Management of Highway operations requires an evaluation of the many inter-related functions on a continuous process or real-time basis. The continuous process must at any point in time indicate revisions in the current program and schedule and must assess overall progress in the light of changing conditions. The large-scale storage units and new concepts in random access memory devices permit the computer to play this major role in Highway management.

The information stored in random access files and the computer programs making up the management operating system must involve every action that management takes to insure the most effective operation and control.

The inter-related functions of the computer-controlled management operating system encompass five major management and planning areas; they are:

1. Priority Programming of Projects
2. Unit Cost File Maintenance
3. Project Cost Estimates
4. Cash Forecasting
5. Scheduling Projects and Resources

A change or revision in schedules is a common occurrence in Highway operations and, because of the dynamics involved, can cause many ramifications. Management science is like most sciences in that for every action there is a reaction. Each change or action taken in one of the above functional areas has a definite effect in each of the other areas.

A long-range plan must, of course, serve to define the Department's objectives and must be based on an evaluation of the existing and future needs. As the program moves forward, the long-range plan must be continuously updated due
to changing conditions and needs and, most important, compared to cash forecasts and schedules so that the adequacy of existing financial provisions can be appraised.

Costs, cash forecasts, and schedules, all of which are an integral part of the long-range plan, will be maintained on a current basis by the management operating system which is made up of a series of computer programs. Since one computer program can automatically trigger the use of another computer program to update an inter-related function, data banks maintained on direct access files will store the following data:

1. Weighted Average Unit Prices
2. Detail Project Descriptions
3. Work Items by Project
4. Cash Expenditures
5. Cash Receipts
6. Cash Forecasts
7. Manpower Resources
8. Critical Path Network
9. Schedule of Events

Maintenance of Unit Costs

Unit costs are updated at regular periodic intervals from contracts awarded on a low-bid basis. The bid-checking of contractor proposals using the computer, commonplace in most Highway departments, not only checks the contractors' extensions but also lists each proposal in ascending order of low bid for distribution prior to the actual award. After the low-bid data is determined, it is stored on random access files for use in the calculation of weighted average unit prices. The computer can also analyze the computations statistically to determine the reliability of each unit price by measuring the spread or variation of prices being averaged.
The weighted average unit prices can be printed in report form for distribution and also stored in a random access file for later use by other applications such as project cost estimates and total needs study costs.

**Project Cost Estimates**

The mass of data utilized in the preparation of engineers' preliminary cost estimates and the lack of time usually available for checking the computations make the computer process a logical means of reducing the many engineering man-hours which are unnecessarily spent in accounting, checking, and tabulation. In addition to time-saving advantages, there are many other advantages to be derived from the system which are listed as follows:

1. Future comparison of actual contract costs
2. Automatic updating when unit prices change
3. Detail summaries by fund, mile, characteristics, etc.

The process makes use of the unit price data stored in a random access file. For flexibility, the estimator can override a unit price when needed because of differences in a project or accept the stored unit price. Factors or constants such as average density for each item measured in tons or width of trench for each size of pipe are included in the stored program to provide short-cuts for the estimator. For example, when the item number for a pipe is recorded on the estimate form, the call for a pipe item will automatically produce the structure excavation for that pipe size and the mechanical tamping and/or gravel back-fill, as well as the length and cost of the pipe itself.

The resultant project cost estimates are also stored in disk packs for later use in applications such as Invitations to Bid, Proposals to Contractors, accounting master records for project monthly pay estimates, and for comparison of actual versus estimated costs, as well as cost data for needs study costs.

**Cash Forecasting**

This phase is an integral part of the management operating system as all operations and schedules are based upon the availability of funds. Cash forecasting has the capability of producing projections for a wide range of data such as for construction contracts, right-of-way, maintenance, administration, debt service, etc. It can also logically determine award dates of
contracts for the maximum utilization of funds without exceeding legal and cash flow limitations.

Historical data or pay-out curves on construction contracts become the basis for the system of forecasting. Some of the variables that may affect or alter the rate of pay-out include type of construction, geographic variations, size of contract, contract terms, and scheduling variations.

A chain of events can take place as unit prices increase or decrease. By applying this change, the computer system will modify the project cost estimates which in turn are utilized in the cash forecasting program. If a large cash forecast change occurs, this would result either in a change of award dates or an adjustment of manpower resources. Regardless of the change, management is notified on an exception basis of problems which may arise so that action may be taken promptly.

A by-product of the contractors' monthly pay estimate application will serve as input to update payment curves used in cash forecasting.

**Scheduling**

Scheduling includes the process of developing, monitoring, and controlling an action plan to accomplish the overall program. Knowing the letting date of a project and time requirements to complete each activity in the design of a project, a date can be determined to authorize the design of the project.

All projects must be included in the scheduling process so that the various activities in one project can be correlated with those of other programmed and concurrent projects.

The output of the scheduling process is presented in two different forms. One is "activity-oriented" to develop production schedules for each production unit in a bar-graph form for easy interpretation. The other is "project-oriented" to depict the overall status of each project in a bar-graph format.

The result of effective scheduling should be an orderly processing of projects through each major activity, the meeting of letting dates, and a fully-informed management with the necessary tools to make scheduling and programming decisions.
Two network levels appear to be justified, the "working" network and the "executive" network. The working network is the standard "step-by-step," piece by piece, detailing of every action required in the process -- in short, a detailed diagram. The executive network should be a communication medium between the project supervisor and the highway executive head.

Another by-product of a cost accounting system whose chart of accounts is correlated with critical path network activities will be the automatically provided standard normal costs, time, and manpower requirements for each activity.

Conclusion

The two principal characteristics of information processing are that it is correlative, and it is translatory. Some of the information from one application can always be used in another. Some of the data from a past project are included in cost estimates for a new bid, and portions of the performance data on today's construction will affect the specifications for the next projects.

The Highway Management System to be solved requires the system to gather data from multiple sources in a correlative and discriminatory way and to recognize or translate the data into some prescribed arrangement.

The system can be organized to control data which affect several separate stages of aspects of the management and production cycle. Effective and economical use of data processing equipment requires a recognition that these systems deal with common data, and that an integrated information network reduces redundant data files and systematizes the flow of information from man to man, man to machine program, and program to program.