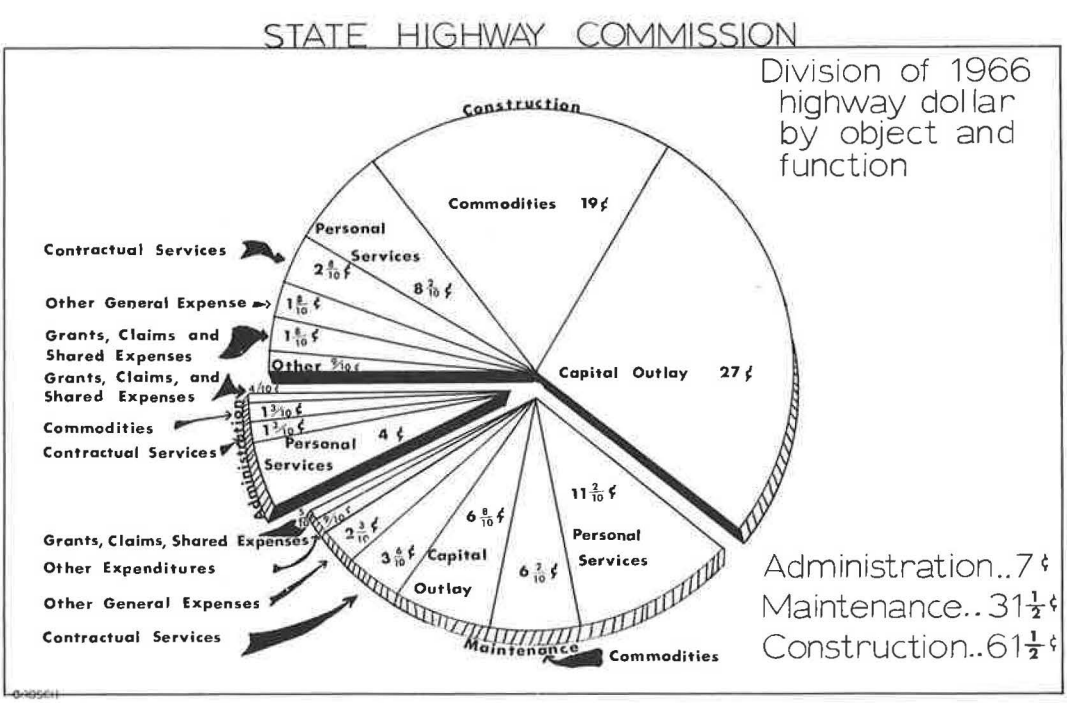

Figure 2. Pie chart illustrating relationships among budgetary items.

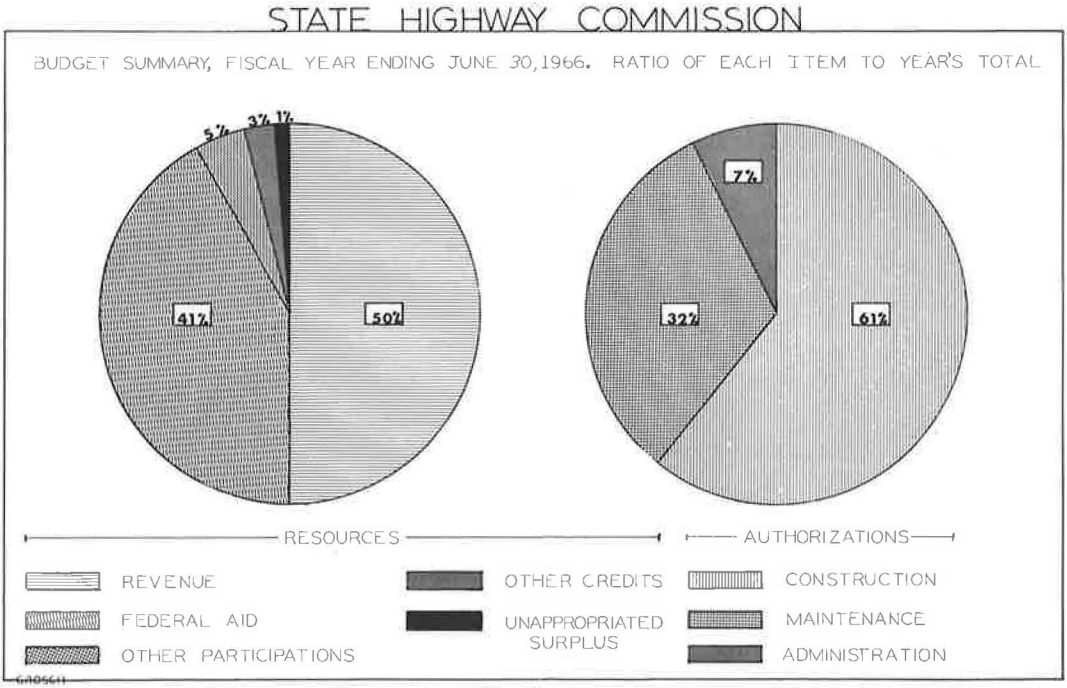

Figure 3. Pie chart illustrating relationships among budgetary items.

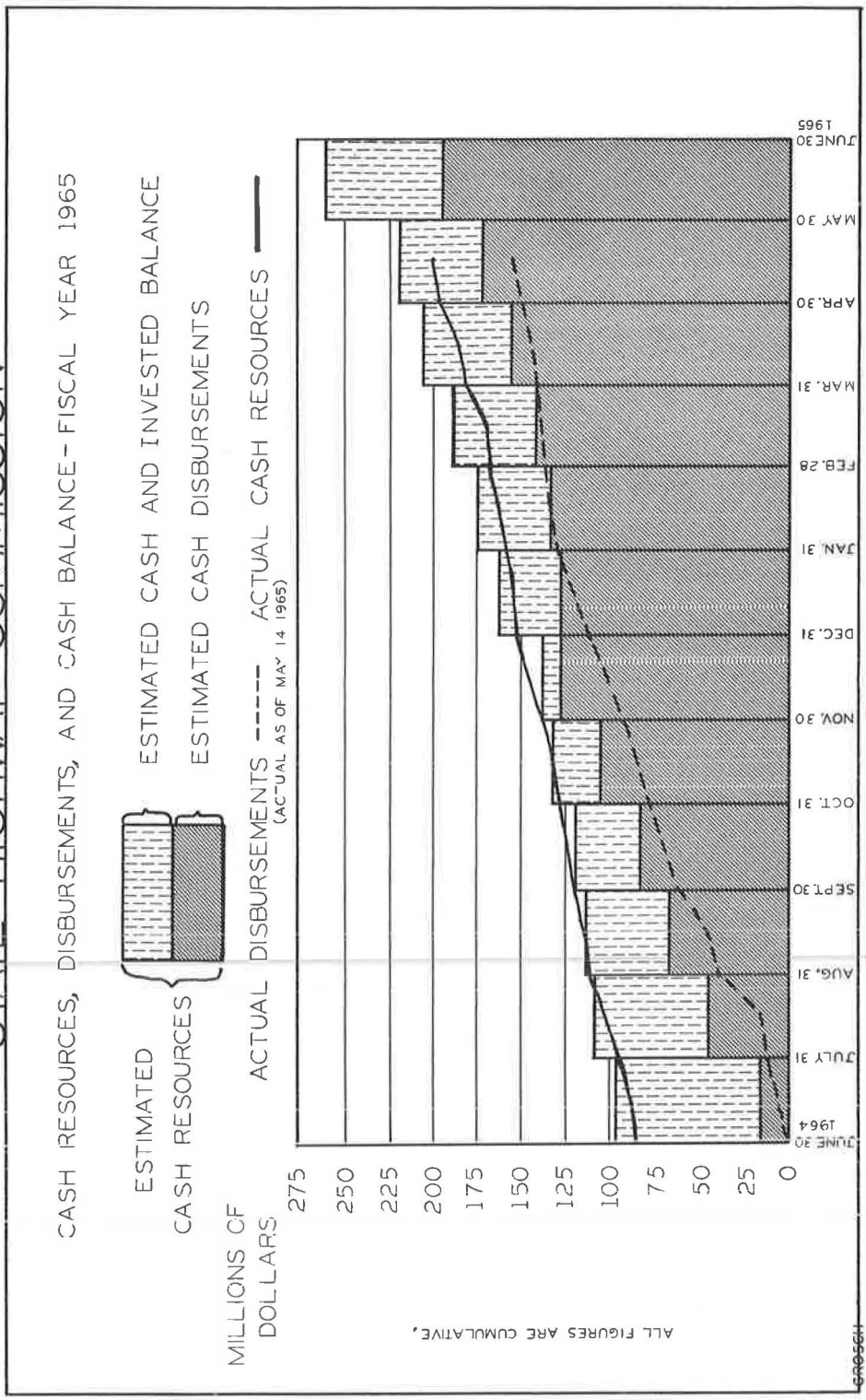

Figure 4. Chart showing estimated and actual cash resources, disbursements, and cash balances.

volving the financial information for the same budget unit—administration. Most highway administrators indicated that the most useful information in a budget status report was the comparison of total budget and free balances, together with percentages spent or obligated against percentage of the time elapsed in the period. These comparisons are facilitated in Exhibits 2 and 3 (Appendix).

Figures 2 and 3 are pie charts, unrelated to the previously mentioned exhibits, illustrating graphic aids which may be employed to provide at-a-glance relationships among budgetary items. These visualizations might be useful for public relations, conferences with officials of other governmental agencies, and legislative committees.

General Purpose Statements.—To illustrate financial reporting in this category, general fund year-end comparative balance sheets are shown in the Appendix as Exhibit 4. Quick comparisons of the general situation at the end of fiscal 1965 may be made with that which prevailed at the end of 1964. Included are narrative comments which the financial officer might make.

Figure 4 (not related to Exhibit 4) shows amounts involving cash resources, disbursements, and cash balances, both estimated and actual, and also illustrates the possibility of an "open-end" chart, in which data for a succeeding month may be added as appropriate.

Special Purpose Statements.—Exhibit 5 (Appendix) shows the format of an equipment operating fund, following which are pointed out the kinds of questions which can be answered through a perusal of this statement. Comparative statements of general bonded debt and interest are presented as Exhibit 6 (Appendix) followed by observations indicative of the purpose and usefulness of this type of statement.

Exhibit 7 (Appendix) clearly discloses the two amounts of Federal-aid funds in which many highway administrators have indicated the greatest interest, i.e., (a) the amount available for programming, and (b) the unprogrammed balance.

Exhibit 8 (Appendix) combines the status of the primary program with a forecast of unprogrammed balance as of December 31, 1965. Such a report would be updated periodically. A similar report would be prepared for each class of highway. Inclusion in the report of amounts that must be placed under agreement by certain dates lessens the possibility of inadvertent lapse of any part of an apportionment. Details regarding individual projects would be supplied in a supplementary schedule, either accompanying the summarized form, or available on request, as preferred by the recipient of the report.

Exhibit 9 (Appendix) is a small section of 23 pages of an actual state report listing status of Federal-aid appropriations by class of highway, county and project number. Highway management personnel who desired to know state-wide totals for each stage of Federal-aid as of February 28, 1965, could have found the separate totals of each of the above classes of highway on several pages of the original report, but these totals apparently were not brought together at any point.

A condensed summary of the information contained in the original report is given in Exhibit 10 (Appendix), which brings together in one place the essential facts the administrator needs to know.

SUMMARY

Each financial report to management should be specifically tailored to provide in the clearest possible manner the essential financial information needed by management for its specific purposes: decision-making, planning, or evaluating performance.

Management personnel should not be expected to be able to detect all the significant elements and relationships in a financial statement with the same readiness that a financial official would, any more than the latter would be expected to understand the intricacies of engineering design.

Too many financial reports submitted to management obscure the significant data by cluttering the report with detail needed by the accounting department but not essential to the recipient.

Exhibit 1

X State Highway Commission
Eight-Year Program
($'000's)

	Actual 1962-63	Actual 1963-64	Actual 1964-65	Est. 1965-66	Est. 1966-67	Est. 1967-68	Est. 1968-69	Est. 1969-70	Est. 8-yr. Total
Costs									
Operating Requirements									
Construction	57,092	62,404	64,685	65,651	63,160	63,558	65,744	65,858	508,152
Maintenance and Traffic	17,263	17,250	18,050	19,100	19,900	20,700	21,500	22,400	156,163
Administration	2,976	3,445	3,099	3,700	3,875	3,900	4,075	4,125	29,195
Other Services and Expenditures	7,537	9,488	8,064	8,458	8,020	8,370	9,070	9,120	68,127
Sub-Total	84,868	92,587	93,898	96,909	94,955	96,528	100,389	101,503	761,637
Debt Service, Interest and Expense	515	490	389	400	400	400	400	400	3,394
Debt Retirement	4,162	4,080	4,146	5,000	5,000	5,000	5,000	5,000	37,388
Total Costs	89,545	97,157	98,433	102,309	100,355	101,928	105,789	106,903	802,419
Income									
Revenue from State Sources	58,602	59,986	62,791	64,500	66,000	67,500	69,000	70,500	518,879
Federal Aid	32,241	34,331	35,342	36,338	32,250	32,250	31,350	31,350	265,452
Other Credits (Excluding Debt Financing)	261	230	300	300	300	300	300	300	2,291
Total Income	91,104	94,547	98,433	101,138	98,550	100,050	100,650	102,150	786,622
Excess of Income over Costs	(1,559)	--	--	--	--	--	--	--	(1,559)
Amount to Be Provided from Prior Year's Surplus	--	1,559	--	--	--	--	--	--	1,559
Amount to Be Provided by Debt Financing (Minimum)	--	1,051	--	1,171	1,805	1,878	5,139	4,753	15,797
Total Sources	89,545	97,157	98,433	102,309	100,355	101,928	105,789	106,903	802,419

For the purpose of this example, zero fund balance at the beginning of fiscal 1963 has been assumed.

Exhibit 1A

X State Highway Commission
Eight-Year Construction Program
($'000's)

	Actual 1962-63	Actual 1963-64	Actual 1964-65	Est. 1965-66	Est. 1966-67	Est. 1967-68	Est. 1968-69	Est. 1969-70	Est. 8-yr. Total
Interstate, Federal Aid	20,667	22,389	23,132	23,989	19,800	19,800	18,900	18,900	167,577
" , State Funds	2,333	2,488	2,570	2,665	2,200	2,200	2,100	2,100	18,656
" , Total	23,000	24,877	25,702	26,654	22,000	22,000	21,000	21,000	186,233
Primary/Urban, Federal Aid	6,890	7,108	7,269	7,350	7,350	7,350	7,350	7,350	58,017
" , State Funds	9,110	10,892	11,431	7,350	7,350	7,350	7,350	7,350	68,183
" , Total	16,000	18,000	18,700	14,700	14,700	14,700	14,700	14,700	126,200
Secondary, Federal Aid	4,581	4,726	4,833	4,900	5,000	5,000	5,000	5,000	39,040
" , State Funds	12,819	14,074	14,667	13,200	13,400	13,600	13,800	14,000	109,560
" , Total	17,400	18,800	19,500	18,100	18,400	18,600	18,800	19,000	148,600
Forest Highways, Federal Aid	103	108	108	100	100	100	100	100	819
" " , State Funds	104	112	112	100	100	100	100	100	828
" " , Total	207	220	220	200	200	200	200	200	1,647
Unallocated, State Funds				5,427	7,280	7,468	10,444	10,358	40,977
Indirect Construction Costs, State Funds	485	507	563	570	580	590	600	600	4,495
Total Federal Aid	32,241	34,331	35,342	36,339	32,250	32,250	31,350	31,350	265,453
Total State Funds	24,851	28,073	29,343	29,312	30,910	31,308	34,394	34,508	242,699
Grand Total	57,092	62,404	64,685	65,651	63,160	63,558	65,744	65,858	508,152

* *

Example of Narrative Comment:

The projected requirements of state funds to match Primary/Urban Federal Aid in Exhibit 1A appears to be inadequate, if the experience during the fiscal years 1962-1965 is a fair criterion. Based on this experience, the estimate of required matching state funds may be several millions of dollars short. This point, in turn, suggests that the estimated total state funds of $242,699,000 required for the eight-year period may be seriously inadequate and that the minimum debt financing estimate of Exhibit 1 may be much too low.

Exhibit 2

STATE HIGHWAY COMMISSION

BIENNIAL BUDGET REQUEST FORM

Budget Unit Administration Date Jan. 15, 1965

Item or Code	BUDGET INFORMATION SUMMARY						BUDGET REQUEST
	Fiscal 1963-1964 (Previous year)		Fiscal 1964-1965 (Current year) 50 % of Period Expired				1965-1967 Biennium
	Budgeted	Expenditures	Budgeted	Expenditures to Date	Encumbrances to Date	Spent or Obligated to Date	
.1	$1,229,300	$1,217,150	$1,339,788	$ 609,153	$ --	45.5%	$ 3,188,200
.2	266,300	246,827	322,716	144,919	--	44.9	771,500
.3	851,200	854,145	840,766	592,505	59,789	77.6	1,820,600
.4	364,600	379,458	263,201	118,754	68,148	71.0	584,000
.5	222,000	215,185	263,865	198,184	13,687	80.2	627,300
.6	- 0 -	16,876	152,500	71,406	12,600	55.1	72,500
.7	2,022,700	1,898,764	1,182,741	744,616	--	63.0	2,946,900
Total	$4,956,100	$4,828,405	$4,365,577	$2,479,537	$154,224	60.3%	$10,011,000

Signature _____

Exhibit 3

X State Highway Commission
Fiscal Year 1964-1965
Budget Status as of Dec. 31, 1964

Budget Unit Administration 50 % of Period Expired Date Jan. 15, 1965

Item or Code	Total Appropriation	Allotment to Date	Expenditures to Date	Outstanding Encumbrances and Requisitions	Percent Spent or Obligated to Date	Free Balance
.1	$1,339,788	$ 621,700	$ 609,153	--	45.5%	$ 730,635
.2	322,716	136,900	144,919	--	44.9	177,797
.3	840,766	726,900	592,505	$ 59,789	77.6	188,472
.4	263,201	209,700	118,754	68,148	71.0	76,299
.5	263,865	219,400	198,184	13,687	80.2	51,994
.6	152,500	85,000	71,406	12,600	55.1	68,494
.7	1,182,741	1,168,900	744,616	--	63.0	438,125
Total	$4,365,577	$3,168,500	$2,479,537	$154,224	60.3%	$1,731,816

Exhibit 4

X State Highway Commission
General Fund
Comparative Balance Sheets
June 30, 1964 and 1965

Assets	1965	1964	Increase-Decrease* Amount	Percent
Current Assets:				
Cash with state treasurer	$ 9,864,000	$10,069,000	$ 205,000*	2.0*
Cash in bank and on hand	1,721,000	1,498,000	223,000	14.9
Receivables:				
Federal aid	$11,432,000	$ 9,671,000	$1,761,000	18.2
Due from motor vehicle tax fund	1,659,000	1,207,000	452,000	37.4
Due from other governmental units	794,000	814,000	20,000*	2.5*
Other receivables (less estimated uncollectibles: 1965, $21,000; 1964, $19,000)	633,000	504,000	129,000	25.6
Total Receivables	$14,518,000	$12,196,000	$2,322,000	19.0
Total Current Assets	$26,103,000	$23,763,000	$2,340,000	9.8
Non-current Assets:				
Condemnation deposits	$ 9,871,000	$ 9,065,000	$ 806,000	8.9
Materials and supplies	3,765,000	4,001,000	236,000*	5.9*
Prepaid expenses	61,000	77,000	16,000*	20.8*
Total Non-current Assets	$13,697,000	$13,143,000	$ 554,000	4.2
Total Assets	$39,800,000	$36,906,000	$2,894,000	7.8
Liabilities, Reserves and Fund Balance				
Liabilities				
Vouchers payable	$ 1,769,000	$ 2,066,000	$ 297,000*	14.4*
Due to other governmental units and funds	1,869,000	955,000	914,000	95.7
Contracts payable--retained percentage	2,043,000	1,808,000	235,000	13.0
Withholding taxes payable	964,000	988,000	24,000*	2.4*
Other liabilities	173,000	213,000	40,000*	18.8*
Total Liabilities	$ 6,818,000	$ 6,030,000	$ 788,000	13.1
Reserves and Fund Balance				
Reserve for condemnation deposits	$ 9,871,000	$ 9,065,000	$ 806,000	8.9
Reserve for inventory of materials and supplies	3,765,000	4,001,000	236,000*	5.9*
Reserve for encumbrances	15,691,000	16,703,000	1,012,000*	6.1*
Total Reserves	$29,327,000	$29,769,000	$ 442,000*	1.5*
Fund Balance	$ 3,655,000	$ 1,107,000	$2,548,000	230.1
Total Liabilities, Reserves and Fund Balance	$39,800,000	$36,906,000	$2,894,000	7.8

Exhibit 4 (continued)

Example of narrative comment:

1. The general fund had, at the end of each year, enough cash to pay all of its liabilities.

2. Year-end inventory of materials and supplies declined during 1965. This shows the results of the inventory control plan for reducing loss from obsolescence and for minimizing investments in supplies and materials.

3. Total liabilities were more than three-fourths of a million dollars greater at the end of 1965 than they were a year earlier, even though cash greatly exceeded the total of liabilities.

4. The fund balance increased during fiscal 1965, indicating that not all available funds for the year were used. The fund more than "held its own" during 1965.

5. Receivables increased during the year to such an extent that an investigation for the reason seems in order. (Of all balance sheet items, receivables is probably the one most in need of being analyzed in a supporting schedule. The analysis should, above all, show the ages of receivables and indicate known reasons for delay in collection.)

6. Money held by county courts in connection with condemnation proceedings, and drawing no interest, increased by a sizable amount.

7. Although free assets, as represented by the fund balance, increased by a large percentage, neither of the amounts carried over to the following year was excessive.

Exhibit 5

X State Highway Commission
Equipment Operating Fund
Comparative Operating Statements
Fiscal Years Ended June 30, 1964 and 1965

	1965	1964	Increase-Decrease* Amount	Percent
Revenues:				
Equipment rentals	$4,017,340	$3,887,676	$129,664	3.3
Miscellaneous income	566,181	540,921	25,260	4.7
Total Revenues	$4,583,521	$4,428,597	$154,924	3.5
Direct Costs:				
Direct labor	$ 652,950	$ 633,004	$ 19,946	3.2
Supervision	44,003	43,218	785	1.8
Parts and supplies used	701,718	695,030	6,688	1.0
Fuels and lubricants	982,823	976,001	6,822	.7
Heat, light and power	21,666	22,734	1,068*	4.7*
Depreciation of equipment	2,059,718	1,915,836	143,882	7.5
Miscellaneous direct costs	11,418	19,805	8,387*	42.3*
Total Direct Costs	$4,474,296	$4,305,628	$168,668	3.9
Excess of Revenues over Direct Costs	$ 109,225	$ 122,969	$ 13,744*	11.2*
Indirect Costs:				
Administrative salaries	$ 63,043	$ 61,071	$ 1,972	3.2
Depreciation buildings	17,332	17,332	--	--
Office expense	3,407	4,522	1,115*	24.7*
Miscellaneous expense	1,539	8,392	6,853*	81.7*
Total Indirect Costs	$ 85,321	$ 91,317	$ 5,996*	6.6*
Excess of Revenues over Total Costs	$ 23,904	$ 31,652	$ 7,748*	24.5*

As was stated to be true of a warehouse fund operating statement, such a statement of an equipment fund serves as an indicator of trends and conditions, but management must decide by use of supplementary schedules and other data, what were the causes and what action, if any, is called for.

Was the increase in rentals due to greater usage, higher rates, or some combination of the two? Is enough being spent on supervision or would a larger outlay for this cost bring about a reduction in other costs? Are accurate records being kept to show the "down" time of each major piece of equipment, to the end of determining the cause and suggested remedy? Is maximum value being obtained from retired equipment or is some of it disposed of prematurely? Or, on the contrary, is some equipment being kept in service after physical or functional obsolescence has rendered it inefficient, in comparison with an available substitute?

The operating statements which have been illustrated above are not independent parts of the reporting structure of state highway departments but relate closely to the balance sheet, statement of cash receipts and disbursements, and statement of changes in fund balance which are prepared for working capital funds, to portray their total activity and financial condition.

Exhibit 6

X State Highway Commission
Bonded Debt and Interest Group
Comparative Statements of General Bonded Debt and Interest
June 30, 1964 and 1965
(000's omitted)

Amount Available and to be Provided for Payment of Bond Principal and Interest	1965	1964	Increase-Decrease* Amount	Percent
Bond Principal:				
Amount in debt service fund	$ 53,027	$ 50,450	$ 2,577	5.1
Amount to be provided in future years	126,973	159,550	32,577*	20.4*
Total Available and to Be Provided	$180,000	$210,000	$30,000*	14.3*
Bond Interest:				
Amount in debt service fund	$ 8,400	$ 10,100	$ 1,700*	16.8*
Amount to be provided in future years	9,500	13,275	3,775*	28.4*
Total Available and to be Provided	$ 17,900	$ 23,375	$ 5,475*	23.4*
Total Available and to Be Provided for Payment of Bonds and Interest	$197,900	$233,375	$35,475*	15.2*
Bonds and Interest Payable in Future Years				
Bond Principal:				
Highway construction bonds	$100,000	$110,000	$10,000*	9.1*
Highway refunding bonds	80,000	100,000	20,000*	20.0*
Total Bonds Payable in Future Years	$180,000	$210,000	$30,000	14.3*
Interest:				
Highway construction bonds	$ 12,500	$ 15,125	$ 2,625*	17.4*
Highway refunding bonds	5,400	8,250	2,850*	34.5*
Total Interest Payable in Future Years	$ 17,900	$ 23,375	$ 5,475*	23.4*
Total Bonds and Interest Payable in Future Years	$197,900	$233,375	$35,475*	15.2*

The following observations indicate the nature and purpose of the above statement:

1. Although having the form of a balance sheet, it does not technically qualify as such. It is a summary including some information from a statement of debt service requirements and some from a balance sheet of a debt service fund which shows amounts and kinds of assets held for debt service requirements. This statement should be used in conjunction with the other two statements mentioned. With no alteration of form it can be used to summarize the same kind of information about a large number of bond issues.

2. Amounts to be provided for payment of principal and interest are significant for long-range planning of a highway program because they reveal the amount of future revenue not available for construction and maintenance.

3. Statements of this type are sometimes prepared without including any information about future interest requirements. This seems to detract somewhat from the value of the statement which, when both principal and interest are included, conveys a better idea of the total cost of highways built by means of debt financing.

4. This statement is not a major item in the financial management of a state highway department. Its value derives from the fact that it summarizes in brief form a considerable amount of information about the department's long-term debt position and requirements.

Exhibit 7

X State Highway Commission
Status of Federal Apportionments by Classes of Highway
as of Oct. 31, 1964
(Including Federal Apportionments for Fiscal 1966)
($'000's)

	Balance of 1966 and Prior Apportionments to Be Placed under Agreement	PS&E Approved	Available for Programming as of Oct.31, 1964	Reserved for HPR	Program Approved	Unprogrammed
Interstate	$216,462	$44,425	$172,037	$2,721	$26,479	$142,837
Primary	10,487	1,001	9,486	213	955	8,318
Secondary	14,592	4,491	10,101	133	--	9,968
Urban	19,322	6,504	12,818	202	3,068	9,548
Total	$260,863	$56,421	$204,442	$3,269	$30,502	$170,671
Amount deferred under Federal Government reimbursement schedule			171,761			
Unobligated balance available under reimbursement planning, as of Oct. 31, 1964			$ 32,681			

Exhibit 8

X State Highway Commission
Federal Aid Primary Program Status as of July 6, 1965
With Forecast of Unprogrammed Balance as of December 31, 1965
(to nearest $1,000)

Apportionment which must be under agreement prior to 6/30/66	--
" " " " " " " " 6/30/67	$2,110,000
" " " " " " " " 6/30/68	5,124,000

Apportionments (including 1966 apportionment)	$42,547,000
Less: Under agreement	37,423,000
Balance Available for Agreement	$ 5,124,000
Less: Under P.S. & E.	602,000
Unobligated Balance, July 6, 1965	$ 4,522,000
Less: Programs approved, Stage 2	2,500,000
Unprogrammed Balance	$ 2,022,000
Less: Proposed programs, July 6-August 31, 1965	1,520,000
Anticipated Unprogrammed Balance, August 31, 1965	$ 502,000
Anticipated 1967 Apportionment in September, 1965	3,100,000
Estimated New Balance	$ 3,602,000
Less: Reserve for HPR-PR-1(3) and HPR-1(75)	62,000
Estimated Unprogrammed Balance as of December 31, 1965	$ 3,540,000

Exhibit 9

(Disguised excerpt from actual report)
X State Highway Commission
Status of Federal Aid Appropriations as of February 28, 1965
Postwar Secondary

Project No.	Location	Unprogrammed	Program	PS&E	Progress	Final	Total
	ADAMS COUNTY						
A 686	Kelley Hill Road	-	-	-	$ 138,650.00	-	$ 138,650.00
A 687	Putney Road	-	-	-	183,000.00	-	183,000.00
A 687-1	Orchard Rd-Mason Rd	-	-	-	196,460.00	-	196,460.00
A 807	Rt. 67-Oak Road	-	-	$ 176,500.00	-	-	176,500.00
	Completed Projects	-	-	-	-	$ 1,016,872.17	1,016,872.17
				$ 176,500.00	$ 518,110.00	$ 1,016,872.17	$ 1,711,482.17
	ALLEN COUNTY						
AL 451	Uniondale-Osceola	-	-	-	$ 15,865.00	-	$ 15,865.00
AL 451X	River Road	-	-	-	26,977.00	-	26,977.00
AL 452X	Railroad Road	-	-	-	15,872.00	-	15,872.00
	Completed Projects	-	-	-	-	$ 15,440.00	$ 15,440.00
					$ 58,714.00	$ 15,440.00	$ 74,154.00
	STATE ROADS PROJECTS						
D1-843-1-270	Shady Park Road	-	-	$ 113,400.00	-	-	$ 113,400.00
R-467-1-420	Valley Route 34	-	-	-	$ 531,100.00	-	531,100.00
R-489-1-420	Niles Rd-Battel Rd	-	-	768,783.00	-	-	768,783.00
	Completed Projects	-	-	-	-	$ 9,988,135.12	9,988,135.12
				$ 882,183.00	$ 531,100.00	$ 9,988,135.12	$11,401,418.12
UNPROGRAMMED BALANCE		$6,461,582.98	-	-	-	-	$ 6,461,582.98
TOTALS FOR STATE		$6,461,582.98	$45,900.00	$2,480,253.00	$5,176,036.71	$22,171,425.31	$36,335,248.00

Exhibit 10

X State Highway Commission
Status of Federal Aid Appropriations as of Feb. 28, 1965
($'000's)

	Unprogrammed	Programmed	P.S. and E.	Under Agreement		Total
				In Progress	Final	
Primary	$ 3,823	$ 4,027	$ 410	$ 15,788	$ 33,088	$ 57,136
Secondary	6,462	46	2,480	5,176	22,171	36,335
Urban	10,332	1,373	1,532	19,327	27,704	60,268
Interstate	109,754	25,796	5,900	204,842	49,051	395,343
Total	$130,371	$31,242	$10,322	$245,133	$132,014	$549,082

Cash Flow and Budgeting Using Network Scheduling

BYRON O. MARSHALL, JR., Ernst and Ernst, Cleveland
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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.

Paper sponsored by Committee on State Highway Budgeting and presented at the 45th Annual Meeting.

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.

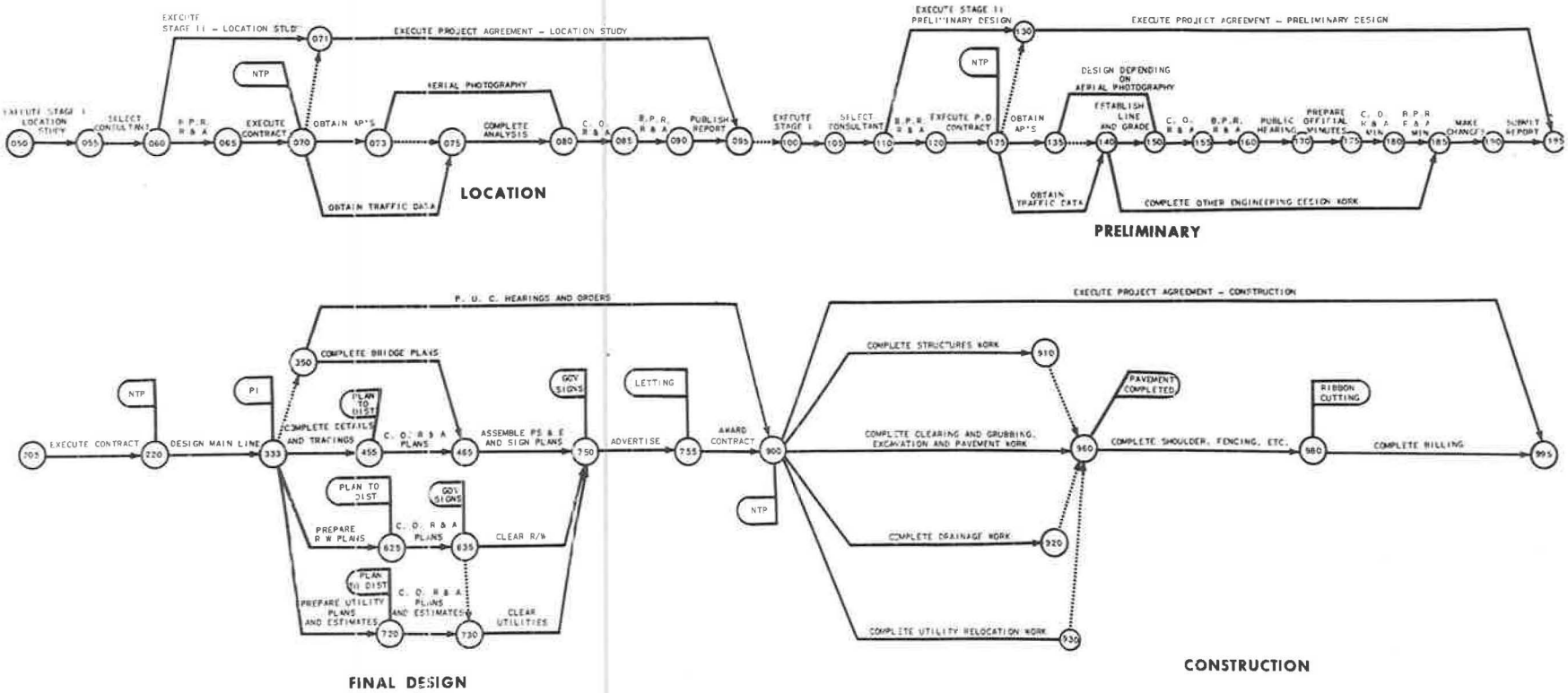

Figure 1. Long-Range Network.

	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	L 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.

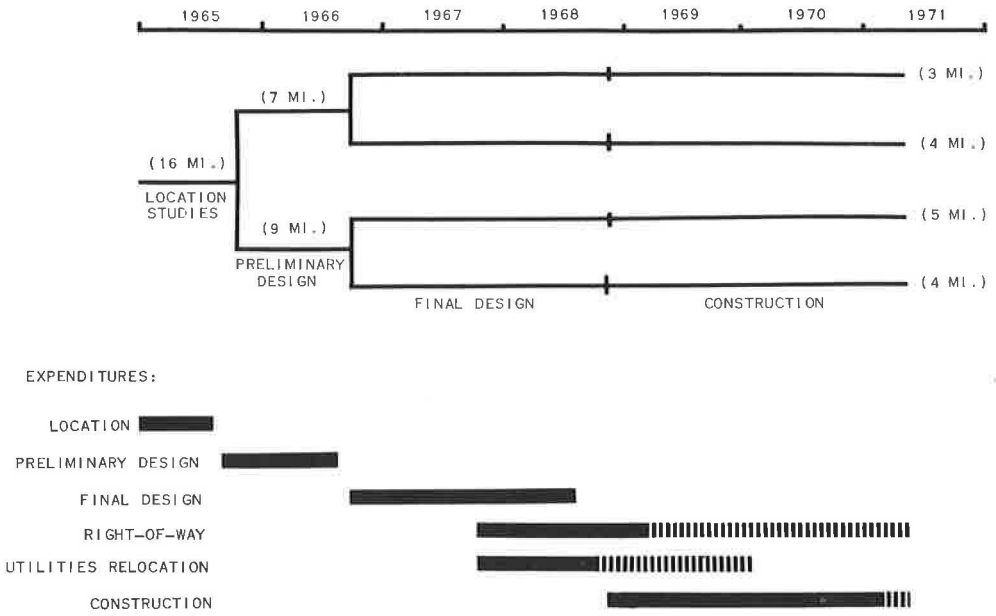

Figure 3. Typical expenditure schedule.

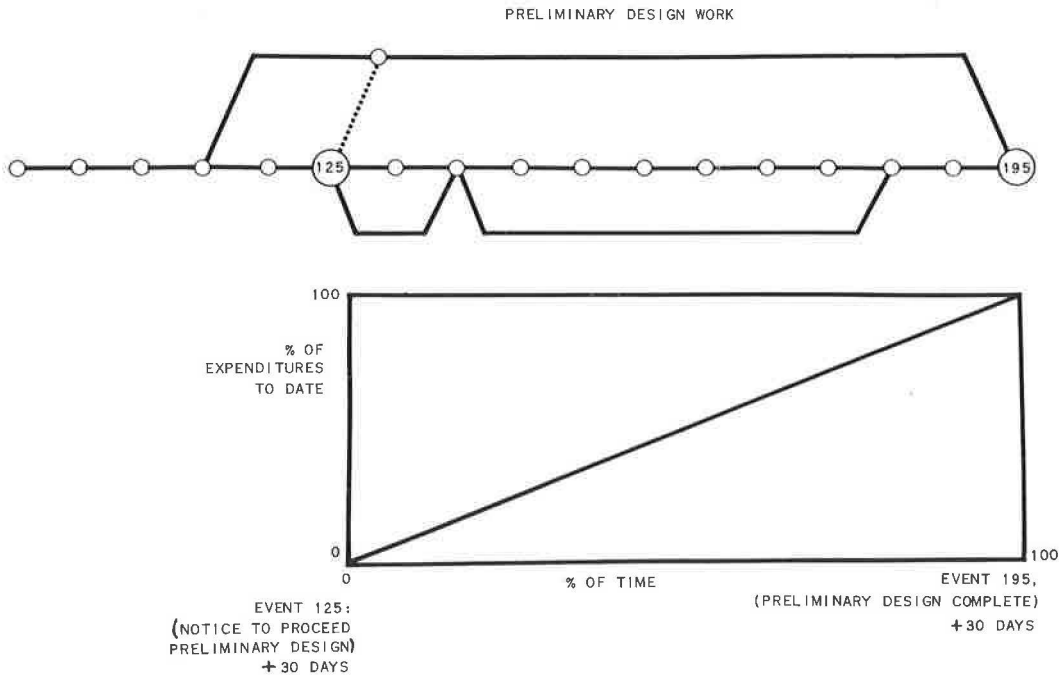

Figure 4. Expenditure curve, preliminary design.

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

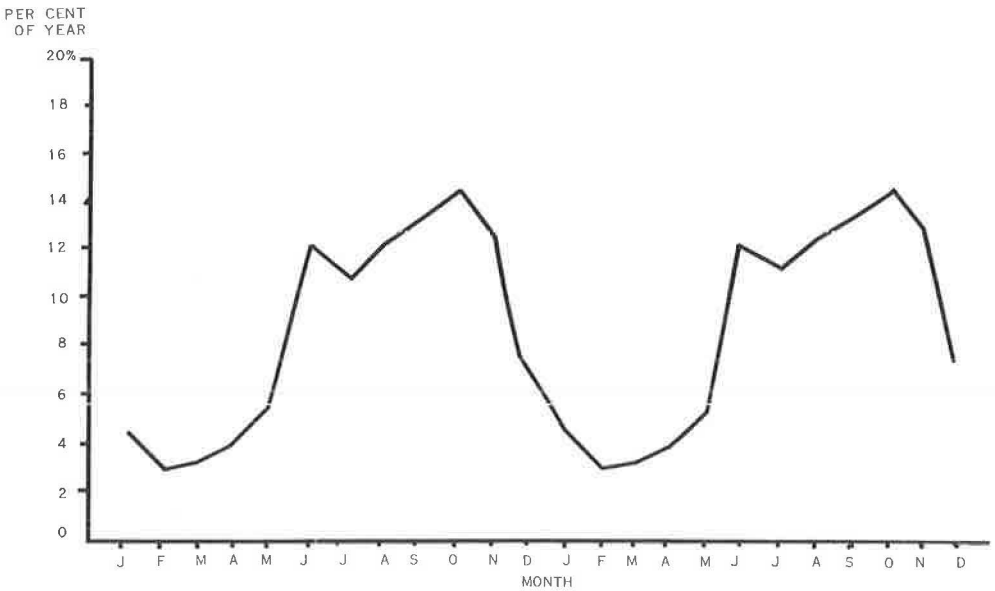

Figure 5. Seasonality of construction expenditures.

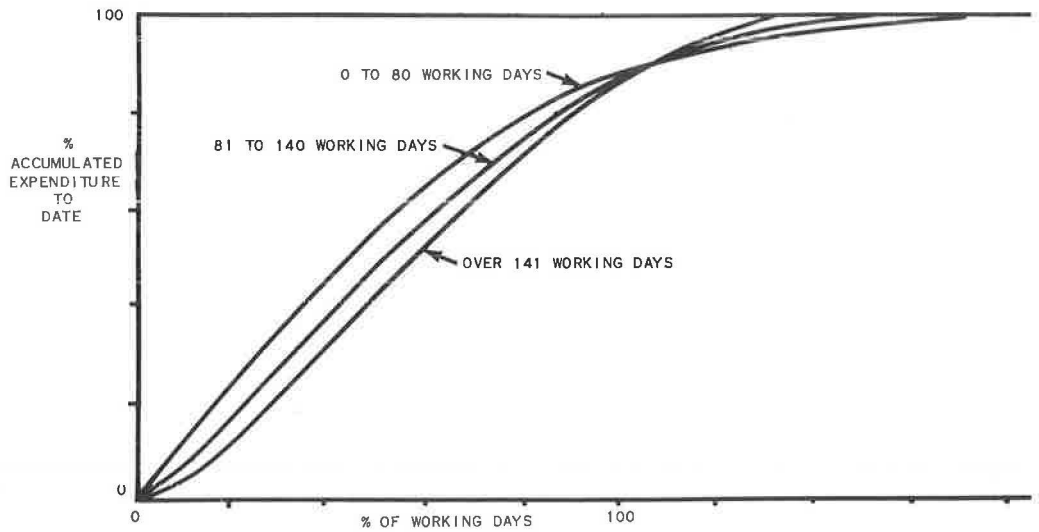

Figure 6. Construction expenditure curves.

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

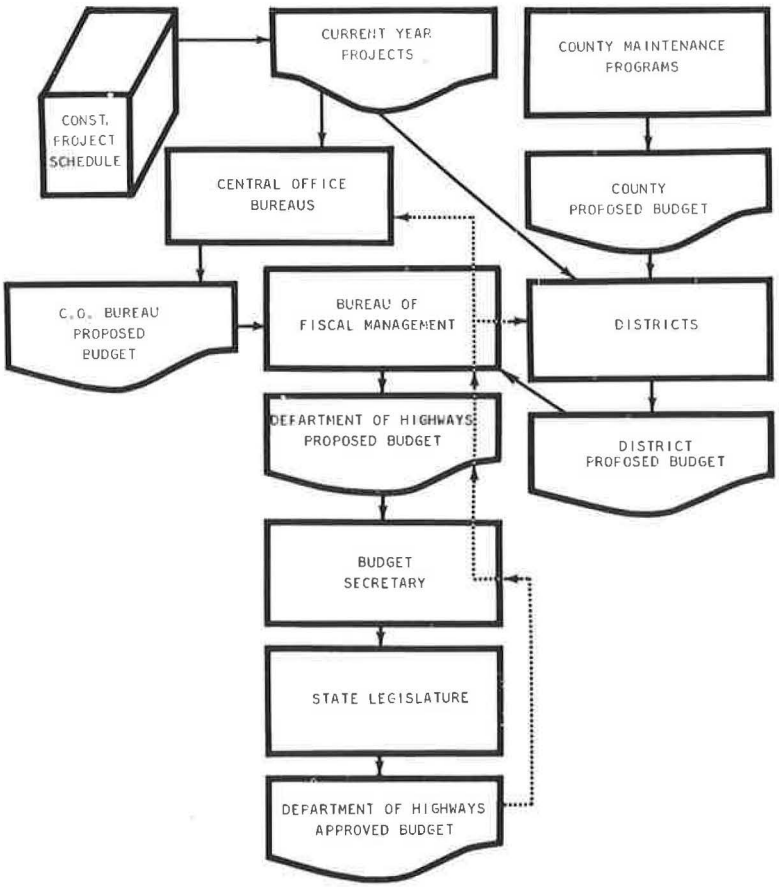

Figure 8. Budgeting procedure.

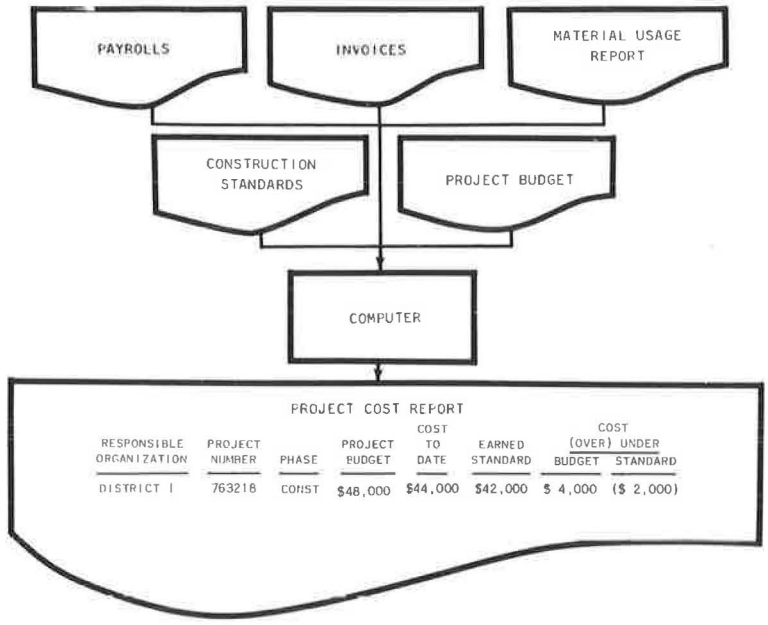

Figure 9. Development of project cost report.

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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Work Sampling Applications to Highway Personnel Management

K. L. BERGSTRALH, Senior Associate, Roy Jorgensen and Associates

•HIGHWAY agencies need reliable answers to the following questions with regard to staffing of highway and bridge design units: How many technicians should be employed per engineer? How many beginning level and intermediate technicians should be employed per advanced technician? Can staffing patterns be developed, in terms of personnel classifications, based on measured needs for engineers and technicians?

The objective of this research undertaking was to develop a technique to provide answers to the foregoing questions.

Research projects based on the technique described in this paper were completed by the Indiana State Highway Commission, the Virginia State Highway Department and the State Road Commission of West Virginia. The specific results of these projects are not reported in this paper. Composite and simulated data are used for illustrative purposes.

TECHNIQUE

The technique developed in this research is based on work sampling. Any single observation of a person at work gives the observer a limited impression of the work normally performed by that person. Several observations made over a period of time give a more reliable impression of the work performed. The making of a statistically valid number of observations provides a statistically reliable indication of the work performed.

The term "work sampling" is used to mean the making of observations of work performed by the persons employed in a given organizational unit. These observations, when properly classified and tabulated, can be used to analyze the characteristics of the workload and the proportions of the workload attributable to each person or personnel classification.

The principal steps involved in work sampling are (a) identifying and coding the work and auxiliary activities; (b) determining the number of work samples and the total sampling period required for statistical validity (the sampling plan); and (c) conducting the sampling program.

Work Activities

The workload of any given design function requires the performance of a wide variety of tasks. Because the performance of these tasks contributes directly to the accomplishment of the workload, they are called "direct production tasks."

Direct Production Tasks. —The conduct of a work sampling study requires identification of each significant task performed. The way in which these tasks are identified is shown in Table 1. Any element of work that can be performed by one person, or by two or more persons working together, is shown as a direct production task.

Auxiliary Activities. —Employees have need to perform certain personal tasks during working hours, such as making personal telephone calls, visiting with one another, and taking rests.

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TABLE 1

DIRECT PRODUCTION TASKS LISTED IN RELATIVE ORDER OF DIFFICULTY
(Typical Bridge Design Division)

Task Code	Task	Task Code	Task
107	Computing costs by simple formulae	402	Drawing, structural, intermediate
109	Handling files, supplies, equipment	403	Tracing, complex
110	Maintaining time-activity records	404	Designing, geometric, intermediate
111	Maintaining bid sheet file	409	Answering informational requests
202	Drawing simple sketches, layouts, plots	410	Attending technical meetings
203	Tracing, simple	412	Studying project correspondence
208	Calculating watershed areas	413	Making field visits to assist field personnel
209	Searching plan files for data	454	Making preliminary layouts
210	Issuing prints	464	Drawing graphs, charts, maps
211	Recording bridge data	501	Designing, intermediate structures
214	Reviewing consultants' fee vouchers	502	Drawing, structural, complex
302	Drawing simple structures	504	Designing, geometric, complex
303	Tracing, intermediate, compositional	505	Checking and applying computer output
304	Designing, geometric, simple	507	Making cost estimate studies
306	Calculating quantities from plans	508	Making hydraulics studies
307	Making cost estimates, preliminary	509	Instructing and training personnel
308	Collecting hydrologic data	512	Investigating characteristics of materials
309	Studying new specifications	514	Preparing reports, procedures, instructions
312	Photo-compositioning of details from previous designs	515	Establishing and maintaining automatic data processing systems
313	Reviewing situation plans	516	Handling technical correspondence
315	Obtaining data for special studies	601	Designing, structural, complex
316	Checking and following-up status of plans	610	Reviewing consultants' plans
317	Processing new material for technical file	612	Analyzing and writing specifications
401	Designing simple structures	613	Supervising design work

Organization and direction of a large and complex workload necessarily involves other periods of time-loss, such as waiting for assignments, waiting for data, and waiting for decisions.

These activities, because they do not contribute to the accomplishment of the workload but are unavoidable in the employment of manpower, are called "auxiliary activities."

The extent to which these auxiliary activities must be identified separately is dependent on the objectives of each work sampling study. If one of the objectives, for example, is measuring the time spent by the employee force in making personal telephone calls, this particular activity must be listed and coded. If the objective is limited to analysis of the workload characteristics, these activities not attributable to the workload can be grouped under one code, auxiliary activities. There is need to make record of these observation, if only to account for the observations made.

Sampling Plan

The sampling plan is based on: (a) the calendar period over which work sampling should take place, (b) the number of work samples required for satisfactory statistical validity, and (c) randomness in the taking of samples.

Calendar Period. —Work sampling should take place over a period of weeks or months considered to be representative of the annual workload. Periods used in the studies on which this paper is based spanned 24, 30 and 35 working days.

Sample Number. —Any person familiar with the science of statistics can calculate the number of samples (observations) that should be taken. The total number is based on: (a) the level of statistical validity desired, and (b) the frequency with which each variable is expected to occur.

Random Sampling. —Given the total number of days available for sampling and the total number of samples to be taken, tables of random numbers can be used to select the days and the times of day during which observations should be made. These days and times of day should be made known only to the observers.

Sampling Program

The conduct of a work sampling program consists of: (a) having observers make observations on the random days and at the random times of day selected, and (b) recording those observations.

Observers. —Persons selected as observers should be able to glance at an employee at any given time and identify the task then being performed. In bridge and road design organizations, advanced technicians are usually qualified to perform this function, subject to a trial run during which they can learn to identify unfamiliar tasks.

One observer can make the rounds and take the samples for a 30- to 40-employee force, usually within a 10- to 12-min period. Another observer should be trained and prepared to make the observations on occasions when the first observer is absent or otherwise unavailable for this work.

TABLE 2

RECORDING OF WORK SAMPLING OBSERVATIONS

Employee	Personnel Class.	Observation Number and Code						
		1	2	3	4	5	6	7
1	3	101	102	102	101	703	101	103
2	6	403	507	509	302	606	403	403
3	2	307	308	103	103	401	209	211

Recording. —Each observation should be recorded in code. Typical recordings are given in Table 2, where four items of data are recorded: (a) name of employee, (b) personnel classification of employee, (c) number of each observation, and (d) task or activity being performed by employee at time of observation.

Each of these items of data is coded for machine sorting and tabulating.

WORK SAMPLING PURPOSES

The information obtained from work sampling can be applied to the solution of personnel classification problems as well as problems of staffing patterns.

Personnel Classifications

The tasks performed in a bridge or road design division range in difficulty from collating and stapling plan sheets to analyzing design data and developing design standards and policies. The knowledge, skills and abilities required to perform each of these tasks increase in proportion to the increased difficulty and importance of each successive task.

Theory. —If the design tasks can, with satisfactory accuracy, be ranked in order of difficulty from the simplest to the most complex, and if the proportion of the total workload represented by each task can be determined, two possibilities exist: (a) the total workload can be divided into groups of tasks and a personnel classification can be created to represent each task group, and (b) the recruiting, training and management of manpower can be guided by these divisions of the workload.

Data Analysis.—The design tasks indicated in Table 1 were arranged in order of the relative difficulty of performance of each task, by a committee of design engineers and technicians.

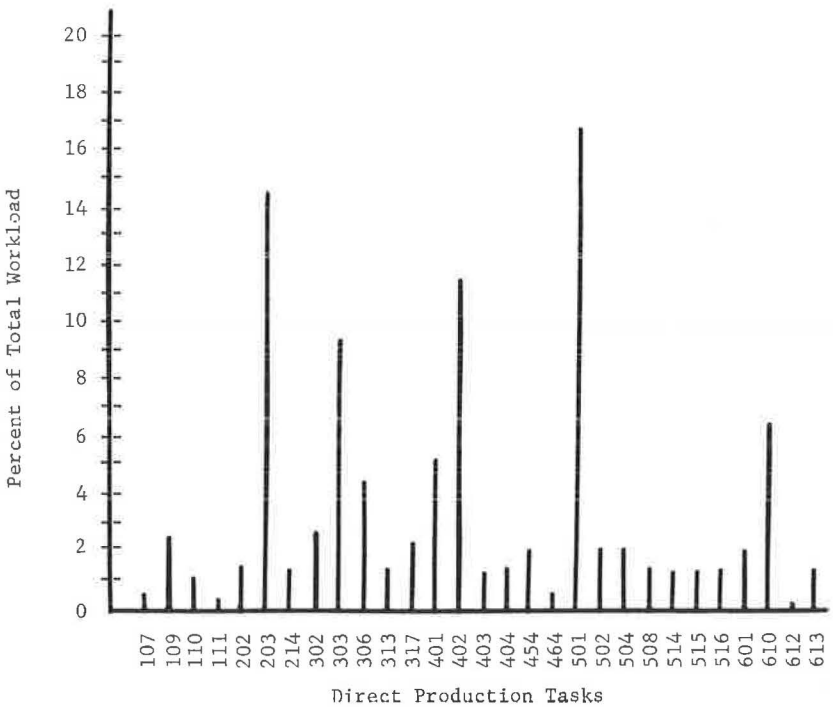

Figure 1. Distribution of direct production tasks; percentage of total workload represented by each task; typical bridge design division.

TABLE 3

DIRECT PRODUCTION TASK GROUPS BASED ON SIGNIFICANT DIVISIONS OF THE WORKLOAD
(Typical Only)

TASK GROUP 1

111 Maintaining bid sheet file
- 107 Computing costs by simple formulae
- 109 Handling files, supplies, equipment
- 110 Maintaining time-activity records

TASK GROUP 2

214 Reviewing consultants' fee vouchers
- 202 Drawing simple sketches, layouts, plots
- 203 Tracing, simple
- 208 Calculating watershed areas
- 209 Searching plan files for data
- 210 Issuing prints
- 211 Recording bridge data

TASK GROUP 3

317 Processing new material for technical file
- 302 Drawing simple structures
- 303 Tracing, intermediate, compositional
- 304 Designing, geometric, simple
- 306 Calculating quantities from plans
- 307 Making cost estimates, preliminary
- 308 Collecting hydrologic data
- 309 Studying new specifications
- 312 Photo-compositioning of details from previous designs
- 313 Reviewing situation plans
- 315 Obtaining data for special studies
- 316 Checking and following-up status of plans

TASK GROUP 4

464 Drawing graphs, charts, maps
- 401 Designing simple structures
- 402 Drawing, structural, intermediate
- 403 Tracing, complex
- 404 Designing, geometric, intermediate
- 409 Answering informational requests
- 410 Attending technical meetings
- 412 Studying project correspondence
- 413 Making field visits to assist field personnel
- 454 Making preliminary layouts

TASK GROUP 5

516 Handling technical correspondence
- 501 Designing, intermediate structures
- 502 Drawing, structural, complex
- 504 Designing, geometric, complex
- 505 Checking and applying computer output
- 507 Making cost estimate studies
- 508 Making hydraulics studies
- 509 Instructing and training personnel
- 512 Investigating characteristics of materials
- 514 Preparing reports, procedures, instructions
- 515 Establishing and maintaining automatic data processing systems

TASK GROUP 6

613 Supervising design work
- 601 Designing, structural, complex
- 610 Reviewing consultants' plans
- 612 Analyzing and writing specifications

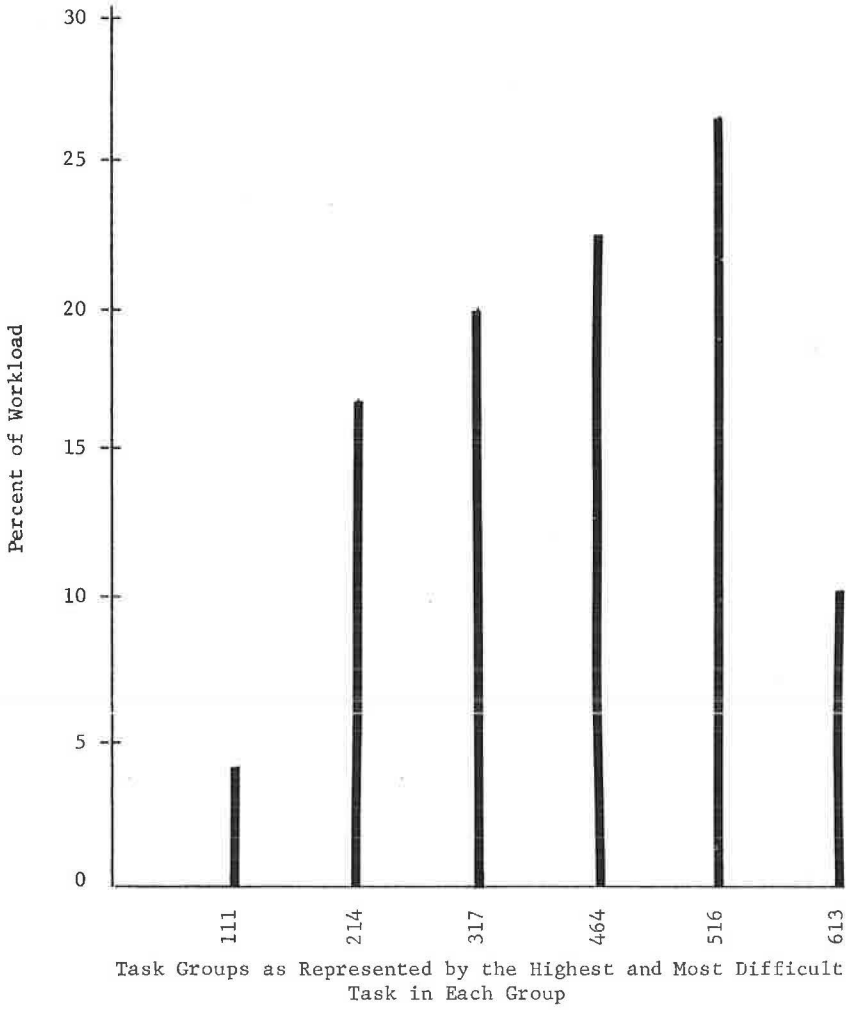

Figure 2. Distribution of the total workload by direct production task groups; typical bridge design division.

Figure 1 shows the percentage of a total bridge division workload represented by the direct production tasks given in Table 1. Tasks that individually represent less than 0. 2 percent of the total workload are included with the next higher task until 1. 5 percent of the workload is represented. Task number 107 represents approximately 0. 3 percent of the total workload. Task numbers 109, 203 and 303, respectively, represent 2. 1, 14. 3, and 9. 6 percent of the workload.

Task Groups. —Using the task distribution shown in Figure 1, minor segments of the workload can be combined with major segments to form task groups. Such task groups, represented by the highest and most difficult task in each group, are given in Table 3. (Tasks representing 0. 2 percent of the workload, or less, have been omitted from Fig. 1.)

Figure 2 shows the distribution of the total bridge division workload by task groups. The proportion of the workload attributed to each task group is equal to the sum of the proportions attributed to each task within the group as shown in Figure 1. The task groups represented by the code numbers are those given in Table 3.

Personnel Classification. —Each task group can be used as the basis for developing a personnel classification. In developing a classification series, allowance must be

made for a reasonable overlap between one classification and the next, but the work around which a classification is formed should be represented by the highest and most difficult task within each task group and by the significant direct-production tasks in each group.

Division of the workload into task group segments, and utilization of the task group segments, with guidance concerning the significance of tasks from the work sampling results, permit the position classifier to reflect the workload characteristics in the classification plan. This reflection is based on reliable data.

Staffing Patterns and Ratios

In theory, the work performed in a large and complex organizational unit comparable to a design division in a state highway department can be so organized and assigned that: (a) engineers can consistently apply themselves to the solution of engineering problems, (b) advanced technicians can consistently apply themselves to advanced technician tasks, and (c) intermediate and beginning-level technicians can consistently apply themselves to intermediate and beginning-level technician work. In practice, there is need for flexibility in the assignment of work.

This section of the paper is devoted to the use of work sampling data in the development of staffing patterns.

Data. —The distribution shown in Figure 2 indicates the following with regard to workload characteristics:

1. Four percent of the workload is attributable to Task Group 1, and 17 percent to Task Group 2.
2. Task Groups 3, 4, 5 and 6 account for 20, 22, 27 and 10 percent of the workload, respectively.

Staffing. —An analysis of the manpower staffing needs on the basis of work sampling results is given in Table 4. The percentages of the workload performed by each task group have been converted to manpower ratios for each task group. The work attributable to Task Group 6 (10 % of the total workload) has been used as the base.

In Staffing Pattern One, for every person employed to perform work assigned to Task Group 6, three persons should be employed to perform work assigned to Task Group 5, and two persons, preferably one beginning-level engineer and one advanced technician, should be employed to perform work assigned to Task Group 4.

On the basis of these ratios, five engineers and six technicians should be employed in a bridge design manpower unit, provided the workload is uniform from day to day with regard to proportion of work attributable to each task group. (The number of units required is dependent on the size of the total workload and the amount of work that can be produced by a manpower unit.)

According to Staffing Pattern Two, nine engineers and eleven technicians can be employed in a manpower unit in a bridge design division.

Of the engineers, two should be employed in the highest classification, five should be employed in the intermediate classification, and two should be employed in the lowest classification.

The technician distribution provides for three in the highest classification, and four, three and one in each of the successively lower classifications.

The 20-man staffing pattern more accurately reflects the workload distribution than does the 11-man staffing pattern, as shown by the 2 percent deviation and the 7 percent deviation, respectively.

Peak Engineering Time. —The analysis in Table 4 assumes that the workload is consistent from day to day with regard to the percentage of work attributable to the engineering level of employment. Should this not be the case, the number of engineers employed would have to be proportionate to the peak demand or delays which would occur in the performance of the engineering phases of the work.

One study included an analysis of the peaks and valleys of demand for engineering time. This single study showed less than a 2-percent range in the time devoted by engineers to engineering tasks as against technician tasks.

TABLE 4

ANALYSIS OF MANPOWER STAFFING NEEDS FOR A DESIGN DIVISION IN TERMS OF WORK SAMPLING RESULTS

Task Group	Workload Distribution per Work Sampling[a] (%)	Staffing Pattern One			Staffing Pattern Two		
		No. of Persons	Percent of Force	Cumulative Deviation from Optimum[b] (%)	No. of Persons	Percent of Force	Cumulative Deviation from Optimum[b] (%)
Task Group 6	10						
Engineer III		1	9	-1]	2	10	0
Task Group 5	27						
Engineer II		3	27	-1]	5	25	-2
Task Group 4	22						
Engineer I		1	18	-5	2	25	+1
Technician D		1			3		
Task Group 3	20						
Technician C		2	18	-7	4	20	+1
Task Group 2	17						
Technician B		2	18	-6	3	15	-1
Task Group 1	4						
Technician A		1	9	-1	1	5	0
Total engineers		5			9		
Total technicians		6			11		
Total personnel		11			20		

[a]The workload distribution to individual task groups can be modified by reforming task groups.

[b]The assumption is made that the deviation will be cumulative. In actual situations, persons in the higher classifications usually perform work in each of the lower task groups, causing the deviations to increase over those indicated. Also, any deviation from these averages toward temporary increases in the engineering workloads increases the need for engineers in proportion to technicians.

This one study notwithstanding, the number of engineers indicated as required in Table 4 must be considered minimum. Any deviation from the average distribution of the workload into task groups must be considered a basis for employment of additional engineers, there being a need to staff the organization to provide for a near-peak demand for engineering knowledge and skill.

SUMMARY

The objective of this paper was to set forth techniques, based on work sampling, that can be used to find answers to manpower management questions. Specific problems discussed concerned engineer-technician ratios, advanced technician-subordinate technician ratios, and personnel classification and staffing pattern development.

The following can be accomplished through work sampling and analysis techniques:

1. The tasks that must be performed in the accomplishment of a given workload can be defined (the tasks and their relative level of difficulty can be determined readily and quite accurately by a small committee of engineers and technicians).
2. The proportion of the total workload represented by each task can be determined by work sampling.
3. Given the proportions of the total workload represented by each task, and a workable method of task analysis, task groups can be formed to represent significant segments of the total workload; each successive task group should require a higher level of knowledge, skills and abilities for performance than the next lower task group.
4. The tasks within each task group, and the knowledge, skills and abilities required for their performance, can be used to create personnel classifications; these classifications will reflect the characteristics of the workload itself and the needs of the manpower force for the accomplishment of that workload.
5. The proportions of the workload attributable to each task group can be used to guide decision-making concerning the manpower force needed in each personnel classification, although staffing to meet above-average demands for knowledge and skill may be necessary.

The taking of work samples and the analysis of work sampling results are a relatively simple undertaking. The time required for a work sampling program is no greater than that required for a job audit program or a time-sheet analysis program; it is usually much less, and significantly more accurate.

Investment Analysis by Computer Methods for the State Trunk Highway System in Wisconsin

Part I: Methodology for Computing Remaining Investments

ORHAN BAYCU, Chief of Planning Surveys, Planning and Research Division, Wisconsin State Highway Commission

•THE MAIN purpose of a highway needs study is to determine the magnitude and costs of a program needed to overcome deficiencies in a particular highway system and attain adequacy within a desired period of years.

The so-called "investment analysis approach" establishes needs from the relationship that exists between highway investments remaining in service and travel requirements (1).

One of the major tasks in estimating needs using the investment analysis approach is the determination of investments remaining in service. Road life and cost records have been the general source of such computations. Difficulties, however, have been encountered in the past mainly because of the inadaptability of existing procedures to modern computer techniques.

Outdated methods of record-keeping and analysis have prevented new developments in the field of road life and investment studies and have led to the belief that such studies are cumbersome and of little value to the highway administrators.

It is believed that the first step towards the overall revival of road life and investment studies as a whole is the reevaluation of existing techniques for their proper incorporation into new computer operations.

This paper constitutes Part I of a two-part investment analysis for the State Trunk Highway System in Wisconsin, undertaken, for the first time, with computer methods.

Part I of the analysis covers the methodology developed for the automatic computation of remaining investments, and Part II, which is not included in this paper, comprises actual needs estimates using the investment analysis approach.

The developed procedure given here is an introduction to the computer approach in estimating remaining costs in highways, and is intended to replace tedious computations now done manually. It is also hoped that this new technique will pave the way for further developments.

Providing that records are properly organized and updated, remaining investments can be computed with this new method in a relatively short period of time and with a minimum of manpower.

Using this new procedure, Wisconsin's backlog of more than twenty years in remaining cost records for the State Trunk Highway System has been eliminated, and possibilities have been created for the evaluation of highway needs on a 100% sample basis, which otherwise would have been impossible.

OUTLINE OF METHOD

The new method mainly calls for the following:

1. Reorganization of construction and retirement data to include all construction cost items dealing with a specific project on a single construction card, and all pertinent

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remaining costs after a retirement on a single retirement card. (The old procedure required the filling of separate construction and retirement cards for each cost item.)

2. Automatic grouping of related construction and retirement cards into "road life units" which incorporate all original projects and their retirements, and all replacement projects and their retirements, arranged in a chronological order between each construction and corresponding retirements.

3. Machine computation of remaining costs using average salvage values based on the method of retirement.

DETAILED PROCEDURE[1]

Reorganization of Old Records

The following steps are taken in reorganizing old road life and cost records:

1. Old records, including construction cards and primary[2] retirement cards, are corrected and missing data completed as a preparation for their transfer to new Cards #8 and 9. (Appendix A shows layout of Cards #8 and 9.)

2. Old construction and primary retirement data are then transferred to new construction Cards #8 and retirement Cards #9. At this transfer stage:

(a) All construction cost items dealing with a specific project are automatically computed on a single Card #8, grouped under five categories and expressed as follows:

Construction Costs

(1)	Total	(in dollars)
(2)	Surface & Base	(as a percentage of the total)
(3)	Grading	(as a percentage of the total)
(4)	Right-of-Way	(as a percentage of the total)
(5)	Other[3]	(as a percentage of the total)

(b) A single retirement Card #9 is coded for each primary retirement of a specific project reported on a construction Card #8.

Provision is made on each Card #9 to show the "remaining costs" after each retirement, grouped in a similar manner as for construction cards and expressed as follows:

Remaining Costs

(1)	Total	(in dollars)
(2)	Surface & Base	(as a percentage of the construction total)
(3)	Grading	(as a percentage of the construction total)
(4)	Right-of-Way	(as a percentage of the construction total)
(5)	Other[3]	(as a percentage of the construction total)

The computation of these "remaining costs" is discussed later.

Exception: Only total construction costs are reported for bridges and miscellaneous construction ("X" or "Y" types), and total remaining costs for bridges ("X" types).

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[1]The details outlined in this chapter are worded for punched-card handling machines. Where tape-oriented machines are used, certain operations given here can be simplified and some of the duplication in data on various cards can be eliminated.

[2]A primary retirement is a direct retirement of a construction which generally involves the retirement of mileages and costs.

[3]Includes traffic services, landscape, detours, administration, engineering, and miscellaneous costs.

3. Construction Cards #8 and primary retirement Cards #9 are then organized to form "road life units and sub-units," which are obtained by grouping all cards pertaining to the same improvement in a chronological order as follows:

Road Life Unit #1

Sub-Unit #1: Original improvement "A" and its retirements
Sub-Unit #2: First replacement of "A" and its retirements
Sub-Unit #3: Second replacement of "A" and its retirements
etc.

Road Life Unit #2

Sub-Unit #1: Original improvement "B" and its retirements
Sub-Unit #2: First replacement of "B" and its retirements
Sub-Unit #3: Second replacement of "B" and its retirements
etc.

At this stage all construction and primary retirement cards are assigned "serial and sequence Nos." in order to keep them in this "road life unit and sub-unit" order permanently. Also, as a temporary measure, "secondary letters" are coded on matching construction and primary retirement cards so as to avoid further artificial breakdowns of units and enable the automatic computation of secondary retirement Cards #9, which is dicussed below.

Automatic Computation of Secondary Retirements[4]

The following method is used for the automatic computation of secondary[5] retirement Cards #9, which do not exist in old records:

1. (a) All construction Cards #8 and primary retirement Cards #9 are sorted in the following order:

Sequence No.	(cc 77-80)	(reverse sort)
Serial No.	(cc 4-6)	(regular sort)
County	(cc 2-3)	(regular sort)

(b) All construction cards are then matched with corresponding primary retirement cards, Cards #8 followed by Cards #9 having identical total construction costs reported in cc 70-75 #8, and cc 23-28 #9.

This operation should bring all "sub-units" within "road life units" in the reverse order, from latest to earliest years. The main reason is to deal with lengthier units, and possibly avoid the handling of small breakdowns throughout the computation, if units were arranged in the regular ascending chronological order.

2. Using cards as organized above:

(a) Within each "road life unit" (same codes in cc 2-3 & 4-6 for County & Serial No.), and after each primary Card #9, secondary Cards #9 are automatically punched, which will have the following information:

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[4]This section is intended to cover the automatic creation of secondary retirement Cards #9 for roadways (excl. bridges), in cases where no such data exists (Wisconsin 1912-1961 records). Once the basic secondary retirement records are established, future secondary retirements can be handled manually, if so desired, and the procedures outlined here (incl. assignment of "secondary letters") are not needed.

[5]A secondary retirement is an indirect retirement of a construction, caused by a primary retirement of a superseding replacement construction. This type involves the retirement of costs only.

(1) Transferred from each preceding primary Card #9, and as many times as there are preceding Cards #9, retirement values for:

Length Retired	(cc 42-45)
Year Retired	(cc 46-47)
Reason for Retirement	(cc 48-49)
Method of Retirement	(cc 50-51)

Note: Where the "length retired" is greater than the construction length, it is transferred from the corresponding Card #8, and equals the "length constructed" (cc 26-29 #8).

(2) Transferred from each Card #8 in the succeeding "sub-units," and as many times as there are succeeding "sub-units," construction values for:

County	(cc 2-3)	Administ. Group	(cc 12)
Serial No.	(cc 4-6)	Length	(cc 13-16)
Highway Syst.	(cc 7-8)	Type Code	(cc 17-20)
Highway No.	(cc 9-11)	Year Completed	(cc 21-22)
		Total Cost	(cc 23-28)

The above transfers are made providing that each set of primary Cards #9 and construction Cards #8, from which secondary retirement Cards #9 are computed, have the same "secondary letters" (cc 75 #9, cc 50-54 or cc 38-41 #8). If these "secondary letters" are not matched, no secondary retirement card is punched. (This is a temporary measure devised in order to avoid further artificial breakdown of units and expedite the computation procedure.)

(b) Also at this stage, all established secondary retirement Cards #9 are punched with:

Code "9" in cc 1, denoting Card Type #9
Code "2" in cc 29, denoting a secondary Retirement Type
(a primary retirement is coded "1" in this column)

3. (a) After step 2, all retirement Cards #9 (primary and secondary) are sorted in the following order:

Retirement Type	(cc 29)
Year Retired	(cc 46-47)
Total Cost (Constr.)	(cc 23-28)
Serial No.	(cc 4-6)
County	(cc 2-3)

(b) Then all secondary Cards #9 (code "2" in cc 29) are punched with a permanent Sequence No. (cc 77-80) which will be equal to:
(Preceding Card #9 Sequence No.) + 3

4. (a) After step 3, all retirement Cards #9 (primary and secondary) are sorted in the order of:

Sequence No.	(cc 77-80)
Serial No.	(cc 4-6)
County	(cc 2-3)

which will put them in the regular ascending chronological order by "road life units and sub-units."

(b) Within each "sub-unit" (same values in cc 23-28 for total construction cost) a Retirement Factor[6] (cc 30-31) is computed and punched on each Card #9 as follows:

(1) For retirement Cards #9 (primary and secondary) not preceded by prior abandonments or transfers (codes "3" or "4" in cc 50):

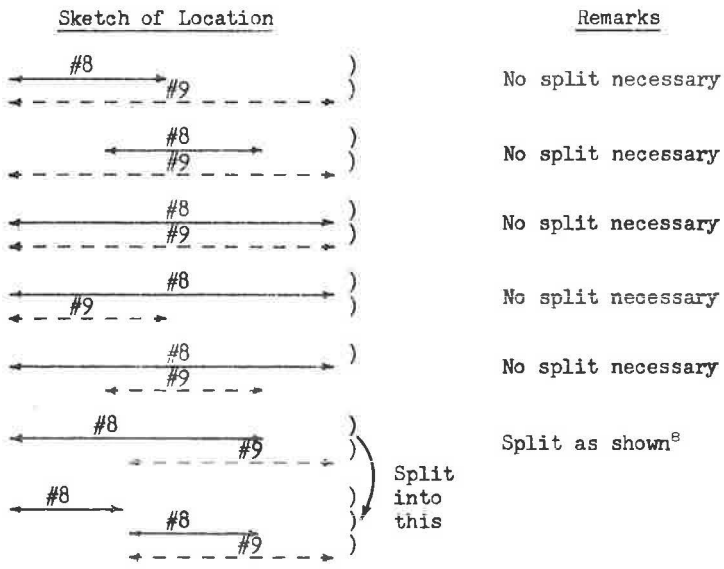
$$\text{Retirement Factor} = \frac{\text{Length Retired (cc 42-45)}}{\text{Length Constructed (cc 13-16)}}$$

(2) For retirement Cards #9 (primary or secondary) preceded by prior abandonments or transfers (codes "3" or "4" in cc 50):

$$\text{Ret. Factor} = \frac{\text{Length Retired (cc 42-45)}}{\text{Length Const. (cc 13-16)} - \text{Lengths Ret. (cc 42-45)}^{7}}$$

Note: If the denominator above is "zero," the retirement Card #9 should be disregarded entirely. If the retirement factor computed is more than 1.00, it should be treated as 1.00.

General Notes for the Splitting of Cards. —In certain cases, corresponding construction Cards #8 and primary retirement Cards #9, as they exist in the records, have to be split in order to make possible the automatic computation of secondary retirement cards outlined above. Below is a sketch showing the general procedure followed, as applied to cards organized in reverse, descending chronological order:



[6] A retirement factor is generally the ratio between the mileage retired and the mileage constructed, with the exception that if a portion of the original construction mileage has been previously abandoned or transferred out, the denominator in such cases is the mileage remaining after such abandonment or transfer, rather than the original construction mileage.

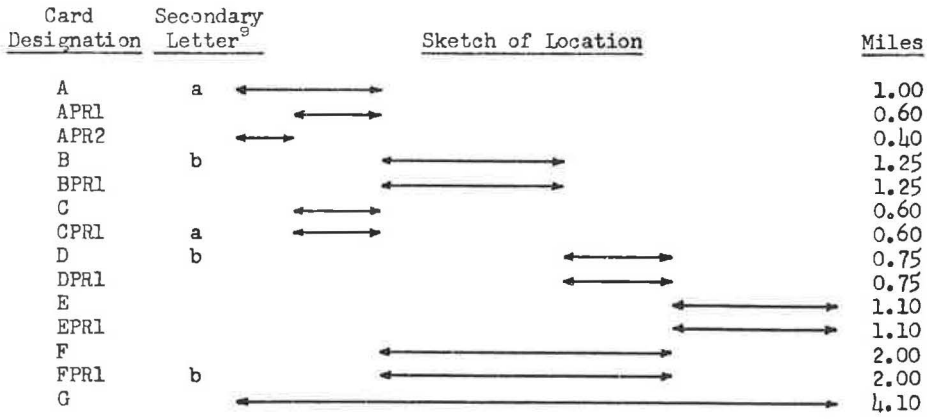
[7] Cumulative total of all preceding Cards #9 (primary or secondary) with codes "3" or "4" in cc 50.

[8] Cards split into two equal portions should have at least $100 difference in total construction costs, to avoid possible duplications in sorting.

Illustrative Example. —The following is an illustrative example for the automatic computation of secondary retirement Cards #9.

The table and sketch below show hypothetical Cards #8 & 9 as organized in the regular sequence of "road life unit and sub-units," in an ascending chronological order:

	Subject	Card Designation	Card Type	Total Constr. Cost ($100)	Year Completed	Year Retired	Sequence No.
Unit / Sub-Units	Construction A	A	8	1000	1912	-	0010
	1st Primary Ret. of A	APR1	9	1000	1912	1915	0030
	2nd Primary Ret. of A	APR2	9	1000	1912	1950	0050
	Construction B	B	8	1500	1913	-	0070
	1st Primary Ret. of B	BPR1	9	1500	1913	1930	0090
	Construction C	C	8	600	1915	-	0110
	1st Primary Ret. of C	CPR1	9	600	1915	1950	0130
	Construction D	D	8	800	1920	-	0150
	1st Primary Ret. of D	DPR1	9	800	1920	1930	0170
	Construction E	E	8	1200	1921	-	0190
	1st Primary Ret. of E	EPR1	9	1200	1921	1950	0210
	Construction F	F	8	2000	1930	-	0230
	1st Primary Ret. of F	FPR1	9	2000	1930	1950	0250
	Construction G	G	8	3000	1950	-	0270



1. After the reverse sort and matching of Cards #8 & 9, as explained in step 1 of the computation procedure, all cards are arranged in the following manner, in descending chronological order:

[9]No "secondary letter" is assigned to cards not involved in a secondary retirement.

Card Designation	Secondary Letter	Sequence No.
G		0270
F		0230
FPR1	b	0250
E		0190
EPR1		0210
D	b	0150
DPR1		0170
C		0110
CPR1	a	0130
B	b	0070
BPR1		0090
A	a	0010
APR2		0050
APR1		0030

2. In accordance with step 2a of the computation procedure, and starting with the first primary retirement card FPR1, secondary retirement cards are computed and punched as follows:

Subject	Card Designation	Cards #9 Referred to 1/		Cards #8 Referred to 2/		Remarks
		Designation	Secon. Letter	Designation	Secon. Letter	
No Secondary Card		FPR1	b	E		Second. letters not matched
1st Second. Ret. of D	DSR1	FPR1	b	D	b	Secondary letters matched
No Secondary Card		FPR1	b	C		Second. letters not matched
1st Second. Ret. of B	BSR1	FPR1	b	B	b	Secondary letters matched
No Secondary Card		FPR1	b	A	a	Second. letters not matched
" " "		EPR1		D	b	" " " "
" " "		EPR1		C		" " " "
" " "		EPR1		B	b	" " " "
" " "		EPR1		A	a	" " " "
" " "		DPR1		C		" " " "
" " "		DPR1		B	b	" " " "
" " "		DPR1		A	a	" " " "
" " "		CPR1	a	B	b	" " " "
1st Second. Ret. of A	ASR1	CPR1	a	A	a	Secondary letters matched
No Secondary Card		BPR1		A	a	Second. letters not matched
" " "		APR2		-		No Card #8 following
" " "		APR1		-		No Card #8 following

1/ Codes for cc 42-51 transferred from preceding primary Cards #9
2/ Codes for cc 2-28 transferred from succeeding Cards #8

Major Data Punched on Secondary Cards #9

Card Designation	Construction Data				Retirement Data	
	Tot. Cost ($100)	Length	Year		Length	Year
ASR1	1000	1.00	1912		0.60	1950
BSR1	1500	1.25	1913	2-00[10]	1.25	1950
DSR1	800	0.75	1920	2-00[10]	0.75	1950

[10]Length retired is reduced to match length constructed.

3. All retirement Cards #9 are then sorted as explained in step 3a of the computation procedure, which organizes them in the following order:

Card Designation	Retirement Type	Retirement Year	Tot. Constr. Cost ($100)	Sequence No.
CPR1	1	1950	600	0130
DPR1	1	1930	800	0170
DSR1	2	1950	800	Blank
APR1	1	1915	1000	0030
APR2	1	1950	1000	0050
ASR1	2	1950	1000	Blank
EPR1	1	1950	1200	0210
BPR1	1	1930	1500	0090
BSR1	2	1950	1500	Blank
FPR1	1	1950	2000	0250

Then, proper Sequence Nos. for the secondary Cards #9 are computed as follows:

For DSR1 = preceding Sequence No. + 3 = 0170 + 3 = 0173
For ASR1 = preceding Sequence No. + 3 = 0050 + 3 = 0053
For BSR1 = preceding Sequence No. + 3 = 0090 + 3 = 0093

4. Finally, in accordance with step 4 of the computation procedure, all retirement Cards #9 are sorted in regular sequence by "sub-units" within the given "unit," in an ascending chronological order, and then the "retirement factor" for each card is computed as follows:

Card Designation	Sequence No.	Length		Retirement		Computed Retirement Factor
		Constructed	Retired	Type	Method	
APR1	0030	1.00	0.60	1	Reconst.	0.60 ÷ 1.00 = 0.60
APR2	0050	1.00	0.40	1	Reconst.	0.40 ÷ 1.00 = 0.40
ASR1	0053	1.00	0.60	2	Resurf.	0.60 ÷ 1.00 = 0.60
BPR1	0090	1.25	1.25	1	Aband.	1.25 ÷ 1.25 = 1.00
BSR1	0093	1.25	1.25	2		1.25 ÷(1.25-1.25)[11]
CPR1	0130	0.60	0.60	1	Resurf.	0.60 ÷ 0.60 = 1.00
DPR1	0170	0.75	0.75	1	Resurf.	0.75 ÷ 0.75 = 1.00
DSR1	0173	0.75	0.75	2	Resurf.	0.75 ÷ 0.75 = 1.00
EPR1	0210	1.10	1.10	1	Reconst.	1.10 ÷ 1.10 = 1.00
FPR1	0250	2.00	2.00	1	Resurf.	2.00 ÷ 2.00 = 1.00

[11]The denominator here being "zero," card BSR1 should be entirely disregarded as a secondary retirement card.

Automatic Computation of Remaining Costs

1. All construction Cards #8 and retirement Cards #9 (roadways and bridges) are sorted by order of:

Sequence No.	(cc 77-80)
Serial No.	(cc 4-6)
County No.	(cc 2-3)

(This operation should group all construction and retirement cards within "road life units.")

2. It should be made certain that the following have been properly coded:

Construction Cards #8		Retirement Cards #9	
Subject	Card Columns	Subject	Card Columns
Length Constructed	26-29	Length Constructed	13-16
Year Completed	57-58	Total Const. Cost ($100)	23-28
Surf. & Base Cost %	61-63	Retirement Type	29
Grading Cost %	64-65	Retirement Factor	30-31
R.O.W. Cost %	66-67	Length Retired	42-45
Other Cost %	68-69	Year Retired	46-47
Total Cost ($100)	70-75	Method of Retirement[12]	50-51

3. Keeping all construction and retirement cards as organized in item 1 above, remaining cost values derived as follows are automatically computed and punched on retirement cards:

a) ROADWAYS:

Cost Item	Remaining Cost Preceding Card #8 or 9	% Retired From Table App. B	Retirement Factor	Remaining Cost (This Card) (%)	Remaining Cost (This Card) ($100)
Surf.& Base %	(%) X	[1-(%) X ( )] =		% 1/	—
Grading (%)	(%) X	[1-(%) X ( )] =		% 2/	—
R.O.W. (%)	(%) X	[1-(%) X ( )] =		% 3/	—
Other (%)	(%) X	[1-(%) X ( )] =		% 4/	—
Total ($100)	(Corresponding Construction) ($) X (%) = $				5/

1/ To be punched on Card #9 cc 52-54
2/ To be punched on Card #9 cc 55-56
3/ To be punched on Card #9 cc 57-58
4/ To be punched on Card #9 cc 59-60
5/ To be punched on Card #9 cc 61-66

Note: All construction and remaining costs given in percentages are expressed in terms of the total construction cost.

[12]Refer to Appendix B for average values used in retiring costs and various methods of retirement.

b) BRIDGES:

Cost Item	Remaining Total Cost Preceding Card #8 or 9	% Retired From Table App. B	Remaining Tot. Cost (This Card) ($100)
Total ($100)	($) X	[1-(%)] =	$ 5/

5/ To be punched on Card #9 cc 61-66

The following is an illustrative example for a roadway dealing with construction and retirement cards grouped in one "unit":

	Item	Subject	Card Type	Year Completed	Year Retired
Unit / Sub-Unit	1	Original Constr. A	8	1941	-
	2	Primary Ret. of A	9	1941	1945
	3	Secondary Ret. of A (Caused by Item 5)	9	1941	1950
Sub-Unit	4	Replacement Constr. A1 (Caused by Item 2)	8	1945	-
	5	Primary Ret. of A1	9	1945	1950
Sub-Unit	6	Replacement Constr. A2 (Caused by Item 5) (Still Living)	8	1950	-

Item	Sketch of Location		
1	Original Construction A	10.00 Mi.	Card #8
2	Primary Retirement of A	9.00 Mi.	Card #9
3	Secondary Retirement of A	8.00 Mi.	Card #9
4	Replacement Construction A1	9.00 Mi.	Card #8
5	Primary Retirement of A1	8.00 Mi.	Card #9
6	Replacement Construction A2	8.00 Mi.	Card #8

Illustrative Example for Remaining Costs Computation

	Subject \ Item No.→	1 (Card #8)	2 (Card #9)	3 (Card #9)	4 (Card #8)	5 (Card #9)	6 (Card #8)
Construction Data	Length	10.00	10.00	10.00	9.00	9.00	8.00
	Year	1941	1941	1941	1945	1945	1950
	S.B. Cost %	30	-	-	80	-	40
	Gr. Cost %	40	-	-	15	-	50
	R.O.W. Cost %	10	-	-	0	-	5
	Other Cost %	20	-	-	5	-	5
	Total Cost ($100)	10,000	10,000	10,000	5,000	5,000	8,000
Retirement Data	Ret. Type	-	1(Prim.)	2(Sec.)	-	1(Prim.)	-
	Ret. Factor	-	$\frac{9.00}{10.00}$=0.90	$\frac{8.00}{10.00}$=0.80	-	$\frac{8.00}{9.00}$=0.89	-
	Length Ret.	-	9.00	8.00	-	8.00	-
	Year Ret.	-	1945	1950	-	1950	-
	Meth. Ret.	-	01 (Reg.)	27	-	27	-
% Retired Costs (Table App. B)	Surf. & B.	-	30	100	-	100	-
	Grading	-	0	100	-	100	-
	R.O.W.	-	0	50	-	50	-
	Other	-	10	95	-	95	-
Computed Rem. Costs*	S.B. Cost Rem. %	(30)	22	4	(80)	9	(40)
	Gr.Cost Rem. %	(40)	40	8	(15)	2	(50)
	R.O.W. Cost Rem. %	(10)	10	6	(0)	0	(5)
	Other Cost Rem. %	(20)	18	4	(5)	1	(5)
	Tot.Cost Rem.($100)	(10,000)	9,000	2,200	(5,000)	600	(8,000)

* Remaining costs are separately computed for retirement cards within each "sub-unit". (Figures in parentheses are not computed, but show the ones punched on construction cards prior to retirements) Refer to next page for computations).

Computation of Remaining Costs for Item 2:

Cost Item	Remaining Cost Preceding Card #8 (Item 1)		% Retired From Table App. B		Retirement Factor		Remaining Cost (This Card) %	Remaining Cost (This Card) ($100)
Surf. & Base (%)	(30%)	x	[1-(30%	x	(0.90)]	=	22%	—
Grading (%)	(40%)	x	[1- (0%	x	(0.90)]	=	40%	—
R.O.W. (%)	(10%)	x	[1- (0%	x	(0.90)]	=	10%	—
Other (%)	(20%)	x	[1-(10%	x	(0.90)]	=	18%	—
Total ($100)(Corresponding Construction)					($10,000)	x	(90%) =	$9,000

Computation of Remaining Costs for Item 3:

Cost Item	Remaining Cost Preceding Card #9(Item 2)		% Retired From Table App. B		Retirement Factor		Remaining Cost (This Card) %	Remaining Cost (This Card) ($100)
Surf & Base (%)	(22%)	x	[1-(100%	x	(0.80)]	=	4%	—
Grading (%)	(40%)	x	[1-(100%	x	(0.80)]	=	8%	—
R.O.W. (%)	(10%)	x	[1-(50%	x	(0.80)]	=	6%	—
Other (%)	(18%)	x	[1-(95%	x	(0.80)]	=	4%	—
Total ($100) (Corresponding Construction)					($10,000)	x	(22%) =	$2,200

Computation of Remaining Costs for Item 5:

Cost Item	Remaining Cost Preceding Card #3 (Item 4)		% Retired From Table App. B		Retirement Factor		Remaining Cost (This Card) %	Remaining Cost (This Card) ($100)
Surf. & Base (%)	(80%)	x	[1-(100%	x	(0.89)]	=	9%	—
Grading (%)	(15%)	x	[1-(100%	x	(0.89)]	=	2%	—
R.O.W. (%)	(0%)	x	[1-(50%	x	(0.89)]	=	0%	—
Other (%)	(5%)	x	[1-(95%	x	(0.89)]	=	1%	—
Total ($100)(Corresponding Construction)					($5,000)	x	(12%) =	$600

The following summarizes the results obtained for the illustrative example:

Item	Project	Year Const.	Total Constr. Cost ($100,000)	Remaining Total Costs ($100,000) Jan. 1 of Each Year 1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1-3	A	1941	10.0	10.0	10.0	10.0	10.0	9.0	9.0	9.0	9.0	9.0	2.2
4-5	A 1	1945	5.0	-	-	-	-	5.0	5.0	5.0	5.0	5.0	0.6
6	A 2	1950	8.0	-	-	-	-	-	-	-	-	-	8.0
	Total for Unit			10.0	10.0	10.0	10.0	14.0	14.0	14.0	14.0	14.0	10.8

Note: The computation is started at each construction Card #8 and followed through corresponding retirement Cards #9. Underlined figures are obtained from Cards #8 & 9, and others are automatic repetitions of preceding values.

4. Total remaining costs for any specific type of road or structure can be computed by machine utilizing all "units" involved within that specific type, and totaling by years remaining values obtained within each "unit."

If an analysis is to be made for a particular cost item (surface & base, grading, R. O. W., or other), all costs have to be converted from percentages into dollars, within each "sub-unit," before the totaling of remaining values for that particular cost item. The table below shows this procedure dealing with grading costs applied to the illustrative example given above:

Existing Data on Cards #8 & 9:

Item	Project	Year Const.	Grading Cost %	Remaining Grading Costs (%) Jan. 1 of Each Year 1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1-3	A	1941	40	40	40	40	40	40	40	40	40	40	8
4-5	A 1	1945	15	-	-	-	-	15	15	15	15	15	2
6	A 2	1950	50	-	-	-	-	-	-	-	-	-	50

Conversion Into Dollars:

Item	Project	Year Const.	Grading Cost ($100,000)	Remaining Grading Costs ($100,000) Jan. 1 of Each Year 1942	1943	1944	1945	1946	1947	1948	1949	1950	1951
1-3	A	1941	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	4.0	0.8
4-5	A 1	1945	0.75	-	-	-	-	0.75	0.75	0.75	0.75	0.75	0.1
6	A 2	1950	4.0	-	-	-	-	-	-	-	-	-	4.0
	Total for Unit			4.0	4.0	4.0	4.0	4.75	4.75	4.75	4.75	4.75	4.9

CONCLUSIONS

Wisconsin has reorganized its road life and cost records for the State Trunk Highway System in accordance with the new procedures outlined here and will be in a position to analyze needs from the standpoint of highway investments remaining in service, as soon as work now under way for computer programming is completed.

The following conclusions can be drawn, however, based on over two years' experience in dealing with the new techniques:

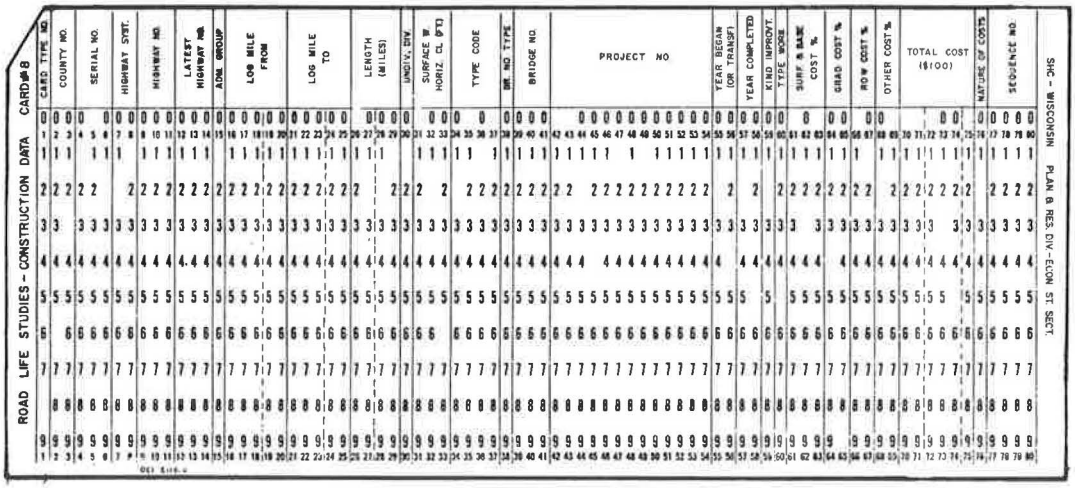
1. The methods outlined in this paper have been proved satisfactory, and it is hoped that they will pave the way for the revival of road life and investment studies, abandoned by many states due to the high volume of manual work involved.
2. The procedures given here are adaptable to regular electronic data processing machines (accounting type) as well as high-speed tape-oriented computers.
3. The new techniques will eventually lead to the development of electronic computer methods for the calculation of survivor curves (service and dollar life).
4. With these new procedures, providing that road life and cost records are updated on a continuous basis, investment analyses can readily be made as often as needed by highway planners and administrators.
5. Further research is required for the expansion of the general retirement table given in Appendix B, in order to meet the specific needs of various states and yield more accurate results. If such a system is developed, retired costs can be expressed as a percentage of individual cases rather than over-all averages.
6. Further research is also needed in order to incorporate depreciation factors into the automatic computation of remaining investments as presented in this paper.

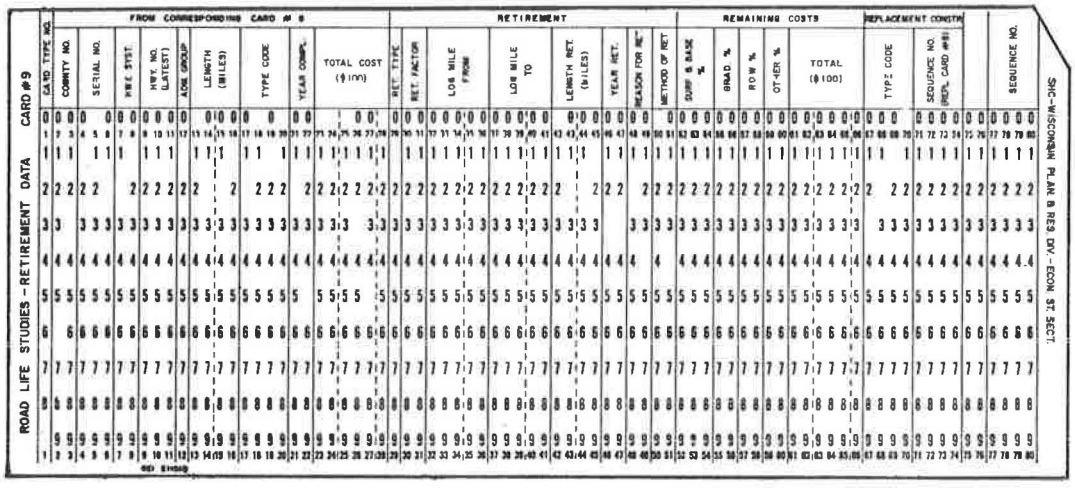
REFERENCE

1. Farrell, F. B. The Investment Analysis Approach to Estimating Highway Needs. Proc. HRB, Vol. 35, pp. 9-13, 1956.

Appendix A

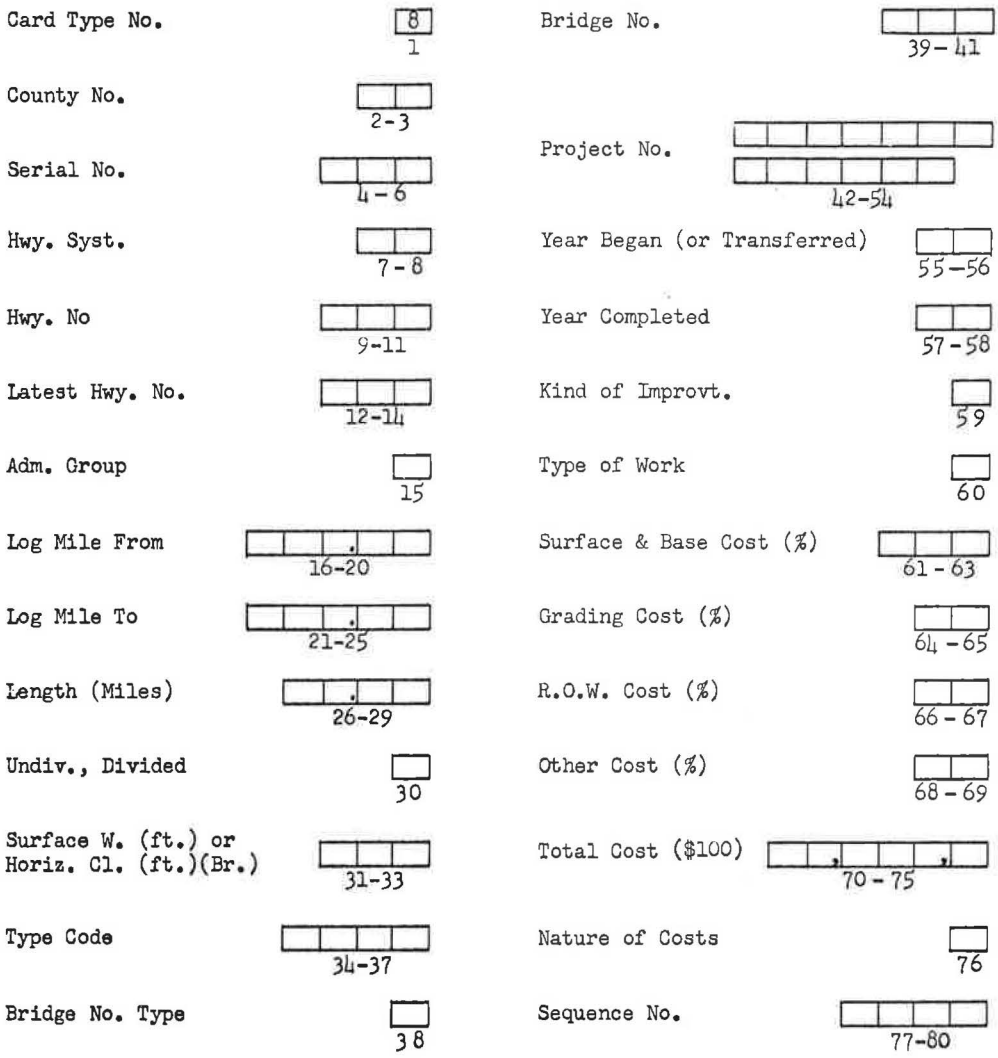
LAYOUT OF CARDS #8 & 9





CODE SHEET - CARD #8

ROAD LIFE STUDIES - CONSTRUCTION DATA



Remarks: cc 50-54 and 38-41 are temporarily used for coding "secondary letters" (1912-1961 records)

CODE SHEET - CARD #9

ROAD LIFE STUDIES - RETIREMENT DATA

Card Type No. [9] 1

From Corresponding Card #8

County No. [ ] 2-3

Serial No. [ ] 4-6

Hwy. System [ ] 7-8

Hwy. No. (or Latest Hwy. No.) [ ] 9-11

Adm. Group [ ] 12

Length (Miles) [.] 13-16

Type Code [ ] 17-20

Year Completed [ ] 21-22

Total Cost ($100) [,] 23-28

Retirement

Retirement Type [ ] 29

Retirement Factor [ ] 30-31

Log Mile From [,] 32-36

Log Mile To [.] 37-41

Length Retired (Miles) [.] 42-45

Year Retired [ ] 46-47

Reason for Retirement [ ] 48-49

Method of Retirement [ ] 50-51

Remaining Costs

Surface & Base (%) [ ] 52-54

Grading (%) [ ] 55-56

R.O.W. (%) [ ] 57-58

Other (%) [ ] 59-60

Total ($100) [,] 61-66

Replacement Construction (if any)

Type Code [ ] 67-70

Sequence No. (Repl. Card #8) [ ] 71-74

Sequence No.(This Card) [ ] 77-80

Remarks: cc 75 is temporarily used for coding "secondary letters" (1912-1961 records)

(Columns 75-76 are reserved for future use)

Appendix B

TABLE SHOWING
AVERAGE RETIRED COSTS ACCORDING TO METHOD OF RETIREMENT

Method of Retirement	Code (#9 cc50-51)	Cost Retired % *				
		Surf. & Base	Grad.	R.O.W.	Other	Total
ROADWAYS						
1. Resurfacing:						
Old wearing course not altered, new course added	01-02	10 1/ 30 60 2/	10 1/ 0 10 2/	0 1/ 0 0 2/	25 1/ 10 5 2/	—
Old wearing course scarified or reworked, new course added	03-04	65	10	0	25	—
2. Reconstruction (Same Line & Grade):						
Old wearing course and base reworked and reused	11-12, 15-18	70	20	0	35	—
Old wearing course and base torn out, not reused	13-14,19-22	100	20	0	40	—
3. Reconstruction (Same Line, New Grade):						
Old wearing course and base torn up and reused	23-24	75	75	0	70	—
Old wearing course and base torn out, not reused	25-26	100	75	0	75	—
4. Reconstruction (New Line & Grade):						
Old R.O.W. partially used, roadway rebuilt	27-28	100	100	50	95	—
Old roadway abandoned or transferred	31-32,41-44	100	100	100	100	—
5. No New Construction As Replacement:						
Old roadway abandoned or transferred	33, 45-46	100	100	100	100	—
BRIDGES						
1. Partial Rebuilding	51-53	-	-	-	-	50
2. Replacement:						
Old structure salvaged and re-used at new location	61	-	-	-	-	75
Old structure demolished, abandoned or transferred	62-63 71, 81-82	-	-	-	-	100
3. No New Construction as Replacement:						
Old structure demolished, abandoned or transferred	72-73 83-84	-	-	-	-	100

1/ P.C. Concrete capped with new concrete or resurfaced with bituminous material.
2/ Resurfacing of gravel and stone to similar type.
* Percentages given here are within each cost item and reflect over-all estimated averages, excluding depreciation.

LIST OF RETIREMENT CODES
(Card #9 cc 50-51)

Method of Retirement of Roadways	Code (Replacement Same Major Type)	Code (Replacement Different Major Type)
1. Resurfacing:		
Old wearing course not altered and new wearing course added	01	02
Old wearing course scarified or partially reworked and new wearing course added.	03	04
2. Reconstruction along same line and same grade which retires a single course road type (gravel, concrete, etc.):		
Old course completely reworked and reused	11	12
Old course torn out and not reused	13	14
3. Reconstruction along same line and same grade which retires a multiple course road type (surface treated gravel, bituminous concrete on gravel or concrete, etc.)		
Old wearing course completely reworked and reused	15	16
Old wearing course and old base completely reworked and reused	17	18
Old wearing course torn out and not reused	19	20
Old wearing course and old base torn out and not reused	21	22
4. Reconstruction along same line but on new grades:		
Old wearing course and base (if any) torn up and reused	23	24
Old wearing course and base (if any) torn out and not reused	25	26
5. Reconstruction along new line and new grades:		
Old right-of-way partially used, but roadway completely rebuilt	27	28
Old roadway abandoned	31	32
Old roadway transferred to local road systems	41	42
Interstate highway transferred to STH system, or vice-versa	43	44
6. No new construction which can be considered as replacing the old roadway:		
Old roadway abandoned		33
Old roadway transferred to local road systems		45
Interstate highway transferred to STH system, or vice-versa		46

LIST OF RETIREMENT CODES (Cont'd)
(Card #9 cc 50-51)

Method of Retirement of Bridges	Code
1. Partially rebuilt:	
New superstructure	51
New substructure	52
Widened	53
2. Replacement at same location:	
Old structure replaced but salvaged by removal to new location and reused	61
Old structure demolished	62
3. Replacement at new location:	
Old structure demolished	63
Old structure abandoned	71
Old structure transferred to local road systems	81
Interstate bridge transferred to STH system, or vice-versa	82
4. No new construction which can be considered as replacing the old structure:	
Old structure demolished	72
Old structure abandoned	73
Old structure transferred to local road systems	83
Interstate bridge transferred to STH system, or vice-versa	84

Grouping of "Method of Retirement" Codes:

Roadways	Codes in Col. 50
Resurfacing	0
Reconstruction	1,2
Abandonment	3
Transfer	4
Bridges	
Partial Rebuilding	5
Replacement	6
Abandonment	7
Transfer	8